THE SUPPORT OF 5G NETWORKS DEVELOPMENT IN SLOVAKIA FOR 2020 - 2025

MINISTRY OF TRANSPORT AND CONSTRUCTION OF THE SLOVAK REPUBLIC

1. INTRODUCTION

In 2019, the Resolution of the Government of the Slovak Republic No. 206/2019 "Strategy of the Digital Transformation of Slovakia" was approved as a framework supra-ministerial strategy, aiming not only to achieve a significant increase in engagement of Slovakia in the European Digital Single Market, but primarily to prepare Slovakia for the nationwide digital transformation of the economy and society. From a global perspective, 5G is one of the most important technologies in the digital transformation.

The introduction of 5G technology will make a gradual change in mobile connection service provision with the potential to increase productivity and economic growth, and it is important that the whole country benefits from this. These new technologies are expected to change the way of interaction with new global opportunities and hitherto unpredictable new applications, change business models, improve lifestyles and increase productivity. It opens the door to potential revolutionary technologies, such as autonomous vehicles and advanced manufacturing, and enables the connection of thousands of devices, becoming part of our daily lives as the Internet of Things. This change will bring social and economic benefits in the long term, but it is conditioned by significant investment in infrastructure construction in the short and medium term.

The presented document aims to contribute to the digital transformation of Slovakia in terms of building a modern, functional and secure electronic communications infrastructure, as it is essential not only for the development of modern services for citizens and entrepreneurs, but to enable interconnectivity, mutual communication and effective management and supervision of all systems.

2. VISION

From the perspective of building 5G networks in Slovakia, the vision is defined as follows:

In accordance with the EU Digital Single Market Strategy, the Slovak Republic will build a top-notch 5G information and communication infrastructure and use the wide range of opportunities offered by this technology for the benefit of the development of Slovak society and economy.

The development of 5G networks in Slovakia and modern applications using them will support the transition to the Gigabit Society and, with the support of applicable legislation, will contribute to increasing the security of electronic communications networks. Connectivity enabled by new technologies will create new business opportunities, open markets and support citizens in their daily lives, e.g. by supporting new communication models at workplace or with the state administration. At the same time, it will provide access to information and services that can be expected to spread to daily lives more than ever. Quality digital infrastructure is the cornerstone of modern industry (Industry 4.0); it will create new opportunities for economic growth and open up new market opportunities.

3. OBJECTIVES

In order to achieve the vision in terms of building 5G networks in Slovakia, which will bring rapid deployment of 5G networks and create new opportunities for domestic businesses and support future investments, mutual cooperation of state authorities, state and public administration, operators and providers of electronic communications networks and services, all sectors of the national economy as well as research and academic institutions is essential.

This will be ensured by coordinated approach of all stakeholders while fulfilling the objectives of key topics, in particular:

- to ensure the efficient use of the frequency spectrum by reorganizing the 3 400 - 3 800 MHz frequency band (hereinafter referred to as the "3.6 GHz band") and to allocate frequencies for 5G networks before the expiry of the current individual permits,
- to release the 26 GHz frequency band based on market demand,
- to meet the development criteria and coverage conditions of operated sections of motorways (D), expressways (R), operated sections of pan-European railway corridors and inland waterways of international importance and provide the Slovak population with 5G networks using the frequencies already allocated, as specified in individual permits,
- to prepare and approve a new law on electronic communications so that it will be effective in the 3rd quarter of 2021,
- to prepare and approve the amendment to Act No. 69/2018 Coll. on Cybersecurity and on the Amendment to Certain Acts, which will define security measures and requirements for the procurement and operation of 5G technologies and networks.

The measures to achieve the objectives that need to be taken to fulfil the vision are described in more detail in Chapters 7 to 11.

4. SWOT ANALYSIS

The shortcomings of the current situation in Slovakia include in particular:

- insufficient support of electronic communications undertakings in the construction of optical network infrastructure by public authorities,
- inefficient mutual cooperation of electronic communications undertakings as well as entities from other network industries in the construction of infrastructure (infrastructure sharing),
- insufficient coverage of high-speed infrastructure in areas with lower population density,
- duplicate infrastructure coverage of several electronic communications companies in one location (e.g. within buildings),
- inconsistent interpretation of conditions for the construction of new optical infrastructure, or modernization of existing infrastructure by building authorities,
- insufficient coordination and definition of competencies within state administration bodies and local governments in the application of valid laws and
- implementation of national strategies for digital infrastructure development.

The comparison of positives and negatives and the current starting position and the future development outlook is shown below.

STRENGTHS	**WEAKNESSES**
• growing interest of the population in new digital multimedia services • developed competition in the electronic communications market • continuous increase in mobile broadband coverage • growing economy and increasing employment levels associated with skilled ICT workforce	• insufficient investment in local networks in locations with high investment costs and low return on investment • willingness of electronic communications network operators to invest in next generation networks, including optical networks, resulting from long-term economic returns and duration of construction proceedings • inconsistent application practice in network construction • insufficient digitalisation of economy and public administration • insufficient legal certainty in the area of network sharing from the point of view of competition rules
OPPORTUNITIES	**THREATS**
• building the Gigabit Society and creating new 5G technologies • the availability of funding for the building of high-speed electronic communications networks under the new programming period • reduction of investment costs of electronic communications network operators through mutual infrastructure sharing • new legislative framework for electronic communications • gradual reduction in the gap in high-speed connection access between rural areas and large cities	• administrative and investment complexity of building new generation networks • effective use of 3.6 GHz frequency band • issues with releasing 26 GHz frequency band • new threats regarding the cybersecurity • transparency of information on security and impact of new technologies on public health • unbalanced requirements of some local governments in building electronic communications networks • lack of skilled ICT workforce

5. 5G TECHNOLOGY

The fifth generation of wireless networks, also known as 5G or IMT-2020, resulted from the development of previous generations of wireless networks (i.e. 2G, 3G and 4G). This generation of wireless technology is thus the next stage in the development of previous and existing mobile radio access technologies.

Essential role with regard to the introduction of 5G technology constitute:

a) Radiocommunication Sector of the International Telecommunication Union (ITU-R), which aims to ensure the efficient use of the frequency spectrum and the non-interference operation of radiocommunication equipment in cross-border communication among all ITU Member States,
b) 3GPP (3rd Generation Partnership Project)[1] and
c) 5G PPP (5G Infrastructure Public Private Partnership)[2].

The ITU-R has defined three application groups for 5G, which form the basis of requirements for various scenarios such as Industry 4.0, intelligent transportation systems, supply networks for smart cities, e-Health, as well as new areas such as augmented reality or holography:

a) **Enhanced Mobile Broadband (eMBB)** - the application environment is characterized by high bit rate, mobility, high bandwidth, increased spectral efficiency and high capacity of terminal connections in the cell and is therefore focused on applications that need high bit rate, such as streaming video with ultra-high resolution or mobile virtual reality applications.

b) **Massive Machine Type Communication (mMTC)** - the application area of machine type communication is characterized mainly by radio transmission with high energy efficiency (sensors connected for 10 years or more), high capacity for connecting devices. Therefore, this application area will focus mainly on the Internet of Things, e-Health, Industry 4.0, smart logistics, environment monitoring, smart grids or smart agriculture.
In particular, machine type communication requires a high density of individual connections with the lowest possible energy consumption. Ubiquitous sensors will enable tracking, monitoring and other processes on a large scale in applications of smart cities and buildings, industry, agricultural production, etc.

c) **Ultra-Reliable and Low-Latency Communication (URLLC)** - the application area with high reliability is characterized by high connection quality, availability and resistance to interference. Ultra-Reliable and Low-Latency Communication applications focus on crisis services (real-time critical data transmission), transport (intelligent transportation systems), infrastructure, healthcare (monitoring of vital data) with regard to personal and public security, or applications used in in the intelligent production.

Despite building the 5G network, the 4G network (LTE-Advanced) will continue to expand and technologies will continue to evolve. Many of the new technologies and

[1] https://www.3gpp.org/about-3gpp, an initiative based on the cooperation of telecommunications standardization organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).
[2] https://5g-ppp.eu/, a joint initiative between the European Commission and the European ICT industry (ICT manufacturers, operators and providers of electronic communications networks and services, SMEs and researcher institutions).

functionalities planned for 5G networks are already used in the 4G network or may be implemented in the 4G network in the future.

Figure 1 shows the continuous development of LTE over time according to 3GPP technical specifications.

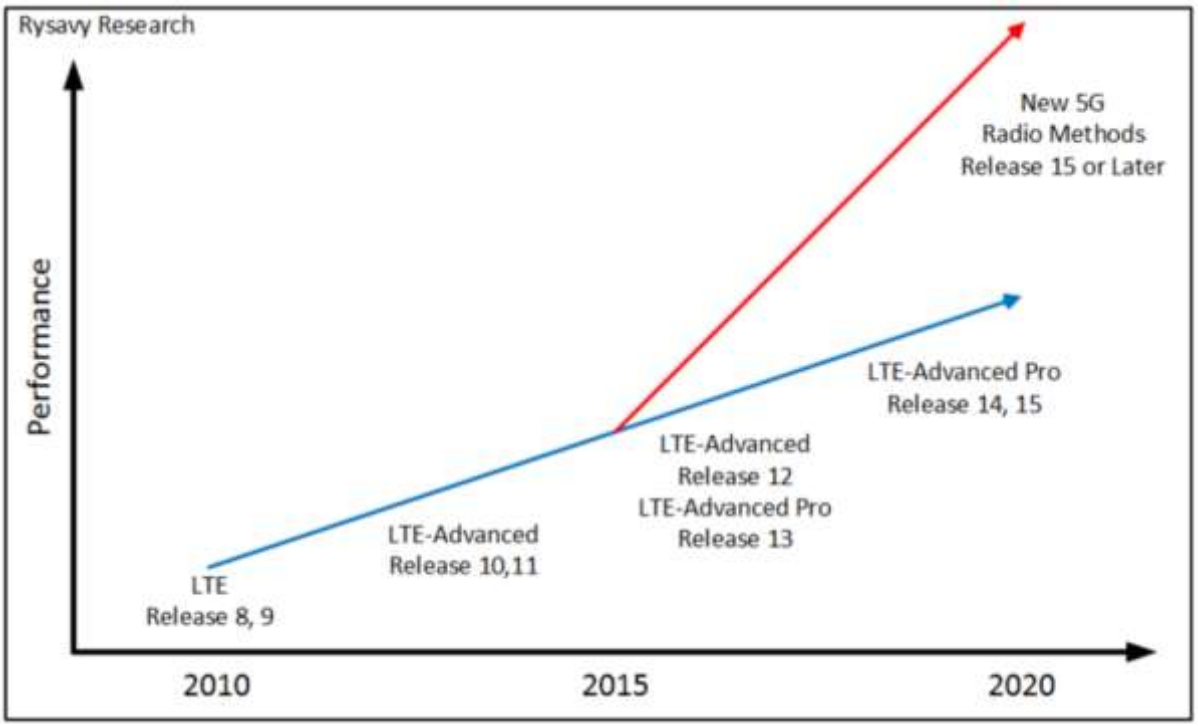

Figure 1 Continuous technological development of LTE and 5G according to 3GPP

Compared to the 4G network, 5G achieves different parameters, for example:

- higher transmission speeds (depending on the frequency band used) for the end user,
- high density of connected mobile devices per square kilometre (more than a million devices – depending on the frequency band used),
- latency below 4 ms (for eMBB applications), or up to 1 ms (for URLLC applications, i.e. depending on the use of the application area, up to 10 times lower than for 4G),
- higher energy efficiency and higher spectral efficiency.

The below Figure 2 documents the difference between the 5G and 4G parameters.

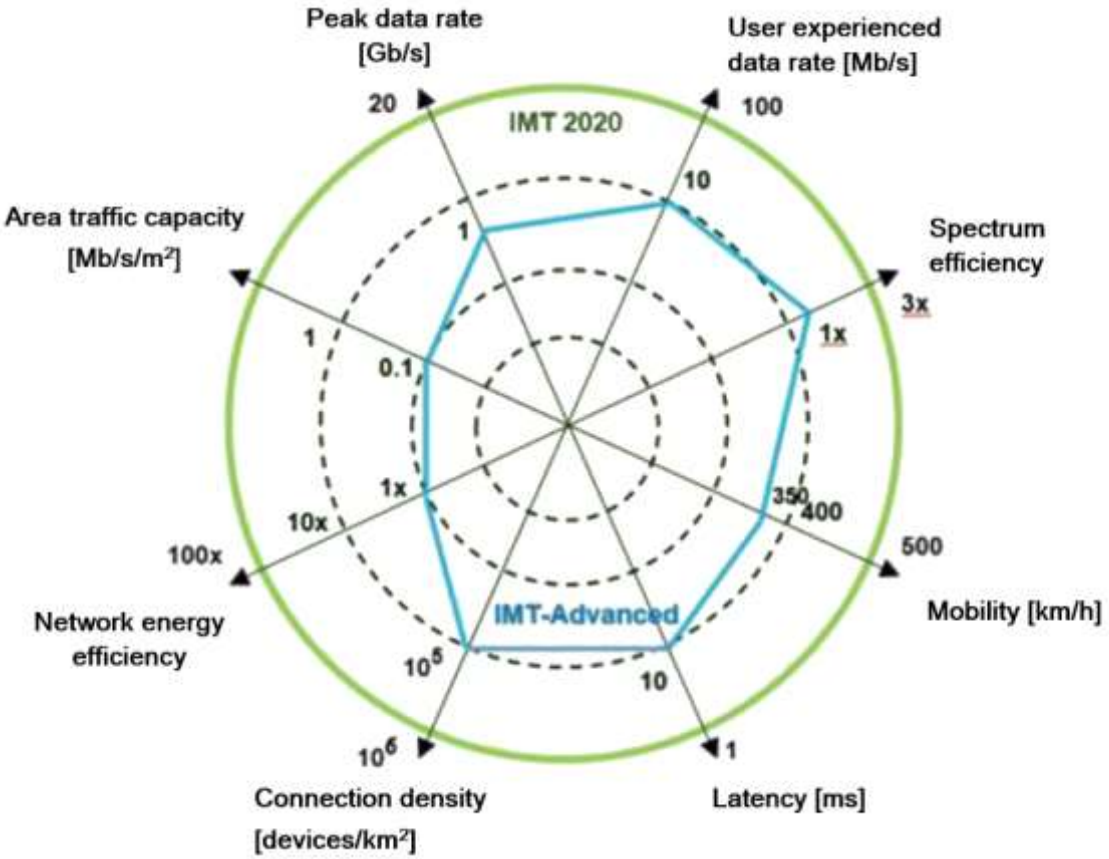

Figure 2 Comparison of 4G and 5G radio networks characteristics (ITU)

One of the key components of the new 5G interface will be miniaturized multi-antenna systems Massive MIMO (Multiple-input Multiple-output), i.e. multi-element antenna arrays employing multiple propagation paths for radio transmission. These allow individual users to route and receive their own signal to the appropriate base station while avoiding interference. This will increase the efficient use of the spectrum, i.e. the transmission capacity will increase. This means that the 5G antenna array will direct its radiated power in real time only to the desired mobile device. Especially in high frequency bands, it is possible to create antenna arrays with a large number of elements in a relatively small space, and the radiating characteristic of the antenna array is able to adapt to actual real-time traffic and thus direct its radiating maxima (lobes) to the required mobile devices.

6. 5G APPLICATIONS

5G technology will strengthen a wide range of future industries from retail to education, from transportation to the entertainment industry, and smart home services to healthcare. Researchers predict the global, social and economic consequences of 5G that will benefit the entire economy and society. Below are just some examples of the applications enabled by 5G technology.

6.1 Industry 4.0

In industrial production, the seamless data exchange between machines, devices, humans and robots will become increasingly important. With 5G, the number of quality-assured and energy-efficient connected devices and components with guaranteed quality and energy efficiency can be increased to hundreds of thousands per base station.

The logistics industry can use intelligent 5G technology for tracking of goods, fleet management, centralized database management, employee planning and real-time tracking and reporting.

5G technology will allow solving mobile control systems of industrial robots in real time. The probability of errors will thus be reduced to a minimum and for example courier services (without driver) will arrive at their destinations on time.

Data-intensive 3D model uploads for control or test equipment can also be performed on a mobile basis. 5G will then be a key element in the flawless vertical interconnection of all operational processes, such as the management of equipment, resources and goods flows. In addition, these developments offer great potential regarding the applicability in a way compatible with the environment, in particular with regard to resource efficiency.

6.2 Smart Agriculture

In the future, 5G technology will also be used in smart agriculture. Agricultural processes have already been partially smart interconnected. This allows access to services such as optimization of machine settings, ideal fertilization and harvesting strategies, and far-reaching process chain automation.

With intelligent RFID sensors and satellite navigation service technology, farmers can track and easily manage livestock. Smart sensors may be used for irrigation control, access control and energy management.

6.3 Healthcare

5G will improve the provision of quality acute and standard medical care through telemedicine applications based on mobile communications and strengthen the provision of equal and quality healthcare and long-term care in urban and rural regions. This includes, for example, the interconnection of ambulances for the transmission of vital data to the hospital, remote treatment and telemonitoring of long-term patients. Further, it includes consultations between doctors using video transmission for acute care and specialists from other hospitals.

Smart medical devices will continuously monitor the patient's condition and activate an emergency alert. In the event of critical situation, hospitals and emergency services will receive timely warnings and can take the steps necessary to expedite diagnosis and treatment. The healthcare database will be accessible from any location and the data analysis collected can be used to research and treatment improvement.

6.4 Smart mobility and autonomous vehicles

As regards transport and mobility, we are at the beginning of the revolution that will impact on all areas of mobility. Automated and connected driving will improve road traffic safer and improve the flow of traffic so as to conserve resources and reduce harmful emissions. Smart mobility also offers opportunities to optimize parking management, for example using automated parking display systems. Moreover, 5G will increase interconnections between different modes of transport. This will facilitate the intermodal transport, as information on the fastest connections will be available immediately by changing or combining means of transport. In the field of applications, it will support the development of smart logistics by providing the selection of the efficient route in real time for route planning and transport of goods.

In the future, vehicles can communicate with smart traffic signs, surrounding objects and other vehicles on the road. Every millisecond is important for autonomous vehicles in order to avoid collisions and ensure the passenger safety.

6.5 Smart grid

Smart grid is a two-way communication network for the electrical network, where devices connected wirelessly can remotely control the status of electricity production, transmission lines and substations, monitor the user's energy consumption, adjust energy consumption of household applications, i.e. save energy and reduce energy losses.

Comprehensive provision of intelligent measurement systems is required to determine the consumption and supply of electricity, control heating systems or monitor electricity supply. 5G networks will enable the connect producers, network operators and consumers in local or regional structures, thus ensuring the communication necessary for smart grid applications.

6.6 Multimedia applications

5G technology will enable the development of applications such as augmented reality, mixed reality or virtual reality, etc. These applications will be useful not only in the field of digital entertainment, but also in the fields of healthcare, training and distance education, remote infrastructure monitoring, manufacturing processes, agriculture, or farming and environmental management.

Extended Reality (XR) applications are some of the most important edge applications in the industry. XR is an umbrella term for different types of realities, referring to all combined real and virtual environments and human-machine interactions generated by computer technology. It includes representative forms such as Augmented Reality (AR), Mixed Reality (MR) and Virtual Reality (VR) and areas interpolated among them.

7. FREQUENCY SPECTRUM

7.1 Baseline

In the upcoming years, a rapid increase in data transmission over mobile networks is expected, driven by new applications demanding large data volumes, transmission speeds, low latency transmission, as well as high demands on security and reliability (e.g. autonomous vehicles, telemedicine, augmented reality, virtual reality, 3D video, ultra high definition video). In order to support all of these requirements, electronic communications service providers will need sufficient bandwidth in the new bands of the frequency spectrum intended primarily for 5G services.

The propagation of radio waves depends on the frequency, and it is therefore important to meet the requirements for the coverage and capacity of 5G networks by appropriate combinations of the frequency bands used. In terms of propagation, low (up to 1 GHz) and medium (1 - 10 GHz) frequency bands have the potential to provide wide coverage, and high frequency bands (above 10 GHz) will be suitable for ensuring high network transmission capacity. Given the favourable propagation properties, frequency bands below 1 GHz are suitable especially for providing basic coverage and coverage of remote areas where a higher range or penetration into buildings is required. Medium frequency bands represent a compromise between coverage and transmission capacity. High frequency bands provide high transmission capacity, but with the reduced range. The possibility of achieving high transmission speeds using antenna beam forming techniques and higher bandwidth efficiency are advantageous.

In order to ensure the cross-border functionality of equipment within 5G networks and prevent the mutual interference of individual bands, harmonization and coordination of the frequency spectrum for 5G networks is necessary.

The 700 MHz, 3.6 GHz and 26 GHz bands are the most likely bands to be used for 5G networks in Europe. These frequency bands are and will be made available to electronic communications network operators gradually in individual EU Member States on the basis of tenders organized by their national regulatory authorities.

It will be possible to provide 5G network services by operators and providers of mobile networks and services also in the frequency bands already allocated, currently used for 3G and 4G networks, depending on their use and availability.

7.2 Frequency bands for 5G networks

7.2.1 700 MHz band

In order to support the deployment of 5G networks, the Decision of the European Parliament and of the Council on the use of the 470 - 790 MHz band was adopted in May 2017[3] related to the coordinated release of the 700 MHz band to ensure the provision and development of new innovative digital services in urban, rural or remote areas. The above decision imposed on Member States to allow, by 30 June 2020, the use of the 700 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services

[3] Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union.

only under harmonised technical conditions established by the Commission pursuant to Article 4 of Decision No 676/2002/EC[4].

Pursuant to Decision No. 2017/899 of the European Parliament and of the Council,[3] the Ministry of Transport and Construction of the Slovak Republic approved the "Plan for the use of the 470 - 790 MHz frequency band in v Slovakia"[5], which stipulates the further release and reallocation (Digital Dividend II) of the 700 MHz frequency band (another 30% of the remaining UHF TV band, the first 20% of the UHF TV band was released in 2012 under the Digital Dividend I) for wireless broadband electronic communications services.

Pursuant to the above Decision, the 700 MHz frequency band was released within the specified period. Then the Regulatory Authority for Electronic Communications and Postal Services ("ÚREKPS") organised a tender in the form of an electronic auction, on the basis of which frequencies from the 700 MHz frequency band were allocated to operators and providers of mobile networks and services. The validity of individual permits for the use of frequencies from this frequency band was set until the end of 2040.

7.2.2 3.6 GHz band

In its 'Strategic roadmap towards 5G for Europe: Opinion on spectrum related aspects for next-generation wireless systems (5G),[6] the Radio Spectrum Policy Group (RSPG) identifies the 3 400 - 3 800 MHz frequency band as the primary pioneer band for 5G use in the Union, the availability of which will be key for the success of 5G in the Union.

Frequencies from the 3.6 GHz frequency band have been determined for terrestrial systems capable of providing wireless broadband electronic communications services and their harmonisation is specified in the Commission Decision of 2008[7], gradually updated by the Commission Implementing Decision in 2014[8] and 2019[9].

The European Electronic Communications Code[10] imposes on Member States to allow the use of 3.6 GHz band or its major part for terrestrial systems capable of providing next-generation wireless broadband electronic communications services (5G) by 31 December 2020. However, a Member State may, in justified cases, extend this period, reviewing it at least every two years. Member States are also required to take all appropriate measures to facilitate the roll-out of 5G, including the 3.6 GHz band reorganisation, thus releasing sufficiently large blocks of the frequency spectrum[11].

By applying the harmonised technical conditions and base station parameters (block spectral mask elements, power limits) set out in the implementing decisions, Member States will prevent harmful interference, improve the efficiency of spectrum use and reduce

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[4] Decision No. 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision).

[5] https://www.mindop.sk/ministerstvo-1/elektronicke-komunikacie-8/strategicke-dokumenty

[6] Document RSPG16-032 final of 9 November 2016, "Strategic roadmap towards 5G for Europe: Opinion on spectrum related aspects for next-generation wireless systems (5G)".

[7] Commission Decision of 21 May 2008 on the harmonisation of the 3400 - 3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community.

[8] Commission Implementing Decision 2014/276/EU of 2 May 2014 on amending Decision 2008/411/EC on the harmonisation of the 3400 - 3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community.

[9] Commission Implementing Decision (EU) 2019/235 of 24 January 2019 on amending Decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3400-3800 MHz frequency band.

[10] Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code.

[11] Article 54 of the European Electronic Communications Code.

fragmentation in its use. However, cross-border agreements may be necessary to achieve this goal.

Currently, frequencies from the 3.6 GHz band are allocated for development mobile/fixed communications networks (MFCNs). The validity of individual permits allocating frequencies from the frequency band 3400 - 3600 MHz expires in 2025 and from the frequency band 3600 - 3800 MHz in 2024.

7.2.3 Frequency bands above 26 GHz

The use of 24 - 86 GHz bands for data rates of 10 Gbit/s and more was the subject of studies prepared for the World Radiocommunication Conference in 2019 (WRC-19). The possibilities of using frequency ranges for 5G for rates of 100 Gbit/s and above this limit are being explored in the long term (e.g. frequency ranges 92 - 115 GHz or 130 - 175 GHz).

For the development of 5G in Europe, the 24.25 - 27.5 GHz (hereinafter referred to as the "26 GHz") band was designated as pioneer band, being also supported by other regions. As for the 3.6 GHz band, the European Electronic Communications Code stipulates that Member States shall, by 31 December 2020, allow the use of at least 1 GHz from the 26 GHz band (provided that there is market demand and the absence of significant constraints) for terrestrial systems capable of providing next-generation wireless broadband electronic communications services (5G). However, a Member State may, in justified cases, extend this period, reviewing it at least every two years.

According to the current NTFS, the 26 GHz band in the range of 24.25 - 26.5 GHz is primarily allocated for civil use, and in the range of 26.5 - 27.5 GHz for military use. The 27 - 27.5 GHz band is allocated for civil use for the inter-satellite service. As part of the NTFS preparation for 2021, it was agreed to release frequencies from the 26.5 - 27.1 GHz band for civil use.

The 24.549 - 25.053 GHz / 25.557 - 26.061 GHz (2×504 MHz) band is used for point-to-point, or point-to-multipoint connections by only one electronic communications undertaking with the validity of individual permits until 16.7.2021 and by military administrations with the validity of individual permits until 21.12.2021. Frequencies from the 25.080 - 25.445 GHz and 26.080 - 26.453 GHz bands are used to build point-to-point connections. Currently, the longest validity of individual permits in both frequency bands is until 31.7.2027 (gradually from the second half of 2021).

The 40 GHz (37 - 43.5 GHz) band also has the potential for a globally harmonized frequency range.

When allocating frequency bands for 5G, it is necessary to consider the demands of applications for the required bandwidth, which may constitute the need for channel blocks with a width of several GHz within the allocated frequency bands at high speeds and capacities required for transmission.

The use of frequency bands for 5G networks in different environments is described in Table 1.

Table 1 Use of frequency bands for 5G networks

Frequency band	Properties	Field of exploitation
700 MHz	**Advantages**: Better propagation properties compared to other frequency bands. Key band for basic indoor coverage. **Disadvantages**: Low bandwidth, low transmission speeds (at 4G level), lower density of connected devices, lower data capacity.	Transport corridors (rail, road, water). Securing data-efficient 5G applications. Use in both residential and rural areas due to better signal propagation.
3.6 GHz	**Advantages**: Better propagation properties compared to bands above 10 GHz, higher density of connected devices and higher transmission speeds compared to the 700 MHz band. Larger frequency bandwidth compared to the 700 MHz band. **Disadvantages**: Lower bandwidth, lower transmission speeds, lower data capacity, low penetration for indoor coverage, lower density of connected devices compared to the 26 GHz band.	Urban and rural coverage.
26 GHz and above	**Advantages**: Large bandwidth, high transmission speeds, high density of connected devices. **Disadvantages**: Unsuitable propagation properties in rugged areas compared to other frequency bands dedicated for 5G networks.	Densely populated areas and indoor areas with a high population density such as shopping centres, stadiums, airports, railway stations.

7.3 Measures to support of 5G development in Slovakia in the field of frequency spectrum

The frequency band availability and frequency bandwidth for 5G networks must correlate with the requirements of the 5G networks, such as high density of connected devices, high transmission speeds, low latency and high connection reliability.

Given the future use of 5G technology as well as the properties and conditions of electromagnetic wave propagation, in addition to the 700 MHz frequency band, the 3.6 GHz and 26 GHz bands will also be allocated for 5G networks in the Slovak Republic according to the population coverage criteria fulfilment. The dates of availability of the individual frequency bands allocated to 5G networks may vary.

7.3.1 3.6 GHz band

The effective use of the 3.6 GHz frequency band will require its reorganisation, which is also conditioned by a legislation amendment.

In order to support and invest in new 5G technologies, as well as in terms of market predictability, it will be necessary to reallocate frequencies from this band sufficiently in advance, depending on the results of the public consultation and market demand before the expiry of valid individual permits, for terrestrial systems capable of providing next generation wireless broadband electronic communications services (5G).

7.3.2 26 GHz band

The 26 GHz band for future use consists of 7 sub-bands, where in some sub-bands (25.053 - 25.445 GHz, 26.061 - 26.453 GHz) point-to-point radio relay connections are currently in operation, mostly used to interconnect base stations in LTE networks. The frequency spectrum in the 748 MHz range is allocated for radio relay connections.

Many individual permits will expire in 2021, making frequencies in the 2.066 GHz range available at the end of 2021. If the military administrations release the remaining 400 MHz, the 2.466 GHz range will be available.

In accordance with the conclusions of WRC-19, this frequency band is also allocated for IMT mobile communications, which will require more precise coordination for the efficient use of the frequency spectrum in the future[12].

In the near future, it will be necessary to discuss the release of the 27.1 - 27.5 GHz (400 MHz) band with the military administrations.

Entities responsible for measures to support the development of 5G in Slovakia in the field of frequency spectrum:

MTC SR, ÚREKPS.

[12] World Radiocommunication Conference (WRC-19, 28.10. - 22.11.2019) allocated the 24,5 – 27,5 GHz band for the mobile service on a preferred (primary) base.

8. INFRASTRUCTURE

8.1 Baseline

The basic requirement for future 5G networks is to ensure the transmission of ever-increasing data volumes using high data rates. This constantly increases the demands on the backbone networks and the distribution part of the network. In the case of 5G networks, they will have to meet not only the requirements for capacity or transmission speed, but also other requirements such as low latency.

A prerequisite for digital transformation and building an information society is the existence of a sufficiently robust, secure and functional high-speed communication infrastructure (optical networks as a basis for mobile and fixed networks of new generations), allowing for permanent interconnection of all systems, mutual communication and efficient management and supervision.

The connection among individual elements of 5G networks will be provided primarily by optical networks. Wireless connections will only be used in justified cases, where they will not cause any restrictions or degradation in network properties, or in the case of impossibility of optical connection construction.

In October and November 2020, two mobile operators of electronic communications networks in the territory of the city of Bratislava launched a test commercial operation of the 5G network.

8.2 Measures to support of 5G development in Slovakia in the field of infrastructure

It is desirable that Slovakia continues to invest in the support of construction of a high-capacity connection, mainly in areas where such a connection is lacking. In geographically demanding areas, where the cost per household covered exceeds a market unprofitable threshold, the commercial market will not build coverage. In the given areas, it will be necessary to support the market and ensure the availability of high-capacity broadband services for all Slovak citizens in accordance with the **National Broadband Plan** using European funds for the development of electronic communications infrastructure and interventions of other available financial instruments.

The Ministry of Investment, Regional Development and Informatization of the Slovak Republic (hereinafter referred to as the "MIRDI SR") in cooperation with the Ministry of Transport and Construction of the Slovak Republic (hereinafter referred to as the "MTC SR") will support the construction of gigabit optical connection available in accordance with the EU Gigabit Society Strategy and measures of the 5G Action Plan for Europe and the Tallinn Roadmap.

Support for the development of 5G networks in Slovakia and the National Broadband Plan are coordinated and complementary documents so that mobile service operators can plan investments and schedule for 5G network construction.

It is also important to create the conditions for effective cooperation of electronic communications network operators in the construction of infrastructure, so as not to duplicate parallel coverage. For the development of 5G networks and the rapid achievement of goals with the rational use of funds, it is necessary to **create the Atlas of Passive Infrastructure** and the effective functioning of the **Single Information Point**, in particular compliance with the rules by all stakeholders.

Promoting effective cooperation of network operators in 5G construction should include clear rules for 5G network sharing. Uncertainty in the rules for network sharing can significantly reduce the rate of network sharing and thus jeopardize technological innovation.

Cross-border road corridors and train connections are expected to be key areas for the first phase of new mobility applications, and funding from cross-border projects such as the "Connecting Europe Facility" is therefore essential[13]. In order to obtain funding from such programs, it will be necessary to identify projects of common interest in the field of digital connectivity infrastructure required to meet the EU digital single market objectives.

In order to ensure the geographical availability of electronic communications services related to the development of 5G networks, the **following objectives** must be met:

- coverage of all operated sections of motorways (D) and expressways (R), operated sections of pan-European railway corridors and inland waterways of international importance in the territory of the Slovak Republic until 2025 (also using the frequencies already allocated),
- 5G coverage of at least 95% of the population of all regional cities of the Slovak Republic by the end of 2025,
- 5G coverage of 90 % of the population outside regional cities of the Slovak Republic by the end of 2027,
- 5G coverage with frequencies from the 700 MHz frequency band of 70% of the population of the Slovak Republic by the end of 2027.

By ensuring the availability of completely new services first in the areas of major urban centres and backbone infrastructure and then in almost the entire territory, conditions for effective competition in electronic communications will be created, which will also positively contribute to the development of the Slovak economy.

Entities responsible for measures to support the development of 5G in Slovakia in the field of infrastructure:

MTC SR, ÚREKPS, MIRDI SR, holders of individual permits for the use of frequencies obtained through an electronic auction for 5G networks.

[13] Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility and repealing Regulations (EU) No 1316/2013 and (EU) No 283/2014, COM (2018) 438 final, 6. 6. 2018

9. EUROPEAN 5G DEVELOPMENT POLICY

9.1 Baseline

Support for the deployment and development of 5G networks composes component part of the EU strategic and legislative documents for electronic communications:

- supporting the transition to a European Gigabit Society[14] with a set of new goals for the development of electronic communications by 2025,
- the European Electronic Communications Code[10],
- 5G Action Plan[15],

The European Commission specified three strategic goals for electronic communications by 2025:

1. All major socio-economic centres (schools, universities, research centres, transport hubs), public service providers (hospitals, municipalities) and businesses using digital technologies should have access to gigabit connections (minimum speed of 1 Gbit/s).
2. All European households, rural or urban, should have access to connection with a download speed of at least 100 Mbit/s, which can be upgraded to a connection with a speed of at least 1 Gbit/s.
3. All urban areas, as well as major roads and railways, should have uninterrupted coverage by 5G mobile networks. As a preliminary target, 5G should be commercially available in at least one major city in each EU Member State by 2020.

The European Electronic Communications Code specifies, inter alia, that measures to reorganise and allow the use of sufficiently large blocks of the 3.6 GHz band and the use of at least 1 GHz from the 24.25 - 27 band are to be taken to facilitate the deployment of 5G technology, provided that there is clear evidence of market demand and that there are no significant constraints for migration of existing users or band clearance[11].

To support investment, especially in 5G, EU Member States should, in general, provide electronic communications network operators with regulatory predictability over a period of at least 20 years in terms of spectrum allocation for wireless broadband. Member States are also required to make new 5G frequency bands available, allowing for faster internet connections and increased connectivity across Europe.

Proposal for a Regulation establishing the "Connecting Europe Facility"[13] (hereinafter referred to as the "the Program") and aiming to provide a legal basis for the transport, energy and digital technology sectors, is currently part of the agenda of the Council. Its approval is expected in 2020. The aim of this Program is to fund cross-border projects in the digital technology sector and thus support the deployment of ultra-high transmission speed and connectivity digital networks such as 5G, and contribute to increased resilience and capacity of digital backbone networks and to digitalisation of transport and energy networks. The Program should help to ensure that all European households, in rural or urban areas, are provided with fixed or wireless connections with ultra high transmission speeds and capacities in areas where the commercial market will not build coverage due to economic return.

[14] Communication from the Commission to the European Parliament, the Council, the European and Social Committee: Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, COM(2016) 587 final, 14. 9. 2016

[15] Communication from the Commission to the European Parliament, the Council, the European and Social Committee: 5G for Europe: An Action Plan, COM(2016) 588 final, 14. 9. 2016

9.2 Measures to support of 5G development in Slovakia in the field of legislation

Slovakia should make effective use of all regulatory tools at its disposal. Measures that will help the development of 5G networks already in the short term include legislative amendments and increased pressure by ÚREKPS towards sharing existing infrastructure and in favour of faster, more efficient and trouble-free construction of optical networks. Such support will be provided by the consistent implementation of the legislation on network sharing rules. It is also important to create the conditions for effective cooperation of electronic communications network operators in the construction of infrastructure in order to adequately optimize the construction of optical networks. One of the most important measures will be the implementation of the European Electronic Communications Code in the **new Act on Electronic Communications**.

From the point of view of cost- and time-efficient construction of infrastructure for 5G networks, mainly in the field of optical network construction, it is essential to ensure simplification of permitting telecommunication constructions by building authorities and prepare clear and uniform interpretation of legislative conditions for building authorities within the process (land and construction proceedings) of permitting construction of this infrastructure.

Conclusions of the World Radiocommunication Conference WRC-19 are also contained in documents closely related to mobile services, especially frequency bands for 5G. This is associated with the need to implement these conclusions in the documents of the Slovak Republic, such as the **Plan for the use of the frequency spectrum in accordance with the approved Government regulation of the Slovak Republic establishing the National Table for Frequency Allocation.** At the same time, new documents can be expected to be published by the European Commission and CEPT, which will also support the development of 5G networks in the EU. It is therefore necessary for the Slovak Republic to react flexibly to these new documents and implement them in a timely manner into the national regulatory framework for 5G networks.

Entities responsible for measures to support the development of 5G in Slovakia in the field of legislation:

MTC SR, ÚREKPS.

10. CYBERSECURITY

10.1 Baseline

5G networks will form the basis of our societies and economies by interconnecting billions of facilities and systems, including in critical sectors such as energy, transport, banking and healthcare, as well as industrial control systems carrying sensitive information and supporting safety systems.

On 26 March 2019, the European Commission published its recommendation on joint action by EU Member States in the field of cybersecurity of 5G networks[16]. The aim of this measure is to ensure a high level of cybersecurity for 5G networks throughout the EU, which is key for ensuring the strategic autonomy of the Union.

Member States should carry out a national risk assessment of the 5G network infrastructure at national level by the end of June 2019. On this basis, Member States should update the existing security requirements for electronic communications network operators to include conditions to ensure the security of public networks, in particular when granting rights to use radio frequencies in the 5G bands. National assessments and measures should take into account various risk factors such as technical risks and risks associated with the behaviour of suppliers or operators of electronic communications networks, including those originating in third countries. National risk assessments have been a central element in building a coordinated risk assessment at EU level, and this joint assessment was published on 9 October 2019[17]. On the basis of their national analyses, EU Member States can take security measures leading to the safe and sustainable operation and use of 5G technologies and networks.

Based on a joint risk assessment at EU level, the European Commission, ENISA and the Member States adopted on 29 January 2020 a joint set of mitigation measures (the Toolbox) [18] to address the security risks associated with the deployment of fifth generation mobile networks. The Toolbox addresses all risks identified in the coordinated EU assessment, including risks related to non-technical factors, such as the risk of interference from state or state-supported actors from outside the EU through the 5G supply chain.

These tools include:

- telecommunications and cybersecurity rules,
- coordination of standardization and certification at EU level,
- a framework for the screening of foreign direct investments in the protection of the European 5G supply chain,
- trade defence instruments,
- competition rules,
- public procurement, in which due regard must be paid to security aspects,
- EU funding programs where beneficiaries must comply with the relevant security requirements.

[16] Commission Recommendation: Cybersecurity of 5G networks, Strasbourg, 26.3.2019 C(2019) 2335 final.

[17] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=62132

[18] https://ec.europa.eu/digital-single-market/en/news/cybersecurity-5g-networks-eu-toolbox-risk-mitigating-measures

The Toolbox used tools defined in EU cybersecurity legislation such as the Network and Information Systems Security Directive[19], the Cybersecurity Act[20] and the European Electronic Communications Code[10]. The Toolbox will help Member States to implement these new tools in a coherent way.

In the field of cybersecurity, the European framework for cybersecurity certification for digital devices, processes and services should be an essential support tool to promote uniform levels of security. When implementing it, Member States should also cooperate immediately and actively with all other stakeholders to develop specialized EU-wide 5G certification schemes. Once made available, Member States should introduce mandatory certification in this area through national technical rules[20].

In the field of electronic communications, Member States shall ensure that the integrity and security of public electronic communications networks are maintained and oblige operators to take appropriate technical and organizational measures to manage the risks associated with the security of networks and services.

Given the potential of 5G networks for the European economy, the single market and European citizens, the Telecoms Council on 3 December 2019 in Brussels adopted Council Conclusions on the significance of 5G to the European Economy and the need to mitigate security risks linked to 5G.

The Council calls upon the Member States and the Commission with the support of ENISA to take all necessary measures within their competences to ensure the security and integrity of electronic communication networks, in particular 5G networks, and continue to consolidate a coordinated approach to address the security challenges related to 5G technologies and on the basis of the ongoing joint work on the 5G security toolbox to identify effective common methodologies and tools to mitigate risks related to 5G networks[21].

10.2 Measures to support of 5G development in Slovakia in the field of cybersecurity of 5G technologies and networks

In the area of cybersecurity of 5G technologies and networks, Slovakia **carried out the National Risk Analysis for the implementation of 5G technologies** at the national level, serving as a basis for the elaboration of a joint 5G risk assessment at the EU level. Other priorities in the framework of ensuring the security of 5G technologies and networks for the Slovak Republic include:

- on the basis of the National Risk Analysis, the Joint Risk Analysis and the EU Toolbox, to prepare an amendment to Act No. 69/2018 Coll. on cybersecurity and on the amendment to certain acts, defining security measures and requirements for the procurement and operation of 5G technologies and networks,
- to actively communicate with ÚREKPS, operators of electronic communications networks and other important entities in this field when preparing recommendations and measures,
- to apply the latest knowledge in the field of security when preparing and implementing recommendations and measures,

[19] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[20] Regulation (EU) 2019/881 of the European Parliament and of the Council of 17 April 2019 on ENISA (the European Union Agency for Cybersecurity) and on information and communications technology cybersecurity certification and repealing Regulation (EU) No 526/2013 (Cybersecurity Act).

[21] Council Conclusions on the significance of 5G to the European Economy and the need to mitigate security risks linked to 5G, Telecoms Council, Brussels, 3.12.2019.

- to regularly review the risks associated with the security of 5G technologies and networks,
- to create a certification framework for 5G technologies and networks.

Entity responsible for measures in the field of cybersecurity:

NSA.

11. ELECTROMAGNETIC RADIATION WITHIN 5G NETWORKS AND THEIR SAFETY

11.1 Baseline

The 5G electromagnetic field differs from fields of previous mobile generation networks in its complex two-way transmission of beam formed characteristics from the base station to the mobile station and back. In this context, there are increased concerns about the possible impact of 5G networks on health and safety. The increased exposure may not only result from the use of much higher frequencies from the 5G frequency band, but also from the possible accumulation of different signals, their dynamic properties and complex interactions, which can occur especially in densely populated urban areas.

High demands are placed on 5G networks in the field of energy and spectral efficiency. The energy efficiency of the network in the bands above 1GHz according to IMT-2020 will be up to 100 times higher than in the 4th generation networks and the spectral efficiency of the network will be 3 times higher than in the IMT-Advanced networks. The energy efficiency of the 5G network is based on low energy consumption and low to zero radiated power, when no communication is performed. The higher spectral efficiency of the 5G network will consist in the use of new technologies capable of transmitting data at high speeds, low radiated power in the allocated frequency band and high efficiency of the use of the frequency spectrum (efficient data transmission). It is essential to meet these energy requirements in application areas where there will be a huge increase in connected devices, such as the Internet of Things. These technologies will provide massive machine-to-machine (M2M) communication in the low power area (LPWA) in 5G networks. LPWA technologies primarily focus on low-energy, low-cost devices transmitting relatively short messages at lower transmission speeds at intermittent intervals over a wide area (e.g. up to 10 km). In terms of penetration capability, many LPWA technologies tend to use spectrum in the lower frequency bands (e.g. below 1 GHz).

5G networks will use cells with a lower level of performance than existing cells in 4G networks. The total exposure of electromagnetic fields (EMF) in the deployment of 5G networks should be comparable to the EMF levels of existing 2G, 3G and 4G mobile networks and should remain well below the EMF public exposure limits defined at international level and recommended at EU level.

Council Recommendation 1999/519/EC[22] sets maximum emission levels with exposure limits of the public to EMF being in accordance with the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[23].

ICNIRP issued new guidelines in March 2020. After 20 years, and based on an extensive review of scientific knowledge and public consultation, the new ICNIRP guidelines confirm the appropriateness of existing EMF exposure limits with a few required and related adjustments to measurement methods in terms of higher frequency band limits . The European Commission is closely examining the findings of ICNIRP and will re-examine the situation in relation to Council Recommendation 1999/519/EC on the basis of the opinions of the relevant scientific committees (e.g. the Scientific Committee on Health, Environmental and Emerging Risks (SCHEER)[24]).

[22] Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)

[23] https://www.icnirp.org/

[24] https://ec.europa.eu/health/scientific_committees/scheer_en

By decision of the Minister of Transport and Construction of the Slovak Republic, a working group for cooperation in the field of 5G networks (the "Working Group") was established as a working and advisory body of the MTC SR, which is to create conditions for mutual cooperation in the development of 5G networks. The Working Group performs tasks focused mainly on the prevention of the spread of misinformation and hoaxes in the field of 5G networks and the sharing of expertise and relevant information in the field of 5G networks between scientific institutions, academia, public administration and professional associations.

The MTC SR also implemented, in cooperation with the Research Institute of Communication, Banská Bystrica, a project aimed at mapping the EMF intensity in selected locations of the Banská Bystrica self-governing region with different population density, while measurements were performed at different times of the day. Based on the measured values, it was identified that the highest measured value represented approximately 15% of the permissible action value set by the Decree of the Ministry of Health of the Slovak Republic.

11.2 Measures to support of 5G development in Slovakia in the field of the impact of 5G networks on the population health

The protection of public health is of primary importance and the safety of citizens is paramount. Any risks that new technologies pose to the health and safety of citizens must be properly assessed and appropriate mitigation measures must be taken. This precautionary approach has already been taken into account in all European Commission initiatives, including 5G initiatives.

Citizens must be reassured that the electromagnetic field of antennas does not pose a threat to their health in everyday environments, even if several antennas are built in their immediate vicinity (on poles, bus stops, billboards, etc.).

In addition, it will be important for operators of electronic communications networks that the deployment of 5G networks, including small cells, is carried out in accordance with legislation on limitation of exposure of the general public to electromagnetic fields. It will be important to maintain consistency and legal standards, ensure transparency and debate on public exposure to electromagnetic fields when deploying 5G technology.

At the same time, in connection with the introduction of the new 5G technology, theories began to appear about its harmfulness to human body or that bees, birds and trees die in places where 5G networks are operated. Such articles are published not only on web sites but also on social networks. Sharing such information can lead to lower confidence in the state and democracy, to activist pressure on local governments to stop or delay the land-use authorisations, and to economic losses.

At the same time, it is necessary to take seriously the concerns of those who are against the introduction of 5G for reasons related to electromagnetic fields. In this context, a broad and inclusive discussion will ultimately contribute to building trust among citizens in activities aimed at the continuous development of mobile networks. Recent events show that joint action is needed in this area.

As part of the prevention of undesirable levels of exposure to electromagnetic fields, it would be appropriate to create at least three specialized workplaces of public health authorities to monitor the levels of intensity and density of electric, magnetic and electromagnetic field power flow.

In order to ensure the transparency of information on the impact of new technologies on the population health, it will be necessary to conduct expert discussions on this topic, to which

state authorities such as the Ministry of Transport and Construction of the SR, the Ministry of Health of the SR, the Public Health Authority of the SR, with the support of other relevant institutions, such as research institutes. The awareness campaign must be based on digital literacy, education and transparency and provide citizens with clear information from credible sources on public exposure to EMF when introducing 5G technology, which will allow citizens to critically evaluate the information available.

It will also be necessary to continue the project of mapping the level of EMF intensity in the Slovak Republic, both in the period before and during the deployment of 5G networks into operation and publish the results of measurements in the form of an interactive map on the website of the MTC SR

Responsible entities for measures in the field of the impact of 5G networks on the population health:

MTC SR in cooperation with relevant representatives

12. CONCLUSION

The ambition is for Slovakia to become a dynamic data economy within the European Single Market and to have effective regulation of the telecommunications market. Coverage of 5G networks must be ensured not only with the use of the existing optical infrastructure, but also in correlation with the plans for the construction of optical networks under the National Broadband Plan. The legislative environment will be set up to allow the application of new business models based on artificial intelligence platforms. It is assumed that there will be sufficient demand within the economy for innovative solutions to maintain a sufficient market and create innovation.

5G technology is an important tool for all future digital services and is therefore one of the priorities of the Digital Single Market. In addition to the growing demands for connectivity from media applications, a flawless, common fixed and wireless infrastructure offering different levels of adjustable reliability and service quality will require professional communication, depending on specific operational needs. These are industries and services, such as automotive, transport, manufacturing, healthcare, as well as next-generation safety and rescue services. 5G networks will form the backbone of the wide range of services necessary for the functioning of the EU internal market. They will also be essential for the operation of vital social and economic functions, such as energy, transport, banking and healthcare systems, and industrial control systems.

In order to meet these ambitions, close cooperation is needed among public authorities, including regulators, operators and providers of electronic communications networks and services, all sectors of the national economy, investors and research and academia institutes.

Summary of measures to support the development of 5G networks in Slovakia

	Measures	Date	Responsible entity
	Frequency spectrum		
1.	Reorganise the 3.6 GHz frequency band and allocate frequencies from this frequency band for the construction of 5G networks before the expiry of the current individual permits	2021 - 2022	ÚREKPS MTC SR
2.	Release the 26 GHz frequency band based on market demand	2024	MTC SR, ÚREKPS
	Infrastructure		
3.	a) Cover all operated sections of motorways (D) and expressways (R), operated sections of pan-European railway corridors and inland waterways of international importance in the territory of the Slovak Republic (also using the frequencies already allocated) b) Cover 95% of the population of regional cities of the Slovak Republic with the 5G network c) Cover 90 % of the population outside regional cities of the Slovak Republic with the 5G network d) Cover 70% of the population of the Slovak Republic with the 5G network using frequencies from the 700 MHz frequency band	2025 2025 2027 2027	Holders of individual permits for the use of frequencies obtained through an electronic auction for 5G networks.
	Legislation		
4.	Prepare a bill of the new act on electronic communications	Effective in the 3rd quarter of 2021	MTC SR
	Cybersecurity		
5.	Submit a bill of the amendment to Act No. 69/2018 Coll. on cybersecurity and on amendments to certain acts to the Slovak National Council meeting.	2nd quarter of 2021	NSA
	Electromagnetic radiation within 5G networks		
6.	To provide citizens with clear information from reliable sources on the exposure of the public to EMF when deploying 5G technology and to continue the project of mapping the level of EMF intensity in the territory of the Slovak Republic	continuously	MTC SR in cooperation with relevant representatives