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Characteristics For Verifying 5G Applications In Production

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Abstract

5G offers the manufacturing industry a wireless, fast and secure transmission technology with high range, low latency and the ability to connect a large number of devices. Existing transmission technologies are reaching their limits due to the increasing number of networked devices and high demands on reliability, data volume, security and latency. 5G fulfils these requirements and combines the potential and use cases of previous transmission technologies so that unwanted isolated solutions can be merged. Use cases of transmission technologies that previously required a multitude of solutions can now be realized with a single technology. However, the general literature often refers to 5G use cases that can also be realized over cables. In this paper, a literature review presents the current state of research on the various 5G application scenarios in production. Furthermore, concrete characteristics of 5G use cases are identified and assigned to the identified application scenarios. The goal is to verify the identified 5G use cases and to work out their 5G relevance to be able to concretely differentiate them from already existing Industry 4.0 applications.

Keywords

5G-Technology, 5G use case, Industry 4.0, Networked, production

1. Introduction

Due to the challenge of digital transformation, the demands on existing transmission technologies are continuously increasing [1]. Not only the sharp increase in the number of end devices to be networked, but also the exponential growth in the volume of data transferred via data networks are pushing existing transmission technologies to their limits. [2] But also higher demands on reliability, security or even latency of the transmission pose challenges to established transmission technology [3]. In order to meet the increasing requirements, the performance of transmission technologies has also had to evolve significantly in the last few years [4]. The mobile communications technology 5G is assigned a special role in this context. This transmission technology addresses not only end users as customers, but also industrial applications for the first time. [5] In particular, the special performance parameters and characteristics of 5G make it unique compared to existing transmission technologies and provide ideal conditions for it to become a key technology of the digital transformation [6].

Numerous studies demonstrate the great economic relevance of 5G based on similar findings [7–10]. In particular, the great value creation potential of 5G in the manufacturing, energy and raw materials industries is always emphasized [9,10]. In these industries alone, 5G benefits to gross domestic product (GDP) are projected to be as high as 5% in 2030 [9]. This can be attributed not least to the realization of various future-proof 5G use cases and the associated development of new business areas and services. For example, an increase in flexibility in production can be realized by eliminating the need for fixed cabling or by making the edge control of robots wireless. Furthermore, there is the possibility of realizing anomaly detection systems or comprehensive asset tracking via the connection of large numbers of end devices [11]. In summary, machine-based decision-making, dynamic automations, or even visualizations of any kind noticeably increase the value creation of companies. But also the development of new business models with

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the help of additional amounts of data from sensors leads to an optimization in terms of time, costs or even quality [12].

The use of 5G will have a positive impact on virtually every industrial sector [7]. In this context, the joint use of infrastructure elements (infrastructure sharing) harbours great potential. Here, various sharing concepts can save costs of up to 25% even with two consortium partners [13]. Industrial parks and technology centres can benefit greatly from the joint development of 5G campus networks since the rollout phase of 5G is cost-intensive and therefore especially attractive for mergers.

This paper will lay the foundation for the evaluation of 5G use cases. In this paper, the 5G technology will be described and characterized based on relevant features. Based on this, 5G use cases shall be derived based on the previously identified characteristics and consequently assigned to the characteristics in the form of strong or weak dependency.

2. Basic terminology

Industry 4.0: Industry 4.0 (or also called the fourth industrial revolution) represents the consistent further development of three preceding industrial revolutions. It is based on historical and technological approaches of the intelligent factory and computer-integrated production. The fourth industrial revolution involves the beneficial networking of people, machines, products, systems and companies along the value chain and across the product life cycle. The aim is to produce more efficiently or more productively and to generate more customer benefits. [14]

Mobile radio: The definition of mobile radio is "radio, radiotelephony or radiotelephone traffic between mobile or between mobile and fixed stations" [15]. Mobile communications are therefore understood to mean communication between different devices, at least one of which is mobile. Challenges here are addressability when changing networks, continuation of communication after interruption, compatibility with other layer protocols, scalability and efficiency. [16]

5G: 5G is the fifth generation of mobile communications, with the associated New Radio (NR) standard. The ITU (International Telecommunication Union) has been compiling performance requirements for 5G since 2016. These include an increased down/upload rate, lower latencies, and an increased number of connected devices per km². Furthermore, both a higher tolerance for the movement speed of the end device and lower energy consumption are required. [17,11]

5G frequencies: In addition to the frequencies already in use today in the range from 0.7 to 2.4 GHz and 5 GHz, 5G can also use frequencies up to 100 GHz. However, the frequencies are initially envisaged, as well as the range between 3.4 and 3.7 GHz, which is intended exclusively for 5G. In addition, the 3.7 to 3.8 GHz frequency will not be used for public networks, but will be kept free for companies or organizations to build private 5G campus networks. [17,11,18]

5G campus network: A campus network is an internal service network of an organization or company [19]. Typically, a campus network consists of a data centre, the office network, and a connection to the Internet. These networks cover specific areas such as a corporate campus or a university campus. The important parts of a campus network according to the 3GPP are the radio network, with which terminals are connected via base stations to the user plane function and the 5G core control plane. [20] Campus networks can be implemented with different levels of integration to the public networks of the mobile network providers. For example, campus networks can be completely isolated (self-operation) or based purely on public networks with only virtual separation (network slicing). But there are also various intermediate forms (hybrid network).

3. Research method

In this study, an exploratory multiple case study was chosen as the research method, while the research design follows the phenomenological approach of qualitative research. The study relies on a non-random, purposive sample. Diversity was considered in the selection of participating companies to ensure that all conflicts of interest described above were addressed. In total, four SMEs, two large companies and two telecommunications companies were interviewed, with interviewees mostly from middle and senior management. The interviews conducted aimed to identify and validate relevant 5G characteristics as well as relevant use fields and use cases for 5G. Based on this, further evaluation of 5G campus networks will be conducted. The interviews followed a semi-structured approach with a duration of 60 minutes per interview. Due to the vast experience with video calls within the pandemic, only virtual interviews have been conducted for the time being.

A three-step approach was chosen as the basis for the interview structure, in which the 5G technology and the description of it were first discussed in an overarching manner. Subsequently, the reference to the 5G use cases in production was made and potentials were collected. Finally, the relationships between features and use cases were considered and evaluated. This research method was chosen to fully capture the specific expert knowledge of the individual subjects and to be able to determine their individual perspectives. The differentiated description of features and use scenarios makes it possible to fully capture and outline the current situation.

4. Results

For the first time, the fifth generation of mobile communications offers the possibility of setting up and operating private campus networks for industrial purposes. As a result, the unique performance parameters of 5G private campus networks make new application scenarios even conceivable. In the following, the 5G performance parameters gathered based on case study research are presented and described in more detail. In a second step, the use cases gathered based on the case-hour research are outlined and detailed. Finally, the characteristics are assigned to the use cases in the form of strong and weak dependence on each other.

4.1 5G performance parameters

In addition to the overriding performance parameters such as low latency, high data rates or high terminal density, 5G has many other performance parameters that will allow new innovative application scenarios in the future. These performance parameters will make it possible for the first time to improve existing applications as well as to run entirely new application scenarios in production. Among other things, the possibility of setting up extremely reliable private campus networks means that many existing cable connections will no longer be necessary in the future. An overview of 5G performance parameters and characteristics and the potentials for industry derived from them is summarized in Table 1.

Table 1: Overview of 5G performance parameters

Nr.	Performance parameters and characteristics of 5G	Potentials resulting from the performance parameters and characteristics of 5G
1	High Data Rates [4,21,22]	Basis for high data rate applications (example AI applications with live camera data).
2	Device Density [23–25]	Basis for applications with high numbers of devices to be connected (e.g. tracing of assembly activities by connecting the tools)
3	Low Latency [26–28]	Basis for applications with real-time requirements (e.g. robotics control/ AR/ ...)

		Basis for edge computing applications
4	Motion Support (Low handover times) [29–31]	The basis for moving application scenarios Realization of applications with speeds up to 500km/h
5	Suitable for large area network coverage (indoor and outdoor) [32–34]	Implementation of new use cases also beyond the boundaries of the factory floor/premises
6	Network Slicing (virtual splitting of the network and dedicated allocation of resources) [35–37]	Increasing the reliability of data transmission Enabling mobile applications despite safety-critical properties
7	Standalone Campus Network (in a licensed frequency band) [38–40]	Increasing the security of data transmission Increasing the reliability of data transmission Individualization of the performance parameters of the campus network to the requirements of applications to be realized
8	Summary of Technologies (Includes properties of existing technologies) [7,41,42]	Merging of different technologies like • Positioning tracking • means of communication (telephone) • Data transmission Cost reduction by lowering the maintenance effort
9	Wireless (lowering of wired applications) [9,43,44]	Increase flexibility Reduction of costs (maintenance, cable breakage, etc.)
10	Improved Energy Efficiency [45–47]	Up to 10 years battery life for low power devices (IoT)
11	Possibility of selective optimization of a private 5G campus network based on the selected use cases. [48–50]	Setting up individual campus networks Optimization of the networks to the needs of the respective company

4.2 5G Use cases

As a result of the unique performance parameters and properties of 5G and the resulting potential, various use cases in industry will be enabled or optimized. An excerpt of the application fields enabled or optimized by 5G, including exemplary applications, is compiled in Table 2

Table 2: Use cases enabled by 5G

Nr.	Use cases	Description/ Application examples
1	Remote Control [51,52,7,53,54]	Remote control of industrial equipment. **Application examples**: mobile robots, AGVs; mobile cranes, mobile pumps, stationary gantry cranes
2	Monitoring [55,28,56]	The transmission of real-time data allows for a number of different monitoring applications. **Application examples**: Monitoring of various parameters (pressure, temperature, ...), process monitoring
3	Tracing/ Positioning [57–59]	The ability to determine position means that tracking and tracing concepts can be realized via 5G in the future. **Application examples:** Traceability of orders, optimization of the flow of goods
4	Quality improvement [9,28]	In general, the use of 5G increases the quality of all processes and applications. **Application examples**: robot-assisted surgery; remote monitoring of patients

5	Vehicle-to-Vehicle Communication [58,60,61]	Communication between vehicles. **Application examples**: AGVs, Drones
6	Process Automation [62,63,48]	Control the production and handling of substances such as chemicals, food and beverages, etc. **Application examples**: mobile robots, massive wireless sensor networks, closed-loop process control, process monitoring, asset inventory management
7	Factory Automation [62,48]	Automated control, monitoring and optimization of processes and workflows. **Application examples**: Motion control, control-to-control (C2C) communication, mobile robots, massive wireless sensor networks.
8	HMIs and production IT [62,63,43]	Various devices for interaction between people and production systems/ IT-based applications such as Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) systems. **Application examples**: mobile control panels, AR applications
9	Logistics and warehousing [54,60]	Organization and control of the flow and storage of materials and goods within the framework of industrial production. **Application examples**: Organization and control of the flow and storage of materials and goods within the framework of industrial production.
10	Maintenance [64,58]	Monitoring of specific processes and/or equipment, but without directly intervening in the processes themselves. **Application examples**: mobile robots, massive wireless sensor networks, remote access and maintenance, AR applications

4.3 Merging 5G features into 5G use cases

For reasons of clarity, strong and weak dependencies have been considered separately. In the following, the strong dependencies are presented first, while the weak dependencies are explained in the next step.

4.3.1 Strong dependencies between use cases and features

The strong dependencies between use cases and performance parameters are summarized below. This quickly shows that the different use cases have very different effects on the respective performance parameters. As a result, it becomes clear that the potential of 5G is very diverse due to the strong performance parameters. The performance parameter "Point optimization of the 5G network" is particularly striking here, since not a single strong dependency could be detected. However, this is due to the higher-level use cases. Furthermore, it was noted that two of the three main performance parameters (device density and latency) were mentioned very frequently. This is due to the fact that these two performance parameters come together in many industry 4.0 use cases. At the same time, some performance parameters were only mentioned once. This is due to use cases that have very specific requirements. An overview of the strong dependencies between the application scenarios and the performance parameters is summarized in Figure 1.

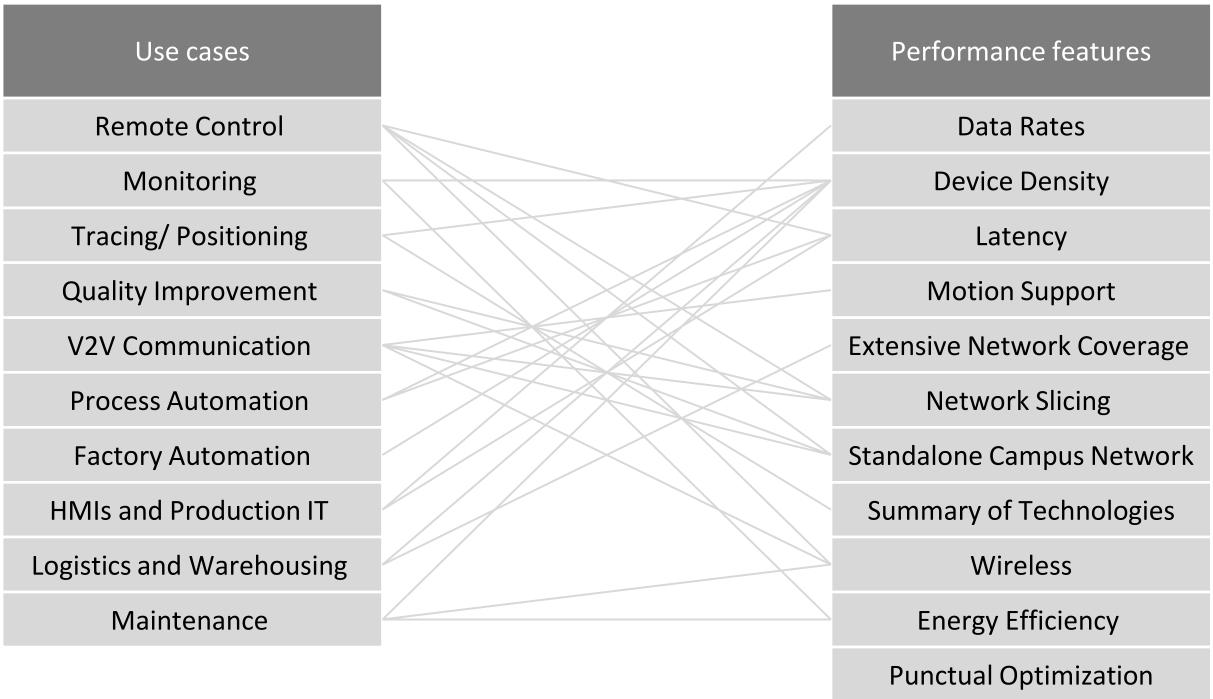

Figure 1: Strong dependencies between use cases and performance features

4.3.2 Weak dependencies between use cases and performance features

In addition to clearly strong dependencies between use case and performance parameters, there are also other, weak dependencies. A good example of this is the possibility of adapting the private 5G campus networks so that they are specifically tailored to the use scenarios. This special performance feature of a 5G network could make all the difference in specific use cases. However, the device density involved in the implemented use case also plays a major role in very many use cases (often either strong or weak dependency). It is noticeable that some performance parameters do not have a weak dependency on the performance parameters at all. The reason for this are special performance parameters, which are quite specifically directed at individual use cases. An overview of the strong dependencies between the application scenarios and the performance parameters is summarized in Figure 2.

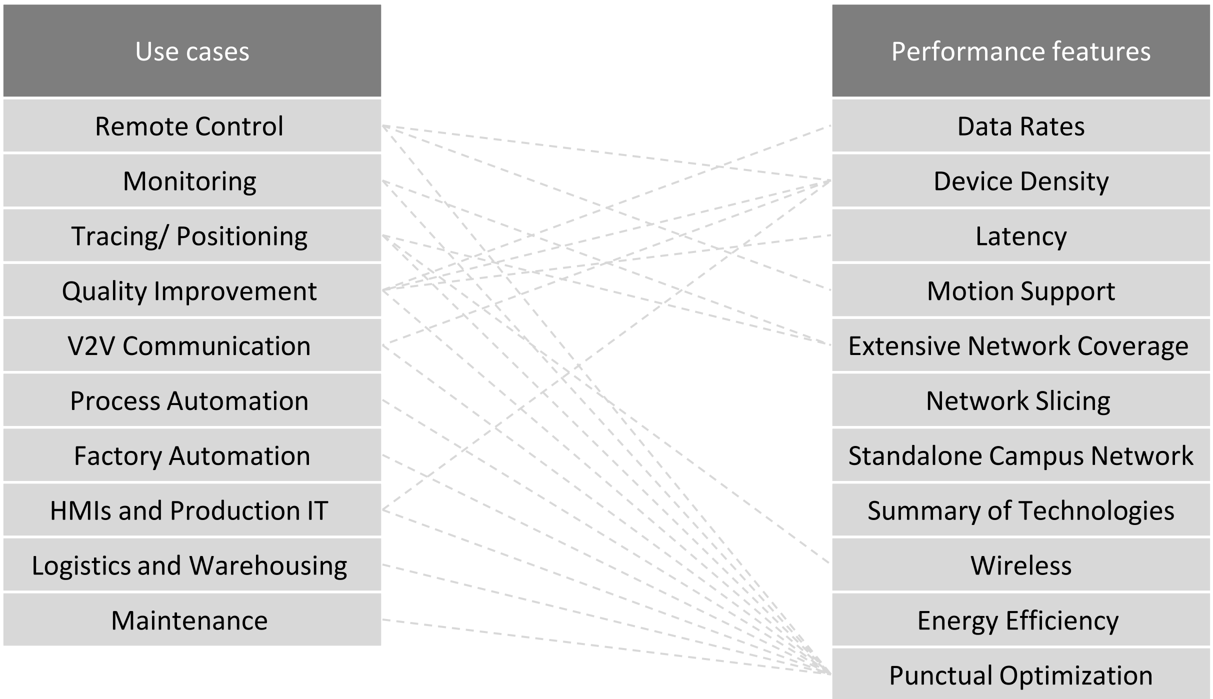

Figure 2: Weak dependencies between use cases and performance features

5. Discussion, conclusion, and outlook

The performance parameters listed here could be linked to different use cases in strong and weak dependencies. By clearly linking the performance parameters to the respective use cases, it was possible to demonstrate that 5G can realize a wide variety of application scenarios. Thus, it could be proven that especially many already existing use scenarios can be significantly improved by 5G. However, the potential of 5G cannot only be evaluated in terms of application cases, since this infrastructure not only realizes new applications and improves existing applications, but also enables higher-level links that could not have been thought of before, especially due to the high number of end devices. Furthermore, it emerged from the interviews that it is very difficult to distinguish clearly between a real 5G use case and an already existing Industry 4.0 use case. Here, sometimes very minor adjustments turn an already existing Industry 4.0 use case into a 5G use case (increasing speed, integrating people (human-machine interactions), etc.). To be able to measure the relevance of 5G in a company, use cases must not only be considered as isolated solutions, but must always be viewed in a higher-level context.

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