Disclaimer: This is a Romanian to English translation of "Strategia 5G pentru Romania*" as adopted on 20 June 2019, meant to facilitate the understanding of this document. Should differences appear between the Romanian and the English version following translation, the Romanian version shall prevail.*

ANNEX

THE "5G FOR ROMANIA" STRATEGY

Contents

1. Executive Summary

The unprecedented boom of the internet and mobile devices we are currently witnessing in Romania is based on the fact that 4 generations of mobile communications technology have been successfully launched and commercialized in less than two decades.

Table no. 1 – Technology generations in mobile communications

Generation	1G	2G	3G	4G	5G
Typical technology	NMT	GSM	IMT 2000 UMTS	LTE	IMT 2020
Typical services & speed	Voice 14.4 kbps	Voice 64 kbps	Voice & Data 2 Mbps	Data < 1 Gbps	Data & more < 20 Gbps
Launch in Romania	April 1993	April 1997	April 2005	October 2012	2020

source: publicly available information

5G, the fifth generation of mobile communications, has been envisaged by many analyses, trials, practical tests and early commercial launches on all meridians, including trials in Romania, ever since 2017. The excitement about the new technology relies on the latter's potential and promised performance: communications will be ten times faster, more reliable and efficient for people and for IoT connected objects in the next decade. 5G is seen as one of the essential ingredients for the economic transformation anticipated by the Fourth Industrial Revolution and for the development of the Gigabit Society. New trends in connectivity occur around us every day, bringing about rapid developments to economies and societies.

Unlike other technology generations, 5G is conceived as a disruptive technology that goes beyond consumer internet and the entertainment industry. 5G is designed to best serve innovative industrial uses: self-driving and connected vehicles, cyber-physical systems and programmable robotics, high precision farming, smart communities and networks, VR surgery, etc. Therefore, new connectivity scenarios have emerged, whose development will be substantially facilitated by the 5G capabilities, capabilities that are meant to add significant value to existing products and services and to create opportunities for new businesses with extended value chains.

A leader in the development and commercialisation of many of today's widespread technologies, the European Union has set an ambitious calendar for launching and developing 5G, based on coordination between Member States, new radio spectrum resources, diminishing administrative barriers to network roll-out and a massive R&D budget.

The competitive dynamics of the communications and information technology sectors, of the existing communications network capabilities, and the exposure to the requirements of the Single Market set the premises for Romania's fully benefitting from the availability of advanced connectivity technologies. Romania's relatively good position allows the anticipation of a commercial launch of standardized 5G services in 2020, along with major European economies.

Nevertheless, capitalizing the main 5G benefits, i.e. the productivity gains in (all) economic and social sectors, the emergence of new jobs, etc. requires massive investment, time and a favourable environment for the development of the required digital ecosystems, both in the private sphere and in the public realm.

That is why, supported by MCSI and ANCOM, the strategic planning project brought together the

competent institutions in Romania, in order to combine their expertise and jointly identify the most appropriate measures.

By facilitating the implementation of 5G, Romania aims to harness the connectivity achievements to boost the competitiveness of next decade's Romanian products and services, as well as to improve community life.

This strategy contains the arguments, information and steps the Romanian state needs to take during 2019-2030, in order to foster the development of 5G in Romania, with due regard to the milestones set in the EU Action Plan and providing for the competitive advantages that people and businesses in our country need.

Thus, we pursue the rapid roll-out of services (by 2020), the accelerated capitalization of 5G benefits (5G coverage of all urban centres and major land transport routes by 2025), reducing barriers to 5G network deployment, promoting new uses and stimulating cooperation between actors who can contribute to all of these developments.

In addition to massive spectrum demand in different bands, the new 5G networks will require significant small cell densification, as well as extensive fibre optic capacities to connect them. A significant expansion of 5G networks is difficult to imagine under the current construction works authorisation regime, so we propose to adapt it to the new realities. We will review the relevant legislative framework and will provide investors and decision-makers with the information needed to accelerate investment processes, to co-ordinate and to in-build the required facilities for 5G in public infrastructure works, as well as the technical guidance required for the administrative territorial units' land planning for 5G infrastructure development.

We will provide enough spectrum resources for the smooth operation of 5G commercial services in the frequency bands that are envisaged for 5G implementation in Europe: 700MHz and 3.4-3.8 GHz before the end of 2019 and millimetre bands in 2020. We will provide for using the 5G capabilities for public protection and disaster relief services, which will be achieved no later than 2025.

For the technical and commercial validation of 5G-based solutions, we aim to facilitate partnerships for R&D, testing and validation, by identifying and supporting 7 pilot projects for new connectivity uses and facilitating the set-up of an ecosystem that could foster the development of 5G-based business models.

We will seek to stimulate smart 5G-based specialization by supporting the carrying out of those projects with a significant connectivity-related component.

The publication of this document is the beginning of a process that will span the next decade and will continue by the implementation of the action plan in section 8.1, the rigorous monitoring of deadlines and the achievement of the proposed indicators, and by investigating any other action that might become necessary within this process.

2. Vision

The past two decades have witnessed a period of tremendous technological development, fuelled by remarkable advancement in the fields of communications and information technology: the internet and mobile devices have entered our daily lives and have seen a spectacular upward trend in Romania and around the world, every new technology generation giving rise to more and more direct and indirect benefits, leveraging multiplier effect in economies and gearing social inclusion and interaction.

At present, the citizens of Romania live, work and do business in a country covered with fixed and mobile networks, use the networks across the European Union like at home, working and enjoying online content anytime, anywhere and in anyway. All these achievements have been facilitated by high-quality, accessible and almost ubiquitous communications networks.

However, there are still "white spots" – i.e. areas not covered by high-speed mobile networks – on the map of Romania, too many citizens are still to take up the new technologies, and few businesses extract added value from the benefits of connectivity.

By fostering the implementation of 5G - the fifth generation of mobile communications - we aim at putting Romania's connectivity performance to work in an active way, in order to increase the competitiveness of next decade’s Romanian products and services, as well as to improve the lives of communities.

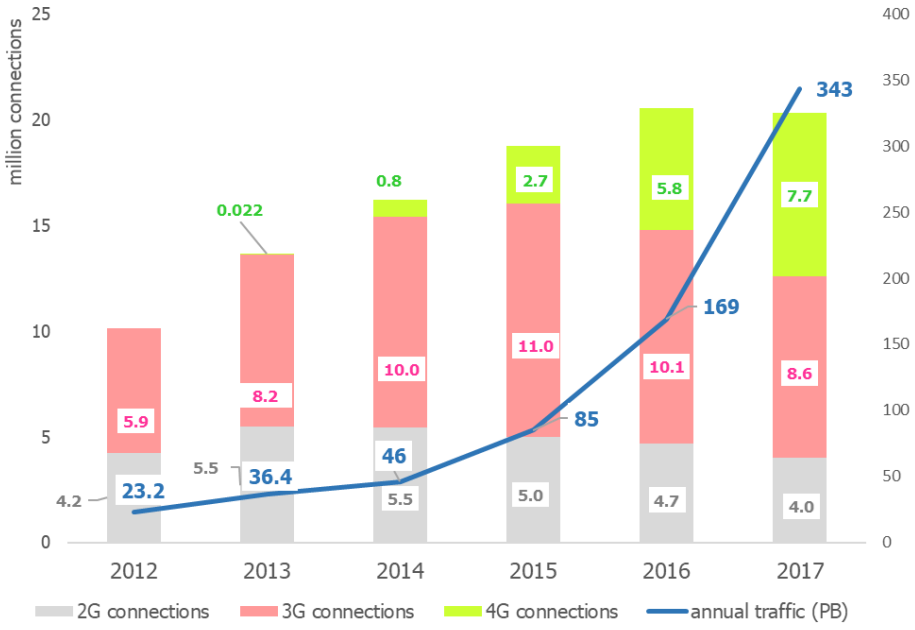
3. A diagnosis of the current situation

Strategies, as well as new networks, are built using and based on the groundwork in place. Therefore, a strategy requires a pertinent diagnosis of the current situation. In the context of the 5G strategy for Romania, the service consumption and the network organisation trends and developments, as well as the dynamics of laying down and planning 5G public policies at the national, European and global levels are highly relevant.

Since the launch of mobile communications in Romania, in 1993, four technology generations have substantially influenced the way people live, work and do business. The latest generation of technology, 4G, launched in Romania in 2012, has been associated with a new trend as regards innovation, devices and the consumption of internet services.

3.1. Significant growth potential in the Romanian market

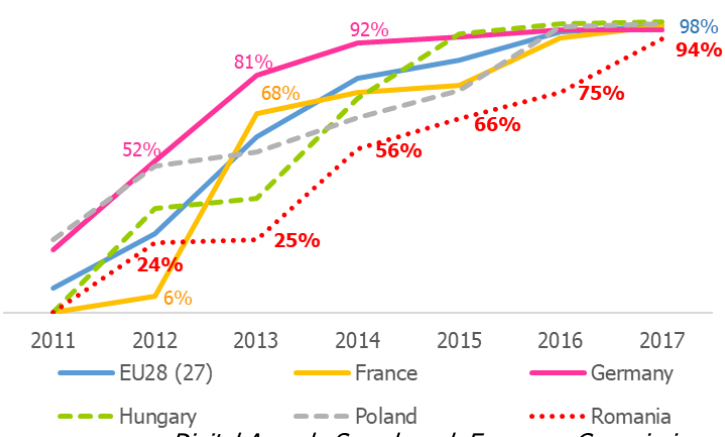
Figure no. 1 – connections and total mobile data traffic in Romania



The exponential growth in mobile data traffic achieved upon the massive spread of connections on increasingly efficient terminals and the deployment of LTE/4G technology on the mobile networks in Romania is highlighted in Figure no. 1. Mobile data traffic actually doubled each year in the last four years.

source: ANCOM statistics

Figure no. 2 – 4G/LTE mobile internet coverage (% households)



source: Digital Agenda Scoreboard, European Commission

5 years after the competitive selection procedure for awarding frequency usage rights organized by the National Authority for Administration and Regulation in Communications (ANCOM) in September 2012, 94% of households in Romania benefited from 4G/LTE network coverage. However, in a European context, this remarkable Romanian performance shows a slower coverage growth rate compared to many Member States, but also brought our country significantly closer to - only 4 p.p. below - the EU average.

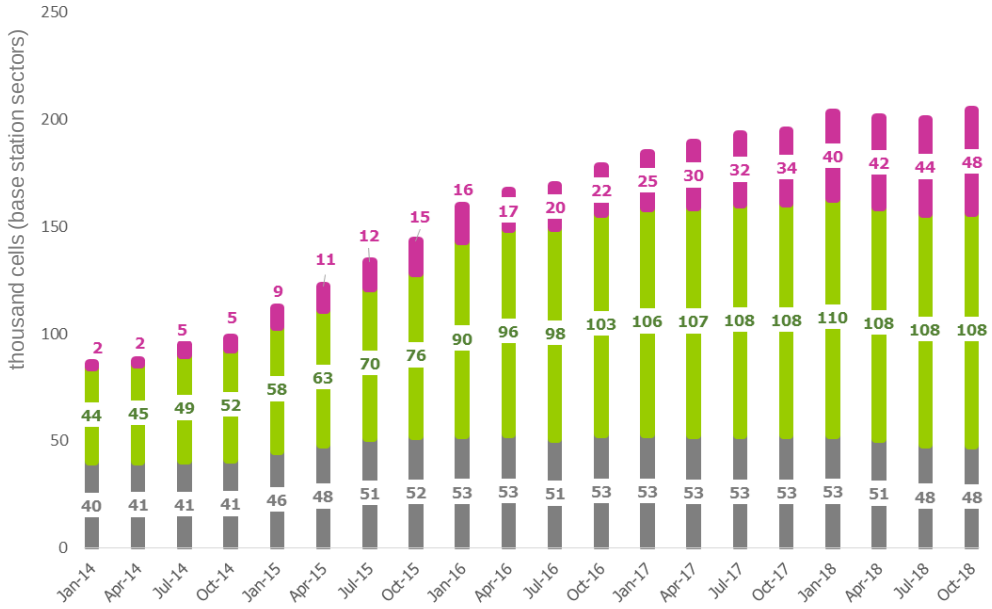


Figure no. 3 – BS sectors (cells) in the Romanian mobile networks

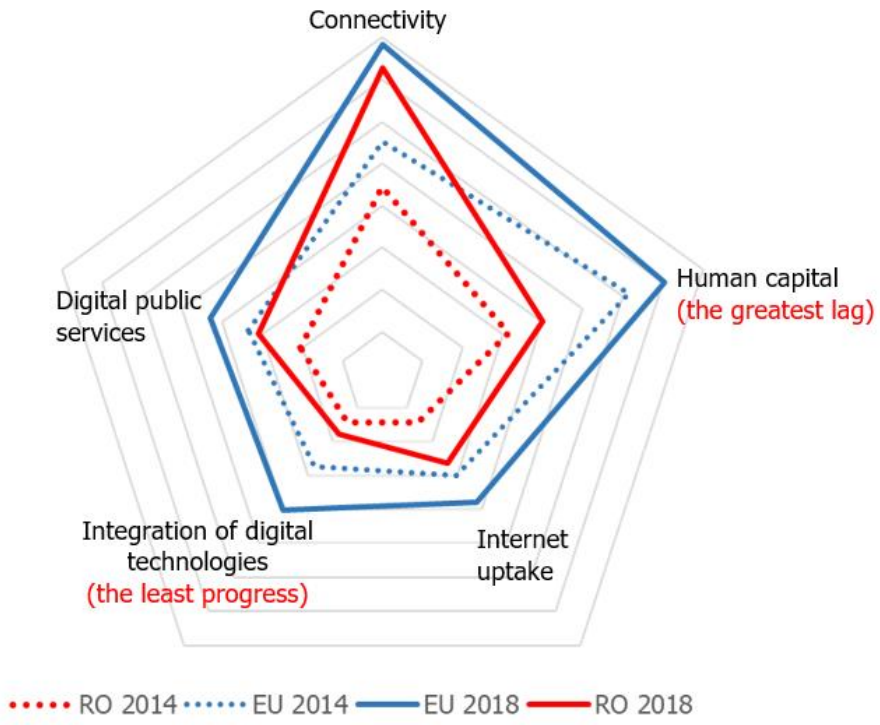
source: ANCOM statistics

The need to answer the growing demand for services required the densification of the number of sectors (cells) installed on the mobile networks in Romania, by an average annual growth rate of more than 20%. Although the number of 4G cells has witnessed the fastest growth rhythm, 3G cells count more than half in the total of active cells on the mobile communications networks in Romania.

Figure no. 4 below is a graphic representation of Romania's progress on the five directions characterizing the digital transformation of the economy and society[1], compared to the average progress made at EU level.

[1] EU Digital Economy and Society Index (DESI): https://digital-agenda-data.eu/datasets/desi/visualizations

Figure no. 4 – Romania's DESI progress



source: ANCOM's representation based on EU's DESI index

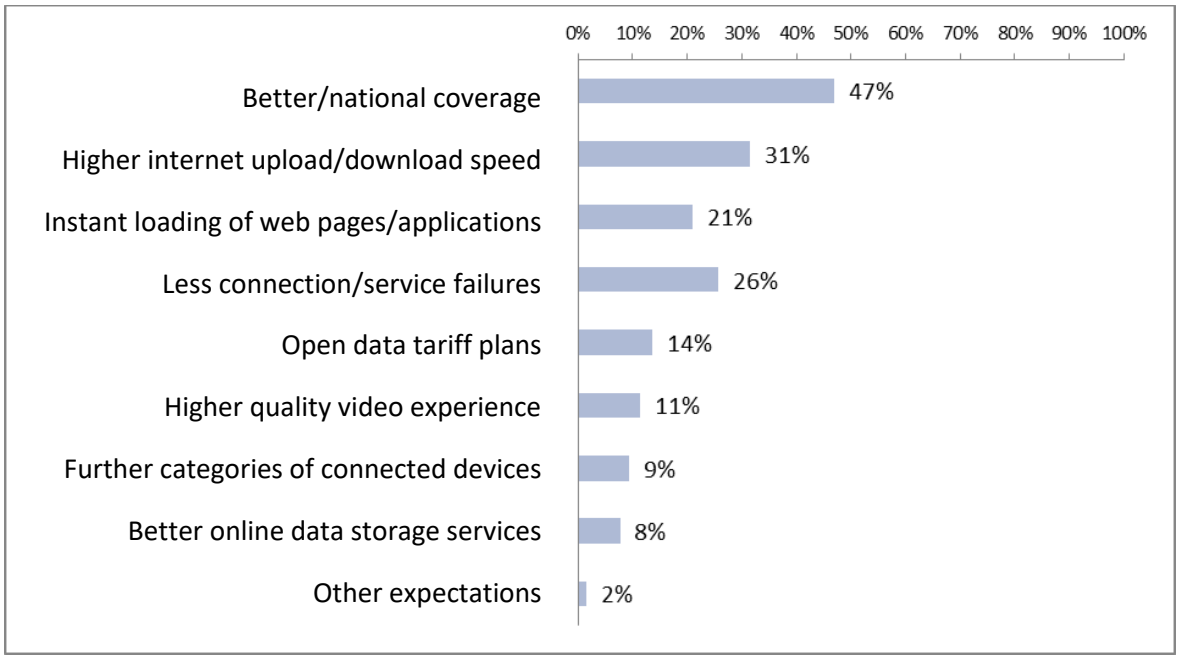
The connectivity benefits are expected to spread gradually and unevenly. Nevertheless, in the past 5 years, Romania's remarkable connectivity achievements have not been fully capitalized, given the major gap in terms of human capital and the modest development in the integration of digital technologies into economic life. Moreover, based on the progress registered in the internet use uptake or in the deployment of digital public services, Romania's 2018 average can barely reach the EU 2014 average, our country constantly being at the bottom of the DESI.

A market survey ordered by ANCOM, conducted on residential users[2] during October-December 2018, reveals a 5G awareness level of 34% of the general population, as well as a series of concrete expectations regarding the implementation of this technology in Romania. Thus, 47% of the respondents expect better national coverage, 31% anticipate higher download/upload speeds, while 26% hope for fewer connection failures and 21% for instant access to images/applications on the internet (21%).

Question: *5G is the fifth generation of mobile communications, it will replace the currently deployed 4G technology and will most probably be launched in Romania by 2020. What are your expectations in the context of its implementation in our country?*

Figure no. 5 – Population's expectations from the implementation of 5G in Romania

[2] https://statistica.ancom.org.ro:8000/sscpds/public/files/164_ro.



Source: ANCOM market survey

Regarding the 5G usage conditions they would be willing to accept if this technology were available in Romania starting the following day, 45% of the respondents would not pay an extra cost to benefit from the 5G technology, while 32% would take up the new services at an extra cost: 15% would choose a paid add-on to their existing tariff plan and 17% would adopt a dedicated tariff plan.

For the general population, the most important benefits of using the Internet of Things (IoT) would be improved comfort, safety, automation and optimization, whereas the greatest challenges would be putting at risk personal data (theft/loss, jeopardizing the confidentiality and the complexity of information collected), as well as the costs incurred with 5G-enabled devices.

Table no. 2 – The most important risks and benefits perceived in connection with the IoT

Benefits		Risks	
Comfort	42%	Data theft/loss	35%
Personal and family safety	35%	Costs of IoT devices	34%
Automation of certain activities	20%	Jeopardizing data confidentiality	25%
Optimization of household consumption	17%	Complexity of the personal data collected	15%
New income opportunities	9%	Difficulty of using IoT devices	13%
Efficiency of IoT devices	8%	Device resilience in time	10%
Other benefits	2%	Difficulty of choosing a device	9%
No benefits	19%	Other risks	3%
		No risks	14%

Source: ANCOM market survey

While public awareness of the concept Internet of Things (IoT) reaches 22%, the actual take-up of IoT services is 4% at national level. The categories of respondents with higher IoT take-up levels are the following: people in urban areas (6%), people with higher education (8%), people aged 16-30, and people in households with monthly income exceeding RON 6000 (30%).

Moreover, according to the ANCOM survey, the following aspects are most appreciated by IoT users:

a) the most appreciated IoT objects in view of their usefulness in everyday life: television (78%), smart home sensors (71%), smart watch/wristband (66%), central heating and air conditioning systems (66%), and smart meters (64%);
b) 79% appreciate that the use of IoT brings along more benefits than costs;
c) 79% appreciate that the use of IoT helps them in their everyday activities to a large or to a very large extent.

According to the survey results, 81% of the respondents agree that Internet of Things may bring considerable advantages to people's lives, and 63% agree that in the next 5 years, IoT will be part of most of the people's lives.

3.2. Emerging trends in Romania and on a global level

Europe has been a leader in the development and commercialisation of many of the aspects of today's technologies spread on a global level, and Romania greatly benefits from the availability of such technologies. In the presence of advanced technologies, economies and societies develop at an accelerated pace.

A series of emerging trends in the global ICT sector are the engines of growth, innovation, rise of new business models and even of disruption in various economic sectors, and 5G can make a significant contribution to supporting these developments. Below, we summarize the most popular trends.

Connectivity: The data traffic upsurge is due to the massive increase in connectivity demand driven by the proliferation of ever smarter phones and other connected devices. Thus, electronic communications networks progressively become channels for the mass consumption of multimedia content (music, movies, live streaming), for the proliferation of OTTs[3] and for the large-scale use of a wide range of various applications and services (social networks, payment applications and e-commerce) and even for the remote management and control of various types of devices (sensors, video cameras, etc.). If, in the medium term, the increase in connectivity demand will continue to be fuelled by smartphones, tablets and other personal equipment, the potential for long-term data traffic growth is expected to be based primarily on connected objects/things. In this context, the 5G contribution will consist both of improving mobile internet performance and opening new opportunities for serving connected industries with cost effective solutions, speed and energy efficiency.

Ubiquitous internet access: fixed internet solutions provided by mobile operators using wireless networks are an already established method for connecting many households and businesses in Romania, especially where fixed networks are not available. However, current technologies do not allow data download speeds and latency levels typically witnessed in traditional fixed networks, and often do not offer the most advantageous option from an economic perspective. In the 5G context, the attractiveness of fixed internet solutions offered via wireless

[3] Over The Top – generic term for services enabling the delivery of any kind of content (music, movies, telephony, instant messaging, audio-visual broadcasting programmes etc.) to the end-user over an internet connection, while avoiding the platforms made available by traditional providers of such services. Widely-used OTTs in Romania are: Netflix, Mubi, Skype, Whatsapp, YouTube etc.

networks increases substantially due to the availability of radio frequencies and technological progress.

Business digitization increases enterprise productivity and helps increase consumer satisfaction, with a positive effect on turnover[4]. The full 5G benefits are expected to materialize at global level by 2035, when the annual production of 5G-enabled goods and services is forecast to stand at $ 12.3 trillion[5]. Also, advanced data analysis techniques can enable companies to achieve advanced segmentation of markets and consumers, including improved prediction techniques regarding consumer behaviour, thus maximizing value added per customer. The 5G data collection and processing capability is facilitated by edge computing, a functionality that can support certain aspects of advanced data analysis and digitization.

Internet of Things (IoT) is the next major economic and social innovation, after connectivity. IoT allows for any physical (thermostat, bicycle helmet, etc.) or virtual object (representation of an object in a computer system) to be connected to other objects and to the internet, creating a network between objects and between people and objects. IoT can combine physical and virtual worlds into intelligent ecosystems that perceive the environment, analyse and adapt to make our lives easier, safer, more efficient and more friendly. The significant increase in the number of connected IoT objects at annual average rates of over 20% by 2022[6] will be fuelled by a wider range of usage scenarios (cases) and by the lowering prices of connected devices/things. On the other hand, the existing coverage of mobile networks places their operators in a good position to provide the connectivity needed for emerging IoT applications. If alternative technologies, including improvements to 4G services, are enough to meet medium-term demand for IoT, 5G brings reliability, low latency, scalability, security and mobility, ingredients that can support the massive proliferation of IoT ecosystems.

Network upgrades[7]: Currently, most of the network upgrades are driven by the need to improve user experience and enhance performance. In the future, upgrades will also be driven by the provision of specialized services for certain vertical industries, but also by the need to meet the demand for network security and integrity for different categories of customers (consumers, business environment, sensitive government services, etc.).

Cyber security, trust and data sovereignty: The IoT proliferation and the possibility to provide more and more industries with customised services determine a growing amount of confidential, and sometimes highly sensitive commercial information, to be carried through communications networks. Due to the heterogeneous possibilities of accessing the network, in combination with advanced data processing and data mining techniques[8], data loss or illegal use may have severe consequences, including reputational risks that may hamper the development of services. Thus, ensuring the security of communications infrastructures must be reinforced by ensuring the security of services from their design stage, through a user-centred approach. Therefore, 5G is expected to allow scalable identity management, distributed authentication, and secured network segments.

---

[4] http://www.adlittle.com/sites/default/files/viewpoints/adl_reimagining_telco_operations_in_a_hyper-digital_world_0.pdf

[5] 12.3 trillion USD is approx. the level of overall 2016 consumption expenditure in China, Japan, France, Germany and UK, or China's 2017 GDP. Source: https://www.qualcomm.com/invention/5g/economy

[6] https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf

[7] update or modernization including higher capacities, enhanced functionalities or performance, used in technology- or software-related contexts

[8] data mining

Consolidation, mergers & acquisitions and packaging: Procurement is an attractive means by which communications operators create new product and service offerings beyond their traditional capabilities, and can enter new markets or launch new businesses. We are already witnessing situations where operators pack products and services or expand the range of services they offer beyond the capabilities of their own networks[9], targeting entry into adjacent industries[10]. The levels of costs and capabilities needed to materialize economies of scale in 5G may foster merger and acquisition plans between network operators, communications companies, and fixed and mobile operators.

3.3. The global 5G race

Following the numerous research, development and testing processes carried out over the past several years worldwide, including the technological standardization in international and regional organizations, it is generally accepted in the communications industry that the commercial launch of 5G services will take place around 2020. Currently, network providers have gone beyond exploratory phases and are working on understanding how they can best meet the specifications of 5G technology, as well as on identifying the most appropriate technology options for their own networks' migrating to 5G.

This state of play underpinned ambitious trials and large-scale pilot projects around the world: in August 2018, 154 mobile communications network providers on all continents had already performed or planned to perform demonstrations, tests, or trials of 5G technology. Of these, 67 operators in 39 states have announced that they will market 5G services before 2022[11].

At European level, the global 5G race accelerates private or public initiatives in different directions. The pace and the multitude of developments in run-up to 5G makes an exhaustive analysis of these developments less relevant in the context of this strategy. However, the recently launched European 5G Observatory[12] is a good (non-exhaustive) source of systematic information on recent 5G developments in markets and networks as well as on public initiatives supporting these developments in EU countries and beyond.

In the EU, 114 5G trials had been conducted by mid-September 2018 especially in the 3.6 GHz band, and commercial 5G services have been launched in Tampere (Finland) and in Tallinn (Estonia)[13]. Moreover, by the same date, 20 flagship cities[14] and 9 digital cross-border corridors for self-driving cars[15] had been designated. In France, 9 important regional cities were selected for 5G testing, alongside 11 cities in Paris suburbs.

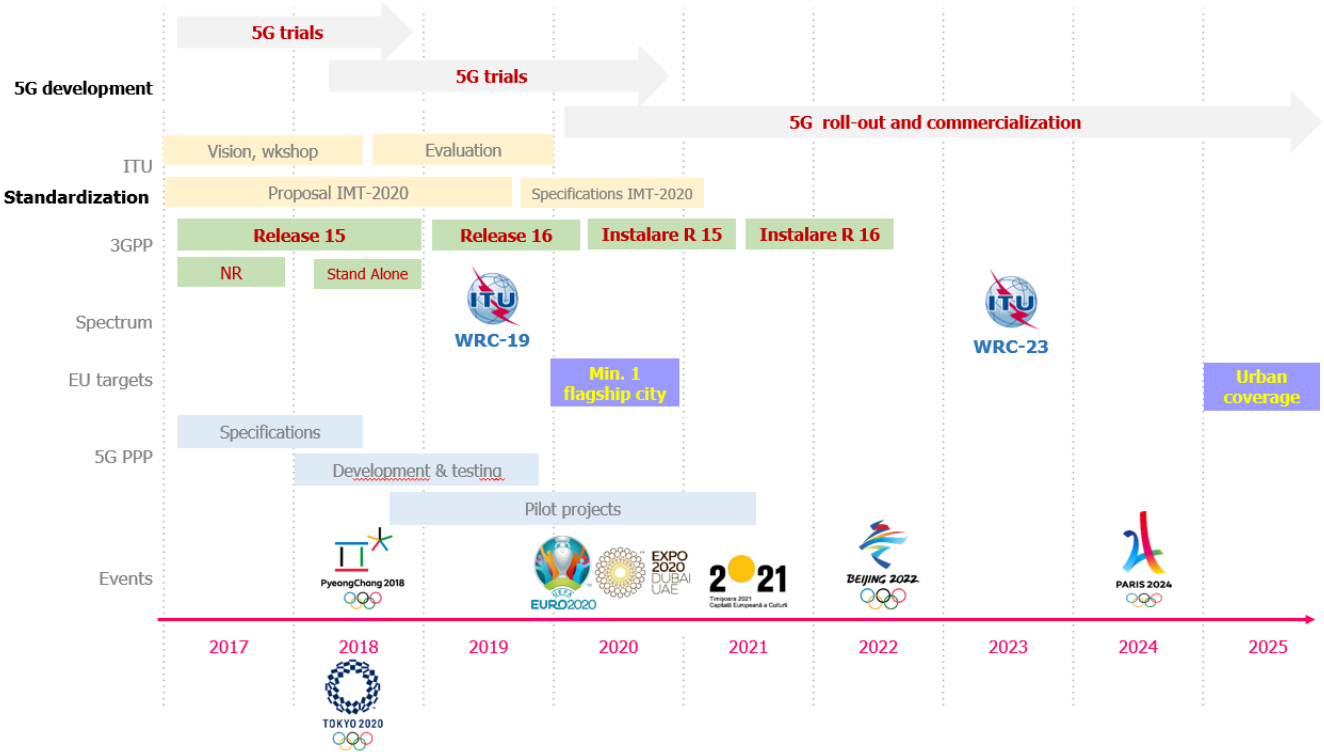
---

[9] see, for example, connected objects tariff plans or *smart home* solutions offered by the communicatons operators in Romania
[10] see, for example, the startup accelerator Orange Fab launched in Romania in June 2017, or the acquisition of IoT provider Evotracking by Vodafone Romania
[11] https://gsacom.com/paper/5g-evolution-lte-global-market-status/
[12] http://5gobservatory.eu/
[13] http://5gobservatory.eu/wp-content/uploads/2018/12/80082-5G-Observatory-Quarterly-report-1-rev12-2018.pdf
[14] Amsterdam, Aveiro, Barcelona, Bari, Berlin, Bristol, Espoo, Ghent, L'Aquila, London, Madrid, Malaga, Matera, Milano, Oulu, Patras, Prato, Stockholm, Tallinn and Turin.
[15] Metz-Merzig,-Luxembourg, Rotterdam-Antwerpen-Eindhoven, Porto-Vigo – Evora-Merida, E8 "Aurora Borealis" NO-FI, Nordic Way 2 (NO-SE-FI-DK), Brenner corridor (IT-AT-DE), Thessaloniki-Sofia-Belgrade, via Baltica E67 Tallinn – Riga – Kaunas, as well as Kaunas – Warsaw.

Romanian communications operators have also conducted several public 5G tests over the past two years, with various objectives[16]: testing beamforming transmission capacities and carrier aggregation in different usage scenarios, testing the massive MIMO solution in real life conditions, or testing 5G performance in terms of speed, latency, etc., for mobile internet as well as for fixed wireless internet. Some operators have already announced the commercial launch of 5G services in Romania for 2020.

Figure no. 6 below illustrates the main milestones achieved or anticipated in the global and European 5G race from the point of view of standardization, radio spectrum availability, as well as the European and global initiatives and events that can favour the 5G development.

Figure no. 6 – Milestones in the global 5G race



source: ANCOM, based on Dot-econ and publicly available information

Thus, the action plans of relevant standardization bodies, such as ITU[17] and 3GPP[18], focus on studying technological requirements and adopting standards by 2020. Network technology is already available: 3GPP announced in December 2017 the completion of the Release 15 of 5G New Radio standard in a critical scenario for network development, depending on existing LTE networks ("non-standalone" scenario), and by mid-2018 the standalone version of new radio networks. Furthermore, five manufacturers[19] have already announced/presented the launch of

[16] https://5g-ppp.eu/5g-trials-2/#1512731004794-672b7993-7792
[17] International Telecommunication Union
[18] The 3rd Generation Partnership Project
[19] Qualcomm, intel, Samsung, Hi-Silicon and Mediatek

5G chipsets, an important step towards the mass production of the first 5G terminals in the first half of 2019[20].

The completion of 3GPP Release 16, expected in 2019, will allow for full compliance with all 5G (IMT-2020) requirements, while marking the second phase in the development of standardized 5G networks.

On the other hand, ITU World Radiocommunication Conferences (WRCs) are vital to materializing the 5G super-speed vision: for example, the WRC-19 conference will focus on the availability and harmonization of the use of new radio spectrum for mobile internet in several frequency bands between 24.25 GHz and 86 GHz.

Moreover, in run-up to the accelerating deployment of 5G ecosystems and with the development of the relevant technical standards, 5G will be able to integrate satellite networks, by using multiple complementary technologies. Accelerating and/or expanding connectivity on platforms in motion (airplanes, ships, high-speed trains) or in underserved areas, ensuring network resilience in the event of natural disasters or incidents on terrestrial networks, activating or accelerating multi-cast high-speed and high-resolution transmissions etc. are spearheads for new generation satellite services.

Furthermore, the big economies of the world have ambitious roles in the 5G race and rely on major public events such as the Olympic Games or the World Football Championship to support the commercial launch of these services. In Europe, the ambitious targets in the "5G for Europe" roadmap are also supported by the European Commission's co-financing of the 5G-PPP initiative[21] launched in 2013.

3.4. Developments and trends in 5G public policies

3.4.1. The European level

The ambitious strategic planning achieved through the Digital Agenda for Europe 2020 gave rise to the connectivity and coverage targets set for 2025 by the document *Connectivity for a Single Digital Competitive Market: towards a European Gigabyte Society*[22]. In the context of recognizing the importance of very high speed networks such as 5G, at European level, it is foreseen to ensure uninterrupted coverage of all urban centres and along the main ground transportation routes[23] by 2025, with an intermediate 2020 target set - the launch of 5G commercial services in at least one major city in each Member State.

Considering the strategic opportunities opened by the new generation technology, the 5G Action Plan for Europe[24] identifies the main challenges and areas that require concerted action,

[20] see, e.g., https://www.forbes.com/sites/jeanbaptiste/2018/09/18/huawei-confirms-release-of-foldable-screen-5g-smartphone-in-mid-2019/
[21] 5G-PPP – a public-private partnership for 5G infrastructures, https://5g-ppp.eu/
[22] final COM (2016) 587, https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-587-EN-F1-1.PDF, and the Staff Working Document of the Commission SWD (2016) 300, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0300&from=EN
[23] highways, national roads, main railway corridors, according to the trans-European transport network
[24] final COM (2016) 588, http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17131, and the Staff Working Document of the Commission SWD (2016) 306, http://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-588-EN-F1-1.PDF

coordinated among Member States. Besides contributing to the digital single market and setting their own strategic objectives in the 5G context, Member States should also develop their own "5G Roadmaps" (Action 1) and "consider using the 5G infrastructure to improve the performance of communications services for public safety and security "(Action 7).

Since the adoption of the forward-looking documents mentioned above, the Member States and the European Parliament have repeatedly shown their support for the overall strategy and objectives proposed: the European Parliament has welcomed the initiative of the European leadership on the development of standardized 5G networks[25],while Member States have emphasized the common ground of action lines for 5G success [26] and have committed themselves to pursuing the elements of a common roadmap for 5G development[27].

Moreover, concerning 5G, the Urban Agenda for the EU[28] calls for "innovation platforms that promotes competition in the mobile connectivity market by allowing new local entrants to serve vertical sectors' specific needs" (action 14).

An important element in European perspective is the recently adopted Directive 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code.

3.4.2. Interactions and synergies with strategies in Romania

Strategic planning in Romania is achieved through several general or sectoral strategies that meet goals, address perspectives and cover different time horizons. These strategies interact when the measures and interventions proposed directly or indirectly target the same area. When strategic approaches complement each other, providing similar development trends for a domain, or building on each other using syncretic instruments, it creates dynamic synergies.

The strategic vision and planning in the Romanian communications sector are formulated and detailed in the National Strategy on the Digital Agenda for Romania 2020[29], as well as in the Program for the roll-out of Next Generation Networks (NGN)[30].

In implementing the above-mentioned relevant national policies and strategies and with a view to efficiently meeting its statutory objectives, ANCOM has laid down, and is guided by, its Strategy for Digital Communications 2020[31], paying special attention to the first key element for carrying out the 5G vision: the frequency spectrum. To this end, ANCOM conducted a public consultation by means of a questionnaire, in 2017, on the principles of granting rights to use the frequencies

[25] Resolution 2016/2305(INI) of 1 June 2017 on internet connectivity for growth, competitiveness and cohesion: European gigabit society and 5G: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2017-0184+0+DOC+XML+V0//EN

[26] Common ministerial declaration *Making 5G a success for Europe* https://www.eu2017.ee/sites/default/files/inline-files/Ministerial%20declaration%205G_final_0.pdf

[27] https://www.mkm.ee/sites/default/files/8.a_b_aob_5g_roadmap_final.pdf

[28] https://ec.europa.eu/futurium/en/system/files/ged/digital_transition_action_plan_for_dgum_300818_final.pdf

[29]https://www.comunicatii.gov.ro/wp-content/uploads/2016/02/Strategia-Nationala-Agenda-Digitala-pentru-Romania-2020-aprobata-feb-2015.doc

[30] https://www.comunicatii.gov.ro/wp-content/uploads/2016/02/Programul-NGN-aprobat-1-1.doc

[31] http://www.ancom.org.ro/strategia-de-comunica539ii-digitale-2020_5535

in 5 radio frequency bands[32], and adopted the national roadmap on the future of a frequency band with great economic value: 470 - 790 MHz[33].

Furthermore, the national strategy for the regulation, implementation and optimization of smart-city digital technologies in Romania, currently under development, will provide key strategic guidance for the development of key components for the sustainability of 5G.

The 5G Strategy for Romania has a high potential for capitalizing synergies with national strategies/action plans in force in other sectors. Some synergies are more visible due to specific cross-sector interdependencies (e.g. physical infrastructure, communications, energy, transport), others may be foreseen due to the 5G capacity to infuse mass technology (R&D-innovation, smart specialization[34]) and connectivity in all economic and social sectors (means of transport, commerce, agriculture, construction works, processing and extractive industries, education, health, etc.), thus contributing to development (competitiveness) with positive effects on the environment and social redistribution (reducing gaps). It is noteworthy, however, that further interactions and synergies (e.g. mobility, technological gap between public and private/commercial services) may occur over time and the intensity or action direction of synergies may differ from the currently expected ones.

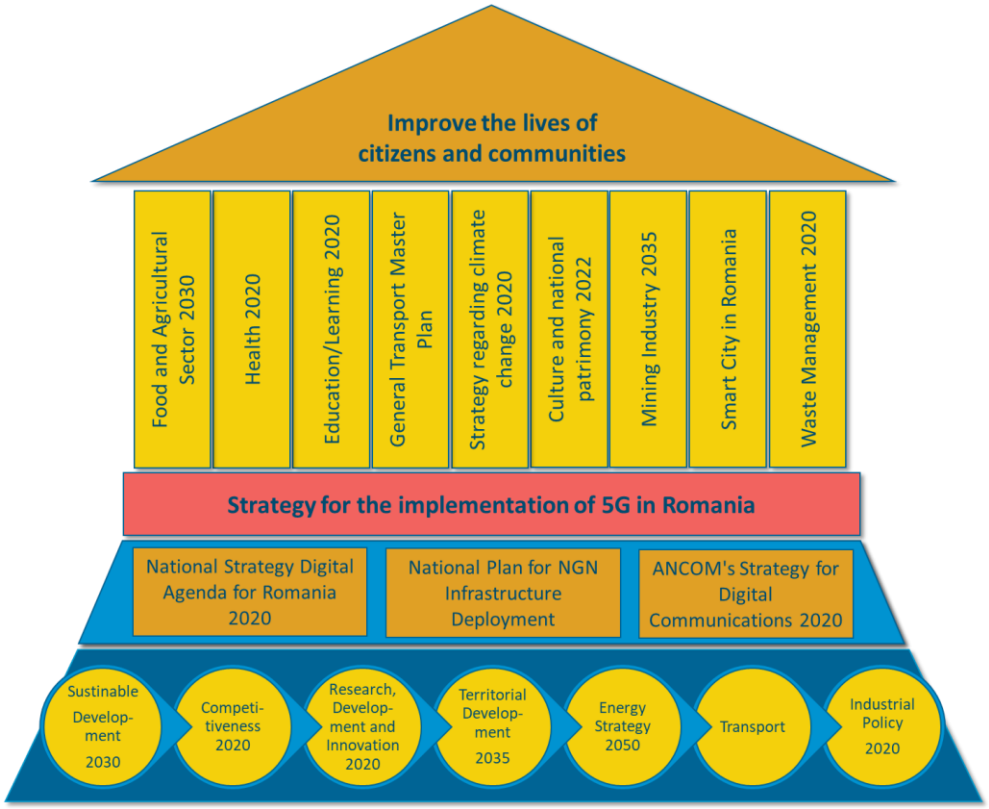
Figure no. 7 below schematically illustrates the main links with other national strategies/action plans, while section 5.4 *Preferred uses* reviews some 5G usage cases in several sectors/areas. Table no. 4 - *How 5G could contribute to approaching challenges and meeting sectoral needs* was complemented by sector-specific elements, identified upon analysing interactions between relevant national strategies.

Figure no. 7 – The 5G strategy considers the following strategies/national plans

[32] Consultation on awarding the spectrum use rights in the frequency bands 694-790 MHz, 791-796 MHz/832-837 MHz, 1452-1492 MHz, 2530-2570 MHz/2650-2690 MHz, 3410-3420 MHz/3510-3520 MHz, 3450-3465 MHz/3550-3565 MHz, http://www.ancom.org.ro/formdata-269-49-322

[33] National Roadmap for the allotment and future use of the 470 – 790 MHz band, http://www.ancom.org.ro/uploads/links_files/Foaia_de_parcurs_pentru_banda_UHF_470-790_MHz_en.pdf

[34] For example, mecatronics, cyber-mixmecatronics, clatronics, programmable robotics are potential uses with impact on the implementation of 5G intelligent systems



source: GLI-5G

4. 5G features

5G is the generic name for a new generation of technologies in the IMT 2020 family, which - through its features and through the innovations it introduces - facilitates the development of genuine digital ecosystems in most sectors of economic and social life.

An extensive characterization of the 5G standardized uses as well as the capabilities and technical requirements for 5G technologies was published by ANCOM in 2017[35].

4.1. Multiple types of connectivity

Even though the 5G technical specifications have not yet been finalized in all respects[36], reviewing the main connectivity use cases illustrates the technical capabilities for which this technology is designed.

4.1.1. Significantly better mobile internet

Significant improvement in mobile internet performance[37] is probably the most obvious 5G functionality: ultra-/super-fast indoor and outdoor speeds with constant service quality, for higher data volumes per connected device, with improved coverage, 5G will enable a significantly better mobile connectivity experience for a larger number of users and in a greater number of locations.

The higher capacity of the radio access network allows for increased transfer rates on multiple connections simultaneously, even in high-density areas, such as on public events and at peak traffic time. Higher network speeds allow consumers to view high-definition content, 4K and even 8K in multiple locations, thus supporting live event broadcasting and high-resolution multimedia transmissions.

4.1.2. High-speed fixed internet

The superior network performance enabled by 5G opens new opportunities for the efficient and large-scale provision of high-speed wireless fixed internet services[38] to households or businesses, including by providing *cloud computing*-based solutions for connecting data and applications in different geographical areas.

The massive increase in network capacity, together with the use of radio frequencies in large blocks (e.g. 50-100 MHz), especially in millimetre wave bands (blocks of hundreds of MHz), will allow for 5G internet solutions to reach speed and latency performance comparable with that ensured by fixed fibre optic networks, and to avoid unnecessary costs with the deployment of local loop cables.

---

[35] http://www.ancom.org.ro/uploads/forms_files/CONSULTARE_ACORDARE_SPECTRU_700_800_1500__2600_MHz_3,5GHz_revizuit_12_07_20171499848014.pdf

[36] Recommendation ITU-R M.2083-0 – IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond

[37] eMBB – enhanced Mobile Broadband

[38] FWA – fixed wireless access

Therefore, although not a separate use case in the ITU vision, given the competition dynamics and specific national circumstances[39], the fixed high-speed internet using 5G wireless solutions obviously has a great potential in Romania.

4.1.3. Massive machine-type communications

5G has been designed for a certain connectivity scenario to match the exponential growth of the number and density of connected objects. In fact, it is the first time that the specific connectivity needs of other sectors are provided for in the technological design phase. Massive machine-type communications[40] encompass mainly all the categories of uses related to industrial digitization, smart transformation of localities along with the emergence of connected objects in all economic sectors, with the development of autonomous systems based on a combination of technologies such as IoT, cloud, artificial intelligence (AI), etc.

These developments are anticipated to bring significant benefits in terms of productivity and value added to products or services, supporting cross-sectoral integration and the emergence of new markets, etc.

Connected objects have typical connectivity requirements that are fundamentally different from those of people: small chunks of data in a low transmission rate, mostly with predictable communication times, generally less sensitive to transmission delay, but requiring a low power consumption (extended battery life) and extended coverage.

Compared to current technologies, 5G brings the capability of connecting a massive number of such objects with a very dense territorial distribution, and as the 5G networks mature, they will allow the provision of communications infrastructure under flexible and accessible conditions, tailored to the specific needs of each industry.

4.1.4. Mission-critical communications

5G has also been designed for the provision of Ultra-Reliable Low Latency Communications[41] (essentially instantaneous) services, with very high availability, ultra-low jitter or no packet loss.

Mature 5G communications networks will enable operators to provide communications for such mission-critical services as - for example - public safety, the technological ecosystem of autonomous vehicles and transport safety, in remote surgery or in high precision control of industrial processes.

Additional connectivity use cases, fundamentally different from those mentioned above, may also emerge in the future. Such a possibility recommends flexibility in 5G networks so that it can accommodate the typical requirements of new use cases.

4.2. Technology differentiators

[39] The limited ubiquity of fixed communications networks, infrastructure-based competition, FWA 5G tests in Romania
[40] mMTC – massive Machine Type Communications
[41] URLLC – Ultra-reliable and Low Latency Communications

The need to ensure the connectivity use scenarios described above triggers 5G to combine multiple innovative technical capabilities and technologies in different ways. Reviewing the most important of them, with a brief explanation of their role in the context of 5G technology, also helps explain some of the challenges and opportunities associated with the 5G development.

Building on 4G, the 5G technology introduces a plethora of enhancements of the existing performance, as well as new functionalities, in line with the new connectivity trends. Different applications have different quality requirements: from low data rates (e.g. data transmitted by sensors and IoT) to very high speeds (e.g. high-resolution multimedia content) and various delays (e.g. delays are less tolerated in videoconferencing than in video streaming where buffering can be used). Excepting self-driving vehicles, augmented reality and tactile internet, many applications can - at least theoretically - be provided by existing networks. 5G networks will have to meet different service quality requirements for different types of applications (e.g. a few seconds delay may be fatal to a self-driving, connected vehicle).

The achievements expected from 5G networks are summarized in Table no. 2 below, in comparison to current 4G performance.

Table no. 3 – Comparison between 4G and 5G capabilities

Indicator	Description	4G	5G
Peak data rate (Gbit/s)	Total traffic per device within one cell	1	20
User experienced data rate (Mbit/s)	Total traffic constantly witnessed by a user	10	100
Spectral efficiency (bit/s/Hz/site)	Average data throughput	10	15-30
Mobility (km/h)	Maximum speed at which a defined QoS can be achieved	350	500
Latency (ms)	The time from when the source sends a packet to when the destination receives it	10	1
Connection density (per km^2)	Number of connections per unit area, for which certain quality parameters can be achieved	100,000	1,000,000
Energy efficiency	The radio interface capability to minimize energy consumption	1x	100x
Area traffic capacity (Mbit/s/m^2)	Total traffic throughput served per geographic area	0.1	10

source: ANCOM, based on ITU-R Recommendation M.2083

The table below briefly presents the performance requirements for high data rate and traffic density scenarios that may be introduced once with the implementation of 5G, according to the latest standards (3GPP Release 16 – service requirements).

Performance requirements for high data rate and traffic density scenarios

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
1	Urban macro	50 Mbps	25 Mbps	100 Gbps/km^2 (note 4)	50 Gbps/km^2 (note 4)	10 000/km^2	20%	Pedestrians and users in vehicles (up to 120 km/h)	Full network (note 1)
2	Rural macro	50 Mbps	25 Mbps	1 Gbps/km^2 (note 4)	500 Mbps/km^2 (note 4)	100/km^2	20%	Pedestrians and users in vehicles (up to 120 km/h)	Full network (note 1)
3	Indoor hotspot	1 Gbps	500 Mbps	15 Tbps/km^2	2 Tbps/km^2	250 000/km^2	note 2	Pedestrians	Office and residential (note 2) (note 3)
4	Broadband access in a crowd	25 Mbps	50 Mbps	[3.75] Tbps/km^2	[7.5] Tbps/km^2	[500 000]/km^2	30%	Pedestrians	Confined area
5	Dense urban	300 Mbps	50 Mbps	750 Gbps/km^2 (note 4)	125 Gbps/km^2 (note 4)	25 000/km^2	10%	Pedestrians and users in vehicles (up to 60 km/h)	Downtown (note 1)
6	Broadcast-like services	Maximum 200 Mbps (per TV channel)	N/A or modest (e.g., 500 kbps per user)	N/A	N/A	[15] TV channels of [20 Mbps] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network (note 1)
7	High-speed train	50 Mbps	25 Mbps	15 Gbps/train	7.5 Gbps/train	1 000/train	30%	Users in trains (up to 500 km/h)	Along railways (note 1)
8	High-speed vehicle	50 Mbps	25 Mbps	[100] Gbps/km^2	[50] Gbps/km^2	4 000/km^2	50%	Users in vehicles (up to 250 km/h)	Along roads (note 1)
9	Airplanes connectivity	15 Mbps	7.5 Mbps	1.2 Gbps/plane	600 Mbps/plane	400/plane	20%	Users in airplanes (up to 1 000 km/h)	(note 1)

NOTE 1: For users in vehicles, the UE can be connected to the network directly, or via an on-board moving base station.
NOTE 2: A certain traffic mix is assumed; only some users use services that require the highest data rates
NOTE 3: For interactive audio and video services, for example, virtual meetings, the required two-way end-to-end latency (UL and DL) is 2-4 ms while the corresponding experienced data rate needs to be up to 8K 3D video [300 Mbps] in uplink and downlink.
NOTE 4: These values are derived based on overall user density.
NOTE 5: All the values in this table are targeted values and not strict requirements.

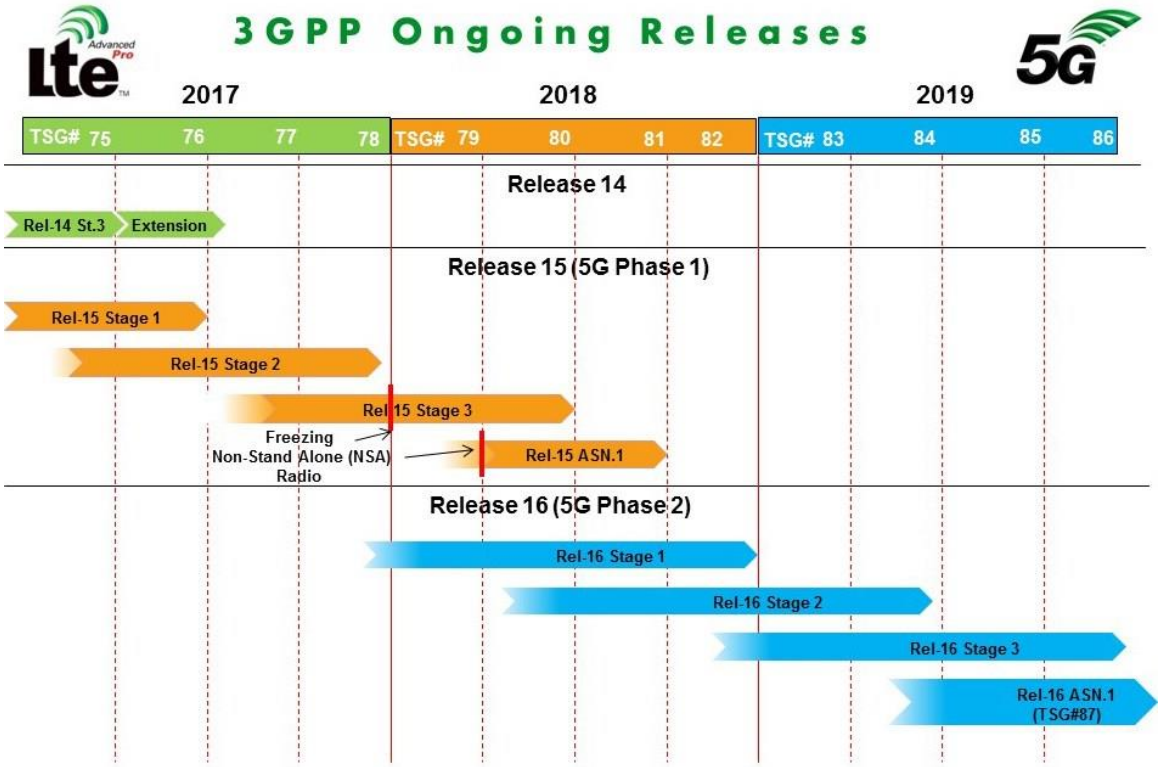
A detailed list of the new technologies in 5G context is presented in Annex no.1 – *Technical capabilities and innovating technologies in 5G context,* which is part of this document.

4.3. Evolution or revolution

On the one hand, the possible emergence of new ways of providing 5G networks, does not preclude considering a generally accepted scenario for the deployment of 5G networks in Romania and around the world, which is based on existing facilities/networks. In most cases, LTE/4G networks are the most advanced mobile communications networks currently in commercial use and are therefore the preferred starting point for the 5G.

On the other hand, even if 5G is considered a disruptive technology both due to the major technological leap and in terms of its capabilities in comparison to 4G (see Table 3 above), the evolution from one technological generation to another is usually achieved by several intermediate steps and rarely through a single "great jump". Figure no. 8 below shows the release schedule and the 3GPP standard releases during 2017 – 2019.

Figure no. 8 – 3GPP standard releases, 2017 - 2019



source: www.3gpp.org

For example:

a) considering the technical issues, some of the 5G typical features[42] may be achieved by the capabilities introduced by technologies evolved from 4G[43], respectively editions 13, 14 and 15 of 3GPP standards;
b) as shown above, only Release 16 of 3GPP standards, expected in 2019, will enable full compliance with 5G (IMT-2020) requirements; nevertheless, the early launch of "5G" deployments is also possible;
c) a similar situation has been registered in the transition from 3G (4th release) to 4G (10th release, the first release of IMT-advanced): the first LTE specifications (3GPPP releases 8 and 9) did not provide for reaching the 4G performance specified by ITU;
d) the technical synergies between consecutive releases (intermediate steps, standard releases) and competition between operators in the realm of innovation and network capabilities often drive to commercial naming of networks: a well-known example therefor is HSPA, considered as 4G in USA and 3G+ in Europe.

[42] e.g. *MIMO, beamforming, massive IoT*, etc.
[43] also known as 4.9G, or LTE Advanced Pro

Co-existence on the network level of several technological generations, and the gradual evolution towards the higher-capability generation has been proven in practice. However, regarding the services to be offered, the difficulties of capitalizing the benefits of the mobile internet or the uncertainty of capitalizing innovative, IoT-type services must be recognized. From this perspective, long-term incentives for the development of 5G networks depend on the extra revenue that can be gained from new services, from new forms of connectivity.

A reasonable expectation is that connectivity will be ensured for a considerable period by a technology mix: 5G implemented in dense urban areas in combination with 4G and indoor Wi-Fi connectivity. Therefore, the need for uninterrupted mobile connectivity of commercial products and services will have to be met by multiple technologies: the developer of an application, service or product with built-in connectivity will want to maximize its market by reducing exposure to 5G deployment at different paces from one country to another, using any networks available.

- *What kind of coverage for what connectivity scenarios?*

From a space-time perspective, 5G services will not have fixed features but will be the result of choices made by the network operator to meet service demand, within the limits of IMT 2020 standards. The simultaneous provision of all connectivity scenarios (enhanced mobile broadband, low latency fixed internet, massive machine-type communications and mission-critical communications), on wide areas and at the same time, and in compliance with all the performance indicators in the standards will be particularly onerous.

Therefore, it is more likely to find geographic areas that, although deemed to be covered by 5G, only benefit from some of the technical specifications of IMT-2020. Moreover, the mix of technical capabilities available in that geographical area may vary over time, depending on the choices made by the network operator[44], in response to changes in service demand.

[44] E.g. Sparsely populated geographical areas may be covered using the 5G standard in terms of satisfying the requirements for mMTC deployments (for example, precision agriculture), while the capacities required for high-speed mobile internet may lack.

5. The 5G Impact

5.1. Impact on costs and productivity

The size and the extent in space and time of the economic impact of 5G in Romania will depend on a multitude of factors. On the one hand, the 5G offer will depend on the speed, the amplitude and the geographical configuration of the network roll-out, influenced by long-term investment cycles, by the costs of implementation and by the legislative and regulatory framework. On the other hand, concerning the demand level, the service take-up speed and integration degree are critical for obtaining economies of scale and for creating digital ecosystems: the ability of users, households and business environment to reap the benefits of the new technology depends in turn on settling some potential challenges related to data protection standards, on ensuring the confidentiality and security of data and devices, on concerns about the security, capacity and reliability of 5G applications, and on resistance to digital change in general.

5.1.1. Productivity growth

Overall, the effect of 5G on productivity growth will be given by the evolution of production factors, inputs and outputs, as a result of the integration of 5G technology. Thus, the effects of 5G on production are expected in two directions: the increased efficiency with which existing products and services are produced and distributed (for example, mobile technologies allow better, easier access for consumers to entertainment or for the business environment to higher quality information), and the efficiency gains brought about by the new products and services that become available, compared to the products and services they replace (for example, the production and use of connected and self-driving vehicles can render the use of transport infrastructures more efficient by reducing congestion and improving navigation, transfer times, etc.).

On a global level, 5G is expected to make a significant contribution to industrial production in 2035[45], with 5G's largest contributions expected in the information and communications technology sectors, public services, agriculture, forestry and fisheries, transport and logistics, the hospitality industry, construction, finance and insurance and, respectively, public utility services.

5.1.2. 5G costs

On the other hand, regarding the necessary inputs, 5G requires additional investment and costs to build the physical infrastructure of the networks (to upgrade and install new base stations, to increase the capacity of backhaul networks, of the software and hardware platforms required, to develop systems and business models for M2M and IoT communications, as well as to acquire the rights to use radio frequencies).

The necessary investment depends, among others, on the forecasts regarding the increase of the existing capacities, on the technical capabilities used for building network coverage and capacity, on the number of users and on the concentration of the service demand[46], or on the frequency bands used for 5G. Radio frequencies directly influence the costs of 5G implementation, in terms

[45] https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf
[46] For example, in Great Britain, 85% of the investment budget is estimated to be necessary for covering areas with low population density

of spectrum costs (licence fees, usage fee, opportunity cost of not using frequencies for other purposes), but also of the investments necessary to "accommodate" services at different frequencies, taking into account the characteristics of propagation.
Despite the technological progress, it is obvious that the implementation of each new technology generation costs more than the previous one.

Considering the patterns of previous developments and subject to the rather indicative character of the figures, at European Union level[47] a 5G investment of EUR 56-58 billion euros is estimated to be necessary by 2025, which means an average investment of **EUR 145/European user**, and **7% more than for 4G** and 20% more than for 3G (after deflation). For Romania, the same study forecasts a required investment in 5G of **EUR2.3 billion**.

It should be noted that other estimates produce significantly different results, including based on the different methodologies applied or purposes considered. Examples in this regard are the estimates of the costs of 5G development in combination with the effects of other public policies, such as achieving strict universal coverage targets or simulating market entry circumstances (greenfield investment).

The implementation of previous technology generations has shown that mobile networks deployment may advance at different paces: there are periods of rapid deployment, especially in places where costs are lowest and expected commercial benefits are greatest, but there are also deployment lags, or even white spots, in commercially less attractive geographical areas.

5.2. 5G benefits

In the context where forecasts of global players in the field show that the number of 5G users will reach 1 billion by 2023[48], the estimated benefits of 5G are proportionally high, being expected to materialize on multiple levels, for both consumers and manufacturers of goods and providers of public or private services.

An input-output quantitative analysis conducted to examine the interdependencies between 38 economic sectors in the European Union[49] shows that the installation and use of 5G networks in Europe will have significant direct, indirect (multiplier) and induced (ripple) effects:

a) at EU level, the multiplier effects are estimated at EUR142 billion and 2.4 million jobs; **for Romania** only, the multiplier effects are estimated at **EUR4.7 billion** and over **252,000 jobs**;
b) the ripple effects estimated for four sectors (motor vehicles, transport, utilities and health) show gains of EUR62.5 billion/year, at EU level.

The benefits of capitalizing on 5G performance are derived from several sources:

a) **direct** benefits for 5G **users**, derived from their access to better products and services (improved in respect of costs, quality, experience, safety etc.);

[47] Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe, https://publications.europa.eu/en/publication-detail/-/publication/ee832bba-ed02-11e6-ad7c-01aa75ed71a1/language-en
[48] Ericsson Mobility Report 2017, https://www.ericsson.com/en/mobility-report/reports/november-2017
[49] See footnote 43

b) **strategic** benefits for vertical **industries**, derived from the better quality of information on production chains, internal operations, market characteristics, segmentation, consumption habits, etc., enabled by using 5G advantages;
c) **operational** benefits and increased productivity for vertical industries, generally following the real-time use of information on internal operations;
d) the advanced techniques of real-time data processing enabled by 5G have benefits for **adjacent sectors or third parties** as to the sector where the data are collected - for example, improving the provision of public services or of the security, based on the traffic management data collected;
e) launch of new business models, enabled by 5G specific capabilities;
f) increasing productivity and creating new jobs[50].

In another prospective analysis approach, the transformation enabled by investments in IoT and industrial digitization **in Romania** will bring significant increases in the turnover of smart industries, from $ 3.7 billion in 2020 to $ 9 billion in 2026 (CAGR + 15% 2016 - 2026). The 5G contribution to achieving these values is estimated to reach 40% in the year 2026[51].

Distribution of benefits by Romania's economic sectors

In the impact study on 5G implementation in Europe, the business environment is expected to achieve 55% of the 5G benefits by 2025. However, in terms of distribution of benefits across sectors, the 5G impact is likely to be felt differently from one country to another and from one sector to another, depending on the intensity of use of advanced technologies and communications services in the intermediate or final production.

Thus, according to the Romanian Industrial Policy Document[52], despite the progress made in the last decade, the technological intensity of the production processes in the Romanian processing industry continues to be modest (8% - in industries with advanced technologies), the gross value added at factor cost, achieved by the industries with advanced technologies, reaches barely 6% of the total.

Deeply intertwined with the European value chains, the supply of industrial products made in Romania is, however, dominated by intermediate goods (61% in 2016) mainly manufactured in economic sectors with low and medium-low technological intensity, and the length of value chains is in inverse proportion to value added, despite their already modest length (1.9). Moreover, it is noted "*a downward trend in Romania's position on global value chains, which shortened, "securing" its downstream position, as an exporter of intermediary products*", including in the context of Romania's ranking last in EU's European Innovation Scoreboard in 2016.

According to Romania's *Industrial Policy Document*, this situation calls for "supporting enterprises' digitization, in the context of *Industry 4.0*, given the overwhelming importance of the EU", as well as "the adoption of digital technologies and the development of clusters in services for the modernization of the Romanian industry and the development of new emerging industries".

---

[50] For example, extrapolating for Romania the results of a study on 5G for *Smart Cities*, in a city the size of Bucharest approximately 50,000 jobs could be created, 10,000 in cities such as Cluj or Iași, while in a town like Lugoj - approximately 400 jobs. https://www.accenture.com/t20170222T202102Z__w__/us-en/_acnmedia/PDF-43/Accenture-5G-Municipalities-Become-Smart-Cities.pdf%23zoom=50

[51] acc. to Ericsson – presentation for GLI-5G, 21 August 2018

[52] As of June 2018, http://www.economie.gov.ro/images/politici-industriale/SIPOCA7/Draft%20Document%20de%20Politica%20Industriala%2025%20iunie_final.pdf

In this context, 5G can make a substantial contribution to supporting industrial policies, thus responding to the real needs in Romania.

5.3. Security of electronic communications networks and services

The increasing importance of digital activities and the intensifying use of electronic communications networks and services by means of a variety of equipment should also be considered from the perspective of security concerns.

Therefore, providers operating in Romania must ensure that their networks are secure or that they take measures to guarantee network security and minimize the impact of incidents that may affect or threaten the security and integrity of electronic communications networks and services. The regulatory framework in the field of electronic communications, in force on the adoption date of this document, is considered adequate to meet these needs.

On the other hand, electronic communications networks must be considered also from the perspective of the need to ensure that they can face cyber security risks. In this context, the European Commission Recommendation of 26 March 2019 on cyber security in 5G networks[53] sets out a series of steps that need to be taken and the networks to be developed will have to comply with the provisions in force or to be adopted as a result of actions taken at national and/or European level.

5.4. Preferred uses

While many of the initial expectations regarding 5G have focused on consumer uses (improved internet) similarly to the case of previous technology generations, more and more technology providers and public authorities anticipate industrial use cases with significant impact likely to generate demand on an industrial scale for the services introduced by the new technology generation.

If - in the long run - 5G networks are to provide the necessary connectivity to cities, businesses and homes of the future, there are virtually no economic or community sectors in which 5G and IoT lack the ability to deliver innovation, productivity benefits or competitive advantages. On the other hand, it should be noted that, at present, even in the most advanced economies of the world, the use scenarios are still to be carried out, and their success will be achieved progressively, step by step, as the digital ecosystems develop. It is also very likely that the roll-out of 5G will be accompanied by further uses that could not be anticipated. There may occur also situations where connectivity providers are not communications operators (current providers of public electronic communications networks). That is, 5G connectivity does not necessarily imply the presence of a mobile communications operator in the value chain.

Concerning a series of key sectors, Table no. 4 below summarizes the issues on which many 5G debates have focused so far, as well as the potential contribution of 5G to meeting specific needs and challenges.

[53] https://ec.europa.eu/digital-single-market/en/news/cybersecurity-5g-networks.

Table no. 4 – anticipated contribution of 5G to addressing challenges and meeting needs in various sectors

Sector	Challenges	Needs	Contribution of 5G
Automotive	• stricter CO2 emission targets • strong competition • pressure on innovation • globalization • *commodification*	• self-driving and connected cars • innovative *infotainment* solution	• dynamic configuration of network resources, for meeting ever more heterogeneous needs • completing V2V communications
Mass-media, entertainment	• constant improvement of the quality of users' experience • new devices and services • exponential growth of mobile data usage	• networks enabling innovative services (VR, AR, tactile internet) for immersive experiences • interactive content, generated by users	• facilitate massive growth of connection speed and data processing capacities • guarantee high service quality
Smart communities (e.g. cities)	• sustainable development • quality standards in public services (sanitation, lighting, safety) • congestion & peak load • diseconomies of scale (home heating, selective garbage collecting) • pressure on costs	• higher capabilities • revamping technology • shorter response time in emergency • better information for city managers	• real time monitoring facilitates forecasts for disaster management, and for congestion response • higher granularity in the data processed, more advanced data analysis capacities
Smart homes	• increased efficiency in energy and water consumption, in heating etc. • environment responsibility	• reduced consumption and pollution • adjustment to the environment factors • time economy (housekeeping efficiency)	• scalable solutions based on IoT sensors and cloud applications
Energy and utilities	• decentralised electrical power supply • pressure on consumption • more renewable energy • addressing blackout situations	• dynamic smart networks, that can be remotely monitored and controlled	• real-time control of transport and distribution networks
Public transport	• emphasis on safety and security • higher numbers of passengers • shorter waiting time	• real time information • passenger entertainment • higher infrastructure maintenance and operational efficiency	• provides coverage and bandwidth required for infotainment and for higher efficiency
Agriculture	• growth in global population • pressure towards cutting down on pesticide use • deficit of labour force in agriculture • subsistence farming with reduced efficiency	• solutions for sustainable agriculture • precision agriculture for increased productivity and efficiency	• remote connecting and control of agriculture equipment • provides the required bandwidth for advanced imaging and drone use

Sector	Challenges	Needs	Contribution of 5G
	• climate change • food waste • globalization and price volatility		
Banks & insurance	• accuracy in risk estimates • (re)insurance premiums • electronic, mobile banking services • alternative money transfer methods • cryptocoins, fintech	• fraud detection • consumer segmentation • enhanced experience • fast transactions	• advanced data processing and analysis techniques • safe solutions
Health	• population ageing • higher numbers of chronic disease cases • number of nights in hospital • expectations regarding personalized medical care • cost of medical care • fragmentation of medical services	• access to medical care solutions • wearable devices for monitoring and even treatment • remote care and monitoring • patient's medical file	• enables guaranteed and secure mobile connections for remote monitoring and care solutions • better imaging and diagnosis using advanced data processing techniques
Industries 4.0	• ageing of labour force • competence deficit • globalization, pressure on cost reduction • environment protection	• enterprise robotics and automation • solution for lower production costs • inventory reduction • freight tracking	• provides and ultra-reliable communications platform in the enterprise • customised IoT solutions • advanced data processing techniques
Education	• low participation of rural population in education and training • early school dropout • adjust labour offer to the market demand • quality of education processes • cost level compared to financing	• sharing resources with a higher number of students/pupils • high quality remote education • accessible continuing education programmes • adjustment to special needs	• tactile internet, virtual reality, no physical barriers to accessing experiments and enables real-time interaction • cloud robotics for special needs
Security, emergency services	• increased recurrence and complexity of security alerts • terrorist threats • focus on cybersecurity	• more monitoring and screening in public spaces • instant access to better information	• enables higher monitoring and detection capacities, including by dedicated applications
Extractive industry	• high production costs • globalization of the raw material market • impact on environment	• environmental rehabilitation • competitiveness	• extractive processes automation for significant efficiency growth

source: GLI-5G, based on publicly available information

In the long run, 5G will have a universal and probably greater impact than is usually anticipated in the studies conducted so far. Moreover, a major challenge is to identify the various 5G usage scenarios and to create the services and pricing arrangements that are appropriate for these uses.

5.4.1. Industry 4.0

Increasing productivity by digitizing the manufacturing industry, also known as the fourth industrial revolution (or Industry 4.0) is fuelled by the development of cyber-physical systems (CPS) [54][55] and by the Internet of Things (IoT). Increasing the significance of CPS necessarily and objectively implies a substantial improvement of connectivity, but also communication and rapid exchange of information between a multitude of different devices, situations that clearly enhance the role of 5G in value-added generating chains.

The most popular uses of connectivity in Industry 4.0[56] are based on machine-type communications and target both the industrial processes within an enterprise (closed circuit) and their integration between different companies:

a) the devices installed on a production line communicate automatically with the control units to ensure the significant flexibility and efficiency of production cycles;
b) autonomous vehicles transport goods safely and efficiently within the factory;
c) process automation, achieved through a large number of sensors and actuators that communicate and receive instructions from the control units contribute to increasing efficiency and reducing inventories;
d) permanent tracking allows the optimization of goods flows, in different processing stages, from raw material to finished product and delivery to the customer;
e) remote assistance and control of robots to perform a variety of tasks, such as measurements, digging under difficult conditions, etc.;
f) augmented reality improves the physical environment necessary for maintenance operations or for personnel training.

Some of the connectivity scenarios required for Industry 4.0, especially the closed-circuit ones, within the enterprise, can be carried out using existing technologies, such as NB-IoT, LoRa, SigFox, etc. and Wi-Fi networks or their evolutions, such as WiGig[57].

However, the massive increase in the density of connected objects, latency, bandwidth, or even energy efficiency requirements may require 5G deployment. Also, the use of 5G will have major comparative advantages, given by the simple network planning and management, but also by the security of the services and the advanced data processing techniques facilitated by edge computing.

The great diversity of connectivity use cases in Industry 4.0 is both an opportunity and a challenge: on the one hand, understanding the specific requirements of the sectors creates the need for information sharing, and on the other hand, productivity pressure fuel the industry's

[54] Cyber-Physical systems
[55] Further information on CPS systems is available, for example, here: https://rria.ici.ro/wp-content/uploads/2013/12/art.5-dumitrache.pdf
[56] According to *The 5G-PPP White Paper on Factories of the Future Vertical Sector*, https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Factories-of-the-Future-Vertical-Sector.pdf
[57] https://www.wi-fi.org/discover-wi-fi/wi-fi-certified-wigig

interest in 5G development, materialized through active partnerships with communication network providers.

In the context of the strategic planning in Romania and the implementation of the National Competitiveness Strategy[58] and the Research, Development and Innovation Strategy 2014-2020[59], the technological refurbishment of the companies due to 5G can become an area of priority intervention defined as an integrated area of development, justifying as well the intervention of public funds to support investments in technological refurbishment.

For example, implementing 5G smart systems in Romania can give rise to uses in the following areas/directions:

a) **remote industrial maintenance** for industrial equipment with ultra-fast intervention and adjustment/configuration;
b) **industrial cybernetization**, offering the possibility of simultaneous coordination (management) of multiple high-tech mechatronic and cyber-mechatronic units of equipment, with variegated orders and in optimum time;
c) **connectivity and integration at regional level** (or multi-regional level) of digital production facilities from different SMEs (associated in clusters/competitiveness poles) that generate high added value through digitized partnerships, in keeping with smart manufacturing, which is much more flexible and adapted to global requirements;
d) **programmable robotics** with ultra-fast connection and integration, which will make all robotic processes exponentially more efficient, faster and which can generate a particularly high technological breakthrough.

Moreover, development will be encouraged especially in intelligent speciality domains, as regards the integrated structures that bring together research companies and organisations with similar and/or complementary technological profile.
By analogy or induction, the term 4.0 is used to characterize technological progress related to digitization and in other sectors of economic life.

5.4.2. Connected and self-driving cars

The automotive industry is marked by the early adoption of a variety of connectivity solutions, aimed at improving the driving experience and road safety, at collecting information on the performance, on pollution or on the maintenance of the vehicle, while being considered one of the predilect industrial sectors for the capitalization of 5G performance.

Here are several of the numerous car connectivity use cases to be developed in the future:

a) enhanced infotainment – on-demand entertainment, travel guidance services and roadside assistance, traffic management, local weather or road condition information services, etc;
b) innovative services, such as insurance according to usage, due to the large volume of telemetry data that can be generated;

[58] National Competitiveness Strategy 2014-2020, Ministry of Economy, 2014, http://www.economie.gov.ro/strategia-nationala-pentru-competitivitate-2014-2020
[59] The National Strategy for Research, Development and Innovation 2014-2020, UEFISCDI, https://uefiscdi.ro/strategia-cdi-2014-2020

c) boost towards autonomous vehicles, by means of collision avoidance solutions, emergency braking, platooning and extending V2V communications beyond the field of vision, based on improved location etc.;
d) remote monitoring of the car's condition and predictive maintenance.

Some of the automotive connectivity scenarios, especially those that do not have real-time provision requirements, such as remote monitoring or predictive maintenance, do not necessarily require the use of 5G. Also, primary vehicle-to-vehicle (V2V) communication solutions - such as DSRC (dedicated short-range communications) or standardized[60] ITS (Intelligent Transport Systems) systems allow direct communication between origin and destination without using a communications network. However, in the gradual evolution towards the self-driving, connected vehicles of the future, such solutions may prove insufficient, especially insofar as, in order to ensure security, the connectivity requirements extend beyond the simple connection between vehicles (V2V), involving connecting vehicles to infrastructure (V2I - vehicle-to-infrastructure) or to pedestrians (V2P - vehicle-to-pedestrian).

Thus, it is anticipated that the role of 5G in the automotive industry will show in several domains: improve the infotainment services on board cars, facilitate the collection and processing of more data needed to provide innovative services etc. Furthermore, 5G performance is considered critical for completing the current short-distance communication requirements through ultra-reliable V2X (vehicle-to-everything) communications, which are needed to improve the autonomy of cars.

Moreover, a study by Deloitte for the association of mobile communications providers in the United States of America (CTIA) estimates that self-driving vehicles could reduce pollution by up to 90%[61], and - in Romania - the *National Strategy on climate change 2013-2020* sets among the strategic objectives[62] cutting down emissions related to road transport and promoting intelligent transport systems, as those enabled by 5G technology.

5.4.3. Transport & logistics

The potential of 5G-based applications is also huge in terms of logistics, freight and passenger transport and of postal services, in the context of globalization and increasing pressures related to environmental protection. The increasing demand for passenger mobility and for transport, storage and delivery of goods, due to the upsurge of international trade and - in the recent years - of electronic commerce, has had a significant impact on the market for postal and transport services and has already generated a wave of innovation and re-technologization. However, the phenomenon continues and grows - the higher the speed, the greater the carbon footprint.

Similarly to the internal logistics of a manufacturing company, in the logistics related to domestic or international trade involving operations of handling, storing, transporting and delivering goods, there are multiple flow optimization opportunities, which new applications based on the new technologies can materialize. Sensors connected to 5G networks, as well as the automation of

[60] E.g., the standard IEEE 802.11p, https://standards.ieee.org/findstds/standard/802.11p-2010.html
[61] "Wireless Connectivity Fuels Industry Growth and Innovation in Energy, Health, Public Safety, and Transportation", Deloitte, https://api.ctia.org/docs/default-source/default-document-library/deloitte_ 2017011987f8479664c467a6bc70ff0000ed09a9.pdf
[62] National Strategy on climate change 2013-2020, Ministry of Environment and Climate Change, 2013, http://mmediu.ro/app/webroot/uploads/files/Strategia-Nationala-pe-Schimbari-Climatice-2013-2020.pdf

processes in warehouses and on sorting and loading lines will increase the efficiency, accuracy and speed of deliveries and will significantly reduce the pollution generated by logistics. Delays inherent in intermodal transport, due to the multiple platforms (road, rail, air, river or maritime) used, can be minimized by means of 5G.

Intelligent public transport solutions in cities or on the roads are best approached in the smart city context.

5.4.4. Energy

First, 5G technology will be more energy efficient than previous technology generations, allowing the installation of off-grid network elements that are independent of the electricity grid and reducing both operational costs and environmental impact.

Moreover, due to its specific features - the capacity to connect a huge number of objects (mMTC), low latency and ultra-reliability (URLLC), the 5G technology seems to meet the constructive and functional requirements of smart-grids - smart networks for energy transport and distribution, able to control real-time consumption, with instantaneous capacity optimization and two-way communication with consumers.

To benefit from the opportunities offered by the global energy transition process, *The Romanian Energy Strategy 2016-2030, with an outlook to 2050*[63], sets new strategic directions for action, including the development of smart networks of energy transport and distribution networks, and shows that smart grids will facilitate the transition of the consumer to the role of prosumer, who injects his/her own electricity production into the grid.

The strategy identifies the delays in the action plan for the development of smart grids and lays down provisions for the financing of investments in transport and distribution networks to increase their efficiency and carry through the transition to smart grids.

Another strategic direction is promoting smart buildings in respect of their construction, architecture, operation, transformation and storage of energy, with due regard to the prosumer target, as well as transforming Romania into a production centre for energy-transition machines, components and materials. The strategy provides that the new technologies will be adopted gradually, at an ever-lower cost, considering the protection of privacy and a high degree of security to cyberattacks.

5.4.5. Public utility services

Beside the direct benefits from investments and the enhanced connectivity offered to local citizens and businesses[64], the new generation of communications is of particular interest to local authorities because it comes with solutions to many of the requirements of smart city applications - the "smart city" - developed in recent years. In fact, many 5G use cases address the need to

[63] The Romanian Energy Strategy 2016-2030, with an outlook to 2050, Ministry of Energy, 2016, http://energie.gov.ro/wp-content/uploads/2016/12/Strategia-Energetica-a-Romaniei-2016-2030_FINAL_19-decembrie-2.pdf

[64] See the IoT objects recently taken onboard in households, according to the market survey ordered by ANCOM

optimize public utilities, transport and safety in densely populated urban areas. Due to the superior technical features of 5G, applications that now operate on LTE networks will materialize their full potential, processing data from hundreds of thousands of fixed and mobile sensors, transmitting information from moving vehicles or from sewers, monitoring the use of certain road segments or the status of bridges, for years.

Studies on the 5G's potential to improve the lives of communities indicate that this technology will make possible integrated traffic optimization applications that combine road use monitoring with traffic lights control and intelligent parking systems, will enable reducing interruptions in water and energy supply, as well as reducing energy consumption on public lighting or improving the efficiency of selective waste collection. For providing these benefits to their communities, local administrations are directly interested in speeding up the issuance of building permits, allowing access to public property and adapting their charging systems[65].

In Alba Iulia, designated a flagship smart city by the Government of Romania, 29 private companies - application developers and communications providers - are already testing, in collaboration with the local authorities, over 60 specific smart city solutions, among which traffic monitoring, air quality and illegal parking detecting systems. The buses of the local public transport system are equipped with GPS, so the citizens can find out their real arrival time. The pilot applications tested in Alba Iulia have been installed at the expense of private companies, the local authorities providing the information they control and the necessary approvals.

Based on the results of these tests and drills, as well as on various success stories in the country and abroad, an inter-institutional working group led by the Ministry of Communications and Information Society is currently preparing the national strategy for regulating, implementing and optimizing smart-city digital technologies in Romania.

5.4.6. Agriculture

For Romania, with about 30% of the population employed in agriculture and a low labour productivity in this sector[66], increasing agricultural productivity is a strategic priority, correlated with the sustainable management of natural resources, the balanced territorial development and with environmental constraints.

[65] How 5G Can Help Municipalities Become Vibrant Smart Cities, Accenture, 2017, https://www.accenture.com/t20170222T202102Z__w__/us-en/_acnmedia/PDF-43/Accenture-5G-Municipalities-Become-Smart-Cities.pdf#zoom=50

[66] The strategy for developing the agri-food sector in the medium and long run: 2020-2030, MARD, 2015, http://www.madr.ro/docs/agricultura/strategia-agroalimentara-2020-2030.pdf

Precision agriculture, focused on improving yields and minimizing economic risks, aims to ensure high control in the management of agricultural production. Agricultural companies are turning to computer systems for real-time monitoring of crops, which facilitates informed decision-making regarding fertilization, sowing, treatment and harvesting.

5G can provide the infrastructure needed to develop precision agriculture due to the bandwidth that 5G networks will ensure and that will become important when sensor-based monitoring systems are combined with advanced imaging received from unmanned aircraft systems (drones) or from special cameras located on-site and with cloud analysis, allowing automatic adjustments in precision agriculture. Agricultural machinery and equipment will be increasingly connected and become autonomous, low latency and network security being crucial requirements.

Scalability of many connected devices will optimize agriculture by improving productivity and crop selection, in pursuit of integrated crop management within smart farms.

Here are a few of the possible applications enabled by 5G in the future, in the field of agriculture:

a) **connected agricultural equipment**: vehicles (tractors, combine harvesters and trucks) remotely controlled by an operator, or automatic agricultural equipment (smart milking equipment);
b) **smart irrigation**: the use of devices and controllers that reduce the waste of water based on information transmitted in real time about the conditions in the field;
c) **crop monitoring**: real-time crop monitoring, which allows tracking the positive or negative dynamics of crop development;
d) **soil sensors**: real-time monitoring of soil or air quality parameters (degree of fertilization, pH, nitrogen, phosphorus, potassium, humidity, temperature) and identification of diseases or insects;
e) **directing and monitoring livestock**: real-time monitoring and management of livestock;
f) **unmanned aircraft systems (drones) in agriculture**: monitoring of agricultural areas, livestock or self-driving vehicles.

5.4.7. Health

Some of the applications that 5G will enable in healthcare, such as least invasive VR-based surgery - including tele-surgery -, indicate that implementing connectivity- and new technology-based medicine solutions can significantly reduce the burden on the medical system and healthcare costs[67]. The availability of healthcare services will improve, access to high quality services will no longer be limited to large cities, permanent monitoring systems will increase the survival rate in heart attack and, most importantly, will prevent the installation or aggravation of various diseases, significantly increasing the quality and duration of people's life, and providing the medical and research community with the information needed to identify new healing solutions and rehabilitation or prevention methods.

Specifically, these new possibilities for collecting and processing large volumes of data on the

[67] Wireless Connectivity Fuels Industry Growth and Innovation in Energy, Health, Public Safety, and Transportation, Deloitte, 2017, https://www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/wireless-technology-fuels-innovation-in-key-industries.html

impact of lifestyle, reactions to different treatments and on patient evolution give hope to researchers due to their potential for discoveries and innovations with a significant impact on health, while studies reveal that patients are willing to use connectivity-based monitoring systems, to let their data be processed in cloud, and even adjust their lifestyle using connected objects (smart watches and fitness bracelets).
In Romania, fragmentation of health services is one of the major current problems, with a negative impact both on the people's access to services adapted to their needs and on the costs for the health system, often the services reimbursed from public money being unnecessarily doubled (e.g. - investigations for a patient's diagnosis are repeated at very short intervals)[68]. Interconnection of the different recording and reimbursement systems and the possibility of accessing updated data in real time could contribute to the achievement of the strategic objective of developing an integrated health system.

The Ministry of Health, through the National Health Strategy[69], is committed to the development of the telemedicine system and to fostering its use at the pre-hospital and inter-hospital level, setting a strategic action direction in this regard.

Increasing the public health system's capacity of response in the event of pandemics or emergencies is also a strategic national defence objective[70], and solutions based on new technologies can contribute to actions of national importance such as reviewing the mechanisms for monitoring the activity in the emergency sector.

5.5. New business models in communications

Beyond the new business models enabled by the digitization of economic sectors, through its features, the 5G development may be associated with changes in the traditional models of providing services and communications networks and with the emergence of new positions in the value chain. Elements featuring the highest potential are mentioned below:

a) service differentiation

The ability to differentiate between services due to virtualization and informatization (given the increasing importance of software), network segmentation, etc. may lead to growing demand for mobile connectivity (for example, niche applications with limited coverage, such as augmented reality in a factory), and to increased complexity of the pricing models (for example, for capturing the particular characteristics of the services offered).

b) growing connectivity demand

Increasing the number of connected objects due to the uptake of IoT, in combination with their ability to be connected to alternative networks (e.g. to 5G private networks, or to Wi-Fi) requires the development of new pricing models, which are not currently available.

---

[68] The National Health Strategy 2014-2020, Ministry of Health, 2014, http://www.ms.ro/wp-content/uploads/2016/10/Anexa-1-Strategia-Nationala-de-Sanatate-2014-2020.pdf
[69] Ibidem
[70] National Defence Strategy, 2015-2019, Presidential Administration, 2015, http://www.presidency.ro/files/userfiles/Strategia_Nationala_de_Aparare_a_Tarii_1.pdf

In particular, the success of the new tariff models depends on giving the right economic signals, in accordance with the respective connectivity scenario, beyond solving the "who pays for connectivity" problem. As well, the position on the value chain can evolve: for example, the communications operator can expand its portfolio by selling devices connected to its own network, the device provider or an intermediary can negotiate connectivity agreements with the network providers to provide a "complete" solution.

c) new downstream intermediaries

To the extent that 5G enables products and services with built-in connectivity, these will be launched on the international market. As a result, 5G opens opportunities for intermediating the provision of services, such as connectivity aggregators for specific products, industries or transnational geographies. Typical use cases are currently deployed in the automotive sector, the communication operators' downstream intermediaries.

d) network densification and upstream intermediaries

Massive site densification, especially in the case of using millimetre waves to meet the requirements of indoor coverage or in semi-public spaces (shopping centres, airports, stadiums, etc.) raises significant problems (contractual, logistical, technical, environmental etc.). Furthermore, the multiplication of challenges in one place, given the need for multi-network coverage, is potentially inhibiting for the owner/manager of the space, as well as for operators.

Such a situation can give rise to new opportunities for intermediation, upstream from the providers of traditional communications networks: specialized in the acquisition, installation or operation of sites in well-defined areas - high-density hot-spots or parks/industrial halls - this type of enterprise provides wholesale connectivity services to providers of mobile networks with national coverage. A typical case in this regard is illustrated by the use of part of the 3.6 GHz band in Ireland.

e) mobile convergence - PPDR

As the performance of mobile internet is drawing near the experience offered to users by the fixed internet or is improving in certain geo-demographic situations (e.g. low population density in remote areas), mobile internet services may evolve progressively from complementing the fixed internet to substituting it. Moreover, with cell densification and function virtualization the boundaries between fixed and mobile networks will become irrelevant.

Furthermore, the competition dynamics in Romania have shown high potential for exploiting the fixed-mobile convergence through organic development, and recently, through the effects of an acquisition on the European market.

Moreover, public protection and disaster relief (PPDR) services, currently provided by an independent network infrastructure, may be ensured by the software evolution and virtualization facilities offered by the networks of commercial operators. These facilities enable creating separate virtual networks on the same physical infrastructure, each with its own specific requirements.

Although it is unlikely that commercial networks will be able to provide a complete PPDR solution from all points of view, they can benefit from the operational and investment efficiencies due to reducing the duplication of physical infrastructures by exploiting synergies with PPDR services.

f) sharing infrastructure, costs and benefits

The actual implementation of certain connectivity use cases is more attractive by sharing infrastructures, being facilitated by the evolution towards software and virtualization. With 5G and the industrialization of IoT/M2M, the sharing of infrastructures, usually achieved between the communications providers, may be extended by the emergence of infrastructure operators or by attracting "verticals". That is, any disparity in investment incentives between "verticals" and communications network providers can be balanced by partnerships or joint ventures.

5.6. Key SWOT elements

The scrutiny of these emerging trends in Romania and around the world - of the global race for 5G, of the European 5G pioneering and of and their impact on public policies, of the benefits, costs and use cases enabled by 5G - generates the main elements of a SWOT analysis on the implementation of 5G in Romania.

Strengths	**Weaknesses**
• the dimensions of Romania's internal market • Romania's membership in the European Economic Area • superior performance • availability of new spectrum resources for 5G • healthy and dynamic competitive environment • the multinational experience of communications network providers • user/consumer equipment becoming more intuitive, easy to use • massive miniaturization • evolution towards software and virtualization of network functions	• limited incremental revenues from the sale of the mobile internet as a spearhead for the 5G transition • limited integration in the medium term of 5G technologies in other sectors (short value chains) • limited commercial attractiveness of some use cases • import of connectivity solutions customized for other markets • poor development of R&D activities • low digital literacy
Opportunities	**Threats**
• digitizing the economy and society • massive increase in demand for internet & data, mobility • the advancement of the Internet of Things (IoT)	• the authorization regime for construction works • connecting cells by optical fibre • legislation (primary, secondary, etc.), procedures, not adapted to the digitalization of the economy and society

• the advancement of knowledge mining from data (data mining) and advanced data processing techniques (data analytics) • size and performance of existing networks and currently used frequency portfolios • the advancement of the ICT & software industry • long investment cycles • the stock of existing physical infrastructures and their usage degree • emerging business and social organization models (e.g. sharing economy and society)	• competing alternative solutions (e.g. NB-IoT, Wi-Gig, etc.) • market structures, inefficient tariff models • risks (including risk perceptions) concerning security, data protection, EMF level, etc.

One could carry out a more detailed SWOT analysis, but we consider that it would bring marginal utility to the strategic planning approach for 5G in Romania, especially due to the limitations of such analyses in the case of such disruptive technologies as 5G, and to the complex dynamics on various world markets, with pronounced cross-border cascade effects.

6. STRATEGIC OBJECTIVES

The strategic objectives highlight the priorities of the 5G implementation in Romania and set points of focus for the decision-making processes of the public and private stakeholders in the field. Objectives or targets cannot provide standalone solutions to the challenges; their achievement requires additional tools in place within a coherent framework - policies, legislation, funding, support measures, investment and work.

In accordance with the provisions of indent 1.1.1. of the Annex to the Government Decision no.870/2006[71], this strategy observes the principles of transparency, responsibility, proportionality, predictability and efficient use of resources.

The 5G players will be able to reap the benefits of this technology step-by-step, at different paces in different sectors, within long-term investment cycles, by 2035. Nevertheless, the strategic objectives envisage targets that may be achieved in the first period of the current strategy horizon (2019-2030) – this is when networks are expected to roll-out and use cases to be validated.

The availability of technical infrastructure and network coverage, price competitiveness and the reasonable cooperation between private businesses and public (local and central) authorities are the main ingredients for the achievement of the strategic objectives.

6.1. Rapid service deployment (2020)

The rapid launch of 5G services stands as an objective due to the expected gearing effects and the need of exposing the technology to the actual conditions in place, and Romania is in a favourable position in this respect, due to the rights of use awarded in the 3.4-3.8 GHz band and to the healthy competition environment.

The Government of Romania, together with the governments of the other EU Member States and with the European Commission, have taken on board an ambitious roadmap which, with a view to ensuring the EU leadership in the global race for the new generation of mobile technology, provides the 5G commercial launch in the top largest cities in 2020, and the coverage of all urban centres[72] and main transport corridors[73] by 2025.

In this vein, in order to foster investment in 5G network deployment, in 2019, Romania will make available **additional radio spectrum resources**, harmonized at European and global level. Then, making the best of the WRC-19[74] outcomes will enable the release of massive spectrum amounts in millimetre bands.

Given the investment efforts needed to build 5G networks, network deployment and the commercial launch of such services is anticipated to begin in the most commercially attractive areas, i.e. in major cities. With a view to incentivizing investments in the rapid launch of

[71] The Strategy for improving the system of public policy elaboration, coordination and planning in the central public administration
[72] https://ec.europa.eu/eurostat/statistics-explained/index.php/European_cities_–_the_EU-OECD_functional_urban_area_definition
[73] Trans European Transport Networks (TEN-T), according to Regulation (EU) no. 1315 din 2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU (Text with EEA relevance)
[74] https://www.itu.int/en/ITU-R/conferences/wrc/Pages/default.aspx

commercial 5G services in certain urban centres, it is important to consider socio-economic criteria regarding the adjacent industrial landscape, the take-up of Smart technologies, the scientific potential related to the size of the university centre, the tourism potential, the organizational maturity of local authorities, the connections to the major transport corridors, and the events to be hosted in the next 3 years.

On the other hand, for a successful and fast 5G roll-out, the top-down approach based on objective criteria needs to be complemented by the open approach of the local communities, which should come forward with facilities and support measures proposed by community administrators.

Thus, following the reconciliation of the top-down criteria with the real opening of communities, the flagship cities for launching **5G commercial services in Romania in 2020** are Cluj-Napoca, Iasi and Timisoara, one of the 2021 European Capitals of Culture.

Local authorities in the three cities will identify, propose and agree with the Government of Romania on specific measures, including facilities concerning the use of the public areas, for the rapid deployment of 5G networks.

Not the least, concrete popularization steps will be taken for raising awareness of the benefits of the new 5G technology among local authorities, citizens and the business environment, as well as for reducing the information asymmetry regarding the effects of cell miniaturisation and network densification.

6.2. Early reaping of 5G benefits

Seizing the 5G opportunities as early as they become available creates both competitive advantages for the communications sector and for the entire economic ecosystem and brings about higher quality of life in the whole Romanian society.

A high pace of efficient investment in 5G networks enables reaching critical mass, which is needed for achieving the economies of scale that allow for providing 5G services cost-effectively. However, capitalizing the potential of a connected economy and society that benefits from smart mobility and regional ICT connectivity requires 5G connectivity beyond the critical mass in cities, in their surrounding areas, and along the main transport corridors.

In pursuit of maintaining competitive gains in the mobile communications sector, we plan to have the following **areas in Romania covered with 5G services, by 2025**:

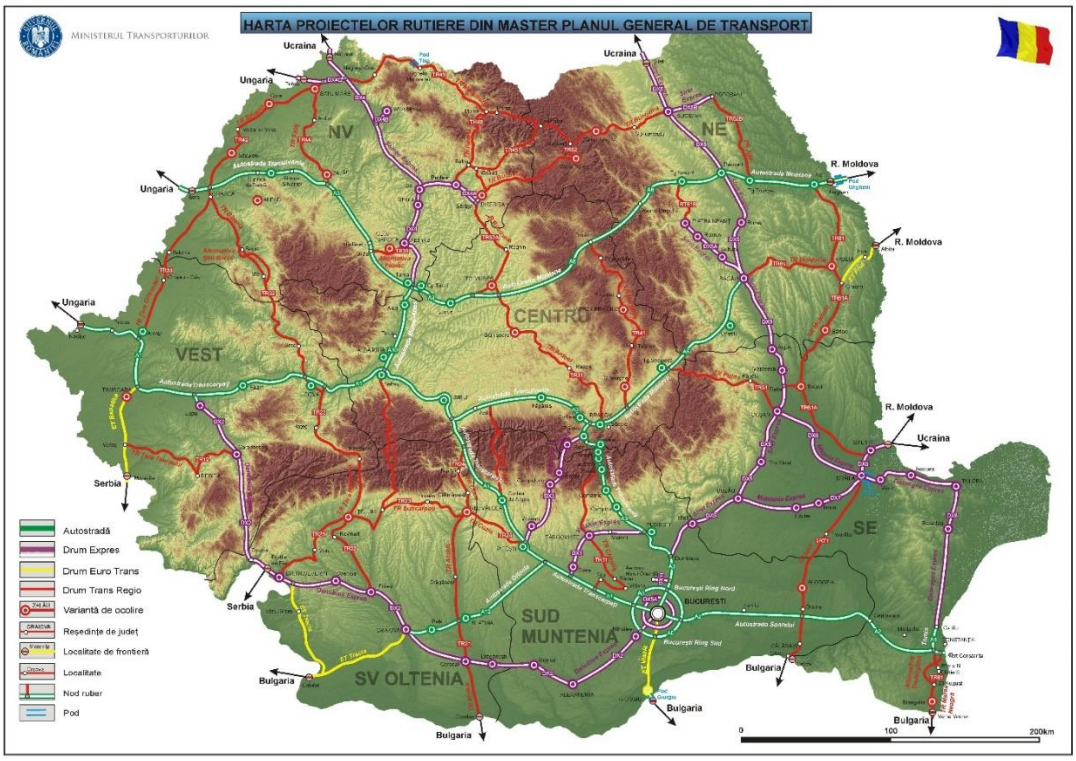
- **all functional urban centres**[75];
- uninterruptedly, all along the highways, expressways and modernized railways completed or to be put into service by 2025, according to MPGT[76] and TEN-T[77] in force on the date of this strategy - see Figures no. 9 and 10 below;
- **international airports, sea** and **river ports**, as defined in TEN-T, with both indoor and outdoor coverage in the M2M communications scenario;

[75] idem footnote 65
[76] Romania's Transport General Master Plan , http://mt.gov.ro/web14/strategia-in-transporturi/master-plan-general-transport/documente-master-plan1/1379-master-planul-general-de-transport
[77] idem footnote 66

- the top 10 industrial parks in Romania[78] (in terms of the turnover achieved in these parks), with both indoor and outdoor coverage in the M2M communications scenario.

The coverage obligations incumbent on the holders of future licenses for the use of radio frequencies will be set in line with these objectives.

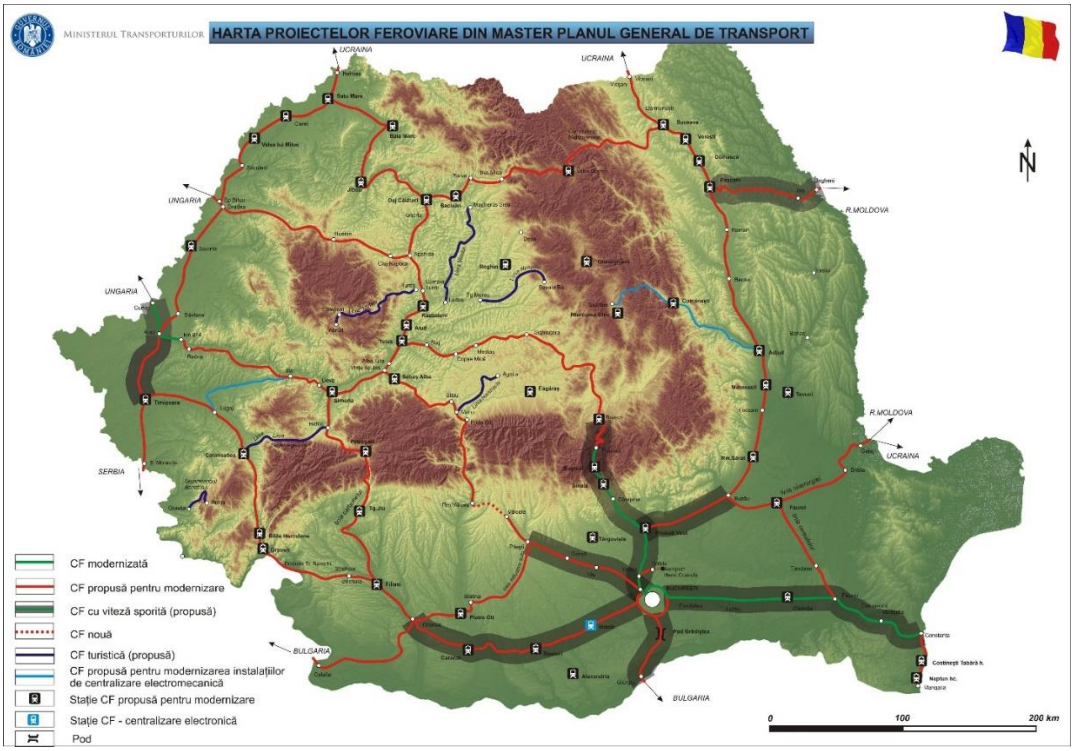
Figure no. 9 – Highways and expressways according to MPGT and TEN-T



Source: Ministry of Transport

[78] http://www.mdrap.ro/administratie/-8388

Figure no. 10 – Railways, according to MPGT



source: Ministry of Transport

6.3. Reducing barriers to 5G network development

Barriers to the development of 5G networks hinder the take-up and increase the prices of services provided on them. To the extent that these barriers are endogenous to investment in mobile communications networks, we will keep working for significantly reducing the level of these barriers by applying concerted measures towards:

a) ensuring an optimal mix of frequency spectrum resources for the efficient long-term development of 5G networks, under secure investment conditions;
b) ensuring optimal (technical, competition and security) mechanisms for network peering;
c) fostering take-up and reducing (tariff and non-tariff related) barriers for access to existing physical infrastructure that can be used by communications networks;
d) reducing bureaucratic barriers for building new physical infrastructure, required for supporting communications networks;
e) designing, authorizing and executing construction works for roads, motorways and railways with in-built infrastructure facilities for 5G network deployment;
f) designing and applying a favourable regime for the installation and use of pico-cells/small cells, including for their fibre-optic connection with backhaul networks.

To this end, in order to stimulate the competitiveness of 5G services, the spectrum resources available below 1 GHz will be used to the utmost extent for public 5G networks.

Moreover, the state of play of public communications network infrastructures in Romania will be assessed and reported at least once every 3 years. We will also use these reports to review public policy on electronic communications infrastructure.

The setup of special or exclusive arrangements for access to essential 5G infrastructures for the purpose of extracting rental fees or building 5G private networks by local public authorities in densely populated urban centres may hinder the development of 5G networks.

6.4. Promote new uses and foster cooperation

The Internet ecosystem has boomed in the context of the symbiosis between online content providers and providers of communications networks used to carry content to the Internet consumers: the demand for data transmission over the Internet is not determined by the content provider (although it generates the traffic), but by the network provider's users, while the demand for Internet access services that fuels the sales of the network provider is generated by the very success of the online content created by content providers.

In a similar way, it can be deemed that a significant share of the 5G success will depend on the symbiosis between connectivity (network) providers, the providers of online content/Internet 2.0 applications, and the providers of connectable objects/devices/sensors: the connectivity demand benefiting the 5G network provider is rooted in the functionalities, the applications, and in the content created, whereas the value of the content made available through IoT, Internet 2.0, etc. generates the success of these solutions[79]. This principle works for most vertical connectivity scenarios, such as 4.0 industries.

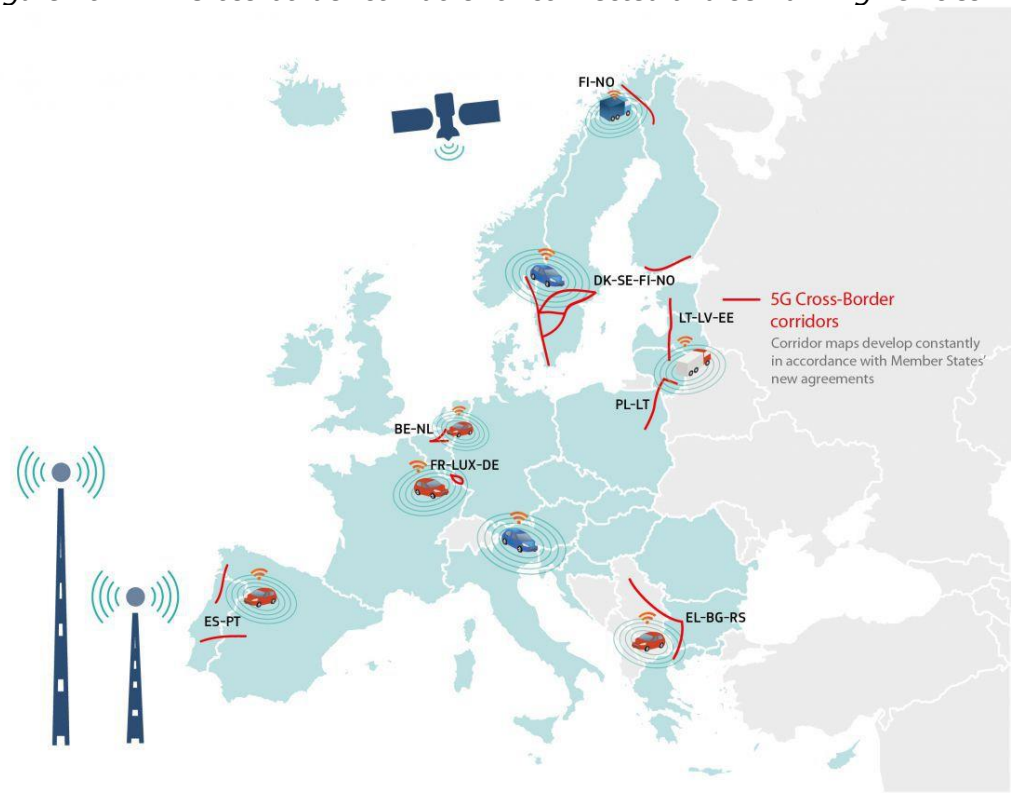
New uses, new connectivity scenarios, bring along important economic and social benefits and also support 5G medium-term growth. Furthermore, 5G's success depends on achieving economies on a larger scale than available in the Romanian market.

Therefore, we pursue promoting new uses and foster cooperation by applying concerted measures aimed at:

a) stimulating **cross-sectoral cooperation for the 5G technological progress to permeate** the whole ecosystem, through the establishment of forums for dialogue, exchange of experience, R&D and testing, which allows for the progress achieved in the Union to be capitalized and enhances the competitive or comparative advantages in the Romanian economic sectors and social life;
b) actively supporting the European and international technical **standardization** processes in communications or in other economic sectors affected by the 5G, as well as the European **harmonization** of the use of radio frequencies;
c) carrying out Romania's intentions to **test and trial self-driving and connected vehicles on a large scale** in our country[80], including by joining or initiating a European 5G corridor across one of the national borders[81];
d) facilitating pro-competitive collaboration between the providers of physical infrastructure in different sectors, in order to increase the efficiency of its use;
e) the participation of Romanian organizations in the **testing** and validation of pan-European 5G **performance** and **uses**, which should foster the meeting of demand for solutions with the technology-based offer in the synergy of the single internal market.

[79] Waze or Fitbit are good examples
[80] http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=43821
[81] See the list of 5G European corridors, https://ec.europa.eu/digital-single-market/en/cross-border-corridors-connected-and-automated-mobility-cam

Figure no. 11 – Cross-border corridors for connected and self-driving vehicles



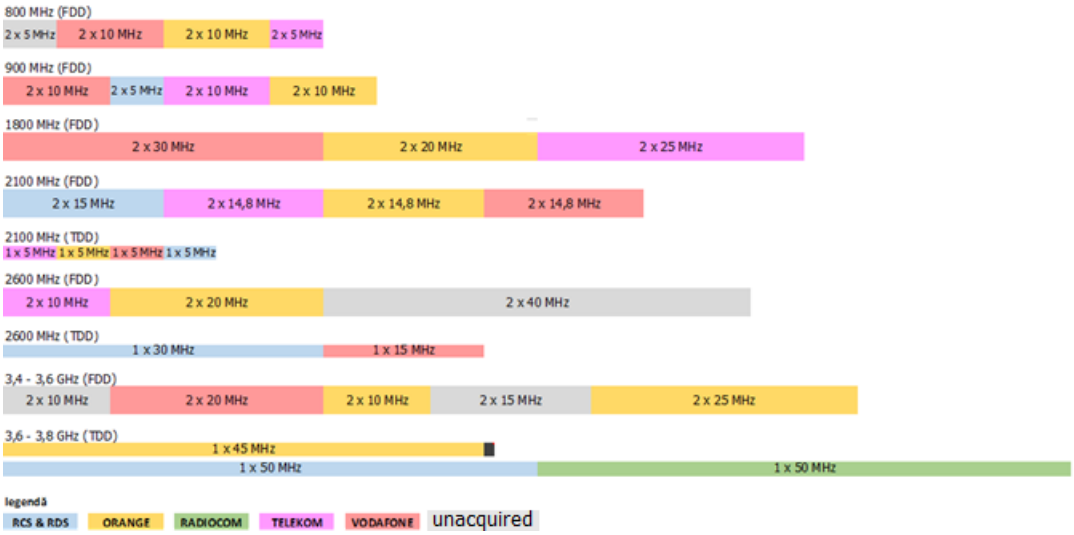
source: European Commission, state of play as of October 2018

7. PRIORITY ACTION LINES

7.1. Optimal spectrum for 5G

Mobile operators in Romania currently use a total of 770 MHz for the provision of public electronic communications services in their national coverage networks. The frequency bands used are 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz and 3.4-3.8 GHz, with usage rights valid until April 2029 at the latest. The amounts of spectrum held by operators are illustrated in Figure no. 12.

Figure no. 12 - Frequencies used for 2G, 3G and 4G mobile communications and usage rights holders



source: ANCOM

Nevertheless, the 5G specific performance - especially in terms of speeds (see Table 2 above) - cannot be achieved with the existing frequency portfolios. Providing speeds of up to 20 Gbps uninterruptedly and reliably, to moving users, requires bandwidths of hundreds of MHz (even up to 1 GHz), a need that can only be fulfilled in mmWave bands.

The 3.4-3.8 GHz frequency band, considered by the RSPG[82] as the most suitable for immediate use of 5G[83], contains enough spectrum resources, thus setting the premises for providing intensive services for data and applications consumption over small cells in high demand density areas. For 255 MHz in this band, four commercial operators have already acquired technology and service neutral usage rights[84] valid until the end of 2025, with greater flexibility regarding the frequency use plan.

Furthermore, due to their characteristics of propagation over long distances, the frequencies in the 700 MHz band will offer mobile communications operators the opportunity to roll-out 5G coverage over wide areas using the existing infrastructure.

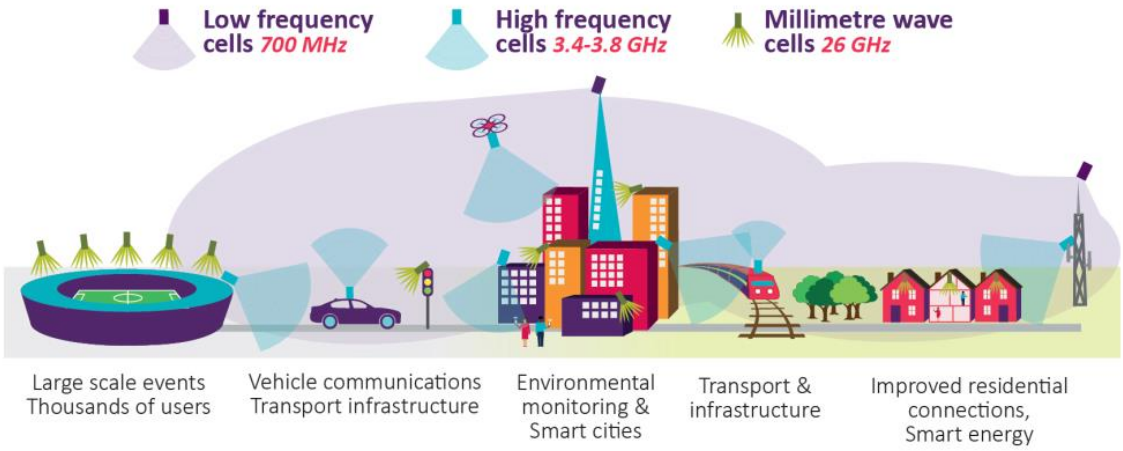
---

[82] *Radio Spectrum Policy Group*

[83] RSPG, "Strategic Roadmap Towards 5G for Europe – Opinion on spectrum related aspects for next- generation wireless sytems", 9 November 2016 and Radio Spectrum Policy Group, "Strategic Roadmap Towards 5G for Europe – RSPG Second Opinion on 5G Networks", 30 January 2018

[84] Moreover, government networks use 55 MHz in this band until 2025

Figure no. 13 – Use case scenarios for key 5G bands



source: Ofcom (UK), BNetzA (DE)

Thus, the 700 MHz, 3.4-3.8 GHz and 24.25-27.5 GHz (26 GHz) bands are key bands for 5G implementation in Romania, similarly to the other Member States of the European Union. The first commercial deployments will take place in the 700 MHz and 3.4-3.8 GHz bands, before the end of 2020.

Considering the results of EC regulatory process for the 26 GHz band, at least 1 GHz will be made available in the upper range of this band in Romania, by 2021. With a view to benefiting from the WRC-19 results, further GHz amounts in mmWave bands are to be made available.

The use of additional spectrum resources for access networks and the continued upward trend of data traffic consequently requires ensuring appropriate capacities on transport networks, as well. Thus, the demand for fibre optic with a view to connecting the cells to the network can be also satisfied by identifying and allocating new frequency spectrum amounts for radio relay lines, as a priority, for commercial operators. To this end, given the very large bandwidths per radio channel that can be ensured (hundreds of MHz and even up to 1 GHz), high and very high frequency bands are envisaged, i.e. 70/80 GHz bands, which feature good propagation characteristics.

Whenever and if needed, we will take due diligence at government level, through ministries and specialized institutions, including by the use of available mechanisms - including on European level - to support the timely and effective cross-border coordination of 5G radio frequencies, with priority in the bands below 1 GHz and in relation to neighbouring countries that are not members of the European Union.

In the vein of the good policies that foster promoting end-users' interests and improving the efficiency of spectrum use, investment in 5G spectrum resources will be secured based on auctions (competitive selection procedures). With the aim to promote healthy competitive dynamics in the communications sector, auctions will allow market entry, including in mmWave frequency bands.

Technological progress in the mobile networks' use of radio frequencies, as well as the new challenges in run-up to the massive development of 5G networks are likely to recommend a

rethinking of current models of setting the tariffs for the use of the frequency spectrum in a pro-competitive approach, which should lead decisively to reducing these tariffs.

Moreover, the spectrum resources currently used by public electronic communications networks will be available to be used for 5G as soon as coordination and technical studies are completed.

Taking into account the potential impact of specialized 5G local micro-networks on innovation and on the competition dynamics in general - as emphasized by the Urban Agenda of the European Union – as well as the risks associated to market fragmentation, the frequency usage authorisation models for the implementation of 5G in mmWave bands will consider the results of the relevant tests conducted at European level.

7.2. 5G-friendly infrastructures

Benefiting from 5G network performance requires massive private investment from communications operators and fostering early investment for the achievement of such performance requires providing for an **incentivizing, attractive environment**. In this respect, the regime established in 2016 for the physical infrastructures of electronic communications networks, as well as for laying down measures to reduce deployment costs[85], creates favourable conditions for access to public or private property, to the physical infrastructure of the operators of electrical power, public lighting, public transport, communications, natural gas, heat and water, and sewerage networks, of urban public transport services, etc., as well as to the physical infrastructure of railways, road transport (including motorways) networks, ports and airports. The 2016 infrastructure regime also introduces mechanisms to facilitate the co-ordination of works and to make an inventory of communications networks, and of the physical infrastructures of network operators[86], and lays down the obligation to provide in-built physical infrastructure enabled for high-speed networks within all new or extensively refurbished buildings[87]. The maximum tariffs for the communications networks' access to public property have recently been set[88], but other important mechanisms, such as the network inventory or the single information point regarding civil engineering works, are not yet in place.

Mechanisms and regulations for the shared use of physical infrastructure should also stimulate intensive use (the long-term productive efficiency), while avoiding cross-subsidization of users/uses/sectors at the expense of others.

Physical infrastructures used to cover Romania with 4G services are valuable assets that can be further used in the context of the upgrade to 5G, but may not be enough to meet the demand for cell densification. Rural macro-cells, and especially metropolitan cells and small cells in the urban area, **can share physical infrastructure,** starting from towers/pillars/poles to power supplies and fibre optic ducts for network connection. Under these conditions, operators achieve significant efficiency gains, while satisfying urban planning and environmental protection requirements with greater ease.

[85] By the provisions of Law no. 159/2016.
[86] For information, see http://www.ancom.org.ro/legea-infrastructurii_4938
[87] See Art. 34 of Law no. 159/2016
[88] http://www.ancom.org.ro/formdata-269-49-361

However, achieving Gigabit speeds and the 5G-specific performance provided in standards requires fibre-optic connection to base stations and traffic concentrators, for the purpose of connecting the cells in urban centres, in suburbs, and in rural areas. 5G traffic growth is estimated to gradually require the densification of urban metropolitan and small cells down to a typical range of 1 km, while rural 5G deployments may be inhibited by the absence of optic fibre infrastructure. Therefore, public interventions to encourage the roll-out of new-generation networks in rural areas can also help to facilitate the deployment of 5G, by the installation of optic fibre or of high-capacity radio-relay links, and by ensuring access to physical infrastructure under favourable technical and economic conditions.

5G performance should be reached not only within a network but also in the communication and traffic exchange between networks, which would usher in the introduction of a national peering obligation during the review of the primary sectoral legislation.

Moreover, the quality parameters can be ensured in the hotspots of cities with high traffic density (such as stadiums, shopping centres, train and airport stations or pedestrian areas) by deploying pico-cells in the 26 GHz band, the range of these so-called "small cells" varying from 20 to 200-300 m depending on the number of users and traffic intensity.

"Small" cells are pieces of equipment too small to be installed on dedicated infrastructures, therefore access to existing infrastructures is essential. Beyond the investment challenges, the proliferation of small cells will increase the difficulty in identifying suitable places for their installation, which will enhance the bargaining power of such site owners in relationship to network providers and may induce the former's rent-seeking behaviour. Although possible anti-competitive effects of such behaviour can be remedied by regulatory instruments, including those within the scope of competition law, public authority intervention may take various forms, for example by **increasing the supply of sites** (e.g. street infrastructure, traffic lights, public lighting poles, public transport pillars, etc.).
Smart mobility and regional ICT connectivity are strategic objectives of the cohesion policy beyond 2020, in Romania and across the Union, and connected and self-driving vehicles are a 5G use case with great development potential and gearing effects. However, given that ensuring latencies of maximum 1 ms involves the installation of a large number of small cells (including their optical fibre connection) along ground-based transport corridors, the need for investment in physical support infrastructure may diminish commercial attractiveness, delaying 5G coverage and inhibiting the development of self-driving vehicle eco-systems.

On the other hand, the design and installation of the physical infrastructure for 5G networks once with the execution of public works on road and railway transport infrastructure, substantially facilitates the development of the autonomous transport ecosystem in Romania. Therefore, it is necessary to **design and build physical infrastructures for high-speed and 5G networks along with the works of construction, repair, modernization, rehabilitation or extension of roads** (motorways, express roads, national roads, county roads) and **railways**. In order to minimize implementation costs and increase the efficiency of this obligation, the provision of physical infrastructures for high-speed and 5G networks needs to be planned by joint measures involving decision-makers in several sectors (communications, transport, etc.) as early as possible in the required activity flow, for example in stage of drawing up the feasibility study/technical documentation/terms of reference, but no later than the stage of submitting the application for the issuance of the building permit.

The sustainable development of communications networks implies compliance with the requirements of the authorisation, urban and land planning regimes. In this context, it should be noted that the authorization regime that enables the electronic communications providers' access to public or private property is an essential factor for network roll-out, while **the complexity of processes and delays in granting authorizations can be significant bottlenecks in the development of competition**. Significant barriers to 5G network deployment raised by the current regime for the **authorisation of construction works** (building permits) are a major risk factor for the development of 5G in Romania: it increases the risks and costs of investment projects, ultimately leveraging 5G services and delaying their adoption.

Ensuring the connectivity requirements typical of post-2020 smart cities cannot be reasonably satisfied under the current regime for the authorisation of construction works. The authorization of construction works must evolve in three directions:

a. simplification, by removing unnecessary complexities, clarifying processes, reviewing deadlines, transparency and digitization of activities;
b. adjusting authorization requirements to technological progress in the execution of construction works, miniaturization of 5G specific infrastructure elements and co-existence/collocation of networks, etc.; there is a justified need for relaxing the planning and authorization constraints of small power (micro-, pico-) 5G cells;
c. reduction of heterogeneity in applying the authorization regime, from one locality to another; a best practice handbook on the application of the authorization regime may provide a necessary guide to the administrative territorial units (ATU).

To this end, an inter-institutional working group will be set up to create a regime for authorizing construction works that is favourable to communications networks, hereinafter referred to as *the Group*. The Group will analyse the situations in place, taking into consideration the best practices in Romania and in other European states, the stakeholders' opinions (central and local public authorities, and private entities), as well as the currently available expertise. The group will propose optimal solutions for reviewing the authorization regime for construction works, to ensure the sustainable development of electronic communications networks. Specifically, the Group will analyse the opportunity, propose concrete intervention solutions and report on the following issues:

a) the removal/replacement of the concept of building permit for the installation of electronic communications networks with the concept of building permit for the installation of the physical infrastructure required by electronic communications network/the adoption of a special legal regime for authorizing the execution of construction/dismantling works for the associated infrastructure of electronic communications networks;
b) replacing the obligation to obtain a building permit for electronic communications networks by the obligation to notify works for simple network elements installation carried out on a limited perimeter and with limited impact on the environment (for example, installation of junctions and connections, of street cabinets, insertion of networks and communications equipment in the underground physical infrastructures built for this purpose or in the existing inbuilt physical infrastructures, installation of technical equipment: optical nodes, amplifiers, etc.);
c) simplifying and standardizing the procedures for approving emergency intervention works (on pillars, poles, ducts, other elements);

d) removing the obligation to enter the PUZ (Zoning Urban Plan), since communication networks are an essential utility for the local communities (these networks should be considered as part of the PUZ/PUG [General Urban Plan] by default); moreover, the PUZ entry should be replaced by the adoption of a flexible construction regime in the case installing base stations for electronic communications at the outskirts of localities – a regime similar to that applicable to communications relays regulated by Art. 102 of the Land Law no. 18/1991, republished, with the subsequent amendments and completions;
e) timely removing the obligation to obtain a building permit for small-area wireless access points, in accordance with Article 57 of Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code;
f) simplifying the authorization regime for the repair, rehabilitation, refurbishment works carried out on the physical infrastructure elements supporting communications networks, as well as for the installation of the networks and/or the associated physical infrastructure following the fulfilment of some legal or administrative obligations;
g) reducing of the number (or regulating a certain set) of endorsements requested on the basis of the urban planning certificate (e.g. for the installation of aerial networks on/in/under the existing infrastructure, both endorsements from the infrastructure owner, the Environment Agency, the network operator - where applicable -, and a temporary occupancy approval for the public/private domain accessed during the assembly/installation period are proposed);
h) providing for endorsement issuance independently from one another, i.e. an endorsement should be issued irrespective of the issuance of prior endorsements by other public authorities;
i) strictly defining the general framework within which local public authorities can set or impose measures and/or technical or commercial conditions regarding the communications networks and the associated infrastructure, such as measures/conditions regarding: taxes on the infrastructure, the prohibition of placing the network components on the poles, the obligation to not build networks at a certain distance from certain objectives;
j) ensuring access to the national inventory of public properties, carried out similarly or in conjunction with cadastral measurement operations;
k) regulating delays in the authorisation issuance process (providing consequences related to deadline observance, introducing the institution of tacit approval in certain cases), in order to strike a balance between the sanctioning regime and predictability;
l) setting up a single information point for the submission of documentation required in the telecom infrastructure authorisation process, according to the provisions of Directive 2014/61/EU of the European Parliament and of the Council of 15 May 2014 on measures to reduce the cost of deploying high-speed electronic communications networks;
m) considering the best practices in Romania and in other European states, in order to simplify the building of the networks - e.g. in Hungary, the carrying out of construction works related to electronic communications networks does not require the authorization of passive infrastructure elements whose any of the characteristics (height or width/length) does not exceed 6 m each;
n) clarifying some requirements - for example, the neighbours' agreement should be requested only from the owners of the apartments located on the last floor of the staircase/section, or from the owners of the land plots that border at least on one side the land where the elements of the communications networks are to be located;
o) developing best practice guidelines for the development of digital infrastructures in ATUs.

Recognizing 5G as a strategic infrastructure, crucial for Romania's sustainable economic and social development, may be an opportunity to grant more importance to planning in the digital transformation of the country. Where ATUs may wish to develop their own digital transformation plans, in some cases they may need specialized expertise, therefore a **Guidebook for Digital Territory Planning** designed for ATUs, developed by specialists and experts in the field, could be of great help. Such a guidebook could provide criteria for assessing connectivity needs, appropriate network building solutions in frequently encountered practical situations, contract arrangements, funding mechanisms, measures to stimulate long-term development of the networks, etc.

7.3. Friendly legislative framework

The most important normative act, intended to facilitate the fast and widespread adoption of next-generation networks, such as fibre-to-the-home and 5G technology, is Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code.

Preparing for the era of ubiquitous and super high-speed connectivity that will create new-generation technologies such as 5G requires reviewing the common rules governing the telecom industry.

Recognizing the importance of providing a favourable framework to support the achievement of 5G performance, we aim to set the premises for transposing Directive (EU) 2018/1972 into the Romanian legislation within 18 months from the adoption of the Strategy and we will make steps towards ensuring the fully-fledged operation of all the subsequent instruments it introduces, by 2021.

In this context, it is necessary to **review some legislative provisions that unduly inhibit** the development of communications networks and raise insurmountable barriers to 5G.

Moreover, a general overhaul of the legislative framework is needed for **adapting it to the new digital ecosystems**, so that we can fully reap the benefits and better manage risks. For example, we recognize the principle of extracting rents from the use of the public property, but we deem that imposing two-digit percentages[89] as rent for the communications networks' using the public property is unacceptable and incompatible with a policy that should incentivize Romania's digital progress.

7.4. Harnessing 5G for public safety and security

In the light of the provisions of the National Defence Strategy for the period 2015-2019[90], "the action lines and the arrangements for ensuring national security are grounded in the national security interests and objectives […]. Moreover, these action lines take into due account the obligation to prevent, combat and counter - in a credible manner, based on the constitutional

[89] See, for example, the fees imposed in Bucharest (12%) and Oradea (26%) under the contracts for the concession of the public domain for building next-genration communications infrastructure
[90] idem footnote 64

principle of unitary coordination - potential threats, risks and vulnerabilities that Romania can face".

In accordance with the Commission Recommendation C(2003) 2657[91], radiocommunications for public protection and disaster response (PPDR) are radio applications used for public safety, security and defence used by national authorities or relevant operators responding to the relevant national needs in regard to public safety and security including in emergency situations.

The requirements for this type of communication have been established by the documents issued by the Emergency Telecommunications Standards Committee (EMTEL) within ETSI. The need for emergency communications includes a multitude of scenarios, ranging from minor incidents such as traffic collisions to major incidents such as terrorist attacks and natural disasters. Thus, the requirements for emergency communications can be classified into the following categories:

- communications from authorities/organizations to individuals (e.g. the System for alerting and warning the citizens in emergency situations RO-ALERT);
- communication between authorities/organizations (e.g. PPDR networks and services and, subsequently, broadband PPDR);
- communication of citizens with authorities/organizations (e.g. The Single National System for 112 Emergency Calls, e-call);
- communications between individuals (e.g. public communications networks).

PPDR communications needs have increased in recent years, with organizations in charge of emergencies requiring access to broadband services such as real-time video transmissions. Also, PPDR communications have specific requirements in terms of priority, availability and security. PPDR applications such as high-resolution image transmissions and real-time video transmissions require higher data rates and capacities than can be achieved by current narrowband PPDR networks (TETRA).

PPDR services are provided by an entity or agency empowered in this respect by national administrations providing rapid and immediate assistance in situations where there is a direct risk to public or individual life, health and security, public or private property, or to the environment, but not necessarily limited to these situations.

The main broadband services needed to carry out the activities of institutions with PPDR attributions are, among others, voice and video transmissions, database interrogations, sensor monitoring and file transfer. Due to the quality parameters that are superior to today's broadband mobile communications systems, the services listed above can be provided through 5G technologies that provide high data transfer rates as well as mechanisms for prioritization, pre-emption and configuration of the quality parameters of various types of services.

With a view to meeting both today's PPDR communications needs and the foreseen ones, taking into account the requirements of Decision 2016/687/EU[92], broadband services need to be implemented, which could support improved data and multimedia transmission capabilities,

[91] Commission Recommendation of 25 July 2003 on the processing of caller location information in electronic communication networks for the purpose of location-enhanced emergency call services

[92] Commission Implementing Decision (EU) 2016/687 of 28 April 2016 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union.

increased data rates and capacities, as well as widely differing requirements in terms of capacity, availability and robustness.

BB-PPDR services could be provided by means of three infrastructure implementation models:

a) dedicated network infrastructure for BB-PPDR - a mobile broadband network: a broadband communications network dedicated exclusively to providing BB-PPDR services;
b) public electronic communications network(s) infrastructure providing broadband services to PPDR users – the state purchases BB-PPDR services from one or several public electronic communications network operators (MFCN);
c) hybrid solutions with partly dedicated and partly public electronic communications network infrastructure – the services are provided partly through a dedicated network infrastructure and partly through public electronic communications network infrastructure.

Choosing a hybrid solution for the deployment of a BB-PPDR network (with partly dedicated network infrastructure while using elements of public electronic communications networks) leads to a more efficient use of spectrum resources and enables both reaping the associated benefits of available technologies and capitalizing the benefits of the 5G frequency spectrum.

On the other hand, cross-border cooperation and the use of harmonized frequency bands Europe-wide are requirements arising also from studies and reports drawn up at European level. The interoperability of equipment at European level is also required by the fact that natural disasters, emergencies and terrorist attacks do not always occur within the borders of a state only. The major benefits of spectrum harmonization are:

a) savings generated by large-volume purchases of terminal and network equipment for the institutions in charge of PPDR;
b) enhanced coordination between intervention teams from different states;
c) the use of roaming equipment.

We therefore deem that the interoperability of BB-PPDR services at the Union level is an important element in ensuring their mission in terms of effectiveness and efficiency, a circumstance likely to recommend the use of the same frequency for PPDR as in the rest of the European Union.

Based on the above considerations, we will make available an appropriate spectrum band for broadband PPDR systems (BB-PPDR) in accordance with the harmonized 700 MHz band resulting from Decision 2016/687/EU.

This provides for flexibility to use parts of the 700 MHz frequency band at national level, for several categories of applications, laying down a set of national options available to the Member States for the use of this frequency spectrum, among which PPDR. Thus, 2x8 MHz will be allocated in the 700 MHz band[93], for the deployment of a network for the provision of BB-PPDR, in addition to the 2x30 MHz available for commercial networks in the 700 MHz band, which can be partially used for the provision of BB-PPDR services by means of the infrastructure of the public electronic communications networks.

[93] Respectively in the paired frequency sub-bands 698-703 MHz and 753-758 MHz (2x5 MHz) and in the paired frequency sub-bands 733-736 MHz and 788-791 MHz (2x3 MHz)

Assigning a virtual "slice" of the shared 5G public networks - either a separate network using 5G technology standardized in appropriate parameters, or a combination of the two to bring together VPN/telephony/internet/messaging services on a single mobile terminal, as well as providing the premises for developing the concept of Internet of Things at the level of SNAOPSN[94] institutions.

Any frequencies remaining unawarded in the 700 MHz band following auctions will be available to be used for the deployment of a network dedicated to the provision of BB-PPDR services, if BB-PPDR services cannot be provided by the institutions in charge of risk management in emergencies with the spectrum resources already used and there are sufficient budget allocations for developing investments in the dedicated component of the BB-PPDR network.

It is necessary to ensure technical compatibility between the future implementations of 5G public communications network and RO-ALERT, the System for Public Alert and Warning in Emergency Situations, by providing the optimal and operational legal framework for the interconnection of public mobile communications networks with the RO-ALERT system. Furthermore, the compatibility of 5G terminals provided on the global market with the RO-ALERT system should be ensured.

Communications between citizens, objects (for example, vehicles) and emergency services conducted through the 112 emergency call centres will be achieved using modern technologies such as VoIP calls, real-time text messaging, image and video transmission. In addition to voice calls, citizens or objects will be able to send to intervention teams their geographic location, accident site pictures, as well as data regarding the health status of people in emergency situations.

7.5. Partnerships for testing and validating 5G uses

The rapid and successful adoption of 5G depends on two pillars: technical validation and commercial validation of solutions. The multitude and diversity of tests and pilot projects undertaken so far in the European Union[95] have shown a concentration of interest on vertical sectors, along with the clarification of some concrete key issues such as:

i. What are the 5G commercial benefits?
ii. How does 5G provide these benefits?
iii. What are the obstacles?
iv. What is the differential contribution of 5G?
v. How is transition from 4G to 5G performed?

In order to answer these questions, the technical and commercial validation of solutions requires testing and pilot projects that exceed the conditions of "theoretical attempts" of "laboratory experiments" by far, so that it involves far-reaching developments of the different connectivity scenarios provided under certain geographical constraints, tailored for specific use cases and for well-defined commercial conditions, as well as the use of specific technical and commercial performance indicators.

The vast majority of 5G trials and pilot projects is and will be achieved through private (commercial and pre-commercial) testing among network operators, equipment suppliers, and an

[94] The National System of Defence, Public Order and National Security
[95] E.g. within 5G-PPP, or other Europe-wide bodies

increasing number of vertical industries. However, accelerating the development of 5G requires the collaboration of verticals from different sectors of economic and social life, hand in hand with research centres and local communities, Member States, the European Commission and sectoral initiatives.

On the other hand, the development of innovative, affordable and reliable applications and applications that use the connectivity performance introduced by 5G to improve the features of existing products or services, or to launch new ones that would not have been possible without connectivity can generate competitive benefits that exceed their import.

The priorities of Romania's Competitiveness Strategy contain objectives involving the employment of resources towards setting up elite production and research sectors in areas with high potential for intelligent specialization (bio-economy, communications and information technologies, energy and environment, eco-technologies), industrial revitalization through intelligent specialization and the transformation of knowledge and creativity into competitive sources of development.

Communications and information technology are one of the smart specialization areas of economic relevance identified by the National Strategy for Research, Development and Innovation 2014-2020 and to which RDI policies should be reoriented, for example: co-financing of projects initiated by private companies, competence centres, innovation infrastructure (business accelerators and incubators, technology transfer centres), doctoral and post-doctoral programs in priority areas, national research infrastructure (national "roadmap"), organizational performance and concentration, a strategic orientation mechanism.

Considering the public interest and the key role of public authorities in a multitude of sectors, such as energy, transport, health, etc. we aim to facilitate partnerships for research and development, testing and commercial validation, through **pilot projects on the new 5G connectivity applications** that:

a) validates the benefits of 5G among "vertical" sectors, including the public sector, for both sides of "markets", producers/suppliers and consumers of goods and services;
b) supports the development of 5G public or private communications networks and of profitable businesses;
c) stimulates the success of 5G adoption in Romania by expanding private testing.

Based on interviews with stakeholders from business, academia and the public sector, **7 potential pilot projects** will be identified, one for each development region, as follows:

a) each potential pilot project will include a **mix** of pilot projects on applications and services developed in several sectors, as well as pilot projects focused on a certain sector of economic or socio-cultural life, making the best possible use of existing developments[96];
b) for a better understanding of the challenges and opportunities, the projects will be targeted at **different regions** with **different topologies**;
c) priority will be given to areas **covered by infrastructure** for fixed and mobile electronic communications networks, such as fibre and LTE, since such areas are better prepared for the fast transition to 5G compared to less covered areas;
d) pilot areas will also be selected based on **maximizing** their socio-economic **benefits** by setting up 5G networks and integrating technologies in the economic sectors or in community life;

[96] For example, deployments already in place in technology hubs, in innovation clusters or industrial concentrations in Romania

e) for each pilot project, there will be at least **one provider of communications networks** (including via satellite) and one **equipment supplier** interested in providing the 5G infrastructure needed to achieve the pilot project;
f) at least one pilot project will target edge computing, for testing and validating the latency performance needed for 5G;
g) at least one pilot project will involve cross-border cooperation between the public authorities in Romania and those from another state;
h) one pilot project could envisage 5G validation for connecting well-defined remote areas.

We will also facilitate the setup of an ecosystem to enable the development of business models based on 5G (named "The Alliance for 5G"), based on open, pro-competitive cooperation of all stakeholders, ideally utilizing the existing associative and collaborative infrastructure: from professional and trade associations to regional development agencies and chambers of commerce and industry, there is already a vibrant system of formal and informal structures. The objective of this mechanism will be to extract knowledge from market development information, to facilitate meeting the demand for solutions with technology-based offer, to increase benefits and lower costs[97]. An important role in this structure lies with the academic and research community, but also with the structures specialized in attracting funding, from EU and beyond.

[97] With a view to avoiding any doubts, we do not intend the 5G Alliance to ensure governance or selection of partnerships or of the pilot projects

8. IMPLEMENTATION AND MONITORING

8.1. Action plan

With a view to accomplishing the strategic objectives and to implementing the priority action lines required for the 5G strategic planning in Romania, we have planned and will pursue the following actions.

The currently identified measures focus on the early years of the current strategy, recognizing our role as a facilitator and catalyst for the economic and social developments induced by technology and driven by the entrepreneurial freedom of the private environment.

No.	Measure	Responsible	Deadline	Strategic Objectives /Action Lines	Indicators
1	Mechanism for following up the implementation of the strategy and of the roadmap	MCSI, with ANCOM support	S2 2019	transversal	Functional mechanism Regular reports Review of measures
2	Specific measures and incentives for the rapid launch of 5G commercial services	Mayoralties of Cluj-Napoca, of Iasi, of Timisoara, the Government	S2 2019	SO1, SO2	Signed MoUs Enforced MoUs
3	Measures regarding the spectrum usage tariff	ANCOM	S2 2019	SO1, SO2, SO3, AL1	Adopted decision
4	Inter-institutional working group for creating a favourable building permit regime for communications networks	MDRAP, MCSI, ANCOM	S2 2019	SO1, SO2	Working group in place
5	Information campaigns regarding the 5G benefits and effects conducted among local authorities, citizens and the business environment to reduce the asymmetry of information on the effect of cell miniaturisation and network densification	ANCOM	S2 2019-S2 2020	SO1, SO2, SO3, AL2, AL3	Campaigns launched Campaigns completed
6	Identification of a (segment of) cross-border European corridor for testing self-driving and connected cars	Government (MT, MCSI, MAE)	S2 2019	SO4, AL2, AL5	Negotiations with neighbouring countries Signed memorandum Notification to the European Commission
7	Competitive selection (auction) for awarding licences for the use of frequencies	ANCOM	S2 2019	SO1, SO2, SO3, AL1	Awarded licences Used spectrum
8	Identification of the 7 potential pilot projects	MCSI	S2 2019	SO2, SO3, SO4, AL4, AL5	7 potential pilot projects identified

No.	Measure	Responsible	Deadline	Strategic Objectives /Action Lines	Indicators
9	Transposition of the European Electronic Communications Code in Romania	MCSI ANCOM	S1 2020	SO3, SO4, AL2, AL3	Transposed EECC Enforced EECC
10	Setting caps on the rents for the electronic communications networks' using the public domain	Government MDRAP MCSI ANCOM	S1 2020	SO2, SO3, AL3	Adopted normative act Enforced normative act
11	Building permit regime that fosters the development of 5G networks	MDRAP, MCSI, ANCOM	S1 2020	SO1, SO2, SO3, AL2, AL3	Normative acts amended based on the recommendations of the Working Group
12	Best Practice Handbook on the level implementation of the building permit regime for electronic communications	MDRAP, MCSI (INSCC)	S1 2020	SO3, AL2	Approved/published handbook Handbook usage degree
13	Financial mechanisms for incentivizing 5G, adapted for the potential pilot projects	MFE	S1 2020	SO2, SO3, SO4, AL4, AL5	Functional financing mechanisms Absorption degree
14	Legal framework for interconnecting mobile networks with RO-ALERT	MCSI, SNAOPSN	S2 2020	SO2, AL4	Adopted normative act Interconnection ensured
15	Designing, authorising and deploying physical infrastructure for high-speed and 5G networks, once with performing construction, repair, modernization, refurbishment or extension works on roads (highways, national and county roads) and railways	Ministry of Transport MCSI	S2 2020	SO3, AL2	Identification of necessary measures. Adopted normative act The normative act is enforced in major public investment works
16	Study regarding the operation of 5G small cells on existing selected/most adequate infrastructures	MCSI (INSCC)	S2 2020	SO2, SO3, AL2	Completed study The study can be used for increasing the site offer
17	Guidebook on the digital land development of ATUs for enabling the Gigabit society	MDRAP, MCSI, ANCOM	S2 2020	SO3, AL2	Approved Guidebook Degree of usage by the ATUs
18	Putting the "5G Alliance" into operation	MCSI, ANCOM	S2 2020	SO4, AL6, AL5	MoU concluded Number, diversity and quality of the players involved Regular reporting of activities
19	Report on the status of communications networks infrastructure in Romania	ANCOM	S2 2020	SO3, AL2, AL3	Published report Regular reports (every three years) on the usage degree, for guiding public policies
20	Competitive selection (auction) for awarding	ANCOM	S2 2020	SO1, SO2, SO3, AL1	Licences awarded Spectrum used

No.	Measure	Responsible	Deadline	Strategic Objectives /Action Lines	Indicators
	licences for the use of radio frequencies in mmWaves				
21	Adoption of the legislative framework on awarding spectrum for BB-PPDR in the 700 MHz band and of the mechanisms for making available the best frequency resources for the chosen implementation model	Government, MCSI, ANCOM, SNAOPSN	2020	SO3, AL3, AL4, AL5	Approved regulations
22	Increased site offer for 5G small cells (following INSCC's study)	Government ANRSC	S2 2022	SO2, SO3, AL2	Public Reference Offers for access to public infrastructures in cities Number of offers, relevance and variety of open infrastructures
23	Operational BB-PPDR services	STS	2023	SO2, SO4, AL4	Launched BB-PPDR services BB-PPDR services used in SNAOPSN
24	Monitoring coverage obligations in licences	ANCOM	2025	OS2	Monitored coverage obligations

Technological and economic developments, and evolutions on market or legislative level may require reviews of the action plan, within the time horizon of this Strategy.

8.2. Financial resources

8.2.1. Current context

For 2014-2020, a total amount of EUR 1,041 billion has been provided in the European Fund for Strategic Investments for the development and deployment of information and communications technologies, especially by: digital content, digital services, high-speed telecommunications infrastructures and broadband networks.

For ICT projects, funding is also available under the 2014-2020 Competitiveness Operational Programme (COP), which addresses the support needs for research, development and innovation (RDI), and for underdeveloped ICT infrastructure, under the Regional Operational Programme (ROP) 2014-2020, which finances regional investments and stimulates the activity of small and medium-sized enterprises, as well as under the National Program for Rural Development (NRDP) 2014-2020, which supports the diversification of economic activities and job creation by improving infrastructure and services in rural areas.

White area broadband coverage projects have already been initiated and even completed in Romania - Ro-NET 1 (completed, funded from the Operational Programme 'Increase of Economic Competitiveness' 2007-2013) and Ro-NET 2 (completed, financed through the Competitiveness Operational Programme 2014-2020), from the European Regional Development Fund (ERDF) and a series of funding schemes from the European Agricultural Fund for Rural Development (EAFRD)

operated by the Ministry of Agriculture. They will also contribute to the development of 5G networks, which requires a solid fibre optic infrastructure.

Another funding mechanism is the Connecting Europe Facility[98] (also known as CEF[99]), an initiative of the European Commission in cooperation with the European Investment Bank for the development of cross-border transport, communication and energy networks, and it also provides EUR 1 billion for the communications sector in 2014-2020.

The European Commission has proposed to keep the Connecting Europe Facility in the next multiannual financial framework, for the period 2021-2027[100], in order to foster investment in cross-border infrastructure in the transport sector (including intelligent transport systems and self-driving vehicles), as well as in the energy and digital sectors. Additionally, funding will be available through the Digital Europe Program in five categories, all with increased relevance from the 5G perspective in Romania: super-computers, artificial intelligence, cyber security, advanced digital skills and the widespread use of digital technologies. Furthermore, the new InvestEU Program will provide financing especially to the private sector, through financial instruments guaranteed by the EU and - within it - digital infrastructure development projects are eligible, which is relevant to the 5G domain (e.g. projects that support the development of high-capacity digital networks and the development and operationalization of digital services and technologies). Moreover, the InvestEU Program will provide project investors/developers with investment advice, and with the possibility to attract financing/investments, by publishing investment projects on the dedicated European portal.

8.2.2. Investment and financial intervention needs

The achievement of the 5G benefits, the development of the use cases enumerated under the action lines set out in Chapter 8, involves investment in research (theoretical, experimental, applied), in public or private communications networks, but also in upstream or downstream industries, but especially in various branches of the national economy, for the development of smart, connected eco-systems of infrastructures, objects and people.

The vast majority of investments in the development of 5G will be made from private sources, in a healthy competitive environment benefiting from a favourable investment and operational framework from the Romanian state.

However, supporting the development of 5G by completing private investment with well-targeted public funding can play an important role in various ways and may evolve based on the progress achieved:

a) expansion and fibre optic connection of 5G cell networks in important public policy areas but with limited commercial attractiveness - for example, to ensure smart mobility and regional connectivity along highways, roads, railways, or to boost cohesion and reduce gaps in small towns and rural areas;

[98] https://ec.europa.eu/info/business-economy-euro/growth-and-investment/financing-investment/connecting-europe-facility-cef-financial-instruments_en#a-common-infrastructure-financing-instrument-for-2014-2020

[99] Abbr. - Connecting Europe Facility

[100] 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, http://europa.eu/rapid/press-release_IP-18-4029_en.htm#_ftn1.

b) the funding models used in practice for financing network roll-out are: the state as a network provider, the state as a partner and the beneficiary/customer state [for reasons of investment and operational efficiency, given the economies of scale and scope typical of the communications sector and in the context of technological leaps, we do not recommend using the "state as a network provider" model];
c) boosting the integration of a critical mass of ”technology” upstream, downstream or inbuilt in the communications sector, which can be done within an innovation cluster, in an industrial park or in a field of activity, until the achievement of commercial sustainability;
d) uninterrupted financing of theoretical and applied research and development activities, in the communications and information technology sector, for new equipment or new uses.

The 7 pilot projects identified according to the criteria under 7.5 above may be the first applicants for such funding.

Looking at the various stages of implementation of the strategy, by 2020 the use cases will be developed, i.e. innovative 5G-based solutions, and fibre-based or other high-capacity backhaul networks, with mass-network developments being anticipated during 2021-2025.

Beyond the 2020 horizon, regional ICT connectivity remains one of the strategic objectives of the European cohesion policy and complements the other thematic objectives set by the regulation on accessing European funds in the period 2021-2027[101], namely innovative and smart economic transformation, low carbon emissions and the sustainable and integrated development of urban, rural and coastal areas through local initiatives.

The 5G potential to gear multiple socio-economic sectors indicates the opportunity that potential incentives for the development of 5G be granted in synergy with other support measures targeting strategic lines of intervention - intelligent specialization, fostering RDI activities, especially towards facilitating the assimilation of RDI results and their implementation in mass production, fostering SMEs, regional development, etc.

In this context, funding may be granted through banking institutions (funded from private sources, or partly or totally from financial instruments) to finance local or regional project ideas.

8.3. Monitoring, assessment and reporting

MCSI is the institution responsible for monitoring, evaluating and reporting the stage of implementation of the strategy. In this respect, it will benefit from ANCOM support. A timetable and a system for monitoring and reporting the state of implementation of the Strategy and of its Roadmap, based on concrete indicators and deadlines, is to be set up.

Additional information on the development of this Strategy is available in Annex 2 – *Methodology,* which is part of this document.

Annexes 1-3 are part of this Strategy.

[101] Proposal for a Regulation of the European Parliament and of the Council laying down common provisions on the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, and the European Maritime and Fisheries Fund and financial rules for those and for the Asylum and Migration Fund, the Internal Security Fund and the Border Management and Visa Instrument, COM(2018) 375 final, 2018/0196 (COD)

ANNEXES

Annex 1 – Technical capabilities and innovating technologies in 5G context

- *network slicing*

Since not all the 5G capabilities (see Table no. 2 above) are compatible with each other, they cannot be achieved simultaneously. Therefore, defining each category of uses (mobile internet, fixed internet, machine-type/M2M communications and mission-critical communications) requires a compromise between different capabilities. This is why network slicing has been introduced and stands as an operating principle – i.e. differentiated network administration, by which each "slice" (segment) is a distinct virtual sub-network that benefits from dedicated resources and delivers its own set of performance indicators, corresponding to the needs of each use case/category[102]. Sub-networks can separate infrastructure resources from the physical network to create independent virtual networks, with features tailored according to specific needs (for example, an optimized segment for connected IoT objects, another segment for mission-critical communications with special security and quality requirements, such as for public safety government services).

It should be noted that network slicing also provides a model for network infrastructure sharing at the very level of equipment using radio frequencies: for example, a single network of transmitters can be used by more than one operator, for example as a short-term solution to reduce costs.

- *software and virtualization*

Efficiently achieving the various compromises needed to simultaneously provide different use categories implies a high level of network agility. Thus, the simultaneous use of multiple generic, reconfigurable and high-performance components instead of those permanently dedicated to achieving predefined tasks ensures the flexibility and dynamism of networks by enabling massive and fast adjustment and configuration of network slices to service demand. This evolution of a significant number of network components is possible through **Software Defined Networking** (SDN) and **Network Function Virtualization** (NFV).

A functionality evolved from Software Defined Networking (SDN) is **cloud RAN**[103], or **centralized RAN**. This type of radio access network has a very different architecture from the currently used one, mainly because base station signal processing units are not on the base stations, being centralized upstream, in the cloud network. Centralization based on cloud computing allows for a complete view on all the base stations (2G, 3G, 4G, and 5G), therefore coordinated signal processing and the management of interference between cells and devices can be achieved almost instantly and with increased efficiency.

[102] E.g. viewing high-resolution media content (4K, 8K, 3D, VR) requires spectrum efficiency, maximum data rates and ensuring the data rate over a certain area, which can be achieved at the expense of other capabilities, such as latency or connection density; on the other hand, simultaneously connecting a large number of objects requires concentrating resources to the detriment of spectrum efficiency and latency

[103] RAN - Radio Access Network

Intelligent administration also enables dynamic allocation of network resources in time or real-time automated capacity adjustments based on demand peaks for specific segments (for example, capacity can be allocated to an office building during business hours and to information gathering from sensors, at night) or based on the instantaneous capacity change (a network of surveillance cameras permanently transmits low-resolution images, but when sensors detect activity within their range, the resolution increases to the maximum).

- *antenna technologies*

Currently, mobile networks are typically congested in areas with a high density of users, a situation that diminishes the bandwidth available to customers, reduces the speed of internet services, and may sometimes lead to the connection failure. Beyond increasing the amount of radio spectrum, a possible remedy enabled by 5G only is the use of a frequency spectrum that has not been used for mobile communications before - the **millimetre waves/mmWaves**. Widely used for point-to-point communications[104], the use of mmWaves in mobile communications for the capacities listed in Table no. 3 above will require very large bandwidth frequency channels (100 MHz and beyond, per user). On the other hand, coverage will be limited, and the signal will not penetrate buildings or obstacles. Consequently, the operators will radically transform the architecture of existing networks by installing thousands of miniature base stations - the so-called small cells. Miniaturization of base stations allows targeted and more efficient use of the frequency spectrum.

Furthermore, the new antenna technologies contribute substantially to increasing spectrum efficiency. Other technologies, currently in the trial-research phase, will help reduce latency - a critical requirement for 5G.

Two antenna technologies are critical to materializing 5G performance: by aligning tens of radiating segments (intelligent micro-antennas) on the same panel, **massive MIMO** can increase simultaneous transmission capacity even 22 times or more, compared to existing capabilities. The productivity of this technique is enhanced by **beamforming**, which allows base station antennas to direct the signal to a certain area/zone, instead of radiating it omnidirectionally. Directional signals make it possible to increase the connection capacity between the base station and the connected terminal while being much less susceptible to interference and ensuring a significantly larger radius/distance from the base station. Thus, the base station's ability to simultaneously serve more users for higher traffic per connected device increases considerably.

If massive MIMO substantially contributes to increasing spectrum efficiency, a new technology, called **full duplex**, is currently in the trial-research phase. In classical systems, transmission and reception are achieved either in different frequency bands (FDD mode) or at different moments in time (TDD mode, in the same frequency). In Romania, most frequencies used by mobile networks are in FDD mode. Full duplex technology allows the transmission and reception of information simultaneously, on the same frequency and at the same location, therefore - in principle - it could double the capacity of the network using the same spectrum resources.

Ensuring the expected performance of 5G wireless networks also involves providing upstream capabilities, in order to connect cells to networks. Widely used in backhaul networks today, current radio relay links will not be enough in the 5G perspective, the unanimously recognized

[104] E.g., for connecting base stations to the network

solution for meeting the capacity and latency requirements is the massive migration to connecting cells to the network using fibre optic. However, network deployment experience shows that point-to-point radio relay links can be efficient for traffic concentration/transport, and for ensuring other connectivity scenarios, such as machine-type communications, given the less stringent capacity requirements, or even for the fronthaul segment (up to the first point of traffic concentration). Very high frequency bands (e.g. 70-80 GHz) are suitable therefor, as they provide sufficient bandwidth, spanning hundreds of MHz, and even 1 GHz.

- *mesh networks*

In a mesh network, all objects/nodes are connected to each other without a central hierarchy, forming a mesh topology, so that each node could receive and transmit data and information.

In addition to avoiding critical points whose failure isolates part of the network, mesh networks have multiple benefits in the 5G context, especially for machine-type communications between connected objects:

- through dynamic routing, equipment connected to a mesh network can look for the fastest and the most secure route for data exchange;
- effective solutions can be offered for covering remote areas (agriculture, forestry), since if a single object in a network of connected objects lies within the coverage of the parent network, it will act as a point of interconnection for the entire network of objects.

Annex 2 – Methodology

This strategy has been drawn up within an inter-institutional working group (GLI-5G)[105] under the coordination of the Ministry of Communications and Information Society, consisting of members from ministries and public administration institutions in Romania, as well as of representatives from institutions within the national defence, public order and national security system, respectively of invited participants - organizations of county councils, municipalities, towns and communes. The technical secretariat of the GLI-5G was ensured by ANCOM.

Since its inception, the GLI-5G has worked in various formats and with different involvement degrees, depending on the analysed issues: documenting and individual work, bilateral or multi-lateral consultations, plenary sessions organized at different levels (experts, decision-makers). Moreover, the GLI-5G resorted to specialists in the field in order to substantiate some points of view, to outline trends or to highlight some challenges. In this respect, it is worth noting that:

a) providers of public mobile communications networks active in Romania presented their opinions and views to GLI-5G on two occasions;
b) global equipment manufacturers presented their views on 5G challenges and opportunities in Romania to GLI-5G, based on their international experience;
c) outlining the 5G challenges and opportunities has allowed the permanent involvement of ATU cooperative organizations at GLI-5G plenary sessions.

Furthermore, MCSI and ANCOM allocated human and financial resources to support the drafting of the strategy.

In drafting the 5G Strategy for public consultation, GLI-5G organised 10 plenary sessions: 3 at the decision-making level, on 18 June 2018, on 19 November 2018, and on 26 February 2019, respectively 7 at expert level on 12 July, 21 August, 30 August, 6 September, 18 October, 25 October and 31 October 2018.

The public consultation on the draft 5G Strategy, foreseen for the period 21 November - 21 December 2018, fulfilled the requirements regarding decisional transparency in the public administration, allowing the participation of a wide range of stakeholders and decision makers in enriching this strategic planning.

The main contributions in the public consultation and the answers to these contributions have been included in a Summary of Comments, with due regard to the provisions of Law no. 52/2003 on decisional transparency in the public administration, republished.

This document was adopted in the GLI-5G meeting organised at State Secretary level on 26 February 2019.

[105] The MoU adopted in the Government working session of 16 May 2018 no. 20/9022/A.I.L

Annex 3 – Acronyms and abbreviations

3GPP (The 3rd Generation Partnership Project) – association of telecommunications standard development organizations

4K – approximately 4000 pixels resolution

5G-PPP – European 5G Infrastructure Public Private Partnership

8K – approximately 8000 pixels resolution

AI – artificial intelligence

CAGR – Compound Annual Growth Rate

CPS – cyber-physical systems

CTIA – Cellular Telecommunications Industry Association

DSRC – dedicated short range communications

eMBB – enhanced Mobile Broadband

FDD – Frequency Division Duplexing, communications network technology

FWA – Fixed Wireless Access, wireless communications technology

Gbps – Gigabits per second

GSM – Global System for Mobile Communications, mobile communications standard

IMT 2000 (International Mobile Telecommunications for the year 2000) - a family of mobile communications standards

IMT 2020 (IMT for 2020 and beyond) - a family of mobile communications standards

IoT – Internet of Things

ITS – Intelligent Transport Systems

ITU – International Telecommunication Union

kbps – kilobit per second

LoRa – Long Range low power wireless technology

LTE – Long-Term Evolution, typically 4G mobile communications standard

Mbps – Megabit per second

MPGT – General Transport Masterplan of Romania

MIMO – multiple-input and multiple-output (radio antenna technology for mobile communications)

mMTC – massive Machine Type Communications, a mobile communications specification

NB-IoT – Narrowband IoT, a wireless communications standard

NGN – Next Generation Network

NFV – network function virtualization – communications network architecture concept

NMT – Nordisk MobilTelefoni, the first fully automated system of cellular mobile telephony

OECD – Organisation for Economic Co-operation and Development

OTT – over-the-top, a generic name for internet applications (e.g. SKype, Facebook, Netflix)

PPDR – Public Protection and Disaster Relief

RAN – radio access network

RSPG – Radio Spectrum Policy Group, high-level advisory group that assists the European Commission in the development of radio spectrum policy

SDN – software defined networks, a communications network technology

SigFox – wireless communications technology, developed for connecting objects

TEN-T – Trans-European Transport Networks

TIC – Information Technology and Communications

TDD – time division duplexing, a communications network technology

UMTS – Universal Mobile Telecommunications System, a typically 3G mobile communications standard

URLLC – Ultra Reliable Low Latency Communications

V2I, V2P, V2V, V2X – vehicle-to-infrastructure, vehicle-to-person, vehicle-to-vehicle, vehicle-to-everything (technology developments for self-driving and connected vehicles)

Wi-Fi – a technology for wireless local area networking

WiGig – Wireless Gigabit Alliance, developing multi-gigabit per second speed wireless communications technology

WRC – World Radiocommunication Conference