The
Federal Government

5G Strategy for Germany

A scheme to promote the development of Germany to become a lead market for 5G networks and applications

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1. Introduction

Digital transformation is progressing so fast that information and communications technologies will soon shape every aspect of the economy and society. Sales figures of mobile end-user devices indicate a clear direction: In 2016 alone, more than 25 million smartphones and 7 million tablets were sold in Germany.[1] By now, around 66 percent of Germans are using a smartphone and 38 percent a tablet to access the internet.[2] This means that going online is becoming increasingly mobile. In 2017, the data volume on German mobile communications networks is expected to be greater than one billion gigabytes for the first time – twice the volume of 2015.[3]

The digital transformation is becoming especially apparent in the *Internet of Things (IoT)*. The number of connected devices in the economy and in everyday life is growing constantly: By 2020, around 770 million devices will be connected in Germany alone.[4] Apart from mobile end-user devices such as smartphones and tablets, vehicles, household appliances or industrial machinery will also be connected to the internet and will be able to exchange data.

In the future, there will be billions of objects, sensors or machines worldwide that communicate with each other. The consumer internet will be enlarged and will become an industry internet. This industrial and intelligent interconnection creates unprecedented challenges in terms of connectivity, capacity, safety and security as well as service quality. Mobile communications is particularly affected by this because many of the digital applications of the future require a radio-based mobile gigabit connection. The next generation of mobile communications (5G) represents a key technology to bring about this digital transformation and, for this reason, is at the centre of public attention. 5G will be a **key component of the gigabit networks of the future** and will require completely new ICT architectures.

For the private and public sectors, in particular, 5G offers enormous innovation and value creation potentials. If production processes in our decentralised economic structure are interconnected, opportunities for increasing productivity, using resources even more efficiently and emitting less emissions will arise. With industry contributing 22.8 % to the whole economic output,[5] Germany can benefit considerably from an early introduction of 5G technology. Moreover, this technological evolution has the potential to improve the quality of life of each and everyone of us. Inter alia, this will be achieved by intelligent health care services, connected mobility, mobile eGovernment and not least by the ubiquitous availability of powerful access to sources of information.

In the autumn of 2016, the Federal Government launched its **5G Initiative for Germany,** which represents a framework for action that is to support the deployment of 5G networks and the development of 5G applications at an early stage**.** The **5G Strategy** of the Federal Government describes the context and the fields of action with regard to the rollout of 5G networks in Germany over the period to 2025. It is our aspiration to make Germany a lead market for 5G applications. We are supporting this objective by taking specific measures in five fields of action:

- Step up network rollout
- Make available frequencies based on demand
- Promote cooperation between telecommunications and user industries; take account of requirements, ideas and solutions of the affected user industries in standardisation
- Targeted and coordinated research
- Initiate 5G in towns and cities early on

Germany and Europe have the opportunity of becoming leaders of innovation in a key technology field of the future. We want to and we will seize this opportunity.

1 cf. Bitkom (2017): Smartphone-Markt: Konjunktur und Trends. Based on EITO and IDC forecasts.

2 cf. ARD/ZDF Onlinestudie 2016.

3 cf. Bitkom (2017): Smartphone-Markt: Konjunktur und Trends. Based on Bitkom forecasts.

4 cf. Cisco (2016): 2020 gibt es fast 800 Millionen vernetzte Geräte in Deutschland. Press release of 7 June 2016.

5 cf. World Bank, World Bank Open Data (2014): Manufacturing, value added (% of GDP).

2. 5G connectivity for the 2025 gigabit society

Using mobile data while being out and about has become a matter of course for many Germans. The current generation of mobile communications, LTE, is already available to more than 96 percent of households.[6]

However, when it comes to achieving mass connectivity in the field of the Internet of Things or realizing real time applications, it is necessary to increase the performance of mobile communications even more. Therefore, standardization bodies have been occupied with developing parameters for new mobile communications modules and network architectures for 5G since 2012 to be able to realize new services.

With the last World Radiocommunication Conference in October 2015, the global race for the introduction of 5G was officially rung in. South Korea, Japan and the United States of America are already in the frontline. As early as the spring of 2015, South Korea announced that it planned to show the first applications based on 5G technology during the 2018 Olympic Winter Games. Japan is working to introduce 5G by the 2020 Olympic Summer Games. China has a showcase of the technology planned for the 2022 Olympic Winter Games in Beijing.

Germany and Europe must not fall short in the competition with these countries. It is our aspiration to make Germany a lead market for 5G applications. Today, already, numerous test beds[7] for diverse branches of industry make it possible to trial 5G ready applications in real world scenarios. This means that chances are good for the German industry to test 5G technologies early on, for example in the fields of automated and connected driving, production or logistics and services, and implement them in their working processes as soon as they are commercially available. However, this requires optimum conditions in terms of infrastructure which, as of now, are to be found on test beds only, to exist throughout Germany.

For this reason it is so important to catch up again with the global leaders when it comes to the expansion of the digital infrastructure. The conditions for the rollout of 5G networks are to be created by 2020 at the latest.

Both the private and the public sector agree that, apart from the targeted deployment of mobile communications networks, a **substantial increase in the deployment of fibre optic** is required to connect mobile communications network base stations in urban and rural regions.

To fully leverage the potentials of a mobile gigabit infrastructure, we are aspiring to have 5G connectivity by 2025. At the same time, we are planning to substantially expand mobile communications capacities in central places as well as rural regions. This means that, besides federal motorways and ICE lines, 5G connectivity with the required level of quality is to be made available at least also on federal highways and regional roads, railway lines and major waterways. Future coverage obligations will ensure that these objectives are achieved to an appropriate extent.

For Germany to become a lead market for 5G applications, we are promoting the development of sustainable and competition-oriented markets. Moreover, to boost innovative capacity, we are committed to a user-friendly **diversity in terms of applications and services**. Start-ups as well as small and medium-sized undertakings, in particular, are to be included in the developments at an early stage and in an active manner.

What is more, Germany will contribute experience and knowledge at international level and, in the context of existing economic and development cooperation, will be an active partner when it comes to the provision of 5G connectivity. This will promote the spread of 5G networks at international level and open up access to new markets for 5G-based products.

6 cf. Bund (2017): Aktuelle Breitbandverfügbarkeit in Deutschland (as at end of 2016).

7 For example: Digital Motorway Test Bed on the A 9 and other inner-city mobility test beds (Funding guidelines for automated and connected driving) as well as 5G test beds in Dresden (5G Lab Germany), Berlin (Fraunhofer FOKUS and HHI) or Munich (5G Vertical Industry Accelerator).

3. 5G technology available from 2020 on

Essential efforts with regard to the introduction of 5G are currently being made in bodies of the **Radiocommunication Sector of the International Telecommunication Union (ITU-R)**, a specialized agency of the United Nations (UN), and of the **3rd Generation Partnership Projects (3GPP)**, a standardization body of the mobile communications industry. Both organisations work with European and national standardisation institutes, representatives from national governments and authorities, network operators, suppliers and user industries.

The ITU-R defines fundamental objectives and requirements (minimum performance parameters) that are to be met by a new mobile communications generation in order to be used in the designated frequency ranges. 3GPP will develop the technical specifications – which are later going to be evaluated and licensed by the bodies of the ITU-R – for achieving the objectives by 2020.

ITU-R has been developing specific requirements and evaluation criteria for the future 5G radio technology under the name of **IMT-2020** (International Mobile Telecommunications) since February 2016. Depending on the use case, ITU-R has defined the following minimum requirements for the performance of 5G, which are to be ensured by the standardisation efforts of the 3GPP:

- Peak downlink rate: 20 GBit/s
- Peak uplink rate: 10 GBit/s
- Minimum downlink data rate for end users: 100 Mbit/s
- Minimum uplink data rate for end users: 50 Mbit/s
- Space capacity for Enhanced Mobile Broadband in buildings: 10 Mbit/s/m²
- Latency for Enhanced Mobile Broadband: not more than 4 ms
- Latency for Ultra-Reliable and Low-Latency Communication: not more than 1 ms
- Connection density: up to 1 million end-user devices per km²
- Reducing energy consumption to 1/10 of that of today's systems
- Increasing relative speeds of movement to 500 km/h

However, the performance of 5G technology will be increased even beyond these minimum requirements in future upgrades.

Application scenarios such as connected vehicles, Industry 4.0, intelligent transport systems and supply networks, smart cities or the e-health sector will be based on the IMT-2020 specifications. Increasingly important applications such as augmented reality, holography and wearables will also build on these specifications. ITU-R has defined the following three application groups for IMT-2020:

1. **Enhanced Mobile Broadband (eMBB):** If the number of users is high, applications with high bit rates, for example ultra-high resolution video streaming, depend on high bandwidths per user and high capacities per cell. In order to make available such data rates, technologies that allow for a significant increase in the spectral efficiency as well as broad frequency ranges are required.
2. **Massive Machine Type Communication (mMTC):** When everyday objects become interconnected, the Internet of Things is becoming reality. Communication with control centres that is made possible by this development places a high demand on the network capacity in terms of the management of hundreds of thousands of logged-in devices per cell. Moreover, signals must be transmitted with utmost energy efficiency in order to facilitate battery lifetimes of connected sensors of ten years or more.
3. **Ultra-Reliable and Low-Latency Communication (URLLC):** Applications where safety and security can be a critical issue, for example in the production area, are dependent on maximum quality, availability and interference immunity (quality of service) of connections. In addition, they require tactile networks that transmit mission-critical data in real time.

As things stand today, the technical requirements[8] to be met by IMT-2020 will be adopted by ITU-R in November 2017. These requirements are to be implemented by 2020 with the development of specifications by 3GPP.
The technologies that are of central importance with regard to the performance characteristics of 5G will take comprehensive effect only through interoperable

8 Draft new report ITU-R M.[IMT-2020.TECH PERF REQ] - Minimum requirements related to technical performance for IMT-2020 radio interface(s). English language version available at: https://www.itu.int/md/R15-SG05-C-0040/en.

interfaces, standards and agreed requirements and application scenarios. However, 5G will not only make industries grow together (mobile communications, ICT and the traditional industry), but it will also bring together areas of standardisation that have been separated to date. It is therefore a key challenge of industrial policy to successfully introduce the requirements, ideas and solutions of the affected user industries into the standardisation efforts.

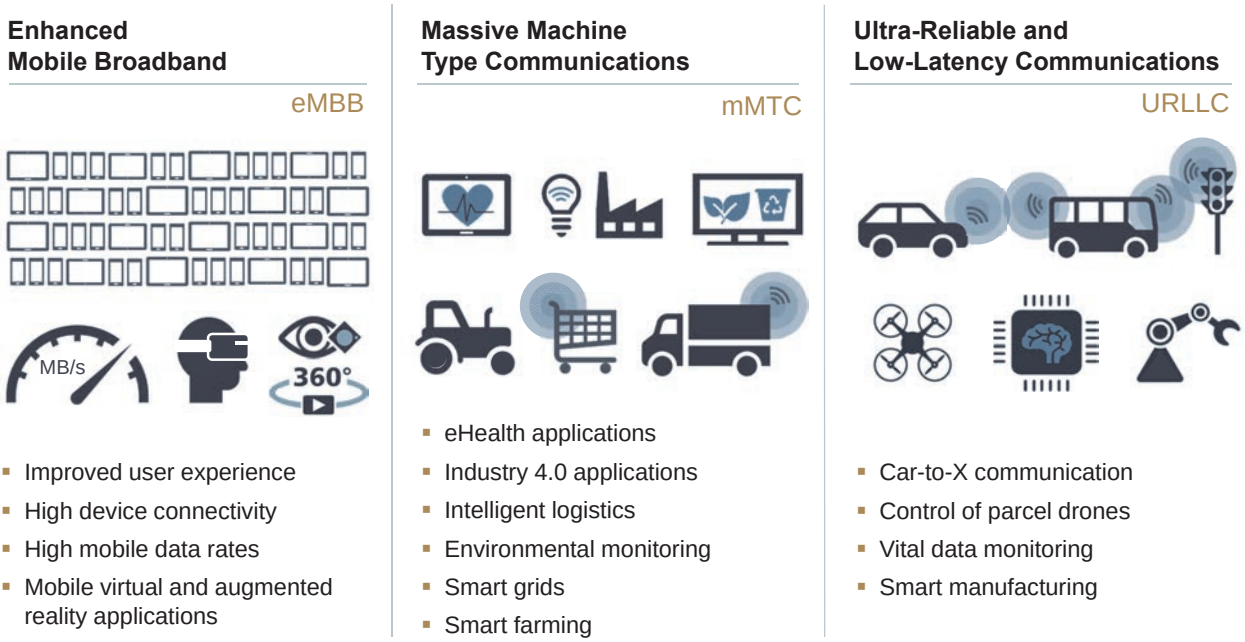

Figure 1 – Three key application groups for 5G: emBB, mMTC and URLLC
Source: Federal Government based on Ofcom 2017: update on 5G spectrum in the UK

Unlike previous generations of mobile communications, where an old technology was replaced by a new one, 5G will evolve a number of existing characteristics, introduce improvements and add new performance characteristics. For instance, Internet of Things services such as the Narrow Band IoT, which has been introduced only recently, will be evolved with 5G. What is more, new technologies will be introduced to be used with 5G.

In September 2018, 3GPP will introduce 5G-specific performance parameters for the first time. The first specifications to facilitate Enhanced Mobile Broadband (eMBB) are also to be made at that time. As of March 2020, all 5G requirements will have been implemented. **The timetable provides for initial trial installations with pre-5G technology from 2018 on. Commercial launch is expected for 2020.**

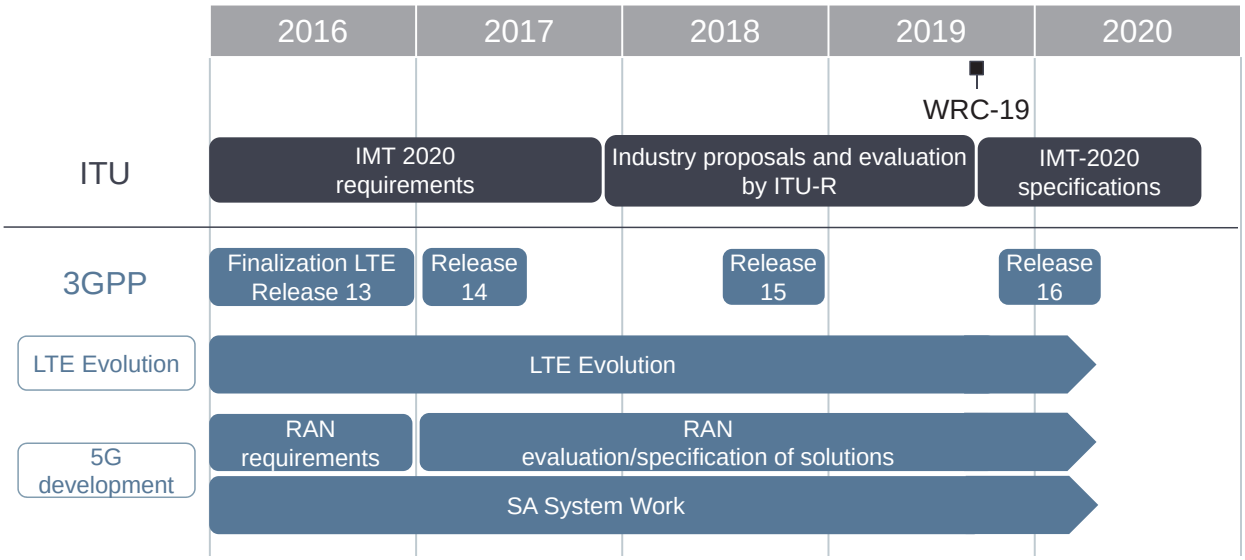

Figure 2 – Timetable of the global 5G standardization process according to ITU and 3GPP
RAN: Radio Access Network with new radio interface (New Radio), SA: Services and Architecture
Source: Federal Government (2016) according to ITU and 3GPP

Two characteristic features of 5G implementations based on the IMT-2020 requirements are the consistent virtualization of network functions and the possibility of reconfiguring the radio interface. As a result, the exact radio technology and the exact quality of service required by an application can be made available in any radio cell. Moreover, differentiated access options for different use cases in terms of data rate, latency and connection density can be made available in separated sections of the network (network slices).

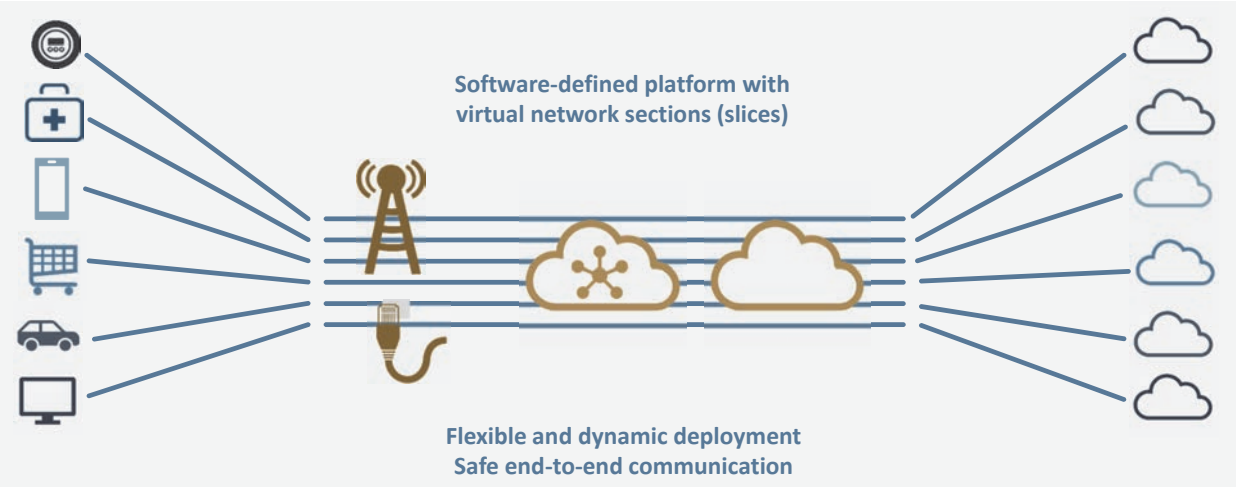

Figure 3 – Functionality of network slicing in 5G networks
Source: Federal Government

Miniaturized multi-antenna systems (Massive MIMO) that calculate the spatial transmission of radio signals and adapt the emitting signals accordingly will be key components of the new 5G radio interface (new radio). In addition, beamforming will make it possible to provide individual users with their own radio signals, to accompany them in a radio cell and block sources of interference. Both methods will contribute to a substantial increase of the spectral efficiency, i.e. the capacity of a frequency.

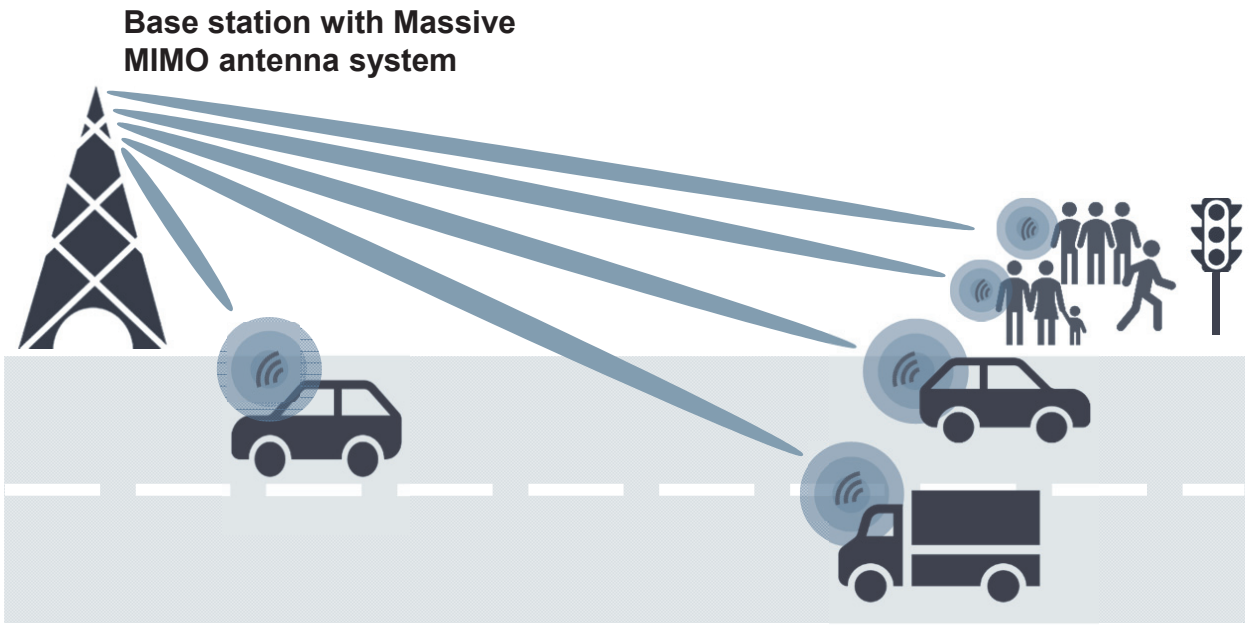

Figure 4 – Functionality of massive MIMO with beamforming
Source: Federal Government

Other key technical aspects of 5G that also play a role in the context of the LTE evolution include signal transmission in full-duplex mode (simultaneous use of a frequency for uplink and downlink), development of existing multiplex technologies for the massive connectivity of several hundreds of thousands of devices in one cell or the use of edge cloud servers for minimal latencies by reducing the distance between end-user device and server.

The requirements of the standardization bodies are critical for the development of chipsets that will be used to process the data in radio modules and end-user devices. Developing a new generation of chips usually takes 1 to 2 years. For the chipsets for 5G to be available in time for the rollout of 5G technology from 2020 on, it is necessary to harmonize the frequency bands that are to be used for 5G at an early stage and at international level.

4. 5G frequency spectrum

By introducing 5G it will be possible to meet growing demands with regard to the capacity, bandwidth, availability and latency of digital radio infrastructures. To realize these requirements and provide supply in rural areas as well as for high-capacity applications, sufficient and suitable radio frequencies will be needed.

For example, because of the favourable transmission conditions in rural areas, low frequencies (below 1 GHz), in particular, will be needed. Frequencies in slightly higher ranges (e.g. in the 3.5 GHz range), in contrast, offer higher bandwidths and provide the capacities for making higher data rates available to a large number of devices. Frequencies in very high ranges (above 24 GHz) will also be needed so as to be able to offer services with very high bandwidths and large capacities. However, unlike low-range frequencies, their coverage is very limited, which is why these networks are confined to local areas.

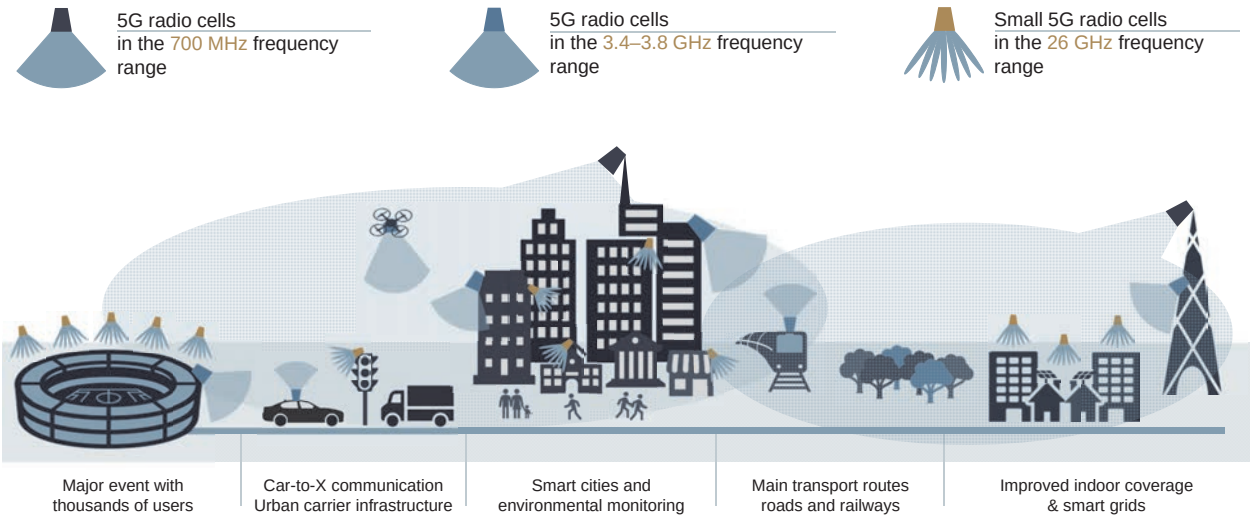

Figure 5 – Using 5G frequency ranges for different application scenarios
Source: Federal Government based on Ofcom 2017: update on 5G spectrum in the UK

Today, mobile communications operators in Germany can already make use of a spectrum of more than 1000 MHz. As soon as 5G transmission and reception technology is available, this spectrum can also be used for 5G services.

However, the realization of services with very high data rates (of up to 20 GBit/s) makes it necessary to allocate additional frequency ranges to mobile communications that allow for making use of channel bandwidths of several 100 MHz or even GHz. Frequencies above 24 GHz (also called the "millimetre band") are very well suited for this purpose. Germany's radio spectrum policy promotes the early identification of harmonized frequency bands at European level and supports the harmonization of the 5G candidate frequency bands that were defined by the 2015 World Radiocommunication Conference. They range from 24 GHz to 86 GHz, and their suitability for 5G will be analysed until the next World Radiocommunication Conference in 2019. Based on the results of the analysis, the Conference will then decide which frequencies are identified for use with 5G.

At the level of European Conference of Postal and Telecommunications Administrations (CEPT), where administrations from 48 countries are represented, it has already been decided to analyse the 24.25-27.5 GHz, 31.8-33.4 GHz and 40.5-43.5 GHz bands for Europe. The Radio Spectrum Policy Group (RSPG), an EU advisory body on frequency policy issues, and the Radio Spectrum Committee of the European Union (RSC) aim to harmonise

the **24.25-27.5 GHz candidate band** (or 26 GHz band for short) Europe-wide with the support of the German frequency policy as early as 2018. The aim is to make use of this 5G pioneer band as early as possible. Corresponding compatibility checks and negotiations with current users in this band as well as users in neighbouring bands that need to be protected have already begun.

The **3.4-3.8 GHz** frequency range will also play an important role when it comes to the introduction of 5G. In this frequency band, there is a good chance that mobile communications companies will be able to use channel bandwidths of up to 100 MHz so that this area can generally be used for data-intensive and smaller-cell applications, e.g. in urban areas. Moreover, due to their favourable transmission conditions, the frequencies in the 700 MHz band that have already been allocated in Germany provide network operators with the opportunity to develop comprehensive 5G coverage based on their existing network infrastructure early on.

5. 5G to become key technology of digital transformation

On the way to the gigabit society, 5G technology plays a key role. Especially in the field of vertical industries, it holds an enormous potential for innovation: High-performance mobile communication infrastructures are an indispensable prerequisite for the vision of fully connected driving, efficiency enhancements in logistics, the management of decentralized energy grids or evolutions in the medical or media sectors. 5G will ensure that the necessary requirements are met even for high user and device densities. In addition, 5G will facilitate the continuous connectivity of wearables, assistance systems, household electronics as well as of a variety of sensors and actuators on the Internet of Things via convergent data networks. The different requirement specifications and the operation scenarios, which are sometimes only of a temporary nature, make flexible networks necessary that, depending on the situation, can provide the required performance parameters in a combined manner.

The following examples show strategic developments of the digital transformation that will be facilitated or centrally supported by 5G:

Intelligent mobility: As regards transport and mobility, we are at the beginning of a revolution that will impact on all areas of mobility. Automated and connected driving will make road traffic safer and improve the flow of traffic so that resources are conserved and harmful emissions are reduced. Intelligent mobility also offers opportunities with regard to the optimization of parking management, for example by means of automated parking display systems.

Moreover, 5G will increase the connectivity between the different modes of transport. This will facilitate the intermodal use of means of transport because information on the fastest connections by changing or combining transport means is immediately available and the journey chain can be booked online. In addition, connected public transport can respond more quickly if there is an increased demand for passenger transport or no service is required on a certain route at a certain point in time. In logistics, the traffic volume will be reduced by applying a highly-efficient route and transport planning scheme. For this purpose, in some cases it will be necessary to implement real-time requirements with 5G, while in other cases it will be necessary to process data streams without interruption taking account of increasing volumes, and there will also be scenarios where area-wide accessibility is required. Therefore, 5G must be made available at least on all major transport routes as early as possible – and in a safe and secure, fast and reliable way.

Industry 4.0: In industrial production, the seamless exchange of data between machines, facilities, humans and robots will become increasingly important. With 5G, the number of quality-assured and energy-efficient connected devices or components can be increased to hundreds of thousands per base station. By means of 5G networks that are organized by the respective user in factory environments, 5G, besides mass connectivity, also offers great potential in terms of controlling facilities, which was previously done on a fixed-line basis. 5G technology will make it possible to address mobile control systems of industrial robots in real time. This will reduce error probabilities to a minimum and (driverless) courier services will arrive just-in-time at the respective loading and unloading stations. Data-intensive uploads of 3D models for controlling or testing facilities can also be carried out on a mobile basis. This will make 5G a key component of seamless vertical connectivity of all operational processes, for example the control of facilities, resources and goods flows. What is more, this development offers great potential with regard to doing business in an environmentally compatible manner, especially with a view to resource efficiency and emission reduction.

Smart Farming: Little attention has been paid to the fact that agricultural processes are already partly connected intelligently across the boundaries of manufacturers or organizations. This makes it possible to access services such as the optimization of machine settings, ideal fertilizing and harvesting strategies and a far-reaching automation of the process chain. Application technology in the agricultural sector that has been specially adopted to individual plants, fields or farms requires a digital infrastructure that makes use of all available communications technologies in an efficient and intelligent manner. 5G will make this possible by facilitating the use of intelligent network switches and the integration of external data sources with high data

throughput (e.g. weather data and allocation with a precision down to the square centimetre).

Smart grids: In order to be able to provide the capacity that is required as a result of the increase in decentralized sources of renewable energy that is taking place mainly at the lower voltage levels, it is necessary to expand the power grid as well as strengthen and control it in an intelligent manner. For this purpose, automated consumption devices (e.g. electric heater with heat pump) are increasingly being used. The electricity market is becoming more flexible and real-time. The underlying infrastructure of the power grids needs to keep pace with such flexibility and, for example, status values and forecasts (e.g. weather, consumption) are needed. To capture consumption and feed-in values, a comprehensive provision of intelligent measurement systems is required. Moreover, the number of approaches is increasing where producers, stores and consumers are virtually connected ("virtual power stations"). 5G will make it possible to connect producers, network operators and consumers within local or regional structures. What is more, 5G will facilitate the implementation of intelligent fixed building services, such as smart metering, the control of heating systems or the monitoring of supply infrastructures such as water, sewage or ventilation systems.

eHealth: 5G will improve the provision of quality-assured acute and standard medical care through mobile communications-based telemedical applications and strengthen the provision of health and long-term care of equal quality in urban and rural regions. For example, this includes the connectivity of ambulances to transmit vital data to the hospital, remote treatment and telemonitoring of long-term patients, video-based medical consultation and telemedical consultations between doctors in smaller acute care hospitals and specialists in other hospitals (teleexpertise) independent of the wire-line hospital infrastructure.

Future media: Developments such as ultra-high resolution content or new services in the field of augmented or virtual reality applications will increase the demand for mobile data transmission with high bit rates many times over. Opportunities for interactive participation or making a contribution offer an unprecedented added value, in particular in tourism centres and at mass events. The focus of the 5G field tests announced for the 2018 Olympic Winter Games and the 2020 European Football Championship will be, inter alia, on augmented and virtual reality applications that will allow visitors to change their perspective or provide other opportunities of changing their experience of the sports events.

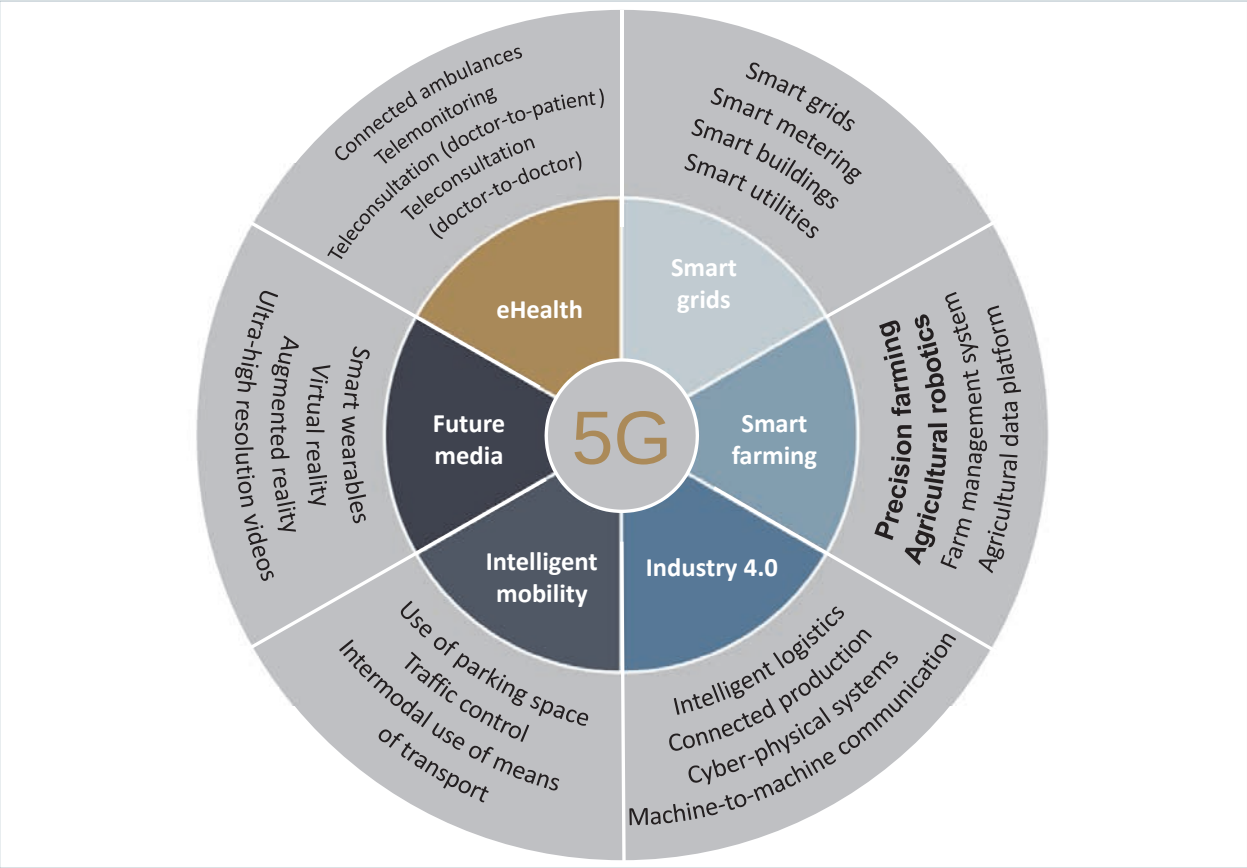

Figure 6 – Application domains of 5G networks
Source: Federal Government

In the future, 5G technology will transport a large part of data of the digital industry. The creation of added value in Germany is very much dependent on the security of the data. In order to adequately protect the new 5G infrastructure, security functions that ensure confidentiality, integrity and availability must be accounted for in the design.

Therefore, the 5G infrastructure must be a robust one to provide efficient protection against attacks on or failures of the IT. Access and access controls, combined with strong authentication features, are an important key to infrastructure protection. This protection can be achieved at national, European and international level with trustworthy public key infrastructures. The security of the transmitted information on the 5G network should be ensured by using state of the art encryption technologies. The Federal Office for Information Security (BSI) accompanies and supports information security with regard to the future 5G network infrastructures and application domains with its expertise and international contacts.

6. Five fields of action for Germany as 5G lead market

Against the backdrop of the digital transformation of society and the economy, the comprehensive availability of digital infrastructures in cities and rural regions is becoming the decisive strategic location factor. This applies, in particular, to the successful introduction and spread of 5G. A fast deployment of 5G networks will create the necessary basis for companies to integrate new digital applications into the value chain at an early stage. This means that 5G networks will form the basis for further innovations that can lead to economic, ecological and social development leaps.

To create the necessary infrastructure prerequisites for this, we are aspiring to have 5G connectivity by 2025. At the same time we are planning to substantially expand mobile communications capacities in central places and rural regions. To fully exploit the performance potential of 5G networks, it is necessary to step up the deployment of fibre optics in a substantial and timely manner.

Within the framework of the **5G Initiative for Germany** that was launched in autumn 2016, the first measures for a rapid development of 5G infrastructures and a comprehensive integration of the technology into the value-added processes have been presented and discussed with the stakeholders. As a result of this consultation process, the Federal Government will implement measures in the following **five fields of action as part of its 5G Strategy** within the available budget:

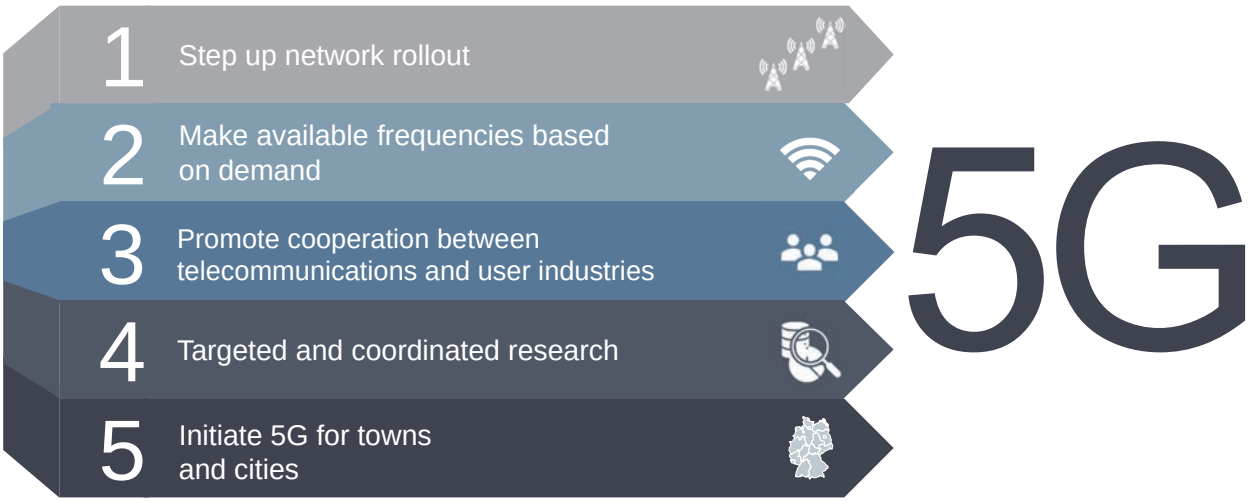

Figure 7 – Five fields of action to develop the 5G lead market in Germany
Source: Federal Government

1 Step up network rollout

- **Facilitate connection of base stations via fibre optic cables**
- **Step up co-usability of passive carrier infrastructures for the development of 5G cells**
- **Support network rollout, maintain health protection**

➲ **Objective: prepare infrastructure and approval procedures for 5G rollout**

To make use of the full performance of 5G networks, massive infrastructure investments by network operators will be required. We are supporting this by creating a framework that will attract investments for the operational rollout of networks. This includes, in particular, the expansion of fibre optic networks to connect base stations and the availability of antenna sites for the necessary densification of networks.

In order to be able to meet the IMT-2020 requirements for average and peak data rates up to the gigabit range for a large number of subscribers and end-user devices as well as for low latencies, the base stations and concentration points must be fully developed with fibre optics. This applies both to macro cells (cell radius up to 50 km) in rural and suburban areas as well as to metro or micro cells (cell radius up to 2 km) in city centres.

In addition, small cells (pico cells) with cell radii between twenty and a few hundred meters for intensive use of 5G at local hotspots such as stadiums or pedestrian zones have to be installed. The reason is that in the future carrier frequencies above 24 gigahertz will be used to provide very high bandwidths at the local level which have only a very limited range and object penetration. Therefore, it is necessary to increase the density of the mobile communications network at the hotspots.

The Federal Government is supporting the development of the networks with the following measures:

Facilitate connection of base stations via fibre optic cables:

In order to realize the full performance of 5G, the Federal Government assumes that network operators – if they have not done so already – will significantly increase their investments in fibre optic connections of base stations and, as a result, will significantly reduce microwave link connections by 2020. The Federal Government expects network operators to make increased use of the possibilities of co-use of passive infrastructures provided by the current legal situation (DigiNetz Act). Depending on these developments, the Federal Government will examine whether it makes sense to further increase fibre-optic connection rates of base stations by the network operators and which additional legal or regulatory measures can be used if this is considered necessary. The promotion of the fibre optic connections of base stations should also be considered in this context, especially in very sparsely populated areas. Potential interactions with possible coverage obligations need to be taken into account, too.

Step up co-usability of passive carrier infrastructures for the development of 5G cells:

The co-use of existing carrier infrastructures will play a key role in terms of the development of small cell networks in city centres. Road infrastructure which already has power connections today, for example traffic lights and street lamps, can be used for the cost-effective development of pico cells.

The Act on the Facilitation of the Deployment of High-Speed Digital Networks (DigiNetzG) that was adopted in November 2016 already defines some requirements with regard to

a) the co-use of public supply infrastructures for fibre optics and the co-deployment of fibre optics within the framework of public road construction schemes as well as
b) the use of public carrier infrastructures to install micro or pico cells.

For the co-use of public supply infrastructure, a working group has already been setup within the framework of the deployment of fibre optic. It comprises representatives from the federal states, the local government associations and the telecommunications sector and is to provide information on issues related to the technical implementation as well as procedural aspects of the DigiNetz Act. The working group is analysing which of the passive carrier infrastructures that the DigiNetz Act makes reference to, for instance traffic lights, traffic signs, street furniture, crash barriers or manhole covers, are particularly suitable for the deployment of 5G by means of co-use. We are aiming to agree on standardized licensing procedures for the timely provision of these infrastructures with the municipal authorities. In addition, the technical security requirements for using these carrier structures, for example with regard to assembly standards, power connections or structural design, are to be defined in the working group of the Federal Government and the federal states.

Moreover, together with the federal states we will examine which legal measures can be used to expand the traditional infrastructure of transmission poles. In addition, we are looking for solutions to facilitate access to public sector properties owned by the Federal Government, federal states and local authorities, so that mobile communications antennae can be installed at these properties.

To support the acquisition of sites and the planning of undertakings involved in the expansion, the Federal Government is also analysing which location data can be made available in the form of open data. The objective for the public sector is to establish a lean uniform national licensing procedure for making existing infrastructure available at reasonable cost and facilitate a comprehensive and dynamic deployment of networks from which the professional mobile communications sector can also benefit.

Support network rollout, maintain health protection:

With the deployment of small cell networks in city centres, the increasing number of private mobile communications devices as well as the emergence of smart cities and smart villages and the Internet of Things, the number of devices emitting electromagnetic fields near humans is also increasing. For this reason, the required approval procedures will become more complex.

We are therefore analysing the need for optimizing the current approval and decision-making processes at the local authority level and at the Federal Network Agency. In particular, we are examining whether there is a need to adapt the existing distance regulations with regard to antenna sites during the site certification procedure. As regards the development of small cell mobile communications networks, we are creating a reliable framework at an early stage. While doing so, we are ensuring that the acceptance of the population and the existing high safety standards for preventive health protection are maintained in all development phases. At the same time, the Federal Government will support the introduction of 5G vis-à-vis the public with transparent information.

2 Make available 5G frequencies

- **Step up harmonisation of 5G spectrum at a global and European level**
- **Make available spectrum below 6 GHz**
- **Create planning certainty for the 26 GHz band early on**
- **Make available test frequencies**

➲ **Objective: support investment in 5G networks with modern frequency policy**

Another prerequisite for the rollout of 5G networks is the provision of a sufficient and adequate spectrum of frequencies as early as possible in order to stimulate investment, innovation and competition with regard to the development of 5G services.

From the provision of test radio frequencies to the timely provision of frequencies for the commercial rollout, the Federal Government is undertaking a series of measures to enable the earliest possible use of 5G technology in Germany.

Step up harmonisation of 5G spectrum at a global and European level:

The Federal Government is lobbying intensively at international and European level for the identification of a harmonized spectrum for 5G and for the definition of harmonized conditions of use at an early stage. In the future, the interests and frequency requirements of other user groups will continue to be considered.

The frequency spectrum that will be used internationally for mobile communications in the future will be finalized within the framework of the ITU World Radio Conference in 2019. As a result of our efforts in the main European bodies, it has been possible to agree on three pioneer bands favoured in Europe: the 700 MHz band, the 3.4-3.8 GHz band (3.5 GHz band) and the 24.25-27.5 GHz band (26 GHz band). CEPT is currently developing the technical and regulatory conditions for a technical harmonization of the 3.5 GHz band and the 26 GHz band in the European Union, and Germany is contributing intensely to these efforts. We will continue to promote the use of the 700 MHz frequencies that have already been made available in Germany for mobile communications throughout Europe.

Make available spectrum below 6 GHz:

5G networks need a sufficient and adequate frequency spectrum with regard to the coverage in terms of space as well as capacity. Expiring frequency use rights must therefore be put on the market again at an early stage. At present, this concerns the 2 GHz (or UMTS) spectrum as well as the 3.5 GHz spectrum. The Federal Network Agency is therefore aiming to carry out the procedure for making available spectrum as early as 2018.

The Federal Government is taking account of the ever-growing frequency requirements of all user groups (including the needs of the authorities and organizations with safety and security responsibilities, the Bundeswehr and users in industrial environments) by pursuing a forward-looking approach with regard to frequency policy and administration.

Create planning certainty for the 26 GHz band early on:

In order to establish investment and planning certainty at an early stage, the Federal Government is aiming to quickly define the 26 GHz band frequencies that can be used at a national level. At the same time, it is planned to make

the frequencies available as early as possible so that usage can start in 2020. To realize this, a step by step approach is also possible. The Federal Government therefore intends to open at least the frequency range between 26.5 and 27.5 GHz as a first sub-range of the 26 GHz band for 5G applications while taking into account security and compatibility requirements of existing services. This approach will enable Germany also to participate in the 5G development in other markets (especially South Korea and the USA).

As an additional measure, we are also investigating the extent to which the use of spectrum in other frequency ranges for 5G applications in Germany – for example by creating flexible use options – is possible and reasonable without losing sight of the security and compatibility requirements of other services.

Make available test frequencies:

Today, applications for test radio frequencies can already be filed with the Federal Network Agency, which can be used for test purposes independently of the specifications of the frequency plan. An example of this is the Digital Motorway Test Bed on the A9.

3 Promote cooperation between telecommunications and user industries

- **Continue the 5G Dialogue Forum**
- **Actively support the standardization process**

➲ **Objective: all sectors must identify potentials and specify their requirements**

In several user industries, international consortia have already been established to integrate the interests of the industries into the standardization and development process of 5G.

In Germany, the introduction of 5G technology is supported across industries by the "5G Focus Group" of the national Digital Summit process (formerly: IT Summit Process). The national Digital Summit and its year-round process form the important platform for cooperation between government, industry, academia and society to shape digital change.

Continue the 5G Dialogue Forum:

In order to intensify the dialogue with the user industries, the “5G Dialog Forum” was set up in September 2016. It supports the active exchange and networking between the telecommunications sector and vertical industries. In workshops, the Dialogue Forum establishes the potentials and current state of the development of 5G for the various vertical industries. The Forum acts as a door opener for companies to participate actively in the development of 5G-based applications in collaborative projects.

A first sector-specific dialogue forum on the 5G prospects for the automotive industry was held in February 2017, followed by an exchange on health issues in March. Other events are already planned for the areas of logistics, cultural and creative industries, Industry 4.0, energy and agriculture.

Today, the modern facilities of authorities and organizations with security and safety tasks (BOS) as well as of the Bundeswehr also include high-performance data communication with high reliability and availability. 5G can, in principle, also meet the requirements of the BOS and of the Bundeswehr. For this reason, the use options for the authorities and organizations with security and safety tasks and the Bundeswehr are addressed in another dialogue forum.

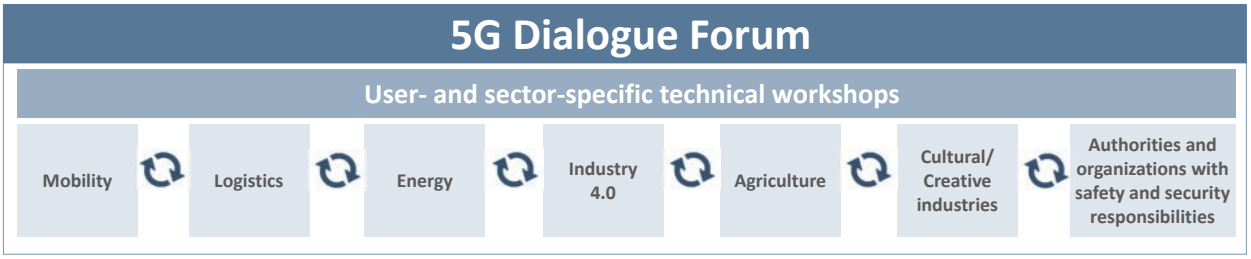

Figure 8 – sector-specific technical workshops of the 5G Dialogue Forum
Source: Federal Government

Actively support the standardization process:

A number of German research institutions and companies are active in the 5G standardization bodies and in the member associations of these bodies. The technical standardization is jointly supported by all stakeholders, mainly carried out by the industry and accompanied by the Federal Government in the corresponding standardization committees (in particular 3GPP, ETSI, ITU and IETF). The goal must be that research and development on 5G result in an open international standard. It is one of the key challenges of industrial policy to successfully introduce the requirements, ideas and solutions of the affected user industries into the standardisation efforts. Furthermore, it is important that the protection against the effects of electromagnetic fields is taken into account as early as the development stage in accordance with the international guidelines and, in doing so, the high level of protection as a standard that is recognized throughout Europe is maintained. This will create planning certainty and there will be no need for national standards.

Against this background, the Federal Government will take the following measures:

- Support the bundling the interests of user industries ("verticals") in the relevant standardization bodies. To this end, the Federal Government will provide a competitively neutral exchange platform for German companies which will make it possible to adopt a coordinated approach (e.g. coordinated joint contributions) in the negotiations in relevant international bodies. For 5G applications in the field of Industry 4.0, the Industry 4.0 Standardization Council will collect the positions of the user industries with the support of the Industry 4.0 Platform and will introduce them into the exchange platform.
- Identify specific requirements of “verticals” and include them in 5G standardisation. Active support will be given to taking account of the requirements of the user industries by means of a coordination centre for ICT standardization established at the Federal Network Agency.
- Analyse whether and to what extent it is possible to support the standardization activities of German undertakings and research institutes in the field of 5G, for example with the WIPANO financial assistance programme, in order to facilitate an increased contribution of the interests of the German industries.

- In addition, the question of the extent to which these technologies are protected by patents and which players hold these patents, particularly standard-essential patents, is of central importance for industrial policy when it comes to the use of 5G applications. The Federal Government will therefore commission an expert opinion in which the current situation with regard to 5G patents is analysed, a forecast of the developments with regard to market-relevant 5G patents is established and the impact on mobile communications and industrial companies (as licensees) is researched. In particular, licensing conditions with regard to the competition- and site-specific framework must be investigated.

4 Support 5G research

- **Support research**
- **Fund research in a targeted manner, support test beds**
- **Connect and coordinate research activities in Germany**

➲ **Objective: increase commitment of German businesses in the field of applied 5G research**

At European level, 5G research takes place mainly within the framework of the 5G Public-Private Partnership Programme (5G PPP). The 5G PPP is based on an initiative of the European Commission, the manufacturing industry, telecommunications operators, service providers, small and medium-sized enterprises and research institutes. Among other things, the objective is to coordinate research and development activities across Europe. In the first phase, which was launched in July 2015, 19 different projects whose research results will be included in the 5G standardization process were selected and funded. Phase 2 started in June 2017 with a total of 21 new projects.

At national level, publicly funded research on 5G is conducted into both the fundamentals and the applications of 5G technologies. The aim is to strengthen local 5G research activities and intensify their coordination.

Fund research in a targeted manner, support test beds:

The Federal Government is funding research and development for innovative 5G solutions on a large scale in its “Industrial Communications of the Future” initiative. The focus is on three research priorities: “reliable wireless communications in the industry”, “5G: industrial internet“ and “5G: tactile internet”, for which up to 80 million euros will be made available. Moreover, the Federal Government is funding further research and development activities within the framework of different programmes with regard to applications where 5G is an important driver in the realization process. For example, the combination of a driving simulator, test vehicles and the "CERMcity" urban test field in Aldenhoven that has been developed by the RWTH Aachen and funded by the Federal Government facilitates the seamless transfer of research results from the laboratory to the road.

An example of an application-oriented collaborative research project in the field of Industry 4.0 is the "TACNET 4.0" project (highly reliable and real-time 5G connectivity for Industry 4.0): the objective is to integrate the 5G mobile communications network seamlessly into industrial communications networks. Only in this way can numerous machines, robots and other IT systems communicate wirelessly in a limited space with high data rates and without delay and be remotely controlled and maintained. With "TACNET 4.0" a concept has been created that will facilitate the fruitful use of 5G technology by the manufacturing industry in the future at reasonable costs.

Other funding programmes address applications where 5G plays a central role. This applies, for instance, to the A9 Digital Motorway Test Bed programme for the trialling of automated and connected driving. One focus of the programme is on the development of the latest real-time communication methods such as 5G and previous versions with approximately the same performance.

After the successful implementation of the digital test bed on the A9, the Federal Government published the Funding Guidelines for Automated and Connected Driving on Digital Test Beds in Germany in June 2016. Under these guidelines, the trialling of the technology on inner city test beds is also supported. Test beds for automated driving are already being funded in the following regions: Berlin, Braunschweig, Dresden, Düsseldorf, Hamburg, Ingolstadt and Munich. The first notifications of awards of funds totalling 9 million euros were handed over to the test fields in Berlin and Dresden at the end of March 2017.[9]

Another example is the "PMSE-xG" project in which the special requirements of event technology with regard to reliable and delay-free 5G connections are to be investigated and developed.

In addition, other user industries are also encouraged to seek collaborative schemes, demonstrate the use of 5G applications on further test beds and identify the economic potential in terms of efficiency and productivity enhancements as well as new business models.

The Federal Government supports research activities in the field of the impact of electromagnetic fields of 5G with a focus on frequencies above 20 GHz. Moreover, we are proactively investigating the effects of the new technology and the newly built networks with regard to their electromagnetic fields.

Connect and coordinate research activities in Germany:

In Germany, 5G research and development is carried out in a wide range of places. In addition to some research and development centres that are directly financed by the network operators and equipment manufacturers, almost all universities with IT faculties and numerous non-university research institutions are conducting research on issues with 5G relevance.

9 The goal of the Berlin "DIGINET-PS" project is the processing and provision of static and dynamic road traffic information for automated driving. The "Harmonize DD" project on the Dresden digital test bed is developing a comprehensive new cloud-based overall system to support highly-automated and conventional vehicles for improved interaction in mixed urban traffic.

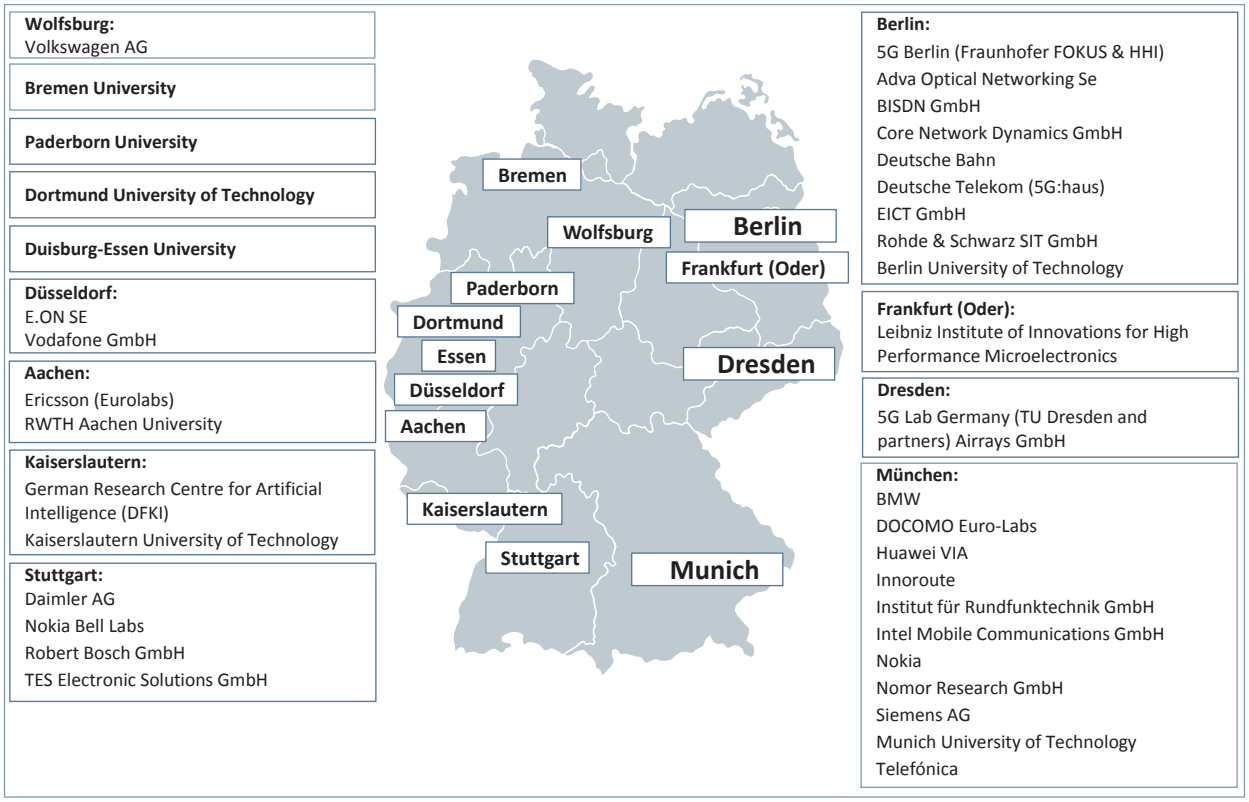

Figure 9 – 5G research centres in Germany (selection)
Source: Federal Government

To carry out 5G research efficiently, it is important that research activities are coordinated and linked up. The Federal Government will implement the following measures:

- Register all relevant 5G research projects in Germany with the respective fields of research, differentiated by basic research and applied research
- Identify cooperation options by clustering the research areas and linking-up the research establishments
- Transfer research findings to all relevant stakeholders (among others, the 5G research community, standardization bodies and vertical industries)
- Fund basic research projects that can be used to assess the impact of 5G technology and increase the acceptance of 5G in society

5 Initiate 5G for towns and cities

- **Organise a 5G competition**
- **Support project planning with the help of industry partners**
- ➲ **Objective: develop tailor-made 5G applications for regions**

5G provides municipalities with a variety of solutions for societal challenges, such as the development of sustainable energy management, the shaping of sustainable mobility to relieve the burden on transport infrastructure, the mitigation of the impacts of demographic change, or the maintenance of similar living conditions in rural areas.

In concrete terms, this means: With the help of 5G, cities and municipalities will be able to implement supply services and administrative services more effectively and efficiently. Whether for parking space management, public transport, traffic management, health care, the management of decentralized electricity or municipal waste disposal, 5G can provide a solution to many of the current challenges. What is important is that the opportunities and challenges of the use of this technology need to be evaluated based on the objectives of integrated and sustainable urban development. For this, the Smart City Charter of the Smart City Dialogue Platform provides important guidance to local stakeholders.

Organise a 5G competition:

The Federal Government will organise a competition in different categories. Participating districts, cities and municipalities will be called upon to address three important municipal challenges, for example from the areas of mobility, refuse collection and disposal, health care or energy supply, and show in an initial outline how and by when these challenges can be tackled with 5G from 2020 onwards.

Support project planning with the help of industry partners:

Funding for the development of detailed project concepts will be awarded to the most convincing project outlines. The Federal Government will support municipal applicants in approaching suitable industry partners and, where appropriate, also start-ups in their activities and the formation of consortia. Funds made available by Federal Government will total at least 2 million euros.

Figure 10 – 5G application examples for municipalities
Source: Federal Government

7. Key Milestones of the 5G Strategy for Germany

The aforementioned measures to support 5G rollout and 5G applications in Germany will be evaluated and evolved as required. The following illustration shows key measures in the five defined fields of action in a rough initial chronological sequence. Detailed plans on the measures in the fields of action will be published in the course of time.

Possibilities to participate in the strategy process and the planned measures as well as information on current events in the context of the implementation of the 5G Strategy can be found on the following website: https://www.5g-fuer-deutschland.de

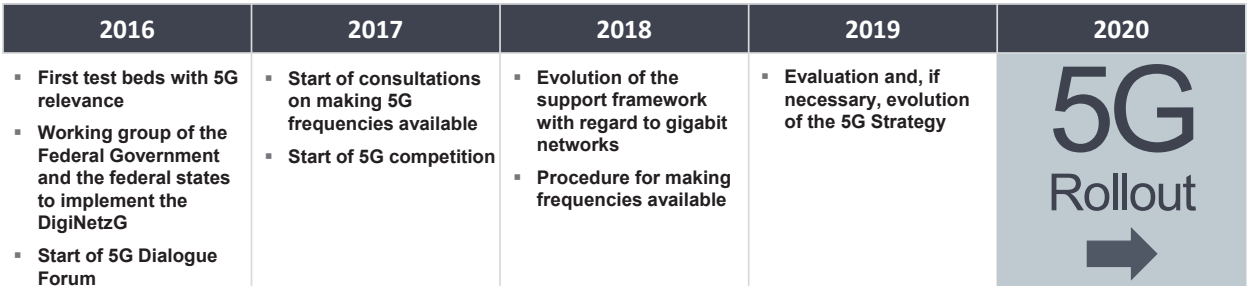

Figure 11 – Milestones of the 5G Strategy for Germany (as at June 2017)
Source: Federal Government

Glossary

3GPP	3rd Generation Partnership Project
5G PPP	5G Public Private Partnership
DigiNetzG	Act on the Facilitation of the Deployment of Digital High-Speed Networks
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunication Standards Institute
GHz	Gigahertz (10^9 Hertz)
GSM	Global System for Mobile Communications
GSMA	GSM Association
ICT	Information and communications technology
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
LPWA	Low Power Wide Area
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
LTE	Long Term Evolution
LTE-A	LTE Advanced
M2M	Machine-to-Machine
MHz	Megahertz (10^6 Hertz)
MIMO	Multiple Input Multiple Output
mMTC	Massive Machine Type Communication
MQTT	Message Queue Telemetry Transport
NB-IoT	Narrowband Internet-of-Things
NGMN	Next Generation Mobile Networks
PER	Packet error rate
QoS	Quality of Service
RSPG	Radio Spectrum Policy Group
RAT	Radio Access Technology
TKG	Telecommunications Act
URLLC	Ultra-Reliable and Low-Latency Communications
WRC	World Radio Conference

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