Czech Republic
The Country For The Future

Implementation and Development of 5G Networks in the Czech Republic

Towards the Digital Economy

Contents

The **Implementation and Development of 5G Networks in the Czech Republic** document is a sub-strategy focused on a specific area of constructing and developing infrastructure for high-speed communication. It is part of the Digital Czech Republic concept and the Innovation Strategy of the Czech Republic 2019-2030.

1 Introduction

The development of the digital economy and society is one of the main priorities of the Czech government today. The Strategy Paper on Digital Economy and Society (part of the Digital Czech Republic concept), adopted by the Government by Resolution No. 629 of 3 October 2018, declares that "the digital economy is a fundamental pillar of society-wide changes brought about by the so-called Fourth Industrial Revolution". Within its pillar, Digital State, Manufacturing and Services, the **Innovation Strategy 2019-2030**[1] **– The Country for the Future** specifies Construction of high-speed infrastructure as the basis for online services and classifies it as one of the basic tools.

Building a digital economy cannot be realised without high-speed networks or very high-capacity networks, including fifth generation networks (hereinafter "5G networks"). It is also necessary to use analytical tools to work with Big Data, Artificial Intelligence and the Internet of Things (hereinafter the "IoT"), while ensuring the cybernetic security of the entire system.

In accordance with the above, the **Ministry of Industry and Trade (hereinafter the "MIT") is developing activities in the long term to facilitate, simplify and accelerate the organisational, legislative and financial processes of constructing high-speed networks throughout the country**[2] so that the Czech Republic keeps up with current global trends in the introduction of electronic communications networks and services in the complex legal environment.

5G networks and their development is a global phenomenon based on the convergence of fixed networks and wireless high-speed technologies. These reliable, high-capacity, low-latency networks enable the widespread availability of the service, more efficient communication with moving objects and mobile connections at any fixed location, which is expediently designated as MCFN (*Mobile/Fixed Communication Networks*). 5G network specifications are designed to meet the needs of whole industries. The number of wireless devices will significantly increase, with a wide range of sensors and regulatory elements. It is assumed that there may be hundreds of such devices per user, only one of which will be a smartphone.

The amount of data to be transmitted over 5G networks constitutes an essential **increase in the demand for network coverage of the national territory** based mainly on optical fibres. The default concept of 5G networks as a radio communication method is thus significantly expanded and adapted to the needs of specific users. Even the network's configuration itself will be adapted to their needs. Such networks can ensure low latency (i.e. a high response rate) and meet high security and reliability requirements, etc.

The aim of the "Implementation and Development of 5G Networks in the Czech Republic – Towards the Digital Economy" **document** is to define the strategic approach of the Czech Republic to the deployment and use of 5G networks, to promote new opportunities for the Czech Republic industry, to engage the professional public, local governments and academia, and to raise the *Smart City* and *Smart Region* concepts to a higher level of competition in the market for services provided through these networks, in order to achieve the best conditions for end-users.

The document not only deals with the definition of 5G networks, but also outlines visions and procedures, including radio spectrum management, and the prerequisites for their use for 5G networks linked to the

---

1 The Innovation Strategy of the Czech Republic – The Country for the Future (hereinafter referred to as the "Innovation Strategy of the Czech Republic 2019-2030") was approved by Government Resolution No. 104 of 4 February 2019.

2 For example, Government Resolution No. 885 of 5 October 2016 or Government Resolution No. 350 of 10 May 2017, or the adoption of Act No. 194/2017 Coll., on Measures to Reduce the Cost of Deploying High-Speed Electronic Communications Networks

research and development of the necessary applications[3] and services. It also indicates the prerequisites for the deployment of 5G networks, the opportunities to finance some activities, the support for testing new technologies relating to 5G networks and, last but not least, the security of 5G networks. It is important to note that implementation and development of 5G networks in the Czech Republic must be undertaken in accordance with the state aid rules and relevant legal regulations must be applied in the given area in case of identification of the cumulative fulfilment of the defining elements of state aid. The document does not address the construction of optical networks, which will also support 5G networks. This issue will be addressed in the National Plan for the Development of Very-High-Capacity Networks, which is currently being prepared by the Ministry of Industry and Trade.

Without the close cooperation of the state administration with various market players, from business, which is the main implementer of the transition to 5G networks and services, to cities and villages, academia and consumer representatives, it will not be possible to fulfil this plan.

The 5G network system and mechanism and the advanced digital applications and services operated and delivered through them, including the interconnection of people and devices, will constitute a complex ecosystem with an unprecedented impact on the development of the whole of human civilisation.

In electronic communications, we are at the beginning of a significant convergence of fixed networks (especially high-capacity optical networks) and mobile networks. This is demonstrated by the results of DESI 2019[4] for the Czech Republic.

	Czechia				EU
	DESI 2017	DESI 2018	DESI 2019		DESI 2019
	value	value	value	rank	value
1a1 Fixed broadband coverage % households	99% 2016	98% 2017	98% 2018	14	97% 2018
1a2 Fixed broadband take-up % households	71% 2016	73% 2017	74% 2018	14	77% 2018
1b1 4G coverage % households (average of operators)	94% 2016	99% 2017	99% 2018	3	94% 2018
1b2 Mobile broadband take-up Subscriptions per 100 people	77 2016	81 2017	82 2018	22	96 2018
1b3 5G readiness Assigned spectrum as a % of total harmonised 5G spectrum	NA	NA	17% 2018	11	14% 2018
1c1 Fast broadband (NGA) coverage % households	75% 2016	89% 2017	90% 2018	12	83% 2018
1c2 Fast broadband take-up % households	26% 2016	32% 2017	37% 2018	18	41% 2018
1d1 Ultrafast broadband coverage % households	NA	60% 2017	63% 2018	17	60% 2018
1d2 Ultrafast broadband take-up % households	14% 2016	16% 2017	18% 2018	16	20% 2017
1e1 Broadband price index Score (0 to 100)	88 2016	87 2017	88 2018	9	87 2017

Figure No. 1: Results of DESI 2019 for the Czech Republic (Source: European Union)

The document defines the implementation milestones of the actual implementation, while it is necessary to emphasise that many relevant key topics are already addressed in strategic documents, especially the

[3] An application is an application of a service or group of services using a device, infrastructure, processes and procedures.

[4] Digital Economy and Society Index (DESI) (https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic).

Innovation Strategy 2019-2030, the Digital Czech Republic concept, Action Plan 2.0 and others. Thus, many measures are already approved and being implemented. Furthermore, an analysis of the state of development of high-speed networks in the Czech Republic is currently being finalised, which will form the basis for the preparation of a new National Plan for the Development of Very-High-Capacity Networks.

However, it is already clear that it will require the spending of tens of millions to billions of crowns in the national budget to support the construction and utilisation of 5G networks. The costs of the construction and utilisation of these networks will have to be incurred by business entities, and will amount to up to tens of billions of crowns.

This document is linked to the Innovation Strategy of the Czech Republic 2019-2030: IV. The Digitisation pillar and the Digital Czech Republic strategy, together with the second pillar “Digital Economy and Society” and its objectives No. 04 PROMOTING CONNECTIVITY AND INFRASTRUCTURE OF DIGITAL ECONOMY AND SOCIETY, namely the first point 4.01 Construction of electronic communications networks.

At the same time, it is desirable to continuously perceive the process of identifying key factors, research requirements, scientific routing and fundamental experimental issues related to the development of other mobile systems, such as the 6G system. Wireless intelligence in these mobile systems will not only concern data transmission, but will become the framework of communication services. Specific intelligent user operations will be transferred to smart, high-capacity data centres built on state-of-the-art technologies, and the integration of mobility-related scanning, imaging and high-precision positional capabilities will represent new visions for future applications and services.

2 5G Network Technology

2.1 Prerequisites for the construction of 5G networks

A prerequisite for successful implementation of 5G networks is the existence of high-capacity connection of base stations (so-called mobile *backhaul*). Research in the field of 5G networks shows that, in view of the demands on these connections, it is essential to implement them mainly with fibre optic transmission systems. Therefore, optical connections will be presumably utilised from the lowest to the highest network level with a capacity dimensioned with a view to further development.

In order to successfully implement high-speed electronic communications networks, it is necessary, among other things, to implement the measures included in the Government-approved “Action Plan 2.0 to implement the non-subsidised measures to support the planning and construction of electronic communications networks” submitted by the Ministry of Industry and Trade.

2.2 Deployment of 5G networks

Development around the world and Europe shows, that the deployment of 5G networks will take place in two phases.

The fourth generation of mobile networks will be used in the first phase, based mainly on LTE technology, **which will be modified mainly to apply the 5G network deployment scenario for eMBB**, the “improved high-speed and high-capacity mobile networks and services”. This will increase network capacity and speed while gradually reducing latency. This means that even though some operators today refer to their networks and services as 5G, **they are actually in this first phase, also known as Non-Standalone (NSA)**. In the Czech Republic, this has already been tested and implemented in certain selected places. Greater deployment can be expected from 2020. The situation in the Czech Republic is also in line with the global development, because at present, only NSA networks have been deployed around the world.

The second phase is to run purely networks that fully comply with the upcoming specifications for 5G standalone (SA) networks. These allow full deployment of other applications *for mMTC* and *URLLC*. Specifications are currently being finalised and technology tested and further developed, which is related to the need to invest in new central operator systems as well as massive investments in the network itself. At this stage, 5G networks will be completely independent of 4G. The achievement of this phase and the implementation deadlines cannot be easily estimated, and it is reported that this will happen between 2020 and 2021 and onwards, following the completion of standardisation.

In order to enable a high data rate, reduce latency and increase the number of terminal devices, 5G networks must employ several new technologies and procedures, and be based on a different architecture than the current networks.

2.3 Main differences between 5G networks and existing networks

The first significant change compared to existing networks is the use of new parts of the radio spectrum. In Europe, 5G networks will use new parts of the radio spectrum: Current bands with frequencies below 1 GHz are accessed by the 700 MHz band, the centimetre band 3.4 to 3.8 GHz and the millimetre band 26 GHz. Each of these newly used frequency bands has different characteristics that will serve aspects of different parts of the 5G network.

- Band around 700 MHz: Low frequencies, bandwidth limits the amount of data transmitted per time unit, thus limiting the maximum attainable data rates and showing high latency. Wave propagation is burdened by relatively low attenuation, so communication over longer distances is energy efficient and also highly reliable. It is therefore ideal for IoT devices that do not need low latency or for larger data flows such as IoT, or to cover larger areas where there is no requirement to serve a large number of users simultaneously.
- Band above 3.4 GHz: Most of the current development of 5G networks and the launch of the first networks operate in the 3.4-3.8 GHz band. The main news is that the wavelength allows the creation of multi-element antennas of acceptable dimensions and through them so-called beaming (*beaming forming*). This means that antennas with this technology can direct the signal to a specific user, thus allowing significantly more efficient network operation. However, the range is generally smaller than in the previous case.
- 26 GHz band: Represents the first utilisation of millimetre waves in mobile networks. Due to the wide bandwidth, millimetre waves allow the transmission of huge amounts of data (gigabits) at very low latency to a large number of users. However, these features are balanced by a very short range. Radio waves only operate in the range of hundreds of metres and the signal struggles to pass not only through walls, but also through vegetation and even heavy rain. In order to achieve stable coverage, the antenna must be installed, for example, on public lighting poles. This is very demanding not only in itself, but also in terms of connecting each individual antenna to the optical network. Such a large-scale construction of antennas can also encounter resistance from citizens. They are usually sceptical about the construction of new radio communication works and 5G networks are already the target of *hoaxes* and conspiracy theories. Consequently, the construction of microwave infrastructure has not been carried out to a great extent, even though it would bring the most significant benefits for the common user and industrial applications.

The second change compared to the current networks is the emphasis on the best utilisation of optical networks in the case of backhaul connectivity. Optical networks are not limited by bandwidth and represent a key transmission technology due to the dynamic developments in electronic communications. This principle also exists to a lesser extent in current networks – the connection of base stations is often already realised by optical or microwave links. 5G networks take the need for fibre optic connections even further. The reason for this effort is the physical limitations of radio waves affecting both the volume of transmitted data and the data rate and latency. *Fixed Wireless Access*, i.e. a wireless network providing a point-to-multipoint broadband connection, is used in the access part of the network and its use is limited to a short distance, while it is subsequently connected to the optical part of the connection or Core Network.

The third change is the specification of the computing capacity function at the base station level – at the peripherals (edge/edge computing). The mobile service provider may allocate computing capacity within its base stations for use within its or third-party applications. This computing power is especially interesting for solutions that require a very fast response from the application server: due to the location directly in the base station, the response time is shorter in terms of the time between the base station and the server located on the Core Network of the provider or even on the Internet. In order for this solution to be advantageous, the solution needs to be operated on a local level; that is, the sender and receiver of the communication need to be in the same base station with this computing capacity or very close to it. In 5G networks, optimisation of transmission paths to ensure the necessary quality parameters for transmission will be much more feasible. The elements of the 5G networks themselves will also have their own computing and cloud capabilities, so that processes that do not need to be performed at a particular location are performed as close to the user as possible.

The fourth change is the application of *beam forming* and *beam steering*. These are technologies that allow signal beams around 3.4 GHz and 26 GHz to be generated aimed directly at the user. This saves energy but mainly spectrum capacity and increases the amount of data that can be transmitted. Beam forming, however, requires a large amount of computing capacity at the base station level.

3 Features of 5G Networks and Possibilities of their Use

3.1 Features of 5G networks

5G networks are an important element of the new high-speed access networks of the future. Unlike previous generations of 4G mobile networks, the following elements enabling specific technological solutions will be crucial for the implementation of the 5G network environment.

1. Depending on the required coverage, the use of the radio spectrum in the range from hundreds of MHz to tens of GHz. In particular, “millimetre” bands with channels of hundreds of MHz will allow high data rates to be achieved, for example for the transmission of UHD video signals, while serving a large number of communicating entities in a small space.
2. The possibility of flexible control of the transmission channel width and hence the value of the available data rate in the range from kbit/s, for example for IoT applications, up to Gbit/s for *eMBB*, will allow the use of 5G networks for a very wide range of real-world applications.
3. By adapting the network structure and virtualisation of its network functions, the use of the edge cloud will allow low latency values, even for network fragmentation (piko or femto base stations), indispensable for autonomous driving and manufacturing process automation applications.
4. Flexible allocation of the radio spectrum through dynamic TDD, while at the same time utilising radio spectrum sharing methods efficiently, will enable far greater efficiency in spectrum utilisation while supporting the deployment of many real-world applications.

The International Telecommunications Union (ITU) defines three main areas of standardisation, which will together form fully fledged 5G networks[5] (the speed of deployment may not be uniform):

1. **Enhanced Mobile Broadband – eMBB**
   Generally available data at any time
   Mobility approx. 500 km/h
   Maximum data rate 10-20 Gbit/s

2. **Ultra-Reliable and Low Latency – URLLC**
   Radio interface latency up to 1 ms
   Endpoint latency up to 5 ms
   99.9% reliability in data rate range of 50 kbit/s – 10 Mbit/s

3. **Massive Machine-Type Communication – mMTC**
   Billions of interconnected "things", low cost of interconnection, low power consumption
   Approximately one million devices per 1 km^2
   Data rate 1-100 kbit/s per device
   Powering the device with a battery that is estimated to last up to 10 years.

Recommendation ITU-R M.2083-0 (09/2015) sets out the following basic parameters for IMT-2020 systems, i.e. 5G mobile networks:

- Maximum data rate (estimated): tens of Gbit/s
- Data rate (commonly available): 100 Mbit/s – 1 Gbit/s
- Connection density: 1 million connections per km^2
- Endpoint latency: milliseconds
- Traffic density: 10 Mbit/s per 1 m^2
- Mobility: up to 500 km/h

At the same time, however, there is a convergence, i.e. connecting and outgrowing fixed and mobile networks. While the two types of networks have existed more or less independently of one another so far, separated by the technologies used, such as satellite networks, in the near future, these technologies and their use will converge and become interconnected. Sharing networks and their parts will be as common as virtualisation.

The standards adopted by 3GPP are fundamental to the development of 5G networks. The 3rd Generation Partnership Project (3GPP) constitutes a mobile applications cooperation agreement entered into in December 1998 to develop a third generation (3G) mobile phone network within the scope of the ITU IMT-2000 project. 3GPP specifications were based on developed GSM specifications, commonly known as UMTS. However, 3GPP is continuing to develop standards for newer 4G and 5G networks, in particular the technical standards known as Release 14, Release 15 and Release 16.

Although network virtualisation is already known and used today, in 5G networks, virtualisation will reach a much higher level and will be used to a greater extent.

---

5 https://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/rd/technical_journal/bn/vol19_3/vol19_3_007en.pdf.

Convergence and virtualisation are increasingly used not only in terms of more efficient utilisation of technical resources, but also because of the less expensive construction and use of networks. Cost reductions, green solutions and savings in renewable and unique natural resources will drive innovation.

3.2 Possibilities of using 5G networks

The use of 5G networks will be very broad and will cover virtually all areas of the national economy and many areas of residents' lives. Innovative and newly created applications and related mobile services will be able to benefit not only from high data rates but also from very low delays. A wide range of possibilities can be expected, for example in the field of virtual reality.

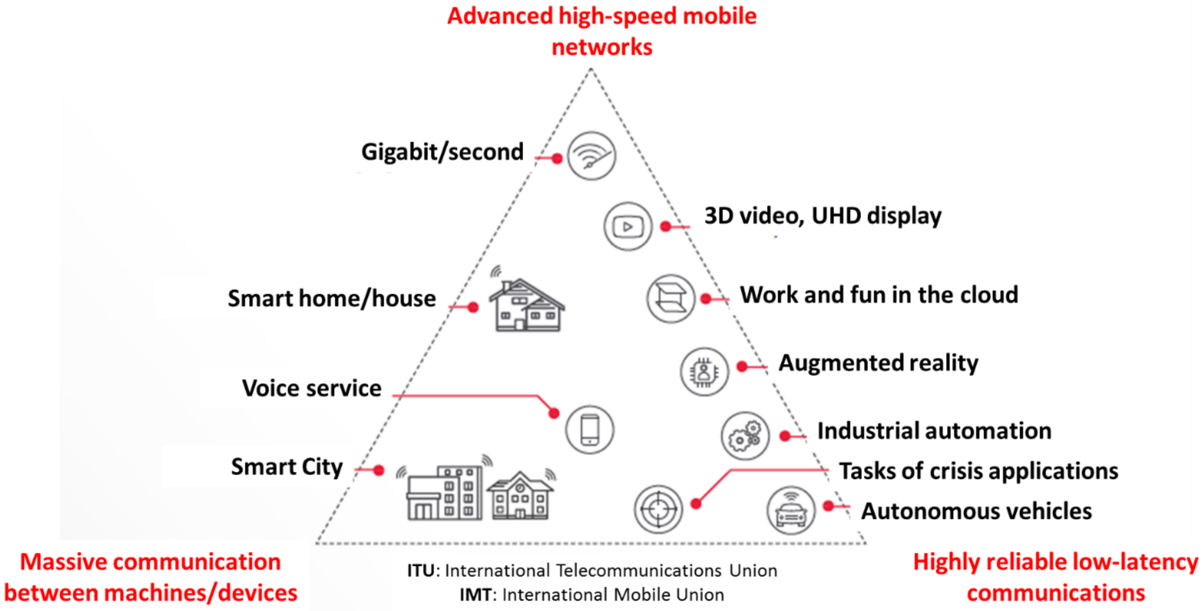

Figure No. 2: 5G Network use scenarios
(Source: Setting the Scene for 5G: Opportunities & Challenges, ITU)

5G networks represent significant potential in industrial applications (digitised production lines, robotic systems). The importance of 5G communication can be seen in the introduction of various biomedical practices. A separate area is its use in transport and transport infrastructure. Its development within the expected automation of transport is and will be, among other things, the key element of the so-called *Smart City* and *Smart Village*. Its use can also be seen in meteorology, security, power engineering and many other sectors. 5G networks will also support the anticipated massive development of the IoT and facilitate new directions in entertainment, including the ability to stream extremely high-definition video and virtual reality.

The development of the above-mentioned applications is closely related to the routine introduction of Artificial Intelligence, the mass use of which will largely depend on the existence of fast and reliable very-high-capacity networks. 5G networks also meet the required capacity and low-latency requirements.

The increase in the number of connected points and data volumes will also bring challenges in ensuring cybernetic security. With the increase in the numbers of connected IoT devices, cars, industrial control systems and other points, cybernetic attacks will have an increasing impact on the real world and the economy. To ensure security in the 5G network environment, large volumes of data will need to be analysed in real time, and error and *malware* detection alongside addressing cybernetic security events will need to be automated to a much greater extent than today. It will also be necessary to give high priority to the issue of security and credibility of the supply chain providing the 5G ecosystem for technologies; this ecosystem is expected to have a large number of suppliers.

The development of reliable fast networks with short response times will allow the centralisation of computing operations in a relatively small number of high-performance computing systems and usage of very simple and inexpensive devices such as remote terminals, which, due to the large number of these terminals, will help to achieve significant financial savings.

In parallel, the 5G networks will make it possible or even necessary to decentralise (bring nearer to the terminal device) or allow direct communication of terminal devices with each other (D2D communication), which will, with regard to the parameters of the 5G networks, be feasible. This fact will be used mainly in applications for Industry 4.0 or in communication between vehicles with autonomous driving.

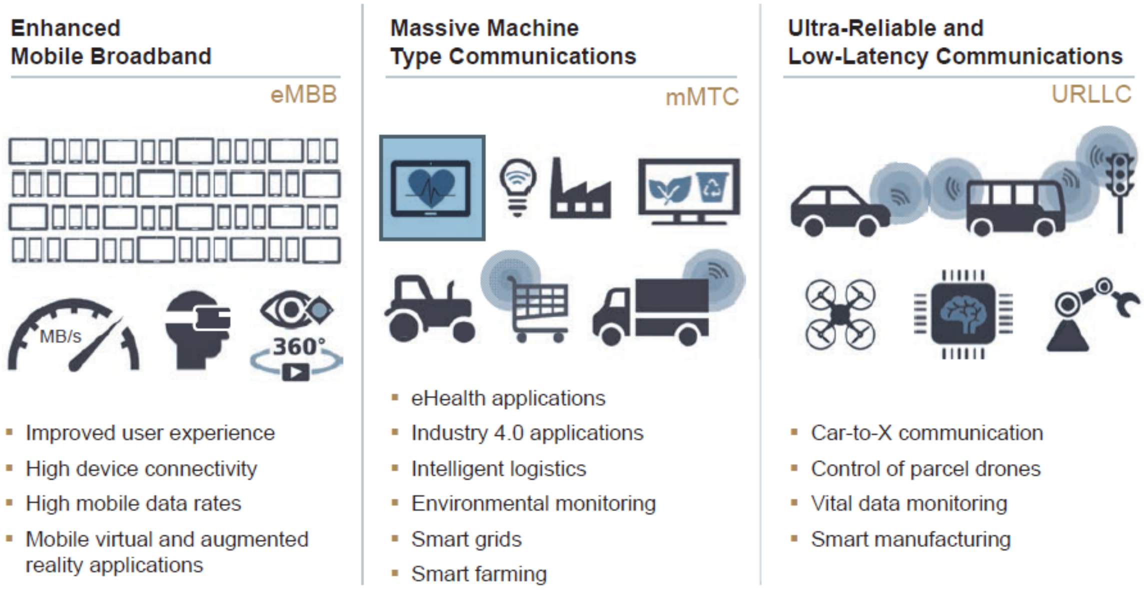

Figure No. 3: Examples of specific applications in the three areas of application of mobile 5G systems (Source: Update on 5G Spectrum in the UK, Ofcom 2017)

3.3 Synergies with construction of other communication networks

Due to the necessity of constructing very-high-capacity networks, the possibility of using these networks is not only suitable for providing transmission capacities for 5G networks, but also for other electronic communications networks. These are mainly public communication networks, but also non-public networks, for example, communication networks for energy support (*Smart Grid*). It should be noted that sharing such networks or physical infrastructure is not a simple task, but addressing it could significantly reduce the costs of constructing and operating electronic communications networks.

Given the relatively wide range of providers of electronic communications services, the possibility of shared networks exists in this context. The state will support activities in this respect, in accordance with the relevant measure, which is specified in the Action Plan 2.0 to implement non-subsidised measures to support the planning and construction of electronic communications networks.

4 5G Networks Services

5G networks will allow a wide range of applications across industries, in modern transportation systems, in health care, agriculture and the operation of Smart Cities and Smart Villages.

4.1 Industry 4.0

Industry 4.0 is based on deep industrial integration through information technology and related real-time or near-real-time data processing, information sharing and continuous communication.

The Fourth Industrial Revolution is based on the connection of the virtual cybernetic world with the physical world. This brings about significant interactions of these systems with the entire society, i.e. with the social world. Elements of the physical world will be interconnected through high-speed Internet connections, where each such element has its own individual IP address, which is the essence of the *IoT*. Software modules representing physical elements in virtual space together solve tasks, coordinate their activities and make decisions using the services they provide to each other or which they invoke via the Internet of Services (*IoS*).

It is necessary to take into account special interfaces between people and robots enabling mobile communication, even on the basis of natural speech, visual or tactile information – therefore, there is also a connection to a third type of Internet, the Internet of People (*IoP*). Here, too, Artificial Intelligence and cybernetics must provide adequate solutions, especially in learning, self-learning, self-optimising, self-diagnosing, self-repairing and self-configuring systems, including sensors, in a distributed environment. Process simulation and modelling, modularity, parametric equation and reconfigurability, even if remote, are also characteristic. It is also necessary to prepare for equipment and technologies that do not yet exist. An already partially observable phenomenon will be remote assistance in repair and maintenance (not only within the territory of one state, but also across borders).

This integration has three basic pillars:

1. **Vertical integration** of manufacturing systems means information interconnection across the hierarchical and management structure of an enterprise. The framework of vertical integration is primarily the manufacturing enterprise itself. In vertical integration, the two key knowledge industries of control engineering and automation meet the information system development industry.
2. **Horizontal integration** across the supply chain connects all links in the supplier-customer value chain from suppliers to manufacturers to distribution to the end customer and subsequent service. Sharing information and data across the supply chain increases process flexibility, optimises inventory levels and significantly reduces manufacturing costs, but also relies heavily on the high availability and quality of the high-speed Internet infrastructure.
3. **Integration of all engineering processes**, which is a specific example of horizontal integration, takes place largely within a manufacturing enterprise. It is the integration of all engineering processes throughout the entire product life cycle, from life cycle planning, through rough processing, design, development, implementation, testing, verification to after-sales services. Integration of engineering processes is the basic tool for receiving feedback and managing core processes for optimised delivery according to individualised customer requirements.

Industry 4.0 is also built on **Big Data analysis**. Big Data is usually considered to be petabyte data (10^{15} bytes) and more that exceed the capabilities of current database technologies. The processing and analysis of Big Data in industry provides a major innovative impetus to implement the vision of the Fourth Industrial Revolution. These are mainly image, but also text, data from the Internet, business data, security data, various signal and measurement sources, but also combined multi-modal data, which are, for example, characteristic of the autonomous traffic control systems, entertainment and media, the financial sector, transport and sales of products. A significant element of Industry 4.0 is cybernetic security, namely maintaining the confidentiality, integrity and availability of data to maintain the *business continuity* of manufacturing processes.

Robotic automation of industry by introducing **autonomous robots** as part of the Industry 4.0 concept is one of the methods that aim to increase labour productivity. The effect of robotic automation in productivity gains will not be limited to the industrial sector. At the same time, the development of robotic automation will have to be promoted by constructing the necessary infrastructure at all levels.

In light of the increasing demand for sophisticated processes, which are the pillar of the Industry 4.0 initiative, the demand for a high-quality electronic **communication and communication infrastructure** is growing. The accompanying phenomenon of process automation comes primarily from an increase in non-personal communication associated with the operation of a large number of sensors and cooperating devices, as well as the transmission and processing of Big Data. Therefore, reliable and secure high-speed communications via wired, wireless and satellite networks are general requirements.

One of the pillars of Industry 4.0 is also the collection and evaluation of data from various sources, whether from the IoT, company information systems or directly from manufacturing machines or *Machine2Machine (M2M)* communication. The key role in optimising logistics processes in particular will be held by data and information on the location of objects, both at the level of individual factories, buildings or complexes, as well as in a geographically large territory at the level of, for example, regions. High-quality digital maps with good attribute description of a suitable range will be of crucial importance. Up-to-date location information will play an important role in optimising the movement of materials and goods. An integral part of manufacturing systems will be navigation systems inside buildings (so-called *in-door*) and outside buildings (so-called *out-door*), including satellite systems (GNSS). This data is stored in **data repositories** and can be processed using **cloud computing**. The basic characteristics of clouds include the fact that they are shared resources (HW, SW), which are highly scalable. These resources are accessible to the users according to their needs anywhere and at any time via an Internet connection, and the users pay only for those resources that they use. To collect, store, process and back up data, enterprises can use public data repositories shared and accessible to anyone, private repositories operated directly or by a third party, but only for the needs of the enterprise, or they can also use a hybrid model that combines public and private repositories. The latest deployment model is a community cloud where the infrastructure is shared by several enterprises that can be linked by an area of interest or security policy.

A possible key technology that could enable a change in manufacturing processes and bring a significant increase in flexibility is **additive manufacturing**, i.e. the process of joining material according to 3D digital data, most often layer by layer, which is referred to as “3D printing”. Today's additive manufacturing systems are already connected to the Internet and are creating an IoT.

The characteristic of Industry 4.0 is the interconnection of the physical and virtual worlds. The enhancement of human perception by adding new information which we are not able to notice fast enough or even at all, is addressed in the area called **augmented reality** (*AR*). The main domain of augmented reality is the addition of visual information, i.e. the enhancement of visual perceptions. An additional channel is audio, usually in navigation systems and educational applications. Adding additional information, such as tactile or olfactory, is not typical of augmented reality and appears more in virtual reality applications. In simple augmented reality systems, augmenting visual perceptions have the character of text labels placed anywhere in the visual field; in advanced systems, augmentation is visually rich (2D, 3D) and is placed exactly in the space of the monitored objects or even overlapping and replacing them.

The need for human-to-machine or machine-to-machine interaction places great demands on sophisticated **sensors**. Sensor technology, as a field comprising methods and instruments for measuring and recording physical quantities, in a broader sense also image and spectral information or detection of the chemical composition of substances, is essential, one could say a key part of all industrial automation systems, and not only industrial automation systems, but should be extended to other sectors such as transport as well.

4.2 Smart Cities, Smart Villages

Smart Cities and Smart Villages mean the application of ICT in the energy and transport sectors, thereby accelerating sustainable progress.[6] These concepts for applying sustainable development principles to municipal organisations rely on the use of modern technologies to improve the quality of life of their residents and streamline public governance. This concept is widely used in energy and transport, as well as in parking, public lighting and waste management.

The aim of Smart Cities/Smart Villages is to both make life easier for their residents and reduce costs related primarily to the operation of urban infrastructure.

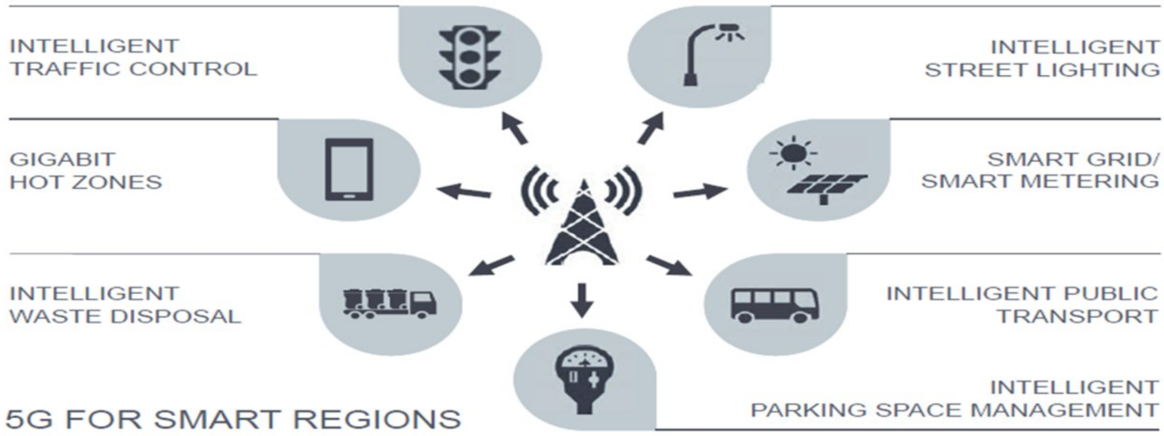

Figure No. 4: Example of Smart Cities/Villages service and application structure (Source: 5G strategy for Germany, 2017)

However, the *Smart City/Smart Village* concept does not only cover the two areas mentioned above, but can also be applied to others, such as water management, waste management, *e-government* or crisis management. Smart City/Smart Village is a programme change driven by the political representation of the city/village. It is a gradual process, not a state. In contrast to conventional planning and operation, Smart City/Smart Village simplifies the process of engaging academia and the general public using electronic tools (e.g. communication platforms or social networks). It provides the possibility for city/village strategies to not only be produced by a technically competent supplier in cooperation with the city/village department, but by working groups made up of experts from various institutions, local entrepreneurs and interest groups that the city effectively coordinates using electronic media. The resulting strategies can then be submitted for comments in electronic public forums and discussed with the public at open meetings so that the introduction of their final form is generally accepted by citizens and at the same time reflects as many ideas as possible (*e-government* or electronic state administration is seen here as a sub-component of Smart Cities/Smart Villages). Such a procedure also anticipates prudent investment in new technologies that will support these new programmes, which has an impact on the investment but above all on the operating costs associated with the technology.

The basis of Smart Cities and Villages involves, similarly to the IoT, automated data collection terminal devices for high-level information systems that store, aggregate, evaluate and automate the corresponding activities (e.g. traffic control via traffic lights). Sensors, detectors or reading devices that collect various data (e.g. about traffic, air pollution, etc.) send this data to higher elements, which interconnect and further use the data.

---

[6] See the updated Smart Cities Concept Methodology 2015 (Beta TB930MMR001) Smart Cities Methodology 2019 and European Communication C(2012) 4701 final (https://ec.europa.eu/transparency/regdoc/rep/3/2012/CS/3-2012-4701-CS-F1-1.PDF) updated version of Smart Cities Methodology 2019 (https://mmr.cz/getmedia/f76636e0-88ad-40f9-8e27-cbb774ea7caf/Metodika_Smart_Cities.pdf.aspx?ext=.pdf)

Smart Cities often include a variety of mobile applications that allow residents to use this data, for example, to plan the most appropriate transport connections.

The use of technologies to increase the safety and comfort of the inhabitants of not only the largest cities is nothing new, but 5G technologies will offer widespread deployment. Moreover, the areas will be divided into so-called campuses according to their purpose, which will differ in terms of certain specific requirements for electronic communications networks and/or services, security or used applications.

Intelligent transport systems (ITS, transport telematics) integrate information and telecommunication technologies with transport engineering with the support of other related industries (economy, transport theory, systems engineering) so as to ensure modern transport organisation and management processes for transport infrastructure and vehicles, in order to use the transport system more efficiently, eliminate traffic problems, optimise transport performance, increase traffic safety and improve driver and passenger comfort.

Resource management systems are very popular and widespread and include Smart Grids, smart solar and wind energy systems and smart water management. These are projects from the areas of the environment, local government, economics and lifestyle.

Participation platforms increase the possibility of citizens' involvement and participation in governance. Current modern technologies complemented by information and communication means enable *online* sharing, voting, decision-making, *crowdsourcing*, platform designing, etc. Compared to existing solutions, these activities can take advantage of extremely high-definition video streaming or virtual reality streaming. Open data provide the ability to create different applications or participate in various public services. These methods, according to the participants as well as the official representatives of the administration, local and regional authorities, represent better methods than traditional conventional techniques in both administration and the economy. Generally speaking, the goal of participatory platforms is ultimately to create and deliver better public services. The development of information and communication technology supports the creation of such platforms in virtually any city or village.

Smart neighbourhood projects focus on building districts, and the 5G ecosystem will contribute to carbon neutrality and sustainability through the process optimisation. This is the area of *smart* environment, mobility, economy and lifestyle. They are typically designed for 10,000 to 40,00 residents, either on a green field or by converting a previously developed area (e.g. *brownfield*). They serve to strengthen the economic and population importance of the city, using the latest information and communication technologies to fulfil the concept of a Smart City. These are holistic projects that represent a comprehensive grasp of the issue of Smart Cities in the future.

A **testing micro-infrastructure** introduces pilot testing and demonstration of technologies for Smart Cities. It interconnects smart environments, mobility and the economy in particular. The infrastructure seeks to connect as many physical objects as possible using sensors and systems so that they can work with minimal human interference. Typical examples are the introduction of monitoring systems using sensors for public lighting, energy flow management, parking, mobility, waste collection, environmental monitoring (air quality, water, and temperature), electric charging stations, free use of *Wi-Fi,* etc.

Data sets and applications for open data areas include traffic forecasts, presentation of attractive areas, and support for cycling, visualisation of city development, presentation of election results, searching for events, enrolment in schools, reservation of public areas, searching for best areas for housing, parking, support of business controls, etc. They also include assistance to improve mobility for people with disabilities.

For common use, there will be applications that will use the Internet. We already know some of them today, such as streaming and downloading videos, virtual and augmented reality. The use of 360 degree video, holographic communication and projection and applications to improve the safety of citizens is expected. We do not even know about many of the services: they will appear in line with society's needs and the possibilities offered by technology to make the offer to consumers more interesting and richer. These services can be characterised as the ultra-wide mobile communication as described above.

Smart street lighting is considered to be the most common solution within *Smart Cities*. The basis is an IoT device which has the potential to include the following technologies when using bi-directional information:

- **smart sensors compatible with IoT systems** can collect data needed to improve urban life, such as weather, air quality, temperature, pedestrian traffic, motor vehicle traffic;
- **electric vehicle charging can be integrated into street lightning;**
- ***Wi-Fi hotspots*** to improve the fast Internet coverage of the city
- enabling deployment of **Li-Fi technology**.

In addition, smart street lightning can be supplied from renewable sources such as solar or wind energy, meaning that they can eventually send excess electricity back to the power grid.

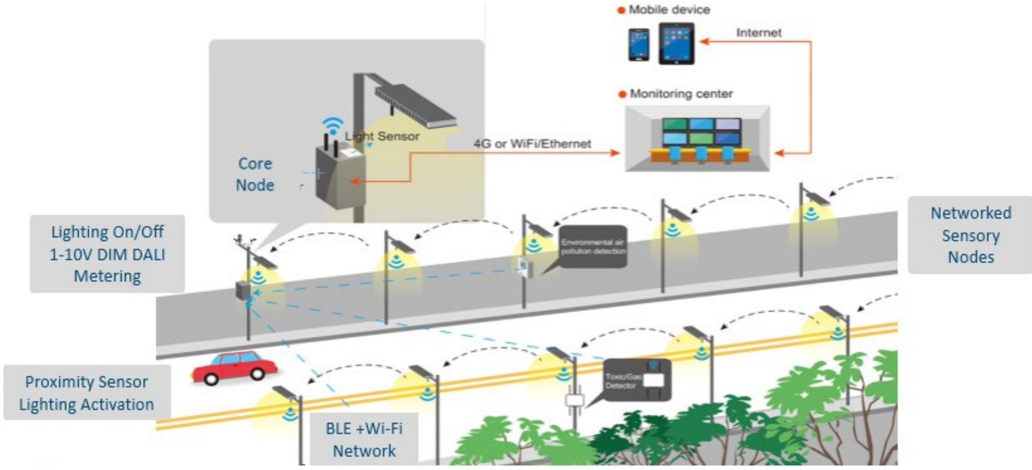

Figure No. 5: Example of smart street lighting
(Source: IoT Central)

There are many aspects of automation in intelligent street lighting, and in addition to the comments below, it is necessary to mention safety support, active elements for 5G networks, and the possibility of charging cars and phones:

- **Remote monitoring**
  The automatic street lighting system must be capable of monitoring the current status over the Internet. Important data such as operating hours, power consumption and faulty equipment must be available.
- **Integration with existing infrastructure**
  It is necessary to gradually upgrade existing infrastructure.
- **Fail safety**
  Automatic systems must be designed to operate autonomously even when the Internet connection is interrupted and in all weather conditions.
- **Plan**
  The automatic system must be based on a daytime running lamps plan. The plans must be flexible enough to match the changes in sunrise and sunset times throughout the year.
- **Manual control**
  While the system should run without human intervention, the ultimate power to turn street lighting on or off must, of course, rest with people.
- **Sensor integration**

Automatic systems would be more efficient if they could sense the intensity of ambient light. For example, in foggy, stormy, or smog conditions, it would be necessary to activate street lighting regardless of the time of day. Automated systems should therefore include sensor integration.

- **Wireless nature**

  Automatic street lighting solutions should be based on wireless technologies, thus avoiding additional excavation and construction assembly activities.

4.3 Intelligent transport systems, automated and autonomous mobility

5G networks will have a significant impact on the development of intelligent transport systems (*ITS*), in particular cooperative ITS (*C-ITS*). In the case of cooperative transport systems, 5G networks will be able to extend the coverage and services provided to end-users. In this context, the use of 5G networks is expected to improve communication between cars (*C2C*), cars and infrastructure (*C2I*) and especially between cars and other road users (*C2X*). This will increase both efficiency and safety. There is also potential for 5G networks in rail transport. 5G networks will increase the attractiveness of transport for passengers, offering a new quality of communication channels for transport and logistics processes.

Other possibilities are seen mainly in the field of train security (e.g. ETCS 2 communication, train integrity detection). Currently the most advanced mobile data communication (4G) still operates with a central point for data exchange. The current state does not allow for direct communication between two units (*C-ITS*). An important improvement in the current situation will be deploying one of the cornerstones of the future 5G network, co-called *edge computing*.

5G data networks are a prerequisite for the development of automated and autonomous mobility, including automatic train control, especially in view of the need to ensure stable, high-capacity, fast and above all secure communication, but also with regard to on-board *infotainment* and *entertainment* systems or the development of the related service industry. Support for pilot projects and real testing, including cross-border projects, is an area that needs to be targeted by concrete measures, including adequate financial security, also in line with the EC Communication Towards automated mobility.

4.4 Electronic health care

5G networks have the potential to significantly catalyse the development of eHealth services and applications, which will enable deeper integration with medical services and thus support the modernisation and reform of health care. Examples of the new 5G services include:

1. Telemedicine – all forms of distance health-care provision using information and communication technologies, either for the exchange of information between the patient and the health service provider (physician) or between health service providers. Telemedicine applications can be used in prevention, diagnosis, treatment, rehabilitation and palliative care. For data transmission, telemedicine applications can gradually use all phases of the deployment of 5G networks in the existing and new parts of the radio spectrum. Applications proven in previous-generation networks, such as those that focus on transmitting up-to-date biomedical patient parameter data to clinics, including modern IoT (or IoHT – Internet of Health-care Things) concepts using cloud services, will naturally prevail. The benefits of high-quality audio and video transmission, for example for real-time teleconsulting, will be able to fully develop, especially in 5G networks in higher-frequency bands. This also applies to services and applications with the aim to promote healthy lifestyles and citizens' and patients' communication with databases containing useful information in order to increase the level of care for their own health and strengthen their position in health-care processes.

2. Virtual reality, where 5G networks allow the creation of various communication applications to improve the care of patients with specific diseases, including personalised programmes to help manage difficult surgical procedures, illnesses and other conditions, as well as the education and training of medical staff and education in general.

3. Fast access to health and other data for health-care professionals in hospitals and ambulances, emergency services and home health care. This area of application also includes data analysis from remote databases, including so-called Big Data, the use of Artificial Intelligence systems to support the decision-making process of professionals in diagnostics and when performing medical services, communicating with robots and data operation of devices and personnel in highly digitised hospitals.

4. In the future, digital technologies will also enable new forms of health-care provision in near-patient locations as part of the decentralisation of routine interventions from hospitals, for example, to outpatient facilities using new devices and systems requiring Big Data flows between different components and remote specialists.

5. Operational transfer of large data files, which are generated for example by imaging technologies during diagnostics and procedures and stored in hospital repositories. As the resolution of digital imaging technologies and image sequences increases, large data files are generated that are, in urgent cases, needed immediately so they can be used at the right time by the physician who views them, i.e. via a mobile tablet.

6. Assistive technologies that help elderly people or people with disabilities to handle routine tasks, as well as technologies that fall within the scope of social services but are used by patients and citizens with impaired health. Such technologies will communicate remotely, for example, with geographical information sources, and transmit signals from sensors and cameras for possible operational intervention by a caregiver who cannot be constantly close to the person in need. The solution fits fully with the Smart Homes and Smart Cities concepts.

The services and applications above require to varying degrees the availability of bandwidth for fast data transfer, fast response and low latency, even in densely populated or temporarily populated areas. Only achieving a reliable connection in near real-time will enable digital technologies to be seamlessly integrated into the processes in health-care services, which is a prerequisite for so-called digital health care. There will be specific requirements for the stable availability of 5G networks within certain required specific parameters.

Another significant use of 5G networks is in medical services. The combined methods of reimbursement of telemedicine services will require strict differentiation between network traffic in order to provide medical services and other traffic. In addition, there may be applications which need large-scale access and capacity in 5G networks, whilst controlling their use only for a given purpose, especially if they should be partially funded from public funds. Another aspect that reflects sectoral requirements for 5G networks is the coverage of specific territories by certain types of 5G network services, as health-care facilities that may introduce innovative digital services with increased bandwidth requirements and number of connections in the future may not always be located in city centres. In addition, some digital health technology applications may have the potential to maintain the availability of medical services in rural areas.

From the perspective of cybernetic security and the emphasis on ensuring the privacy of individuals, eHealth is an important chapter. New health technologies will process and transmit highly sensitive patient medical data and other data that need to be adequately secured, yet be readily available to the authorised physicians, health-care professionals, patients themselves or health insurance companies. All eHealth systems, from telemedicine to hospital information systems, must then be highly protected from interception, unauthorised access, tampering and malware.

4.5 Electronic education

Digital education fundamentally changes the approach to teaching methods. Augmented and virtual reality in education and future media will significantly increase the demand for mobile high-speed communication. Interactive participation in training sessions with multimedia applications (e.g. distance education, etc.) is becoming increasingly popular, and modern communications networks open up entirely new possibilities in this area. The increased use of digital technologies in education will further facilitate the trend towards individualised learning and therefore meet people's needs to learn regardless of location and time.

Secondary, higher and further education offers prepare graduates for professional success. Educating young people and adults will create new jobs that will create a platform for innovation. New education methods will also enable the retraining of employees.

As a result of the introduction of Industry 4.0 and the deployment of Artificial Intelligence and new technologies, it will be necessary to focus, throughout the entire society, in all age groups, on the development of digital competences and other skills which will be necessary in relation to the expected changes on the labour market and in society, i.e. social skills, creativity, IT thinking and digital literacy. Therefore, it is necessary to support the enhancement of basic and advanced digital skills of pupils and teachers, complete the implementation of the Digital Education Strategy 2014-2020 and set new strategic goals for digital education.

4.6 Smart Agriculture

Agriculture is an important area which will be greatly influenced by the development of 5G networks. Future biological, social and economic challenges, the imminent shortage of natural resources and climate change will underline the need for new comprehensive approaches and innovations in agriculture. New approaches are reflected in Smart Agriculture, which includes agriculture, the food industry and forestry, including the sustainable management of natural resources through precise processes and sustainable agricultural production while reducing environmental and climate impacts, and producing high-quality and safe food.

Within Smart Agriculture, new technologies such as Artificial Intelligence, robotics, blockchain, the IoT, high-performance computing and fast high-speed connectivity will enable deep transformation, including in the monitoring, automation, observation and analysis of agricultural and industrial operations. Sensors for cattle, feeding, milking, cleaning and guidance systems (fully autonomous milking robots, feeding boxes, GPS guidance, unmanned aerial vehicles, drones including the use of satellite data) will be used to a much greater degree. All the above-mentioned equipment will allow for significant cost savings and environmentally friendly management. Savings and a more environmentally friendly approach will be achieved through variable dosing of seeds, fertilisers and other products, and monitoring of the temperature, humidity and chemical composition of soil and animal health. Transferring Big Data from remote sensors and robots rapidly will allow the farmer to respond immediately to the situation and implement the necessary measures. It can be assumed that the development of these technologies will bring about an improvement in the quality of life in rural areas, with the potential to attract the younger generation and stop the gradual depopulation of rural areas.

4.7 Smart Culture

Culture by its nature is an important part and a mirror of the changes leading to the so-called Society 4.0 – Culture 4.0 is a logical and necessary part of the process. Due to rapid technological development, the Czech Republic is undergoing major changes. Digitisation, automation, robotic automation, SMART solutions and augmented reality are new agendas for the dynamically changing world. They bring both positive and negative impacts, demands and new opportunities for the whole of society. The culture per se allows the issues arising between people and technology to be overcome. It puts people first. Personalised and tailor-made solutions are sustainable and can change discourse and make the world a good place to live. With its approaches and stimulating creativity, it creates new solutions – innovation together with entirely new forms of economy. Smart Culture has the potential to increase the availability of information on the Czech national identity, as well as the possibility of increasing awareness of the Czech Republic through the use of modern “SMART” solutions such as virtualisation, digitisation, augmented reality and other targeted possibilities for cultural information at the current location of the user while introducing cultural objects at the site and any other sights in the area, etc.

4.8 Crisis communication and communication of security and rescue services

5G networks will create the conditions to deploy and develop a range of applications to support the performance of PPDR activities. The possibility to provide detailed information to PPDR units in the field (e.g. visual information from the area of intervention before arrival; advanced navigation; use of biometrics for examination, identification and registration of persons) or transfer detailed information from the area of intervention to remote control units (i.e. real-time video transmission) are key in increasing the efficiency and security of PPDR activities. This will be a transition to procedures that are more based on the exchange of situational intelligence before/during/after the intervention, as well as during the daily routine activities of the relevant services. The fast availability of accurate information without distortion (especially in the form of video and photography), which results from the exchange of information through voice communication, is particularly important. These new capabilities bring more effective decision-making, faster mobilisation of appropriate PPDR services and units in sufficient quantities, and more effective interconnection of operational management across PPDR services. The result is the timely and more efficient performance of PPDR activities.

New applications that increase the safety and efficiency of PPDR activities and monitor the vital functions of PPDR units in real time will be particularly important for PPDR units intervening in dangerous and unknown terrain during ground operations (e.g. FRB of the Czech Republic). Biomedical telemetry includes for example monitoring/recording/measuring vital signs as well as other variables such as air quality in the environment, including the presence of toxic gases at ambient temperature. Intervening PPDR units transmit information to the operational control at the site of the intervention and possibly also to remote workplaces. The use of this application is subject to further investments, for example in equipment.

In the future, biomedical telemetry can also be used for remote medical assistance (see below) and specific applications such as identification of persons (e.g. recognition of face, finger prints, iris, cornea, dentition, body proportions and movement pattern). These applications can be used within a specific activity (i.e. during an intervention) or permanently (i.e. during long-term monitoring by means of camera systems).

4.9 5G networks' ecosystem and consumers

An average user will be able to benefit from a number of the above services, particularly in health care and education, while at the same time having significantly increased and improved services, such as smart transport services (increased volume and detail of information). However, entirely new services will emerge, such as live holographics call or links between augmented and virtual reality with common reality (while walking through the city, it will be possible to get information on buildings, traffic, air quality, etc. from smart glasses).

Very high data rates on 5G networks will completely change the behaviour of the average customer. The results of the T-Mobile stress test from the summer 2019 for unlimited data consumption are presented as a guideline for determining how customers' behaviour will change with unlimited data consumption, according to which:

- average monthly consumer consumption was approx. 12.1 GB,
- approx. 1/10 of the data used was used in roaming,
- 34% of the data was used to transmit video from YouTube, 14% of the data was used on Instagram data.

Although prices of data tariffs in the Czech Republic are higher than the EU average according to DESI 2019,[7] the consumption of Czech customers is close to that of mobile customers worldwide. This fact is illustrated by the Tefficient report in the evaluation of mobile network customers for the first half of 2019.

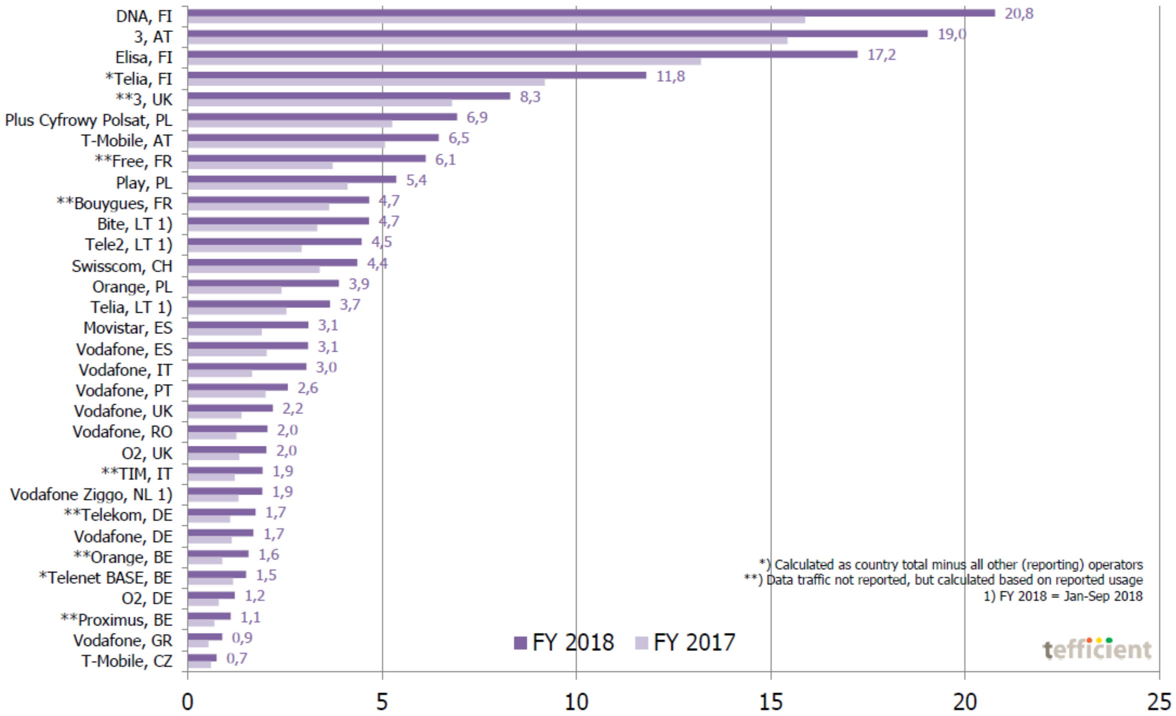

Figure No. 6: Example of monthly data usage in GB per 1 SIM card provided by European mobile network operators (Source: www.tefficient.com)[8]

5 Security and Risks Related to 5G Networks

Many aspects of security need to be taken into account when constructing 5G networks, both nationally and internationally. Therefore, when planning and constructing networks, it will be necessary to address security risks and place emphasis on ensuring the privacy of their users when selecting individual suppliers. It will be necessary to avoid purchasing all network elements or complex solutions from one unproven source. In this regard, the state will support solutions that will not jeopardise national security and are in line with the action taken by the European Union.

5.1 Risks

For ease of reference, the risks of electronic communications networks (both 5G and previous mobile systems) can be divided into two categories in terms of potential attackers: external cybernetic threat actors (states, hackers, cybercrime groups) and providers with malicious intent (hardware, software or service suppliers). However, it is necessary to reflect that this division is not strict and these groups of attackers may be interconnected. For example, a state actor may abuse their influence on a supplier and penetrate the network through it. In addition, so-called insiders – individuals working in the supply chain with their own

[7] https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic.

[8] https://tefficient.com/wp-content/uploads/2019/09/tefficient-industry-analysis-3-2019-mobile-data-usage-and-revenue-1H-2019-per-operator-5-Sep.pdf.

agenda, which may be in the personal interests, economic interests or interests of external actors, also pose a risk. In terms of CIA triad risks, the security of data sent through 5G networks can be evaluated as follows:

Confidentially: Confidentiality, i.e. ensuring that data is not accessed by unauthorised actors, is a problematic aspect of electronic communications networks, which applies both to 5G networks and the previous mobile systems. The risk of attacks by external actors is low, but there is a significant risk on the part of some suppliers, with regard to their close links to state actors with potentially problematic interests, which are against the interests of the Czech Republic. **Even when encrypted communication is used, network traffic produces a large amount of metadata that can be of value to an attacker**. The second problem is the possibility of breaking the encryption. Encryption can be broken in the future when sufficient technical resources (e.g. quantum computers) are developed. **If an attacker stores certain data, they can break it at a later time. Information gathered in this way may also be worthwhile for the attacker.** The structure and nature of electronic communications networks is then an effective tool for collecting this data for suppliers with malicious intent.

Integrity: Data integrity (i.e. the assurance that data has not been altered by a foreign actor) is the least threatened area in electronic communications networks, provided that end encryption is used. Data is only present on the network for a short period of time, thus reducing vulnerability. Only if the attacker had the encryption key or other form of *backdoor* that allows fast decryption, would they be able to compromise the integrity of the data in real time.

Vulnerability: Each digital infrastructure of 5G networks can be associated with a variety of generic technical weaknesses. These can affect SW or HW or arise from possible security errors in internal security control processes. Due to the fact that 5G networks will be largely SW-based, there is a significant risk and vulnerability of the entire network due to improper SW development, deliberate programming of SW with unsolicited specific functionality for monitoring, collecting and sending information via hidden interfaces via backdoors. In addition, it is likely that other 5G network security vulnerabilities may arise, especially in connection with software transition and virtualisation through Software Definition Networks (SDN) along with Network Functions Virtualisation (NFV)

Availability: Data availability is the primary vulnerability of electronic communications networks. Although decentralisation increases the resilience of network to external threats, the strengthened role of suppliers in 5G networks increases vulnerability on their part. In the event of an attempt to disrupt data availability, suppliers have a significant advantage in the form of direct network control or the ability to control some of its elements through backdoors, etc. When an operator, provider or attacker makes key parts of a network inoperable from outside, important data transmitted through the network will almost certainly become unavailable.

5.2 Emphasis on supply chain security

Although 5G networks do not bring new fundamental weaknesses and, on the contrary, can strengthen security features against external attacks due to their higher degree of decentralisation, **they show increased vulnerability to abuse by suppliers. This is mainly due to the increased complexity of the computing devices necessary to operate 5G networks**. These devices may contain both software and hardware weaknesses. In the case of unintentional security vulnerabilities, they pose an increased risk of attack by external actors, but above all, they represent the possibility of deliberate abuse by the supplier. As the Huawei Cyber Security Evaluation Centre (HCSEC) report in the UK pointed out, not even developed states are technologically capable of examining a sufficient number of suppliers' products in a timely manner, and close cooperation between state and supplier, as in this case, is the key. **Thus, computing devices that will be part of the 5G networks infrastructure can hide both inadvertent and intentional weaknesses utilised by the supplier, which cannot be effectively traced and eliminated**. However, 5G networks cannot operate without these computing capacities. For example, antennas using signal beam formation, one of the key elements of 5G networks, need high computing power. **It is highly unlikely that the state will be able to test that none of these devices contain software or hardware weaknesses by the supplier, and it will therefore be forced to trust the supplier of these technologies**.

The second, problematic security aspect is the lack of efficient peripheral and core division in an effort to reduce latency**. Due to this new decentralised structure, there is no possibility to split networks into core and peripherals, which was a method of preventing suspicious suppliers from entering into sensitive parts of the network (core) in the previous generations of networks and allowing them to participate only at the periphery where there is significantly lower risk**. Potentially sensitive data may be routed through any part of the 5G network and misused by the supplier.

Another risk associated with 5G networks is the emphasis on the development of the Internet of Things (*IoT*). Allowing large quantities of IoT devices into the network is likely to pose a significant vulnerability –IoT devices face a long-term problem with their very low level of security. Such a device connected to the 5G network can become a weakness through which attacks on other components can be conducted.

5.3 Activities of the Czech Republic in the 5G cybernetic security

The Czech Republic has contributed to the solution of 5G networks cybernetic security through a series of recommendations called *Prague Proposals*, which focuses on four areas (politics; technology; economy; and security, privacy and resilience) to summarise the main perspectives and principles which should be followed to ensure the safe construction of 5G networks, especially where supply chain security is concerned. These conclusions are globally applicable, with some states (e.g. the US) officially subscribing to them.

It is in the interest of the Czech Republic to maintain and further develop the high standard of security that has been developed by non-state actors and, in cooperation with state structures, has maintained the relative cybernetic security of state institutions, enterprises and citizens for years. The Czech Republic is also supporting and participating in the launch of the new EU system of security certification of ICT products, processes and services through the National Cyber and Information Security Authority. This EU certification system will serve as one of several effective steps that will be needed to ensure 5G network security.

6 International, European and National Context

6.1 Prediction of 5G network development

Ericsson expects[9] that the development of 5G networks will be enormously rapid, initially focused primarily on personal communications – by the end of 2024, the coverage of 5G networks will reach 45% of the world's population, i.e. approximately 1.9 billion customers will use the 5G network services. More than 20% of mobile data traffic will be through 5G networks. During this period, the total volume of the data stream is to be increased eightfold, mainly due to increased consumption of content by end-users.

By the end of 2023, more than half of North American (approx. 63%), nearly half of Asian (approx. 47%) and one fifth of Western European mobile users are to be connected via 5G networks. The world's largest penetration is expected in China, where nearly 600 million people are expected to use 5G networks by 2022.

In addition, Ericsson estimates that there are approx. 1 billion mobile IoT connections globally. This figure should rise to 4.1 billion in 2024. The main sectors that will benefit from IoT will be health care and transport,

---

9 Ericson Mobility Report: June 2019 (https://www.ericsson.com/49d1d9/assets/local/mobility-report/documents/2019/ericsson-mobility-report-june-2019.pdf).

where the system will allow the deployment of autonomous driving, bringing benefits in terms of traffic flow, accidents and overall traffic safety through the introduction of traffic automation.

As early as 2018, the GSMA[10] identified 154 mobile service operators in 66 countries who had started testing 5G network technologies. A number of mobile operators have also tested key 5G technologies incorporating new radio (NR) interfaces that operate in spectrum bands that have not previously been used in mobile services. So-called *Network Slicing* has also been tested, which supports the provision of services tailored to specific types of customers, as well as a combination of technologies called *Massive MIMO*, which is needed to achieve very high data rate and supports very low transmission latency.

6.2 European strategic activities to support 5G networks

The European Commission has published a Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – the **5G Action Plan for Europe** No. COM(2016) 588of 14 September 2016.[11]

The Communication notes that 5G technology "will support new types of applications based on the connection of devices and objects (so-called Internet of Things) and universality of use thanks to software virtualisation allowing the use of business models in various fields (e.g. transport, health care, manufacturing, logistics, energy, media and entertainment). While these transformations have already started on existing networks, they will require 5G to reach their full potential in the coming years".

It stresses the need for a coordinated approach to 5G network solutions. The following are identified as key factors:

- Encourage the timely deployment of 5G networks in large urban centres and along major transport routes;
- Encourage Europe-wide multi-stakeholder testing;
- Facilitate implementation in a given industry through a venture capital fund to support innovation based on 5G networks;
- Unite leading actors in their efforts to enforce worldwide standards.

Other items in this document to achieve the above objectives set out the procedure for spectrum identification, harmonisation and authorisation, monitoring fibre optic link deployment, network cell establishment, standard availability and implementation, conducting technological experiments, etc.

According to the European Commission, national economies could gain up to EUR 113 billion through the deployment of 5G networks by 2025, with global benefits estimated at more than USD 12 trillion by 2035.

In relation to the 5G Action Plan for Europe, it is necessary to mention the European legislation on electronic communications, which is concentrated in Directive (EU) 2018/1972 of the European Parliament and of the Council establishing the **European Electronic Communications Code.**[12] This essential piece of legislation is designed to support the development of 5G networks, starting with recital 24, which emphasises the integrity of 5G network coverage of urban areas and major transport corridors, through a number of other recitals to Article 54 on the timing of the frequency band allocations for 5G networks.

---

[10] Global Progress to 5G – Trials, Deployments and Launches, Global mobile Suppliers Association, July 2018

[11] https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan.

[12] https://eur-lex.europa.eu/legal-content/CS/TXT/?uri=CELEX:32018L1972

The European Commission has also addressed the cybernetic security of 5G networks in the context of the upcoming construction of the networks.[13]

The European Commission issued Recommendation No. 2019/534 of 26 March 2019, Cybernetic Security of 5G Networks. The recommendation addresses cybernetic security risks in 5G networks and, to this end, sets out guidelines on appropriate risk analysis and risk management measures at the national level, developing a coordinated European risk assessment and establishing a process to develop a common "toolbox" with the best measures for risk management.

The Commission's recommendation aims to:

1. assess security risks affecting 5G networks and take relevant action at the level of Member States,
2. coordinate risk management at the EU level,
3. develop a common set of measures to mitigate security risks related to 5G networks.

As part of these tasks, the Commission envisages including security certification and its framework throughout the system.

On 9 October 2019, Member States, with the support of the Commission and the European Cybersecurity Agency, published a report on an EU-wide coordinated risk assessment in the area of cybernetic security of 5G networks.

The EU Telecommunications Council followed this report and, on 3 December 2019, adopted conclusions on the importance of 5G networks for the European economy and the need to mitigate the security risks associated with 5G networks. These conclusions emphasise that 5G networks will be part of the crucial state infrastructure. One of the key messages of the conclusions is that the approach to 5G network security must be comprehensive and based on a risk assessment approach. Ensuring 5G network security is considered to be an ongoing process. Technical and non-technical factors need to be taken into account during the risk analysis, with important components coming from trusted suppliers only.

The Czech Republic has contributed to the solution of cybernetic security by a series of recommendations called the Prague Proposals from the International Conference on 5th Generation Networks Security held on 2 and 3 May 2019, opened by the Prime Minister of the Czech Republic. The Prague Proposals are globally applicable and have also been acting as an input into the debate on a common approach to securing the digital communications infrastructure at the EU level.

6.3 Key activities of the Czech Republic in support of digital agendas

Innovation Strategy of the Czech Republic 2019-2030 – The Country for the Future

The **Innovation Strategy of the Czech Republic 2019-2030** is crucial for the deployment of 5G networks. It covers key development strategies and concepts for the Czech Republic. It sets the basic objective and vision of the Czech Republic. By 2025, the Czech Republic should rank among the top ten most innovative EU countries, and by 2030, it should have moved forward and rank among the seven most progressive countries.[14] To achieve this, the implementation of related strategies is being gradually coordinated at the state administration level. Therefore, in accordance with the implementation of the government's Digital Czech Republic programme,[15] the Czech Republic intends to rank among the European leaders in the Artificial Intelligence. This is by nature closely related to the development of 5G networks and very-high-capacity networks in general.

---

13 https://eur-lex.europa.eu/legal-content/CS/TXT/PDF/?uri=CELEX:32019H0534&from=EN
EU coordinated risk assessment of the cybersecurity of 5G networks" z 9.10.2019: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=62132 (s.21)

14 According to the Global Innovation Index.

15 The Government approved the document by Resolution No. 255 of 15 April 2019.

From the perspective of 5G networks, the document accentuates research and development, support for start-ups, digitisation of the state, production and services, mobility and related construction activities in relatively great detail. Excellent research in academia and business requires financial and non-financial support and coordination at the highest level to maximise efficiency. For the successful and timely implementation of the Innovation Strategy of the Czech Republic 2019-2030, which is closely linked to this document and its implementation, effective use of existing and future EU support instruments is foreseen, for example in the Multiannual Financial Framework for 2021-2027, including Digital Europe, Horizon Europe, InvestEU, The Connecting Europe Facility, Creative Europe, etc.

National Artificial Intelligence Strategy of the Czech Republic (NAIS)

The **National Artificial Intelligence Strategy of the Czech Republic (NAIS)**[16] is a document which addresses the main areas in achieving the Sub-objectives of the Innovation Strategy of the Czech Republic 2030 – a national priority specialisation of the Czech Republic in Artificial Intelligence – while one of the main objectives is the concentration of excellent AI R&D by building a European centre of excellence in the Czech Republic. AI R&D support is also focused on 5G technologies and applications, Industry 4.0, intelligent transport systems, automated and autonomous mobility, Big Data processing, Smart Cities, etc.

Digital Czech Republic

Digital Czech Republic is a programme with a strategic role at national level – it is the government's digitisation programme of the Czech Republic 2018+[17] – it covers three pillars and three sub-concepts, which form one logical whole. It deals with areas ranging from the interaction of the Czech Republic in the European Union in the digital agenda, through digital public administration to the preparation of the Czech Republic's society and economy for digitisation.

In 2019, the implementation plans of the Digital Czech Republic programme were also approved by a Government Resolution.[18] The basic strategic material was thus elaborated into three main implementation documents: Information Concept of the Czech Republic, Czech Republic in Digital Europe and Digital Economy and Society. Of these, Digital Economy and Society is essential for the deployment of 5G networks, as it sets Sub-objective 4.4. - Efficient development of telecommunications networks, taking into account the competitive market environment and the development of the digital economy, in order to achieve better availability of services at affordable prices.

Action Plan 2.0

Action Plan 2.0 to implement non-subsidised measures to support the planning and construction of electronic communications networks, which is currently in the approval process, aims to identify a range of existing barriers and increased financial demands adversely affecting the planning and construction of electronic communications networks and the existing financial barriers affecting the operation of these networks. The document outlines measures to gradually eliminate these negative phenomena. The first version of the Action Plan was immediately based on the National Plan for the Development of New Generation Networks,[19] Action Plan 2.0 builds on this previous version and identifies additional or unresolved barriers, including the design of solutions and their guarantors and development of high-speed electronic communications networks, a technical prerequisite for the development of 5G networks.

---

[16] The Government approved the document by Resolution No. 314 of 6 May 2019.

[17] The Czech Government approved the summary strategic document Digital Czech Republic by its Resolution No. 629 of 3 October 2018.

[18] This is Government Resolution No. 255 of 15 April 2019.

[19] The National Plan for the Development of Next-Generation Networks was approved by Government Resolution No. 885 of 5 October 2016.

Action Plan for the Memorandum on the Future of the Automotive Industry in the Czech Republic

As part of its activities aimed at the development of automated and autonomous mobility and related strategic documents, the MIT is also supporting the deployment of 5G networks in the Czech Republic, including support for reducing barriers to the deployment of 5G networks in urban and rural areas. The **Action Plan for the Memorandum on the Future of the Automotive Industry in the Czech Republic**, the implementation of which involves several key ministries, includes measures related to autonomous management and digitisation, i.e. supporting the development of high-speed Internet and related infrastructure of electronic communications networks along transport routes and open data to support the development of mobility and digital services, including creating an innovative environment for the creation, development and testing of new digital and mobile services.

In June 2019, the MIT, together with the Ministry for Regional Development, issued a document that helps Building Authorities and other entities to make fast and effective decisions on the coordination of the construction of high-speed Internet networks, the Methodological Working Tool, which addresses the relation between Act No. 127/2005 Coll., on Electronic Communications; Act No. 194/2017 Coll., on Measures to Reduce Costs of Introducing High-Speed Electronic Communications Networks; Act No. 183/2006 Coll., the Building Act; and Act No. 416/2009 Coll., on Accelerating the Construction of Transport, Water, Energy and Electronic Communications Infrastructure.[20]

National Plan for Development of Very-High-Capacity Networks

Strategies of the Czech Republic for the development of high-speed electronic communications networks and services so that they can also be used for networks.

Wireless Terrestrial Systems of the Fifth Generation (5G)

In March 2017, the Czech Telecommunication Office issued a document called **Wireless Terrestrial Systems of the Fifth Generation (5G),**[21] in which the first scenario of introducing this new system in the Czech Republic was proposed.

5G networks can be an effective tool for the development of *Smart Cities* according to a concept coordinated by the Ministry for Regional Development, which, inter alia, issued a methodology for the concept.[22] The methodology sets out the definition and components of a Smart City and addresses the synergy of transport, energy and ICT with a view to planned sustainable development. The document also contains sets of indicators that can be quantified and evaluated.

In connection with the above objectives, there is a significant increase in the financial support for applied research in the Czech Republic, especially in industry. Furthermore, massive financial support from EU funds is gradually stimulating the development of an industrial environment based on modern technologies, research, development and innovation.

Mobile communications strategy for security and rescue services

Strategic material in the process of preparation by the Ministry of the Interior. Its main pillar is the use of 5G networks to support the activities of security and rescue services, crisis management and other communication needs in ensuring public order, national security, property protection and public health. The

---

20 https://www.mpo.cz/cz/e-komunikace-a-posta/elektronicke-komunikace/narodni-legislativa-a-predpisy/metodicka-pracovni-pomucka--246718/

21 https://www.ctu.cz/bezdratove-zemske-systemy-5-generace-5g

22 https://www.dotaceeu.cz/getmedia/9c597c78-8651-43a8-8d94-bc9f19da74c5/TB930MMR001_Metodika-konceptu-Inteligentnich-mest-2015.pdf.

document focuses on the technological possibilities of ensuring communication needs, especially in the area of access to the radio spectrum and the possibility of using the networks of commercial operators.

7 Summary of Implementation Steps

7.1 Frequency allocation in the Czech Republic and the expected utilisation

5G networks will be different from previous technologies, among other things, because of the use of a much larger number of radio frequency bands.

The World Radiocommunication Conference of the International Telecommunication Union (ITU) in 2015 (WRC-15[23]) identified a number of bands suitable for IMT-2020 systems (as 5G systems are referred to by the ITU).

The following figure provides an overview of the radio frequency bands as the main current bands suitable for worldwide use by 5G systems:

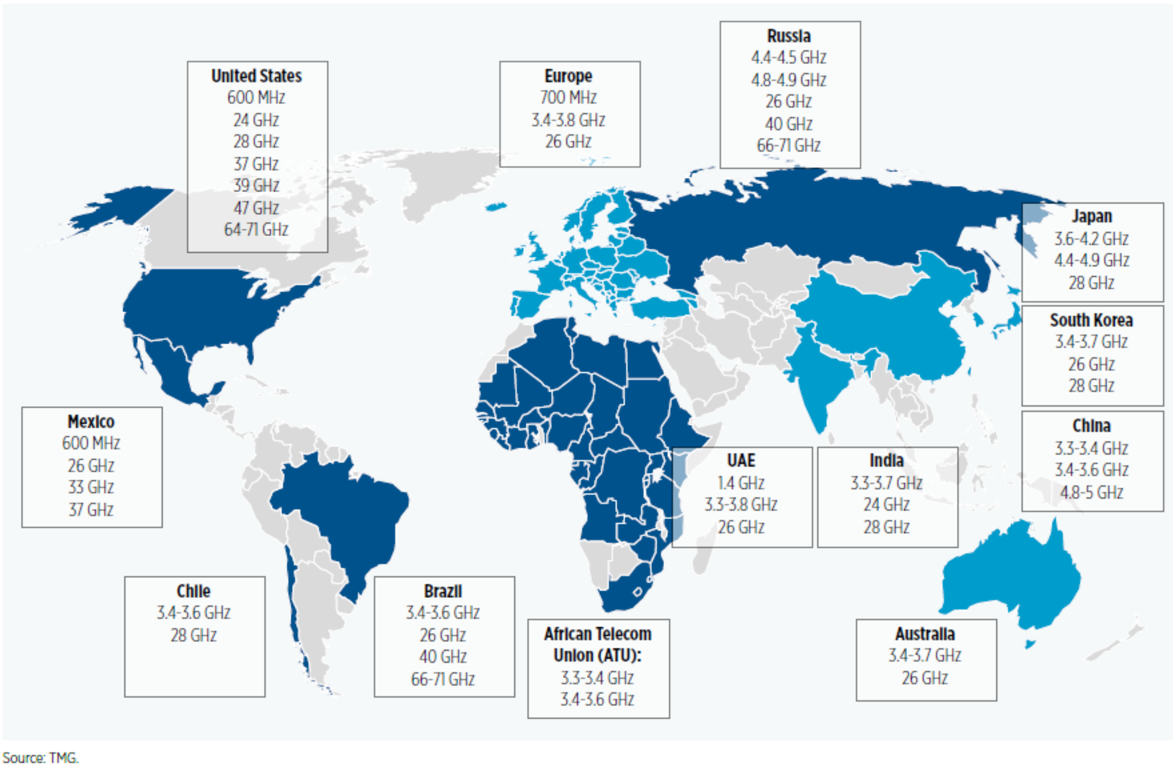

Figure No. 7: Overview of radio frequency bands suitable for the worldwide use by 5G systems (Source: TMG)

In Europe, the 700 MHz, 3.4-3.8 GHz and 26 GHz frequency bands have been identified as a priority for the deployment of 5G systems and the technical conditions for their use have been harmonised. In order to make these bands available in the EU Member States as soon as possible, EC Implementing Decisions on European Harmonisation in the 24.25-27.5 GHz Band had already been adopted on each of these bands before WRC-19. This conference decided to identify this and some other millimetre wave bands for the IMT-2020 after confirming the ITU studies, and also confirmed the conditions of their use. Within the EU, the use of 66-71 GHz and 40-43 GHz frequency bands has also been identified for the needs of 5G networks. These bands,

[23] https://www.itu.int/en/ITU-R/conferences/wrc/2015/Pages/default.aspx.

together with other bands already identified, form the basis for the entry of other operators into the 5G network market. Another EU measure adopted is the gradual adjustment of the technical conditions for the use of the bands for *MFCN* harmonised in the past,[24] so that 5G networks can be operated there or existing networks can be transformed into the 5G system. Harmonisation of other bands with frequencies of tens of GHz will follow.

The harmonisation documents issued in the Czech Republic are implemented by the Czech Telecommunication Office with general authorisations – the Radio Spectrum Utilisation Plan and general measures.

The bidding procedure in the form of an auction for the allocation of the 700 MHz radio frequency was initiated by a public consultation on 26 June 2019[25] on the text of the Tender for the allocation of the rights to use radio frequencies for the provision of electronic communications networks in the 700 MHz and 3400-3600 MHz frequency bands.

In this respect, it is also necessary to take into account the use of all mobile networks that have been harmonised so far, as well as the allocation of additional bands which will apply to the needs of both rail and road transport. Under the terms of the auction, the so-called development criteria will be defined: when, how and in what quality the transport infrastructure, especially the TEN-T railway and road network, should be covered.

It will also be necessary to discuss future campus networks.

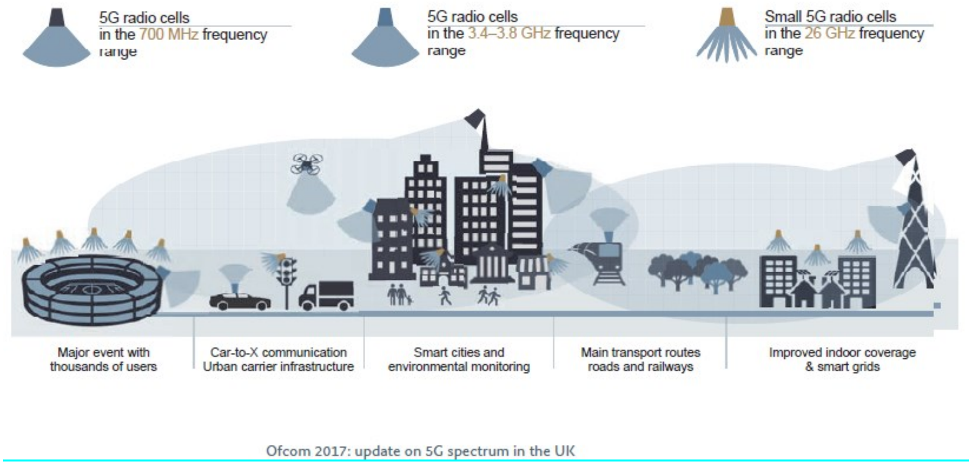

Figure No. 8: Example of using 5G priority bands for different application scenarios (Source: Update on 5G Spectrum in the UK, Ofcom 2017)

7.2 Basic prerequisites for the implementation of 5G networks in the Czech Republic

1. Support **rapid development of 5G networks in a competitive environment** and implement the measures outlined in Action Plan 2.0 to implement non-subsidised measures to support the planning and construction of electronic communications networks.
2. Facilitate **implementation of base stations interconnection by optical cables**, or other networks with very high capacity.
3. Create conditions for cooperation of electronic communications networks providers with owners or operators of buildings, street lamps and transport infrastructure in order to collocate technological elements of 5G networks.

---

[24] These are the 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz bands.

[25] https://www.ctu.cz/aukce-700/verejna-konzultace.

4. Support possibilities for **shared use of passive infrastructure (collocation)** for the development of 5G cells.
5. Support **construction of networks while maintaining control over public health protection**, i.e. prepare infrastructure and authorisation processes for the development and construction of 5G networks.
6. Support **5G spectrum harmonisation** at the global and European level.
7. Enable the **use of radio frequencies by 5G mobile networks** in all harmonised frequency bands below 6 GHz.
8. **Make the 26 GHz frequency band available**.
9. **Intensify cooperation with the historic preservation authorities** to facilitate the deployment of 5G networks.
10. **Strengthen the legislative and non-legislative framework enabling the economically beneficial use of the radio spectrum for test operation** in real market conditions.
11. Promote and **support cooperation between the electronic communications, the user industry** and **academia** and **research**.
12. Create space for dialogue and cooperation in the form of a forum or **alliance for the development and implementation of 5G networks** (alliance participants – telecommunication operators, entrepreneurs, state administration and academia). In addition to exchanging experience and formulating views on the development of 5G networks, it will help to identify opportunities for the use of 5G networks and the emergence of joint projects and provide the opportunity to formulate requirements for legislative, executive, standardisation and harmonisation processes.
13. Allow **all sectors concerned the opportunity to identify their potential and specify their requirements** for the development and use of 5G networks.
14. With maximum effort, support or initiate the creation of **activities leading to the implementation of projects using 5G networks in cities and villages** – *Smart City*/*Smart Village*, with an emphasis on developing, testing and implementing specific applications to improve citizens' quality of life.
15. Given the industrial character of the Czech Republic, prioritise the use of **5G networks in Industry 4.0** along with **Artificial Intelligence** applications.
16. Carry out evaluation of exposure to electromagnetic radiation in accordance with hygiene standards; when introducing new configurations of antenna systems, assess particularly the influence of the radiation pattern.
17. Given the enormous number of devices mainly connected to IoT and the shortage of the IPv4 address space, it is essential to ensure that 5G networks providers deploy and 5G service providers actively offer all services with access to IPv6 Internet, while maintaining access to IPv4 Internet through transition mechanisms (e.g. 464XLAT, NAT64/DNS64, Dual-Stack).
18. Permanently ensure the high level of cybernetic security of the constructed 5G networks and fulfilment of the Prague Proposals.

7.3 Support for *Smart Cities* solution

- For large cities (100,000 inhabitants and more) – in large cities, it is desirable to gradually construct 5G networks with all parameters that do not differ from the world standard. All types of services described above will apply. Due to the high concentration of population and enterprises of all kinds, technical solutions will be characterised by a relatively fast return on investment and excellent sustainability. Private-sector investors, whether financial or professional, will not have to rely on state aid – except for in the removal of legislative and formal barriers.
- In agglomerations with medium-sized towns from 10,000 to 100,000 inhabitants, the full deployment of 5G networks is also envisaged, linked to local conditions, both geographically and above all economically, depending on the industrial or agricultural production in the area. Again, issues with

return on investment and sustainability are not foreseen, but it will be appropriate to use various financial instruments, including public aid, to develop local industry and improve quality of life.

- For smaller villages and remote areas, solutions are expected that are sustainable while meeting the needs of inhabitants and visitors. For these areas, it is necessary to take into account the requirements for new technologies and services and tourism. It is assumed that 5G networks will differ in the density of their base stations and that higher-frequency bands will not be used. The possibility of providing state aid is also envisaged.

7.4 Coverage of major transport nodes and corridors

A very important aspect of developing 5G networks is the use of new technologies in transport. Covering transport nodes and corridors, in particular rail and road infrastructure belonging to the TEN-T network, is an essential step in meeting all the demands of high-speed electronic communication, whether by the population or by carriers. The goal is to cover these important areas with scaled 5G networks and services that match the importance and burden in these areas. These are investment-intensive solutions, so the possibility of using various forms of investment aid from public sources is being considered, especially in the construction phase of these networks.

Support from the European Structural and Investment Funds of the European Union focuses on important areas of society, therefore, it will be appropriate to consider the use of another programme, the Integrated Regional Operational Programme (IROP) managed by the Ministry for Regional Development.

7.5 Role of the state in the construction of 5G networks

Entrepreneurs in electronic communications and other related industries play a major role in the construction of 5G networks.

The state fulfils its role especially in the area of:

- **regulation** – the main objective being: **removing barriers** which impede the construction and operation of communication networks; and **ensuring competition rules,**
- **strategy** – where the strategic objectives of digitisation are an essential condition for the further development and specialisation of the national economy,
- **security** – in particular with regard to the construction and management of critical infrastructure, as well as ensuring cybernetic security,
- **support** – prioritisation and strategic specialisation, platform for communication of all actors, financing industrial research, etc.

In particular, the role of the state is essential in creating appropriate and non-discriminatory conditions for the establishment and safe operation of communication networks.

At the same time, the state must respond in a flexible manner and take appropriate legislative and executive measures to encourage the widest possible competition in the market for 5G services so that opportunities for developing these networks are available to the widest possible range of users.

An important aspect in this respect is the role of the state and state-run organisations to create appropriate conditions for the construction and utilisation of electronic communications networks, especially along the transport infrastructure. Other applications can be found in energy: specifically the transmission system. These networks can be part of the critical infrastructure and need to be approached as such not only during their construction but also in their management and operation.

Based on the results of mapping carried out at regular intervals by the Czech Telecommunication Office, or as part of the mapping commissioned by the MIT, and discussing these results with the professional public, certain locations can be targeted where the commercial intent will not be strong enough to motivate construction as well as economically maintain the operation of electronic communications networks and services at the level and quality required of 4G+ and 5G technologies. In these locations, the state will look for solutions that will be satisfactory for both end-users and service providers and/or operators of electronic communications networks.

8 Supporting the Development of a 5G Network-Based Ecosystem

Common platform for 5G networks

The complexity of the 5G networks environments linked to their applications and services requires a coordinated approach. Therefore, under the coordination of the MIT, a common platform should be established involving relevant entities, i.e. government representatives (ministries, regulators), operators, academia, industry using 5G networks (e.g. Industry 4.0, intelligent transport systems), representatives of cities developing *Smart Cities* and representatives of the designers of applications for 5G networks. Coordination within the strategy of the very-high-capacity network development is important so that both fixed and mobile networks and services develop in synergy.

Support for testing and pilot projects

In view of the long-term development of the implementation of 5G networks and applications based on them, it will be necessary to carry out continuous testing, experiments and development of pilot projects. In this context, it is necessary to simplify the conditions for the implementation of pilot projects and the operation of experimental operations. Therefore, legislative, economic, technical and other barriers that would impede the testing or experiments necessary for the development of 5G networks and applications must be identified and removed to allow testing of breakthrough technologies, for example through the creation of special modes for test environments (so-called regulatory *sandboxes*). One of the priorities is to enable new network solutions to be tested by research organisations outside the commercially allocated frequency bands (identification of bands and conditions for their use for locally limited testing of new device and service functions). At the same time, it is necessary to provide financial support for these activities, either through existing support instruments or by creating a dedicated 5G network tool.

Development of the Smart Cities concept within 5G networks – test cities

In line with the objectives of the Digital Czech Republic, it is desirable to develop 5G networks in the context of promoting the *Smart Cities* related, for example, to the operation of urban infrastructure, transport systems including cooperative transport systems and automation, water management, waste management, *e-government* and crisis management. As part of this activity, the MIT together with the MRD will announce a competition in which they will support several cities (or regions) that most appropriately link the applications of the Smart City concept with the development of 5G technology. The aim of this activity is to stimulate the faster introduction of 5G networks in the Czech Republic, but also to support the development of new unique applications for the needs of regions, industry and, as a result, the whole of the economy and society. There will be discussion of the creation of an initiative promoting the public interest in facilitating, accelerating and reducing the cost of construction of electronic communications networks in cities and villages, i.e. in the form of the *5G-Ready Municipality* concept.

The 5G-Ready Municipality initiative

The rapid and efficient construction of electronic communications infrastructure is in the public interest of the state. The objective of the initiative is to create synergies between urban and state-run organisations (municipalities, companies controlled by municipalities, state-controlled companies, preservationists, etc.) with the aim of reducing administrative burdens, speeding up communication between parties regarding the construction of networks and unifying access to easements and appurtenances. The Czech Republic aims to increase the number of cities and villages labelled 5G-Ready Municipality year-on-year, as the long-term public interest of the Czech Republic is to build a digital society. A state-of-the-art electronic communications infrastructure, whether fixed or mobile, is an essential basis for the successful economic development of municipalities and regions.

Support for industrial applications

In light of the increasing demand for the sophisticated processes which are the pillar of the Industry 4.0 initiative, the demand for a high-quality electronic communication and communication infrastructure is growing, so the collaboration of Industry 4.0 and mobile operators will be key to finding functional business models. However, it cannot be ruled out, for example, that an industrial park operator would be able to provide services within 5G networks providing applications for specific aspects of Industry 4.0. Coordination with the National Action Plan for Smart Grids (NAP SG) in electricity transmission and their telecommunications infrastructure is also appropriate. Cooperation with the automotive industry on the future of mobility will also continue with regard to the specific importance of the automotive industry for the Czech economy.

Cybernetic security

The European Commission issued Recommendation No. 2019/534 of 26 March 2019, Cybernetic Security of 5G Networks. The recommendation addresses cybernetic security risks in 5G networks and, to this end, sets out guidelines on appropriate risk analysis and risk management measures at the national level, developing a coordinated European risk assessment and establishing a process to develop a common “toolbox” with best measures for risk management.

The Czech Republic has contributed to the solution of cybernetic security by a series of recommendations called the Prague Proposals at the International Conference on 5th Generation Networks Security held on 2 and 3 May 2019, opened by the Prime Minister of the Czech Republic. The Prague Proposals are globally applicable and have also acted as an input into the debate on a common approach to securing the digital communications infrastructure at the EU level.

Education and development of digital literacy

5G networks will make a significant contribution to the development and ubiquity of digital technologies and online resources in education. They will be useful for education in the area of network knowledge and services provided by these networks, and for retraining when employees enter Industry 4.0. Fast and high-quality Internet connections and the use of digital technologies in schools and school facilities will support not only education systems at all levels, but also the growth of digital literacy. Education in responsible and safe behaviour in cyberspace is given a new dimension.

Special attention should be paid to the training (retraining) of practitioners in new technologies.

Use of European and national funds

At the European and national level, various forms of programmes can and will continue to be used in the future to support the development of 5G networks and 5G network applications and services, including research and development. The 5G network ecosystem has an overlap with other areas such as transport systems, including cooperative transport systems and automation (autonomous vehicles, automatic train control), computer processing and digitisation of health care, industrial automation and robotic automation, etc. Therefore, it will be appropriate to promote relevant synergies from both European and national sources in the context of the development of 5G networks. The specific financial support mechanisms available are listed in a separate chapter.

Specific possibilities of financial support from public funds

1. **Trans-European networks:** CEF is available for the construction or reconstruction of major transport nodes and corridors. The **Connecting Europe Facility** is an instrument to provide the Union’s financial assistance to trans-European networks in order to support projects of common interest in the transport, telecommunications and energy infrastructure and to exploit potential synergies between them. This investment funding instrument was set up to fund projects between 2014 and 2020, but it is envisaged

that CEF II will be used in a similar manner in 2021 to 2027. CEF II in telecommunications will not only cover the so-called communications corridors, but also the testing and implementation of new solutions for the use of 5G technologies in their particular relation. In addition to the corridor from Berlin via Prague and Brno to the south-east, the Czech Republic advocates that the key projects supported under CEF II include the Prague-Munich relation, especially as both the Czech Republic and Bavaria are areas where industry is highly developed and investments in research and development in the areas of Industry 4.0, the future of mobility, Smart Cities, Artificial Intelligence, etc. are strongly supported.

2. **Cohesion policy (ESIF funds) and other EU programmes**: The Competitiveness and Innovation operational programme for 2014-2020 is used to finance projects for the construction of 5G networks and high-speed electronic communications networks in general. Priority Axis 4, Development of high-speed Internet connection networks and ICT is strategically targeted by point 4.1: Increase high-speed Internet coverage. Calls prepared by the MIT in the last year received widespread support and are directed to areas where high-speed Internet infrastructure coverage is most needed. The development of digital infrastructure will also be given high priority in the operational programmes for 2021-2027 currently being prepared. Increasing the participation of Czech entities in the programmes directly managed by the EU remains a challenge for the Czech Republic. In particular, these are the Horizon Europe, Connecting Europe Facility and Digital Europe programmes, which will be launched in 2021, but activities and priorities of these programmes with a budget of approx. EUR 100 billion (Horizon Europe) and approx. 10 EUR billion (Digital Europe) are already under intensive preparation.

3. **Industrial research in digitisation, innovation, and specialisation:** The MIT is launching several programmes to support industrial research and innovation – in particular the completely new key programmes, TREND and The Country for the Future. Engaging in industrial research will be a priority for attracting investment in the above-mentioned technologies and applications. Development of applications and solutions using 5G networks will be one of the priority areas of the upcoming calls.

    a. **The Country for the Future Programme** (CFF). An essential step, strengthening the dynamics of the development of the business environment in line with the Innovation Strategy 2019-2030, is a **Government-approved programme of financial support "The Country for the Future"**. This programme will enable, among other things, the establishment and further development of Digital Innovation Hubs (DIHs) in the Czech Republic. These centres will provide detailed support to entrepreneurs, among others, in the digital transformation of their industrial enterprises, from strategic decision-making, through testing and validation of appropriate solutions to methodological leadership, or increasing the digital skills of their employees. Other areas of the support programme include support for the Start-up and Spin-off environment in the Czech Republic and support for the development of business innovations. The estimated overall spending on the programme is CZK 9,100 million, of which **CZK 6,100 million constitutes state budget expenditures**. The programme is designed for 2020-2027.

    b. **TREND Programme**. Another key instrument to support the development of innovation and industrial research in the business environment in the Czech Republic is the **TREND** programme prepared by the MIT, which is currently being implemented by TA CR. It is divided into two areas of support. The first is aimed at supporting the development of enterprises that are already advanced in the field of research and development, and the support thus aims at their further development in order to become the technology leaders. The second area of support is aimed at complete novices in applied research, while minimising the demands on the applicant's financial history. The programme will be implemented in 2020-2027: the main beneficiaries of the programme are the companies solving projects themselves or in cooperation with research organisations. The estimated total expenditure on projects in the programme is CZK 15 billion, of which almost **CZK 10 billion constitutes state budget expenditures**. Among others, this programme also plans to issue calls aimed to support projects that will focus on the development of specific new solutions based on 5G network technologies.

4. **Sector-specific research:** Other national programmes can also be used to support research and development in the field of digitisation, such as: the **TRANSPORT 2020+ programme by the Ministry of Transport** implemented by TA CR, one of the four specific objectives of which is Automation, digitisation, navigation and satellite systems. The TRANSPORT 2020+ programme is a seven-year programme implemented 1 January 2020 to 31 December 2026 with a total expenditure of CZK 2,437.5 million, of which CZK 1,950 million constitutes state budget expenditure.
5. **Support for investments with high added value:** In line with the Innovation Strategy of the Czech Republic 2019-2030, the Czech Republic is fundamentally changing the way it supports investments. The support under the Smart Investments pillar thus focuses on investments with high added value and especially those where cooperation with excellent research organisations or innovative small and medium-sized Czech enterprises will be ensured. To implement this strategy, a comprehensive amendment to the Investment Incentives Act, effective from 6 September 2019, has already come into effect. The following step is to prepare a new **Smart Parks for the Future** programme, which will support, inter alia, the deployment of high-speed Internet infrastructure, including 5G networks, in industrial zones, targeted at technologically advanced enterprises with environmentally friendly production.

9 Implementation Milestones of 5G Network Infrastructure Development

Key milestones of national and international importance are the following projects: *Smart Cities* in five selected test cities in 2020 and coverage of major transport corridors and 95% of the cadastral area of each city with more than 50,000 inhabitants in 2025. The milestones listed in the following overview are the main activities that the MIT, state administration authorities and many other institutions in cooperation with the private sector will implement in order to implement 5G networks in the Czech Republic. They will be implemented and supported in a number of partial steps.

2020

I. quarter

1. **preparation of Frequency Auction** and completing the necessary steps for the selection procedure for granting rights of use of radio frequencies for the provision of electronic communications networks in the 700 MHz and 3400-3600 MHz frequency bands
2. **CFF programme** – opening a call for implementation of innovation in enterprises
3. **preparation of the 5G Smart Cities project** – the MIT and the MRD will jointly prepare a project targeted at *Smart Cities* in the context of 5G network development
4. **launch of 5G platform**
5. development of cross-border cooperation with neighbouring countries (e.g. Germany) with a focus on the construction of 5G networks and development of applications and technologies using 5G networks
6. selection of five test *Smart Cities* in the context of 5G network development
7. conducting of the Frequency Auction of the 700 MHz and 3400-3600 MHz bands

8. **cooperation in the preparation of OP C** – focus on the construction of high-speed communications infrastructure

II. quarter

1. release of the 700 MHz band pursuant to Government Regulation No. 199/2018 Coll., on the Technical Plan for the Transition of Terrestrial Digital Television Broadcasting from the DVB-T Standard to the DVB-T2 Standard, and its Authorisation for Use in the Future 5G Networks
2. completion of the changes made to the Radio Spectrum Utilisation Plan for the 26 GHz band
3. launch of further experiments and testing of 5G networks
4. **Smart Parks for Future programme** – the industrial zone development support programme will now focus on the adequate construction of 5G networks for industrial applications
5. **TREND programme** – call for proposals (bonus) to support research and development of applications and technologies using 5G networks
6. finalisation of the Radio Regulations by the International Telecommunication Union

III. quarter

completion of the National Plan for the Development of Very-High-Capacity Networks in preparation for the new 2021-2027programming period

2021

update of the National Frequency Table according to the Radio Regulations of the International Telecommunication Union (following the ITU documents)

2023

coverage of 95% of the population of selected municipalities separately specified in the conditions of the 700 MHz Frequency auction according to the conditions of the 700 MHz Frequency Auction

2025

1. coverage of 100% of the rail and road corridors within the Europe-wide TEN-T network in the *Core Network* and *Comprehensive Network* according to the conditions of the 700 MHz Frequency Auction
2. coverage of 95% of the cadastral area of each city with over 50,000 inhabitants according to the conditions of the 700 MHz Frequency Auction
3. coverage of 70% of the population of the Czech Republic according to the conditions of the 700 MHz Frequency Auction

2027

coverage of 90% of the population of each district of the Czech Republic and 70% of the territory of each district of the Czech Republic under the conditions according to the 700 MHz Frequency Auction

2030

coverage of 99% of the population of each district of the Czech Republic and 90% of the territory of each district of the Czech Republic under the conditions according to the 700 MHz Frequency Auction.

10 Conclusion

When developing an electronic communications network infrastructure, technological changes around the world need to be taken into account, i.e. take into account in projects solutions that combine existing infrastructure with new possibilities resulting from the deployment of 5G networks, the Internet of Things, Big Data, Artificial Intelligence and other new technologies. For this reason, it will be necessary to create separate digital platforms that are naturally compatible with the global information space, which in turn will enable Industry 4.0 to introduce new organisational manufacturing processes, financial services and logistics. Over the next few years, digital technology should be implemented quickly and efficiently in all spheres of the economy through private equity, which in turn will contribute to increasing competition and economic growth, reducing product prices, increasing productivity and improving work skills.

The development of a global telecommunications infrastructure using the LTE standard will eventually reach its technological ceiling. The introduction of 5G networks will provide customers with nationwide mobile high-speed Internet access in places where people naturally gather (traffic nodes, health-care facilities, schools and school facilities, etc.).

While some countries have a head start in deploying 5G networks, other existing delays will be offset by the application experience.

Mobile operators should invest in business models based on three concepts – Gigabit high-speed connection for homes and entrepreneurs, *future campus networks* and digital industrial ecosystems. This will significantly enhance the efficiency of the nationwide deployment of electronic communications networks and enable operators to prepare commercially viable solutions for further upgrades to enable new business models to be implemented.

Increased attention will need to be paid to the cybernetic security of the entire 5G network ecosystem, as the enormous increase in the number of connected points and data volumes at high data rates and the connection of industrial control systems and other points will result in the increased impact of cybernetic attacks on the real world and the economy. In order to ensure security in the 5G network environment, increased attention will need to be paid to the security and credibility of the supply chain providing the 5G ecosystem for technologies, and to make greater use of Artificial Intelligence. The development of 5G networks is closely connected with the development of very-high-capacity networks and therefore the updating of 5G networks will be part of other national strategy documents, including aspects to facilitate, accelerate and reduce the cost of deployment of electronic communications networks. The construction of 5G networks is not an isolated activity, but part of a complex of building a gigabit society.

11 Terminology and Abbreviations

2G, 3G, 4G, 5G – refer to the type of mobile communication standard

2G (1991) generation with speed still based on analogue systems

3G (2001) based on the ITU's IMT-2000 standard with data rates up to 3.1 Mbit/s (UMTS)

4G (2010) data rate up to 100 Mbit/s, LTE technology

5G (emerging) based on ITU's IMT 2020 standards

3GPP The 3rd Generation Partnership Project is an agreement on cooperation in the field of mobile communications.

464XLAT A more advanced technology that adds a second translator to the NAT64 network translator. This translator ensures that a virtual IPv4 interface exists on the terminal device so that applications that require IPv4 strictly work.

4G+ An extended version of the 4G system that enables even faster data transmission by using multiple bands simultaneously.

5GIA The 5G Infrastructure Association – an international non-profit association whose goal is to support research and development of 5G networks in Europe and increase the competitiveness of European industry in the field.

AI Artificial Intelligence.

AR Augmented Reality – elements of the real world, which we see in smart glasses, for example, are enhanced by computer-processed information.

backdoor Method that allows circumvention of the authenticity of the proclaimed subject identity which normally prevents the user from unauthorised use of the computer system.

backhaul the part of the electronic communications network that connects the access network to the Core Network.

Big Data Big data files of millions of items.

bit/s, kbit/s, Mbit/s, Gbit/s Bit per second is a data rate unit; the unit indicates how many bits of information are transmitted per second.

brownfield An unused or underutilised property that is the remnant of industrial, agricultural, residential, military or other activities, which may be an individual building, a building complex, premises with buildings or an undeveloped plot.

CEF The Connecting Europe Facility, an instrument to provide the European Union's financial assistance to trans-European networks in order to support projects of common interest in the transport, telecommunications and energy infrastructure and to exploit potential synergies between them. The fund is guaranteed by the Ministry of Transport. See https://www.mdcr.cz/Dokumenty/Evropska-unie/Programy/Program-CEF.

CEPT (Conférence européenne des administrations des postes et des télécommunication) European Conference of Postal and Telecommunications Administrations.

CFF The Country for the Future – national programme of financial support approved by the government and implemented by the MIT.

Core Network The backbone network.

Comprehensive Network The entire network.

crowdsourcing Process of obtaining necessary services, ideas, contributions, assistance in solving problems provided by a large group of people.

DEP Digital Europe Programme.

DESI Digital Economy and Society Index – an index composed of several sub-indicators monitoring the level of EU Member States and their development in the field of digital competitiveness.

edge cloud A system that distributes clouds throughout the network.

edge computing, also microcomputing Important tool for solving problems with transmission security, data loss and response in various critical applications (e.g. Industry 4.0) – a transfer of computer technology and data processing from the centre to the edge, i.e. the source.

ECG Electrocardiogram, a record of the time change in electrical potential caused by cardiac activity.

eMBB Enhanced Mobile Broadband – enhanced high-speed and high-capacity mobile networks and services. These are services based on LTE technology.

EMS Emergency Medical Service.

ESIF The European Structural and Investment Funds (2014-2020) remain an important investment instrument for the Czech Republic under the European Cohesion Policy.

ETSI European Telecommunications Standards Institute.

EU European Union.

entertainment systems Digital entertainment systems placed on the dashboard of a smart car.

Fixed Wireless Access (FWA) Internet access using wireless technology.

Future campus networks Networks that are built in a certain area (premises, campus) densified to cover this essentially enclosed area.

GIS Geographical Information Systems.

GNSS Global Navigation Satellite System – a high-precision satellite positioning service.

GPS Global Positioning System – a passive rangefinder system for determining position and time on Earth and in the surrounding space.

GSMA GSM Association or Global System for Mobile Communications – a worldwide association of mobile operators.

hoax Fraudulent alarm message distributed via chain mail on the Internet.

HW Hardware – physical computer equipment.

FRB Fire Rescue Brigade.

IEEE 802.11p IEEE standard – Wireless access for moving environments (cars, trains) – a standard describing one of the possible methods of communication within C-ITS systems.

infotainment systems A composite of *information* and *entertainment* – a type of intelligence that subordinates the selection of topics and their processing to the purpose of evoking emotions and amusement.

IoP Internet of People – Internet application for communication of people on the Internet.

IoS Internet of Services – Internet-based software applications used to download, develop or share a specific software application, programme or platform.

IoT Internet of Things – communication of devices with one another.

IoHT Internet of Health-care Things.

IPv4/IPv6 Version 4 or version 6 Internet protocol.

IS2030 Innovation Strategy of the Czech Republic 2019-2030 – Country for the Future.

ITS Intelligent Transport Systems – systems with different forms or levels of communication, e.g.

C-ITS Cooperative Intelligent Transport Systems – transport systems or subsystems communicating with each other.

C2C Car to Car – communication between road vehicles.

C2I Car to Infrastructure – communication from road vehicles to infrastructure.

C2X Car to X – communication of road vehicles with another transport users.

ETCS2 European Train Control System

ITU International Telecommunication Union

Li-Fi Wireless technology that holds the key to solving the issues that 5G networks face. Li-Fi can transmit on multiple gigabits, and is more reliable, virtually interference-free, and uniquely safer than radio technology such as Wi-Fi or mobile technologies.

LTE Long-Term Evolution specification, 4th generation mobile communications.

malware Software designed to damage or break into a computer system.

Massive MIMO See MIMO below.

M2M Machine-to-Machine – communication between machines (see also IoT).

MHz Megahertz.

MFCN Mobile/Fixed Communication Networks 0150 – connection at a fixed location using a mobile infrastructure.

MIMO Multiple Input, Multiple Output.

mMTC Massive Machine-Type Communication – massive communication between machines.

MIT Ministry of Industry and Trade.

mmWawe technology A technology using millimetre radio frequencies.

NAP SG National Action Plan for Smart Grids – national action plan developed by the MIT to ensure an economically sustainable energy system operated with low losses and high reliability of electricity supply.

NAT64 One of the mechanisms facilitating the transition from IPv4 to IPv6; it aims to translate datagrams to enable communication with devices supporting different protocol versions.

Network Slicing Virtual breakdown of a network into multiple layers that are securely separated.

NFV Network Functions Virtualisation – a network architecture based on the technologies underlying the virtualised IT environment together with network functions virtualisation.

NGA Next-Generation Access networks.

NPSTC The National Public Safety Telecommunications Council – a federation of organisations whose mission is to improve communication and the interoperability of public security through joint management.

OP C Operational Programme Competitiveness – successor to OP EIC in the new programming period.

PPDR Public Protection and Disaster Relief.

piko or femto base stations Mobile communications base stations with range of the order of metres, with the femto range currently being the shortest.

R&D AI Research and development of Artificial Intelligence.

regulatory sandbox Operational tool for the effective application of regulatory requirements especially in heavily regulated areas, e.g. when developing new applications or services.

ŘSD Road and Motorway Directorate of the Czech Republic.

SDN Software Definition Network – software-defined network architecture.

spin-off Company that has become detached and independent of the parent company; it keeps hold of intellectual property, technology or a product that is later transformed into new products or services.

start-up Innovative business entity that starts a commercial activity.

SW (Software) computer software.

RIA Railway Infrastructure Administration.

TA CR Technology Agency of the Czech Republic.

TDD Time-Division Duplexing – transmission of time-division signals used to separate the transmission and reception of signals.

TREND New industrial research and experimental development support programme approved by Government Resolution No. 202 of 25 March 2019. The implementation is guaranteed by the MIT, the support provider will be the Technology Agency of the Czech Republic (TA CR). The main objective is to increase the international competitiveness of enterprises, the secondary objective to increase the number of enterprises carrying out their own research and development activities and strengthen the direction of research organisations to internationally competitive applied research with benefits for industry and society. Více na stránkách https://www.mpo.cz/cz/podnikani/podpora-vyzkumu-a-vyvoje/novy-program-trend--244984/.

UHD video Ultra-High-Definition video.

URLLC Ultra-Reliable Low-Latency Communication.

Wi-Fi hotspot Internet connection via Wi-Fi or wireless connection.

WRC-19 ITU World Radiocommunication Conference 2019.