WHITE PAPER

5G Characterization

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Industrielles Internet

Taktiles Internet

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Contents

01 Introduction

The success of the digital transformation of German industry will largely determine the future competitiveness of Germany as a business location. The **Industry 4.0 strategy** is intended to ensure that medium-sized companies, in particular, cope with this transformation successfully. The driver and backbone for the transformation are **new information and communication technologies (ICT)**. Making the development more efficient and providing communication networks adapted to the needs of industry is a crucial task at the moment. As industrial communication systems must be easily scalable, secure, offer high availability and real-time capability for certain applications, substantial development work is necessary.

Thus, for example, commercial communication technologies must be adapted to the needs of German industry. The new 5G cell phone standard offers huge application potential in this context. Fast action is therefore required to make the new technologies usable for Industry 4.0, as the standardization of 5G is almost complete. The 5G strategy in Germany has set this task as a focal point (see Section 7).

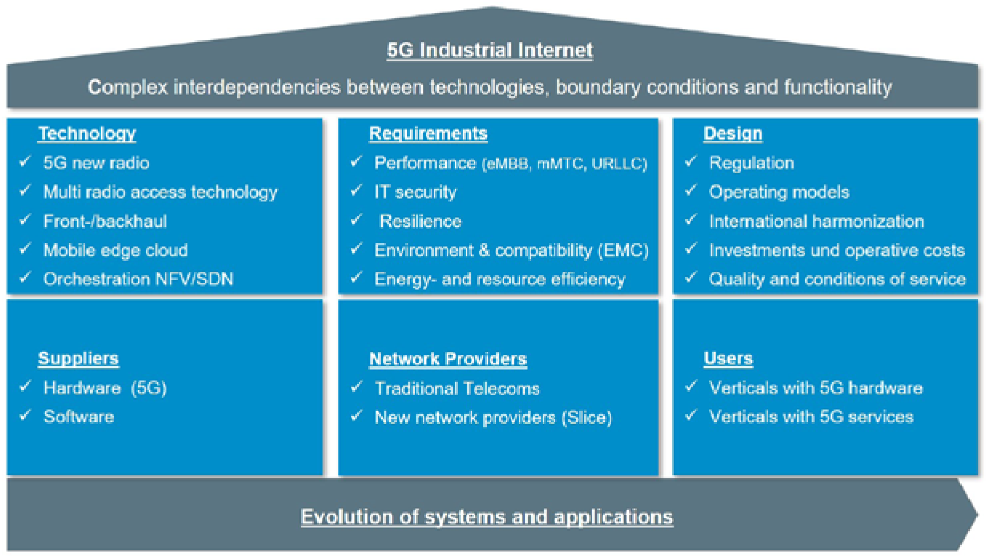

Fig. 1.01
5G Industrial Internet – Design levels, elements and their characteristics over time

In view of the various applications of the term “**5G**” it should first be explained how “5G” will be used below. The abbreviation “5G” has arisen from the cell phone standard as a successor to LTE (4G). Below, however, it does not stand for the new wireless standard, but goes further in referring to a converging network infrastructure consisting of **access and wide area network** that includes all communication technologies and, among other things, satisfies industrial requirements.

This white paper attempts to provide an **integrated description of 5G** with its technical features and application-related aspects in the industrial context. The aim is to reveal in principle and describe the various design levels with their elements and features, and the complex interactions between them. This creates an integrated basis for description of the essential discussion and decision-making processes within the framework of the further organization and introduction of 5G in industry. A matrix has been used to visualize this (see Fig. 1.01).

The elements of technology, requirements and design are located on the first level. The topic of 5G is described from a technical viewpoint here. At the second level, in contrast, 5G is structured from a market perspective. The stakeholders involved and their relations are recorded here along the **5G value creation chain**. Very specific 5G topics such as **slicing** are assigned to the total of six design elements by means of characteristics and are thus shown in a defined interrelationship. The number and composition of the relevant characteristics for a design element may change over time. Time is therefore included as a further element in the form of a timeline in the graphical representation. This serves to portray the integrated description of 5G in terms of an evolution or degree of maturity at the **system and application level**.

The description should provide the interested reader with structured access to the topic of the 5G Industrial Internet. It is designed to allow the development of an understanding of the topic that goes beyond the technological level on the basis of a common linguistic field (glossary). Finally, the description offers a structured entry to the development and assessment of 5G solutions in the industrial context. Small and medium-sized companies, in particular, which are not yet completely familiar with the topic can benefit from this.

02 Requirements

The starting point for a structured description of 5G for future industrial communication is provided by the requirements catalog for technical performance features familiar from **5G standardization** (see Fig. 2.01). Those requirements appear in the center column of Fig. 1.01. Other topics in this block include IT security, resilience, environment and electromagnetic compatibility, and energy and resource efficiency.

In principle, a distinction is made between three application-related performance requirements of 5G:

- eMBB – Enhanced Mobile Broadband – is characterized by high data rates of
- 1 Gbps in the commercial and end-customer-oriented cell phone network.
- uRLLC – Ultra Reliable Low Latency Communication – is characterized by real-time communication with 1 ms latency for applications with high availability.
- mMTC – Massive Machine Type Communication – is characterized by highly energy-efficient, scalable extensive communication with low data rates

5G applications in the area of industrial communications are also fundamentally described by these terms. There are additional requirements in this context, however, which are essential for industrial use. **Secure data transmission that cannot be manipulated** is the top priority here and is therefore also reflected most clearly in industry. Systematic approaches that explore the opportunities of the 5G network architecture are the focal point. However, security must also be understood and implemented at the software and application level, and down to the hardware and component level. Essential hardware modules are still only designed by a very small number of large companies and manufactured primarily by Asian contractors (foundries). The manufacturing conditions and supply chains therefore largely lie outside the European regulatory area of influence; consequently, security and quality cannot be reliably monitored and ensured. In this connection, independent work is required in Germany to guarantee the technological supremacy of our industry over the long term.

Another topic area is connected with this: the requirement for very high technical **reliability and resilience** over time. The latter requirement, in particular, is increasingly moving to the center of the discussion about 5G implementation. Resilience refers to technical concepts that compensate for any potential weakness or failure in a 5G system component and that maintain its function over a defined period by other means. Very high reliability is conventionally ensured by oversizing and redundancy in the system in most cases. But this is not always economical or practical. It is therefore necessary to develop new concepts that meet the service quality requirements set out in the Service Level Agreement (SLA) efficiently and cost-effectively.

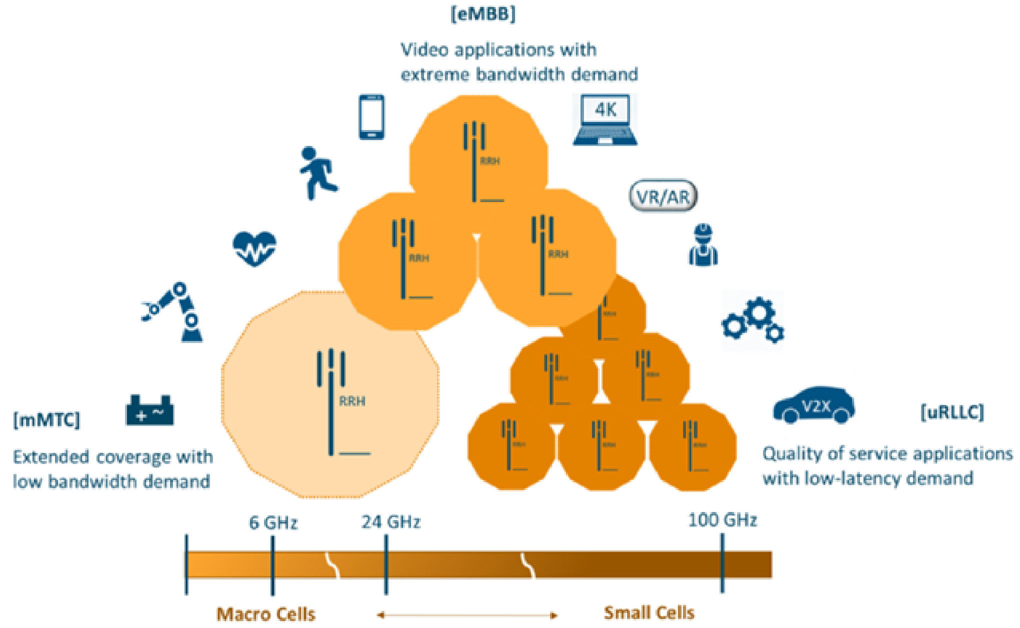

Fig. 2.01
5G performance requirements and service types according to 3GPP standardization

The extended frequency range of 5G, especially in the millimeter wavelength range (30 GHz to 300 GHz), imposes further high demands regarding an understanding of additional environmental factors. This means that both the natural and the artificial environment affect the transmission channel, especially in the area of the air interface. However, attention must be paid to **electromagnetic compatibility**, and not only from the technical perspective. Because of the higher frequencies, the cell radii are smaller and this makes it necessary to increase the number of antenna locations. In this connection, the problem of radiation from the perspective of health protection is gaining in topicality, as the growing number of press articles about 5G and electrosmog suggests. The debate in this connection includes, among other things, whether technologies such as beamforming or beam loading can counteract higher signal rates of 5G and will increase or reduce the actual radiation load on the end user.

The final topic in the design element of requirements focuses on potential environmental impacts. In additional to the **electrical energy demand** in the utilization phase, the raw material demand for the manufacture of the devices and systems should also be examined in more detail. The few existing life cycle assessments and simplified environmental assessments such as the carbon footprint suggest that the environmental burden varies in extent according to the type of product and that it has various causes. In the case of large pieces of telecommunications equipment like antenna systems, base stations and edge routers, the electrical energy demand dominates the environmental assessment in the utilization phase. This equipment should be of an appropriate size and, if possible, equipped with an energy management system that adapts to load.

The effectiveness of the power supply unit and effective thermal management also bring significant savings potential.

The **environmental impact of mobile end devices and sensors**, on the other hand, is determined by the raw materials required and the manufacturing processes. Semi-conductor and circuit board manufacturing, which are energy-intensive and consume a lot of raw materials, have a high environmental impact in this connection. With ever higher frequencies, multiple antennas and beamforming, even more efficient semi-conductors are also required. The material mix also changes as a result. In addition to the standard silicon oxide, increasingly gallium arsenide, gallium nitride and silicon germanium are being used. The environmental impact of these types of components has not yet been thoroughly researched. The fact is, however, that the topics of environmental assessment and ecological design have to be given more attention in order to implement communication systems that will be sustainable in the long term.

Technologies 03

The functional requirements described above are closely linked to the opportunities for technological development. The **design element of technology** is extremely extensive and is depicted only in rudimentary fashion in the graphic (Fig. 1.01). The key technologies listed can be summarized as follows: access networks (5G New Radio & Multi Radio Access Technology) and virtualization (Mobile Edge Cloud & orchestration). The increase in performance values with 5G is achieved primarily in the area of access. The virtualization and 'software-ification' of the network allows a new flexibility that cannot be achieved with existing 4G technology and its current expansions. Many of the technological issues are very closely interrelated. A clear delineation between the topics is therefore difficult. Fig. 3.01 below provides a structural and selective overview of the key 5G technologies.

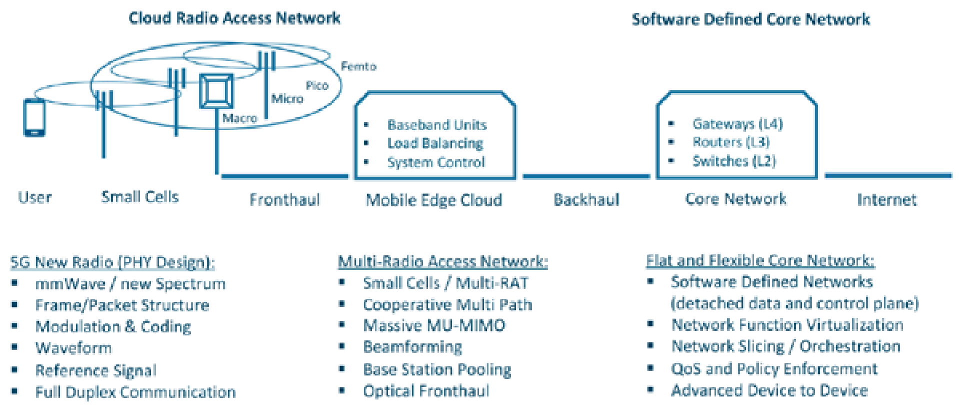

Fig. 3.01
Key 5G technologies

At the heart of the technical 5G development is, on the one hand, the utilization of new frequency ranges including the millimeter wavelength spectrum and, on the other hand, the virtualization and orchestration of technical information resources (memory and computing capacity) in the network.

The new **5G New Radio** air or radio interface is being standardized within the framework of 3GPP. The effective use of discontinuous frequencies is a significant challenge in the 5G context. To maximize the efficiency of the spectrum, the 5G air interface technology must be able to map the various performance requirements of the different services onto the most suitable combination of frequency and wireless resources. Extended coding and multiplexing procedures contribute to enhancing performance at various levels (throughput, latency, energy efficiency. etc.).

Another feature of 5G New Radio is **Massive MIMO** (Multiple Input Multiple Output). Massive MIMO is an antenna technology which achieves data transfer rates of up to 10 Gbps with the aid of hundreds of antennas and advances in parallel digital signal processing and high-speed electronics. Additional antennas help to focus the energy of signals as they are sent and received in ever smaller spaces. Particularly in combination with the planning capability for user end points, significant achievements in throughput and energy efficiency are possible. The more antennas used in the base station, the more data streams can be enabled and end devices operated. The transmissive power is reduced in this way and the data rate increases. The reliability of connection also improves, as Massive MIMO allows greater freedom in the positioning of base stations and selection of data streams for uplink and downlink. In turn, this allows enhanced suppression of interference. It is relatively easy to prevent signal transmission in undesirable directions to stop interference and reduce latencies. Beamforming should also be mentioned in this context. The role of **beamforming** is to create a targeted signal beam (directional radio) in the frequency bands of the millimeter wavelength range with the aid of several antennas and thus to address a specific recipient and block signals from other directions. The recipient benefits from a signal amplification effect and improved suppression of interference. Beamforming is thus a type of spatial filtering which can be achieved in analog, digital or hybrid form.

Wireless full **duplex communication** facilitates simultaneous transmission and receipt of data signals on the same frequency band. Previous wireless networks use HF (half-duplex) mode, which separates downlink and uplink communication orthogonally by means of frequency or time. The capacity of full duplexing communication is restricted, however, by direct self-interference. For a long time, the interference effects were regarded as making transmission and reception on the same frequency inconceivable. The latest studies have shown, however, that full duplex communication is entirely possible with digital self-interference cancellation technology. If other unresolved challenges are overcome successfully, a near-doubling of capacity for data transmission is feasible by switching from half duplex to full duplex.

Concerning the **network architecture**, a distinction is made between two implementation levels in the current 5G New Radio standardization. The first level was standardized on time in summer 2018 with the 3GPP release 15 as so-called 5G non-standalone (NSA). The NSA architecture uses the LTE core network as its basis or anchor. End devices have the option to receive 5G-based high-

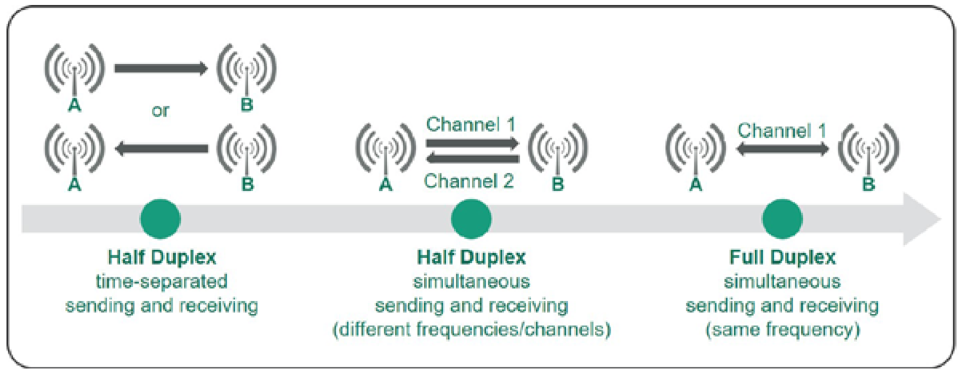

Fig. 3.02: Full Duplexing

bit-rate data. Upload and transport and the network control are carried out via the existing LTE network, however. NSA uses frequencies in the sub-6 GHz band (3.4 to 3.8 GHz spectrum) and has a consistent bandwidth of up to 100 MHz. However, this also requires dual wireless hardware in the network elements and end devices. The second level will be published with the 3GPP release 16 in 2019 and represents the "truly" independent 5G wireless infrastructure. This is referred to in the standardization process as 5G standalone (SA). SA supports spectra in the millimeter wavelength range (26 GHz, 28 GHz and 39 GHz spectrum) and will have a bandwidth of up to 400 MHz. The independent system requires significantly greater investment in network technology and end devices and will therefore be rolled out in about a decade, and at the earliest from about 2023. Economic factors, i.e. the costs of the new networks and equipment, play a limiting role here. Like glass fiber technology, which is being refined technically all the time, implementation across the board is a real financial challenge for everyone involved. The increasing "software-ification" or virtualization in the area of the network infrastructure is becoming ever more important in 5G. Software Defined Network (**SDN**) and Network Function Virtualization (**NFV)** are further key features of 5G. As the EU mentions in its 5G action plan, the entire network will have a programmable, flexible and universal infrastructure through 5G technologies – from the end devices, via the transport networks and edge clouds, through to the core network and clouds in "conventional" computer centers. The 5G infrastructure will bring together the basic information technology resources, storage and computing power via its high-performance network architecture and will offer other application-specific functional areas. This creates the prerequisites for a wider distribution of software functionality or data placement.

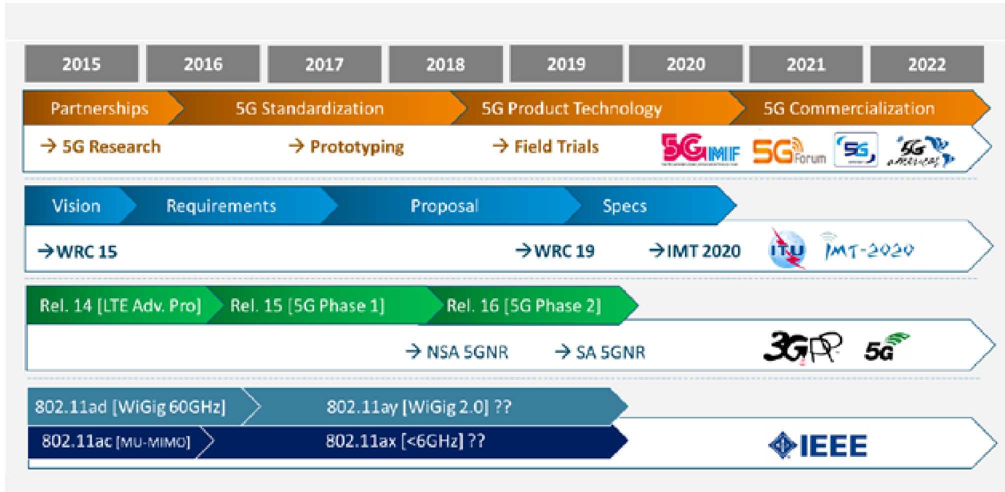

Fig. 3.03
5G standardization activities

SDN and NFV are becoming the standard for software services independent of location. This concept allows small, specific services to develop and operate independently of one another, but also to be tested and combined to create larger solutions ("service composing"). This requires an innovative orchestration of the available services and flexible allocation of the resources required. These services and applications must be able to provide more information regarding their future resource requirements. The established certification process of HW/SW components/systems must face up to these challenges.

In summary, it can be said that the Software Defined Network separates the control and data levels and thus allows virtualization of networks. The network has multi-client capacity as a result and supports a centralized view and configuration of network components. It is the basis for prioritization, quality of service (QoS) and slicing. Network Function Virtualization decouples the network functions from the hardware. Network functions are interchangeable as a result of virtualization and standardization and can be positioned more flexibly. Network services are divided into various "functions" here, and these component-based developments should simplify the recyclability of functions, among other things. In addition to network functions, this also offers the option to execute functions on network hardware from the application level, such as data aggregation functions. Network slicing is a "network as a service paradigm". It allows the realization of QoS for various services on the same physical hardware. This makes on-demand networks possible. An **orchestration of the network** infrastructure is required for this to ensure the required QoS and allow automated provision and adaptation.

Current developments of components of the framework and tools build on existing technologies in the area of the cloud. Combined with other trends in modern software development (scalability, modular structure, automation, app stores), the vision from the 5G action plan of the EU mentioned previously is becoming a reality and making a new flexibility and lower realization of new products and services possible. Through virtualization, however, the apparent decoupling of infrastructural technologies and functional network characteristics is indirectly becoming more closely linked to the application-related domains and data layer at the same time. The 5G networks are not only a communication platform, but are developing into a dynamic application platform. Seen from an economic perspective, the market and the complexity of the value creation chain are expanding. New participants are entering or forcing their way into the market.

SDN

- Separation of control- & data plane
- Virtualization of networks
- Multi-tenancy
- Basis for
  - Prioritizing
  - QoS
  - Slicing
- Centralized view

NFV

- Decoupling of network functions from hardware
- Virtualization of network functions
- Component-based
- Cloud-native design principles
- Service sharing
- SDN is enabler
- More than just network function

Slicing

- Network as a service paradigm
- Realization of QoS for different services on identical physical hardware
- On-demand networks
- Requires orchestration

Fig. 3.04
5G Software Evolution

Design 04

A third element with the title "design" can now be added to the two **design elements of "technology" and "requirements"**, which comprises the non-technical boundary conditions for implementation of 5G. The first condition in this context is the state-controlled or licensed **allocation of frequencies** at a national level. In Germany, it is the Federal Network Agency (BNetzA) that carries the responsibility for this[1]. The first 5G auction covers frequencies in the 2 GHz and 3.4 GHz to 3.7 GHz ranges. On November 26, 2018 the BNetzA published the allocation and auction rules, and applications for participation in the auction were accepted up to January 25, 2019. In parallel to the allocation procedure, the Federal Network Agency developed an application procedure for frequency allocations in the range 3.7 GHz to 3.8 GHz for local and regional use. An application procedure has also been developed for the frequency range from 26 GHz. According to the BNetzA, this also enables regional network operators, small and medium-sized enterprises and start-ups, which will need frequencies only in the future, and communities and representatives of agricultural and forestry to exploit the potential of the coming 5G wireless generation for applications in business and industry or to improve cell phone coverage in rural areas.

As this specific allocation of licenses and thus the provision of separate frequencies for local or regional 5G implementation shows, the issue of **new operating models** including slicing is an important factor in Germany. German industry sees significant potential in the use of 5G, as the well-attended events of the 5G Digital Forum of the Federal Ministry of Transport and Digital Infrastructure (BMVI) show. To guarantee that the requirements of such use are met – particularly regarding secured availability (data rate and latency) and IT security – independent network structure and operation by individual companies and consortia is being considered. However, this means that new network operators also have to act independently on the supplier market with all the associated financial and technical risks. The equipment providers also have to adapt to these potential new customers.

What remains uncertain is the question as to how such local 5G networks will be able to consistently ensure core network functionality including orchestration in combination with external 5G networks. In addition, **IT security** must be guaranteed in the system and all essential components, including the source code, must be certified in accordance with standard security risks. Further standardization activities, such as ETSI in the NFV area, will force the mobile edge cloud not only to open up to functions of the network, but also to facilitate functions on the application level. This is attractive, for example, for applications with low latency. How the telcos will provide users with access to the edge cloud has not yet been clarified. Equipment suppliers and established cloud providers are currently extending their portfolios in this area.

[1] https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/Oeffentliche

Moreover, an individual approach of this sort must also be considered in the international context. As the hardware components required are currently being developed only by a handful of large chip manufacturers and equipment suppliers such as Samsung, Qualcomm, Intel, Broadcom and IBM on the one hand and Huawei, ZTE, Ericsson, Nokia and Fujitsu on the other, the reliance on these few providers is becoming ever greater[2].

The most influential stakeholders in this technical development are therefore located in Asia, the USA and Scandinavia. The European Union with Germany is involved in the fundamental technological development only in certain sub-areas. One indicator that reflects this **technological dominance** well is the number of 5G patents held by individual companies. This list (as of: December 2018) is led by Chinese companies (Huawei, ZTE) with a total of 2,089 patents, followed by Korea (Samsung, LG) with 1,830 patents, the USA (Qualcomm, Intel) with 1,224 patents and Scandinavia (Ericsson, Nokia) with 1,103 patents[3].

The extent to which individual components or products will be available to German industry in future in this highly consolidated global market is uncertain. By contrast, the desire for **international harmonization** is also being expressed by German companies with the use of 5G. Only in this way can it be ensured that 5G communication systems, for example in the context of IT-based services such as remote maintenance, provide an effective benefit and are simultaneously cost-effective.

The **investments and operating costs** represent another aspect of 5G implementation for industrial applications. The first cost when operating one's own network is the license fee for the 5G frequencies. It can be assumed that the investment costs for smaller network operators will be proportionately higher, as volume discounts when purchasing the equipment and service contracts are not offered to the extent usual with very large network operators. With the implementation of small, dense networks, the costs of licensing and of the acquisition of new network system locations should be taken into account. In the context of a new electrosmog debate, legal issues involving those affected cannot be ruled out either.

With regard to the operating costs, the electrical energy demand is very important. Ensuring an uninterruptible power supply, air-conditioning and physical protection for the network systems must also be considered in this connection. If, on the other hand, 5G is purchased as a service for a limited period, the financial consequences of a network failure in the event of a switch to a new service provider must be planned for. Prices also play a role in the context of the new architectures and, in particular, of the network visualization and associated orchestration. The dynamic resource allocation made possible by 5G will be reflected in the prices for these services. The high degree of automation and opportunities for self-service for the user can lead to a reduction in personnel costs, as in the cloud area, and attractive offers for mass applications.

Quality of service and Service Level Agreements (SLAs) are also related to this issue. A Service Level Agreement specifies and describes in detail the scope and quality of the service. This also includes the security standards and the resource transparency. Various services can be divided into different service quality levels to objectify the quality of a corresponding service. Other conditions include internal performance criteria and boundary conditions. Transparency in this connection can be provided by key performance indicators (KPIs). Here a functional unit of the benefit achieved must be defined in relation to a quantifiable effort.

[2] Netze/Mobilfunknetze/mobilfunknetze-node.html
[3] Die Auflistung ist exemplarisch und erfüllt nicht den Anspruch der Vollständigkeit.
https://www.iplytics.com/de/report-de/who-is-leading-the-5g-patent-race/

05 The Value Creation Chain

The industrial value creation chain with its main stakeholders, the equipment suppliers, network operators and users, forms the market basis for 5G development (see Fig. 5.01). These stakeholders fundamentally shape the technical systems and their applications. The term “shape” in this connection includes both the varied activities in the area of research, development and standardization, and production and operational use. The 5G value creation chain is extremely complex and is developing dynamically, as is described in further detail below. The analysis of the mutual influence of the stakeholders along the value creation chain is revealing in that it makes clear any changes regarding the market power of individual stakeholders on the 5G market. The previously powerful role of the network operators, in particular, is now being replaced by the more influential equipment suppliers and users. Technology patents on the one hand (equipment suppliers) and so-called domain knowledge on the other (users) are increasingly influencing business models and the extent of value creation.

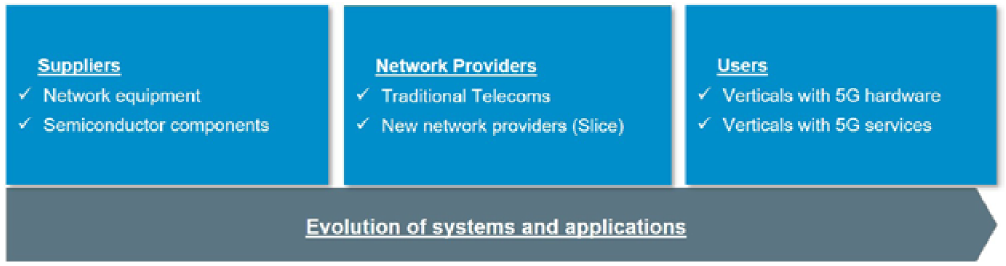

Fig. 5.01
Market design level

The stakeholder group of **equipment suppliers** includes the traditional network equipment suppliers such as Ericsson, Nokia, Huawei, ZTE, Fujitsu, NEC, Cisco, Brocade, Juniper and HPE. These companies sell and lease products to the large network operators (telcos). They develop, manufacture, install and maintain the multilayered technical elements for all levels of modern telecommunications networks. They are very active in the 5G standardization process, such as 3GPP and ITU-T. The network equipment suppliers now no longer see themselves just in the role of service providers for the network operators, but as essential market players in the networked society. Accordingly, a new market is coming into being for the equipment suppliers through the availability of regional and local frequencies for private networks (slicing) away from the owners and operators of the big core networks. The network equipment suppliers are operating in this new area in direct competition with the current network providers.

The network equipment suppliers, as original equipment manufacturers (OEMs), influence, through their demand, semi-conductor-based component manufacturing in particular. This supplier market has consolidated very strongly in recent decades and is currently dominated by a relatively small number of very large technology concerns. The market leaders are Asian and American companies like Samsung, LG, Intel, Qualcomm, Broadcom, IBM, Fujitsu and Mediatek. These companies are creating the technical foundations for 5G telecommunications and have the most patents[1]. In addition, there are still a few large foundries such as TSMC, GlobalFoundries and UMC, which also operate on the market as contract producers with significant technology capacities.

The **network owners and providers** (service provider network) in Germany include, in particular, the three cell phone network operators Deutsche Telekom, Vodafone and Telefónica. Because national and regional roaming is not permitted (roaming: network owners make their networks available to other providers), the roles of network owners and operators are indissolubly linked. Through the option of creating private networks in a limited frequency range, e.g. for company sites or communities, new competition is emerging for the traditional network providers. In addition, a fourth bidder has joined the race in the 5G frequency auction alongside the three established network providers, in the form of United Internet.

Along with giving the network “up-to” performance parameters, the existing network providers have developed further services in data storage, provisioning and analysis in the context of the digitization of industry: network operators, for example, are becoming cloud providers. A 5G network infrastructure would significantly increase the opportunities for developing new services for the user industries once again. These range from the provision of networks with variable performance parameters as required and on the basis of a guaranteed quality of service, through to services as part of or designed to optimize value creation chains and business processes in industry (see also platform operators). The associated new technologies and components such as network virtualization and network slicing or the distribution of services from end devices via the edge cloud to the core cloud, in particular, are being developed and provided by the network and industry equipment suppliers. Existing communication networks such as LTE (4G) will continue to play an important role here and will be the first choice for many applications.

Network providers and equipment suppliers are thus becoming part of important industrial value creation chains in a way that is ever more critical to success. Through standardization, it must be ensured that a distribution of the different services is also possible beyond the various providers. Otherwise, the consequence would be an enormous reliance of industries on individual network providers and equipment suppliers.

[1] https://www.iplytics.com/de/report-de/who-is-leading-the-5g-patent-race/

The group of **users** is divided into industrial equipment suppliers and the user industries. Relevant user industries are in the sectors of vehicle construction, mechanical engineering, the chemical-pharmaceutical industry, food, electrical technology and metal production and processing. Currently, the realization of strategies for vertical implementation through digitization is the priority for the user industries. Only with the availability of powerful communication networks will horizontal integration also move more into focus for companies in the user industries. Networking across the board in companies and beyond company boundaries that is being created in this way is leading to dynamic value creation networks which largely organize themselves and can respond flexibly to one another through continuous communication. The industrial equipment suppliers are both users themselves and solution providers for the user industries in conjunction with new communication networks. The industrial equipment suppliers include the machine and component manufacturers, the automation industry, and the business and industrial IT providers. With their services they create the foundations for vertical and horizontal integration for the user industries by enabling the use of digital material resources and the development of their own new business models. Against this background, important stakeholders in the user industries have come together in the 5G ACIA to influence the technical, regulatory and economic aspects in accordance with their requirements. The opportunity to develop private networks in the wireless sector offers the big OEMs, in particular, new design opportunities for their own communication networks.

Along with the OEMs, new stakeholders in the 5G value creation chain include **communities** and **platform owners and operators** (service provider data cloud). Communities not only have a vested interest in the implementation of their visions of a digital city with all the associated services and opportunities, but also, through their role as a political and legal organizational force, have the power to significantly influence the necessary development of the network infrastructure. Their area also covers engagement with citizens about health issues in connection with a massive increase in base stations for 5G. Probably the largest influence over the 5G value creation chain seems to be exercised by the **platform operators**. These are stakeholders who keep and analyze business and process data and make them available again in accordance with requirements. Their business model depends on ensuring consistent and needs-based communication via standards, including beyond company boundaries. Platforms are currently often offered and operated by larger equipment suppliers such as Siemens, TRUMPF and CLASS. Depending on the scaling, the necessary platform infrastructure is provided by the supplier itself or leased from platform providers such as Amazon, Google, Microsoft or Apple.

Conclusion at the market level

With this detailed consideration of the 5G value creation chain and its main stakeholders, it is possible to make not only an accurate assessment of the current situation, but also a forecast about development trends. The current results are a snapshot of a highly dynamic process in which it is not yet clear which stakeholders and relationships are growing in strength or weakening. For example, large companies and communities are in competition with conventional operators of telecommunications networks, while on the other hand, new market segments are also opening up for the latter. Manufacturers of hardware, operating and application software, cloud and other service providers are also getting ready to participate more fully in the 5G value creation chain. The differences between the computer and telecommunications sectors are decreasing. The new market participants bring important expertise to the 5G market but also have to acquire new specialist knowledge themselves to survive the competition. The traditional market levels are merging increasingly, and the mutual influence of equipment suppliers, network operators and users is increasing significantly. New roles and dependencies are emerging.

In this expanded market environment, new business models are also developing. A important factor in this evolution of business models is software development. On the basis of continuous software development (in contrast to hardware development that tends to be periodic, in line, for example, with Moore's development paradigm), products and system infrastructures are subject to continuous development. Products never become fully mature. Updates are not always completed periodically, but may be triggered by specific events. This increased market dynamism and significant lack of transparency in complex technological systems leads to insecurity in many companies and SMEs. **Important factors in the successful** release of potential in new communication systems are therefore developing in a critical way.

This includes, in particular:

- An understanding of solutions and the derivation of potential for one's own company (cutting costs, increasing productivity, new products/services and business models, new markets and value creation relationships)
- Clarity about the cost/benefit relationship for investment in new ICT
- Clarity about one's own requirements of new ICT and (technological) development strategies
- Security of investment through standardization and the capacity for integration of new technologies
- Dependency on ICT in conjunction with the belief that it can be mastered (configuration, support, troubleshooting) and confidence and transparency in the causality of operating processes
- Availability of essential resources (including personnel, expertise, finance) taking account of the opportunities of the company

06 Social and Political Environment

The starting point for embedding the developments around the topic of 5G into the social environment is the 2030 agenda of the global community, in which goals (see Fig. 6.01) for worldwide sustainable development are defined and to the implementation of which the European Union and the federal government are committed.

Fig. 6.01
17 goals for sustainable development

The use of new information and communication technologies and, in particular, of the associated communication networks are a central and indispensable part of many of the sustainability objectives. An example of this is provided by Goal 3, to "Ensuring healthy lives and promoting well-being for all at all ages", and the role of 5G in the development of digital healthcare services, and by Goal 9, "Building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation", and the role of 5G in the digital transformation of industry.

With the 5G research initiative launched in 2013, Germany has become a pioneer in the development of 5G technologies and their utilization. With a total volume of over €100 million and a total of 20 projects with three funding priorities at different times, research and industry are working in close cooperation to implement the various requirements of the industrial communication of the future in concrete solutions. At the same time, the findings are being fed into the important international 5G standardization process. On this basis, the federal government created an action framework in 2016 for network construction and development of 5G applications and then set up an interdisciplinary

"5G strategy for Germany". With this concerted action by science, industry and politics, an important foundation has been created for positioning Germany as a leading 5G market and implementing important approaches to digitization such as Industry 4.0.

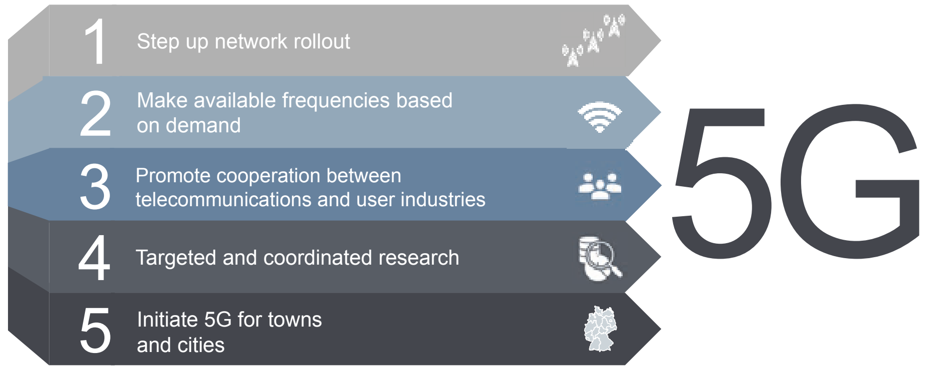

Fig. 6.02
Areas of action for 5G strategy for Germany

The Federal Government's **5G strategy** describes the following central milestones:

2016	2017	2018	2019	2020
▪ First test beds with 5G relevance ▪ Working group of the Federal Government and the federal states to implement the DigiNetzG ▪ Start of 5G Dialogue Forum	▪ Start of consultations on making 5G frequencies available ▪ Start of 5G competition	▪ Evolution of the support framework with regard to gigabit networks ▪ Procedure for making frequencies available	▪ Evaluation and, if necessary, evolution of the 5G Strategy	5G Rollout

Fig. 6.03
Central milestones in the 5G strategy for Germany

Even at a very early stage, the importance of test fields for the implementation of the 5G strategy was recognized. Systematic recording of test fields (see the 5G test infrastructures white paper) has shown, however, that there is still a need for action in the area of visibility and services, in particular in industrial communication. Its is assumed that other test fields exist in the important industrial sector which, for example, are not classified under 5G because they primarily use wired communication, even though they apply the same basic technologies such as SDN and NFV.

The important open discourse about the use of 5G in the various sectors and industries (verticals) has been carried out successfully via the dialog forums and has led to an increased engagement with the topic on the user side. A continuation of this discourse, with the inclusion of the test beds, is both expedient and desirable.

In addition to the practical necessity, the **process of frequency allocation** has made an important contribution to the visibility of 5G in the public perception and therefore across the economy. The topic of local and regional frequencies play a particular role in the industrial context here. This underlines the importance of frequencies of this sort and the associated demand for private networks on the part of the economy and communities. This is also evident in the assessment of the comments on the hearing of the Federal Network Agency on local and regional provision of the frequency range 3,700 MHz to 3,800 MHz for wireless network access.

Through a corresponding funding arrangement, the **development of the glass fiber-based gigabit network** has taken off and has led accordingly to a significant increase in the speed of development across the board. This will support and accelerate the 5G rollout through the creation and connection of additional base stations.

The results of projects funded by the BMBF in the context of the research initiative "5G – Industrial communication of the future" are making an important contribution to the evaluation and further development of the **5G strategy for Germany**. In view of the highly dynamic technological and market developments, an evaluation and further development of the 5G strategy beyond 2020 seems advisable.

Current Overall Assessment 07

The application of 5G technologies in industrial communication differs in certain key aspects from commercial cell phone provision for private end users. At the same time, specific 5G utilization in industry is competing along the entire value creation chain with the end customer business of the large network operators, which is designed for mass consumption. From this situation, some conflicts in terms of objectives come about regarding the higher quality requirements of hardware and software.

The approach to an integrated description of 5G presented in this white paper attempts to present the interaction between the technical aspects and the boundary market and political conditions. This results in a distinction between important design levels, elements and characteristics. By means of this structure, various analyses can be supported. Technological decisions, for example, can be taken more effectively and business models can be developed at an early stage. Given the extremely dynamic pace of innovation in the technology, the integrated perspective helps to assess and plan the rather slow and complex, non-technical implementation more effectively. The authors of this white paper attach a great deal of importance to conveying the new market constellations and their driving forces to the reader. This understanding reveals the actual range of design opportunities today.

It is probably legitimate to claim that the German 5G user industry is facing a challenge. It is certainly possible to identify and exploit significant economic potential. 5G creates its own added value and is therefore not just "better 4G". But the direct design and utilization of 5G is complex under current market conditions and should therefore be viewed much more critically. The stakeholders must be aware of both the geopolitical circumstances, including new trade conflicts, and the fact that the intrinsic evolution of the software will have a significant influence on 5G implementation.

Only those who address the topic of 5G in a strategic and integrated way in their business actions will be able to cope with this dynamism and high degree of uncertainty. This document provides a methodological aid in this connection by offering an overview of the design areas and identifying and explaining the key factors of influence. Just as the technical development passes through clearly defined degrees of maturity (TRL), this structure can help to determine the degree of market and regulatory maturity.

Finally it should be noted that, in view of the highly dynamic technical and market developments, this document can only represent a snapshot and will have to be taken further. This next stage could reach additional findings from an analysis of the changes made to support effective and successful implementation of the 5G strategy in Germany.

08 Glossary

3GPP	3rd Generation Partnership Project
5G PPP	5G Public Private Partnership
DigiNetzG	Law to facilitate high-speed digital networks
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunication Standards Institute
GHz	Giga-Hertz (109 Hertz)
GSM	Global System for Mobile Communications
GSMA	GSM Association
I4.0	Industrie 4.0
IKT	Informations- und Kommunikationstechnik
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	Mega-Hertz (106 Hertz)
MIMO	Multiple Input Multiple Output (multiple antenna procedure)
mMTC	Massive Machine Typ Communication
MQTT	Message Queue Telemetry Transport
NB-IoT	Narrowband Internet of Things
NFV	Network Function Virtualization
NGMN	Next Generation Mobile Networks
PER	Packet error rate
OEM	Original Equipment Manufacturer
QoS	Quality of Service
RSPG	Radio Spectrum Policy Group
RAT	Radio Access Technology
SDN	Software-defined Networking
SLA	Service Level Agreement
TKG	German Telecommunications Act
URLLC	Ultra-Reliable and Low-Latency Communications (qualitätssensible Kommunikation)
WRC	World Radio Conference

Notes

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Fig. 6.01: https://de.wikipedia.org/wiki/Ziele_für_nachhaltige_Entwicklung
Fig. 6.02 and **Fig. 6.03**: https://www.bmvi.de/SharedDocs/EN/publications/5g-strategy-for-germany.pdf?__blob=publicationFile