5G and Beyond Networks for Digital Transformation: Opportunities and Productivity

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Introduction

With Industry 4.0, digitization is seen as the most potent factor that changes our lives substantially. Digital transformation will pioneer a change, combining the effects of various digital innovations that bring new structures, actors, values, practices, and beliefs that affect almost all life and fields such as ecosystems, organizations, businesses, industries, and cities (Kraus et al., 2021). Digital transformation leverages recent digital communication and information technologies such as mobile technology, analytics, social media, or embedded devices to drive significant business enhancements, including novel business models, contemporary operations, and improved customer experiences (Kraus et al., 2021).

Especially businesses can get maximum efficiency from digital transformation and eventually achieve significant operational gains by obtaining information, developing insights, and providing process automation using cloud-based artificial intelligence solutions, deep learning techniques, the Internet of Things (IoT) solutions, and other new digital paradigms (Maroufkhani et al., 2022). Considering all these changes and innovations, fast and secure connection technologies are critical in combining data from many software and hardware-based systems and devices. Current network infrastructures fail to support large numbers of users' significantly increasing demands. With its high bandwidth, mobility, ultra-low latency, high level of security, and reliability, 5G comes to life as a satisfied solution for businesses' digital transformation needs. With edge and cloud computing, an indispensable part of 5G, it will be possible to process vast amounts of data in real-time.

Few recent studies analyze 5G technologies' impacts on digital transformation. This chapter contributes to the literature by presenting a comprehensive study about how 5G and beyond communication technologies and other digital technologies impact the productivity of each other, in addition to considering various fields and industries from health to business. The rest of this chapter is structured as follows. In the successive section, the evolution of communication technologies is explained. Then, 5G and beyond networks are addressed as a paradigm shift, including how this technology works and crucial processes. This chapter also exhibits the impact of 5G and beyond technology on different technologies and industries. We analyze the opportunities and brings of 5G technology by considering the productivity of these digital and enabling systems.

Evolution from 1G to 6G

Approximately every ten years, it is observed that a new generation of wireless mobile telecommunication technology emerges. This evolution is characterized by new frequency bands, higher data rates, and new services one step closer to providing connectivity

for our entire physical world (Guevara and Auat, 2020). Figure 1 shows the evolution of mobile communications in a timeline, highlighting the main features of each generation (Giordani et al., 2020). As illustrated in Figure 1, each of the generations is called 1G (First Generation), 2G (Second Generation), 3G (Third Generation) and 4G (Fourth Generation), 5G (Fifth Generation), and 6G (Sith Generation), respectively.

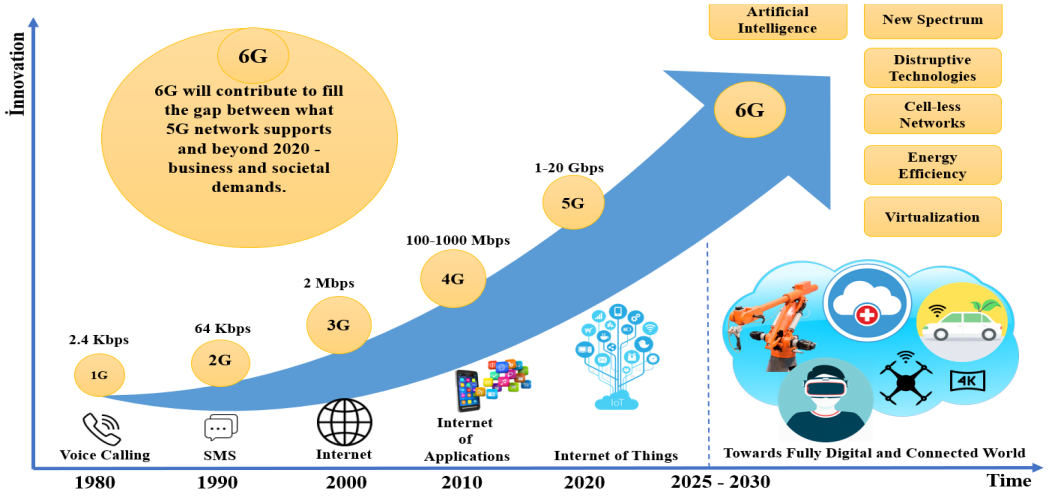

Figure 1. The evolution of cellular networks from 1G to 6G, with exemplary development, stand out for each generation (Giordani et al., 2020).

The first-generation networks emerged in the early 1980s. Although it has many limitations, it can transmit audio data in analog form. The most important limitation is that the low-quality sound is transmitted only in analog form (Elsayed et al., 2022; Guevara & Auat, 2020). Second-generation networks, which can be seen as a digitization step, were introduced in the late 1990s. Innovations in second-generation networks, which stand out with the increase in data capacity, improvements in sound quality, Short Message Data (SMS), Multimedia Message Service (MMS), Wireless Application Protocol (WAP), and Global System for Mobile Communications, were presented as digital services. There was also access to the Internet in 2G. 3G mobile networks introduced in the late 2000s have paved the way for high data transfer speed and wide-ranging Internet access, together with wireless access capability. It has pioneered many new mobile device applications such as the Global Positioning System (GPS), video conferencing, and e-mail access. In 2010, it was introduced as a technology based on the 4th generation network Internet Protocol, as a communication technology that provides high data rate and quality, low cost, and high security (Elsayed et al., 2022). 4G has enabled the ubiquitous high-speed wireless broadband currently used, enabling it to unlock the potential of mobile video and cloud services such as video games, high-definition mobile streaming, and immersive (3D) television. While the 4th generation communication networks support high data rates and low delays, it has also been the starting stage for the Internet of things. On the other hand, the 5th generation and later communication networks, the Internet in everywhere, and a completely interconnected digital world are envisaged. By 2020, 5G base stations have been deployed. The infrastructure has been created and used in some countries. On the other hand, beyond 5G networks, for example, 6G, it is foreseen to start in 2030 (Moubayed et al., 2022).

Why 5G is a Paradigm Shift?

5G is defined as the 5th generation mobile network. It emerges as a new global wireless standard after 1G, 2G, 3G, and 4G networks.

A new kind of network infrastructure is provided by 5G, which is designed to connect virtually everything and everyone, including objects, machines, and devices. The main objective of 5G technology is to provide an extensive network capacity, ultra-low latency, and higher data rates. The next-generation networks promise higher reliability, availability, and an improved user experience. Higher performance and increased efficiency assemble new industries while enforcing new user experiences (Attaran, 2021). The 5G era offers an innovative and disruptive communication infrastructure, as it brings network and service opportunities that were not available before. Beyond the conditions provided by the current 4G, the 5G networks which are highly mobile and dynamic, for example, even in very sparse or dense challenging situations, can provide continuity, higher data rate, lower latency, substantial simultaneous connections, and ubiquitousness. For instance, even in highly dynamic and densely populated areas such as stadiums, and shopping malls, it will be possible to provide enhanced service quality and meet user demands anywhere and anytime (Guevara & Auat, 2020). In addition, 5G will be a key enabler for an actual IoT application by providing a platform to connect large numbers of sensors and actuators with tight energy efficiency and transmission constraints (Sodhro et al., 2020).

Industry and academic studies, powered by this unprecedented growth, have marked the dawn of the 5G era in recent years due to the increasing number of connected devices, mobile data traffic, and the limitations of 4G technologies to meet the enormous data demand. It has focused on defining the features of 5G services with the following steps (Garcia-Roger et al., 2020). A device with 5G will be able to maintain its network connection anytime and anywhere and will have the ability to connect all devices in the network. To this end, the primary 5G system design is expected to support up to one million simultaneous connections per square kilometer and allow for the introduction of various emerging concepts in IoT services (Parikh and Basu, 2020). The IoT approach, which has become easier to implement with the implementation of 5G, is defined as a new digital communication paradigm in which daily life objects can communicate with each other and with users using the Internet. With this feature, it aims to expand and make the Internet concept more comprehensive by enabling easy interaction with a wide variety of devices such as 5G, IoT, home appliances, security cameras, industrial actuators, traffic lights, vehicles, and others. In this context, data is generated and collected from many connected devices. Integrating Cloud Computing and Big Data technologies play an essential role in processing different types of data according to requirements and creating more valuable services. Such technologies are crucial to enabling the IoT paradigm in urban scenarios known as smart cities. As communication networks are an indispensable element that continues exponentially today, they will always constitute the nervous system of new intelligent system paradigms. As the years' pass, the demands will be enormous. At this point, it will become essential for communication networks to transfer much more significant amounts of data at much higher speeds and lower latency. By advancing the work that has already begun for the trend of a fully connected world in 4G and 5G, sixth-generation connections, i.e., 6G mobile network, go beyond personalized communication and integrate not only humans but also vehicles, devices, computing resources, wearables, robots, sensors. It also offers an approach that connects all of them. 5G networks are already designed to operate at extremely high frequencies. However, with 6G networks, for example, terahertz and optical communication, higher spectrum technologies can benefit even more. It is also expected that 6G will bring intelligence to more efficient edge terminals where resources can be used distributive, thereby providing concrete application to distributed learning models that are studied from

a theoretical perspective in the context of 5G. Unsupervised learning and knowledge sharing will support real-time network decisions much more intensely by predictive analytics with 6G (Du et al., 2020).

5G and beyond Networks: Characteristics and Opportunities

Because 5G and beyond networks' performance differs from the current systems due to higher bandwidth, lower latency, and seamless connectivity, it provides an advanced quality of service and experience so that users can access whatever and whenever they need.

Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC), and Ultra-reliable and low latency (uRLLC) communications are the most critical features of 5th generation wireless networks. Table 1 compares the 5G and beyond networks' essential features and characteristics.

Table 1. Key Characteristics of 5G and beyond network 6G

Key Features	5G	6G	References
Time Period	Now	Soon Probably 2030	(Ji et al., 2021) (Nakamura, 2020)
Carrier Bandwidth	Up to 100 MHz	Up to 400 MHz	(Nokia Bell Labs, 2021)
Number of Connected Devices	1 million devices per km^2	10 million devices per km^2	(Nakamura, 2020)
Mobility	Stringent, on-demand, flexible, >500 km/h	Seamless, >1000 km/h	(Siddiqui et al., 2022) (Alfoudi et al., 2019)(Ji et al., 2021)
Security	Cyberware and Critical Infrastructure Threats, SDN-NFV Threats, Cloud Computing related Threats	AI/ML based Intelligent Attacks, Zero-day attacks, Quantum Attacks, PHY Layer Attacks for VLC and THz, etc.	(Porambage et al., 2021) (Wang et al., 2020)
Ubiquitous	Partially	Fully	(Alraih et al., 2022)
Frequency	3 GHz–300 GHz	Up to 1 THz	(Alraih et al., 2022) (Ji et al., 2021)
Data rate	Up to 20 Gbps	Up to 1 Tbps	(Alraih et al., 2022) (Ji et al., 2021)
Latency	1 ms	10–100 µs	(Ji et al., 2021)
Spectrum (Available)	30 GHz	10–100 times higher than 5G	(Ji et al., 2021)
Spectral Efficiency	30 bps/Hz	100 bps/Hz	(Alraih et al., 2022)
Energy Efficiency	High	Ultra-high	(Alraih et al., 2022)
Connection density	10^6 (devices/km^2)	10^7 (devices/km^2)	(Ji et al., 2021)
Coverage	%99,99	%99,9999	(Alraih et al., 2022)
Precision for Positioning	Outdoor: 10 Meter	Outdoor: 1 meter Indoor: 10 Centimeter	(Ji et al., 2021) (Ahvar et al., 2021)
Integration for Satellite	Partial	Fully	(Alraih et al., 2022)
Integration for Automation	Partial	Fully	(Alraih et al., 2022)
Network awareness	Partial intelligibility	Ubiquitous intelligence	(Alraih et al., 2022)
Reliability	10^{-5}	10^{-9}	(Ji et al., 2021)

Key Features	5G	6G	References
Service Level	VR/AR/3D	Tactile	(Ahvar et al., 2021)
Extended Reality (XR)	Partial	Fully	(Alraih et al., 2022)
Haptic Communication	Partial	Fully	(Alraih et al., 2022)
Smart City Components	Segregated	Integrated	(Alraih et al., 2022)
Heterogenous Networks	Integration, Flexible	Fully Integration, Ultra-flexible	(Alraih et al., 2022)
Core Network	Internet of Things	Internet of Everything	(Alraih et al., 2022)
Usage Scenarios	Enhanced Mobile Broad Band (eMBB), Ultra-reliable Low Latency Communication (ulRLLC) and Massive Machine Type Communication (mMTC)	Ubiquitous mobile ultra-broadband (uMUB), Ultra-highspeed-with-low-latency communications (uHSLLC) and Ultrahigh data density (uHDD)	(Zong et al., 2019) (Dogra et al., 2020)
Standardization	5G/New Radio (NR)	No Standardization yet.	(Alraih et al., 2022)
Intelligent Reflecting Services	Not applicable	Yes	(Alraih et al., 2022)
Key Technologies	mmWave, mMIMO, UDN, SDN	THz, SM-MIMO, Laser and VLC, Quantum, Blockchain, AI/ML	(Nasir et al., 2021). (Dogra et al., 2020)
Flexible Spectrum	Flexible Duplex	Free Duplex	(Alraih et al., 2022)
Applications	AR/VR/360 videos, ultra-HD videos, Vehicle-2-Eveything (V2X), Internet of Things, Smart home/factory/city, tele-medicine, and wearable devices	Holographic, haptic, and tactile internet, full-sensory and extended-reality, fully autonomous driving, Industrial, Consumer, Enterprise Internet, Space travel, deep-sea sightseeing, Internet of Everything, and Internet of bio-nano-things	(Alraih et al., 2022). (Dogra et al., 2020) (Porambage et al., 2021)

How Does 5G Technology Drive Digital Transformation?

Digital transformation is defined as using digital technologies to satisfy growing needs, solve problems, provide the desired services, and identify the possible problems so that the developments in many fields can continue following technology requirements. At this point, the fifth generation and beyond wireless networks have vital importance, and they are included as a part of the promised solutions. Of course, there will be potential problems brought by every technology, such as application and dissemination, compatibility of installation and development stages, as in the establishment and spread of the infrastructure of 5G and beyond networks (Zakeri et al., 2020). In addition, technological innovations such as software-defined networks, slicing, virtualization of network functions, and cloud-based platforms will force users and service providers to take different approaches and acquire new solution methods and skills (HPE, 2018). This section analyzes how 5G affects digital technologies, which are indispensable elements of digital transformation, and which features come to the fore in these effects. This section also presents the prominent effects of 5G and beyond networks in different fields and industries; in addition, the key features that can drive these effects are discussed in detail.

Impact of 5G and beyond Technology and Different Digital Enabling Technologies: Productivity

In this section, we reveal a strong relationship between 5G and beyond networks and some of the new digital innovations and technologies. Some of them are Artificial Intelligence, Big Data, Machine Learning, Internet of Things, Cloud Computing, Edge Com-

puting, Blockchain, network slicing, virtualization including software-defined networks and network function virtualization, Tactile Internet, Virtual Reality, and Augmented Reality, as illustrated in Table 2. These technologies are essential for implementing digital transformation, which is connected and interrelated with 5G and beyond networks. We discuss the impacts of these technologies on each other by emphasizing the productivity of these technologies. All these technologies are the backbones of the digital transformation era. 5G and beyond networks provide an enhanced communication infrastructure; the other mentioned technologies in Table 2 also impact 5G and beyond networks, significantly accelerating the deployment and spreading of 5G network systems.

Table 2. Impact of 5G Networks and Digital Technologies on each other: Productivity

Digital Technology or Approach	**Distinctive and key Features or Characteristics for Productivity**	**Impact of 5G Networks and Digital Technologies on each other: + How they increase their productivity?**	**References**
Artificial Intelligence (AI) + Big Data + Machine Learning (ML) + Deep Learning (DL)	Higher bandwidth Secure data Greater data rate Reliability Secure connection High throughput	• 5G enables more speed data analysis in real-time for AI • AI can provide an intrusion detection system for 5G networks • AI can optimize 5G spectrum allocation • AI makes 5G networks proactive and predictive • ML provides 5G networks with predictiveness and proactiveness • AI/ML/DL and Big Data make the base stations (BSs) intelligent so that BSs can make their on decisions network management. • AI/ML/DL and Big Data make 5G networks self-adaptive and self-configurable so that dynamic configurations can be done in real-time depending on processed and analyzed data. • All these opportunities enhance future networks' characteristics such as reliability, latency, and efficiency	(Bansal et al., 2021) (Franchi et al., 2021) (Sairete et al., 2021) (Zhu et al., 2019) (Nguyen et al., 2022) (Mahmoudand Ismail, 2020) (Nekovee, 2022) (Asghar et al., 2022)
Internet of Things	Ubiquitous Connectivity Wide Coverage High Capacity Higher speed of data transmission Reliability Low latency	• 5G accelerates Internet of Things applications • With 5G IoT devices can share their massive data faster, • Integration of 5G networks and IoT solutions enable the realization of various smart city and fully autonomous connected vehicle applications, • Upcoming technology results in significantly increasing IoT devices, forcing the rapid deployment and spreading of 5G network infrastructure.	(Khuntia et al., 2021) (Sun and Ji, 2022) (Chen et al., 2020) (Nasir et al., 2020) (Asghar et al., 2022)

Digital Technology or Approach	Distinctive and key Features or Characteristics for Productivity	Impact of 5G Networks and Digital Technologies on each other: + How they increase their productivity?	References
Internet of Everything	Fully Connectivity Seamless Connectivity Wide Coverage High Capacity Reliability Low latency Higher speed of data transmission	• With the realization of the Internet of Everything paradigm, all devices in a 6G network can communicate. • 6G and beyond networks will realize the IoE paradigm. • The future networks and IoE lift the fully autonomous and connected vehicles and massive machine-type communication in addition to communication among people, infrastructure, and other objects.	(Sah et al., 2022) (Ahmad and Srivastava, 2022) (Asghar et al., 2022) (Chen et al., 2020) (Nasir et al., 2020)
Cloud Computing	Low latency Reliability Seamless Connectivity	• 5G and beyond networks promote major enhancements on this technology. With the future networks, cloud computing has become faster, more reliable, and more efficient, in addition to better synchronized cloud services. • To manage the enormous traffic that arises from billions of nodes and to realize new processing-intensive 5G applications. Therefore, the existing network structure must be transformed as soon as possible, and the networks must provide higher speed, lower latency, and more capacity. Cloud technology accelerates the realization of this new network infrastructure and characteristics because it forms the basis of customer experiences, product services, and business efficiency.	(Asghar et al., 2022) (Nekovee, 2022) (Ahvar et al., 2021) (Barakabitze et al., 2020)
Distributed Mobile Edge Computing	Wide coverage Real-time access Energy Efficiency	• Distributed Mobile Edge Computing is useful for 6G and beyond networks to avoid centralized solutions.	(Asghar et al., 2022)
Multi-access Edge Computing	Ultra low latency Higher bandwidth Real-time access Energy efficiency	• 5G and beyond networks benefit from MEC abilities to access resources required to achieve optimum performance. • MEC utilizes the 5G and beyond networks opportunities such as network function virtualization, network slicing and software-defined networking.	(Asghar et al., 2022) (Ahvar et al., 2021) (Barakabitze et al., 2020)
Network Slicing	High capacity Highly secure Reliability	• Slicing is a critical feature of 5G networks. • It facilitates the implementation of virtual networks based on 5G. • 5G networks can be divided into subnets with different priorities, so isolation from other networks is possible.	(Nekovee, 2022) (Barakabitze et al., 2020)

Digital Technology or Approach	**Distinctive and key Features or Characteristics for Productivity**	**Impact of 5G Networks and Digital Technologies on each other: + How they increase their productivity?**	**References**
Software-defined Networks + Network Function Virtualization	High data transmission, Improved spectral efficiency, optimized resource allocation	• SDN, a programmable paradigm, enables the controlling of the data flow in 5G and beyond networks. It separates the control plane from the data plane. It makes the network more flexible, dynamic, manageable, and remotely controllable. • SDN and NFV are two of the key enabling technologies of 5G networks. • NFV allows network slicing and distributed cloud approaches. • Thanks to NFV, 5G network functions can be allocated dynamically and deployed easily. • NFV also decreases the capital expenditure (CAPEX) and operational expenditure (OPEX) for a network where users have increased demands by utilizing cost-efficient dynamic network infrastructure.	(Asghar et al., 2022) (Tayyaba et al., 2017) (Siriwardhana et al., 2021) (Syed-Yusof et al., 2020) (Asghar et al., 2022) (Barakabitze et al., 2020)
Tactile Internet (TI)	High availability Highly secure Ultra-low latency	• TI is high technology benefits from 5G and beyond networks to allow interactive communication between two tactile edges in real-time with haptic data.	(Dutta and Hammad, 2020) (Mourtzis et al., 2021) (Fanibhare et al., 2021)
Augmented Reality + Virtual Reality	High bandwidth Low latency Higher speed of data transmission High throughput	• AR and VR will be distinctive and main applications for 5G and beyond networks, • 5G enables realistic services for AR, • 5G provides users with a better experience for AR, • With 5G, users can utilize VR content whenever and wherever they need it.	(Chen et al., 2020) (Mihaljević et al., 2021)
Extended Reality	High bandwidth Low latency Higher speed of data transmission High throughput Seamless connectivity	• Extended Reality, including augmented reality, virtual reality, and mixed reality can fully be realized with the 5G beyond networks, especially 6G.	(Asghar et al., 2022) (Siriwardhana et al., 2021)
Blockchain	Low latency Higher bandwidth Real-time access Higher speed of data transmissions	• Blockchain is a candidate solution to make 5G and beyond networks, including billions of devices, more secure and decentralized. It makes the network and operations decentralized, transparent, immutable, non-repudiation, and resilient to cyber-attacks. • With the key features of 5G and beyond networks, Blockchain operations and applications become faster so that real-time transactions are reliably performed.	(Asghar et al., 2022) (Fanibhare et al., 2021)

Digital Technology or Approach	Distinctive and key Features or Characteristics for Productivity	Impact of 5G Networks and Digital Technologies on each other: + How they increase their productivity?	References
In addition to the above-enabling technologies and approaches, there are other technologies in which 5G provides opportunities with its key features such as low latency, higher bandwidth, higher data rate, security, and reliability: Digital Twin, Human Machine Interaction, Industrial Internet, Critical Communication and Infrastructure, 3D printing, Mobile Robots, Sensors, Customer Relationship Management (CRM).			(Nguyen et al., 2022) (Maroufkhani et al., 2022) (Carvalho et al., 2020)

Impact of 5G and beyond Technology on Different Digital Industries and Fields: Productivity

The 5G mobile communications drive network services in different industries, such as transport, retail, medicine, and security; therefore, it accelerates the digital transformation of vertical services. Table 3 presents the impact of 5G and beyond networks on different digital technologies by stressing their productivity gains. This section also explains the detailed analysis of each industry.

Table 3. Impact of 5G and beyond networks on Different Industries in terms of productivity

Digital Industry/ Field	Impact of 5G and beyond networks on Different Industries Productivity	References
Healthcare	• Efficient data processing, • Larger accessibility • Remote control • Mobile remote care • Easily applied telehealth, telesurgery, pharmacy, and telemedicine • Wearable technology	(Attaran, 2021) (Attaran M. & Attaran S., 2020) (Siriwardhana et al., 2021) (Maroufkhani et al., 2022)
Telemetry	• Real-time communication • Internet of anywhere • Higher spectrum availability	(Attaran M. & Attaran S., 2020) (Marin, 2020) (Sampson, 2019) (Giannopoulos et al., 2021)

Digital Industry/ Field	Impact of 5G and beyond networks on Different Industries Productivity	References
Remote Control	• Speed, safe, and efficient remote management • Transmission of huge data, • Greater number of remotely controllable devices • More accurate responses	(Attaran M. & Attaran S., 2020) (Groshev et al., 2021) (Rao and Prasad, 2018) (Mendoza et al., 2021)
Intelligent Transportation	• Safe, highly mobile, comfortable driving and traffic rules • Vehicular Communication: Vehicle-to-Everything • Automotive: Autonomous vehicles (From no automation to fully autonomation), Tele-operated Driving • Road Safety (Pedestrian, Intersection, Driver Safety) • Intelligent Navigation • Large filed and high definition (video, image, voice) media downloading • Smart Public Transport • Connected Vehicles: Interoperable connectivity • Quantum and Blockchain technologies-based transportation	(Alalewi et al., 2021) (Adhikari et al., 2021) (Attaran M. & Attaran S., 2020) (Monserrat et al., 2020) (Guevara and Auat, 2020) (Hamalainen, 2021) (Porambage et al., 2021) (Balkus et al., 2022) (Joshi H. & Joshi S., 2022)
Logistic	• Increasing the number of connected vehicles for land, sea, and air, • Enhancing logistic management • Reducing operational costs, • Green applications, • Complete delivery, • Increase in productivity	(Monserrat et al., 2020) (Maroufkhani et al., 2022)
Agriculture/Farming	• Real-time data and monitoring, • High-definition video streaming, • UAV/Drone and mobile robot-assisted smart farming, • Usage of digital assistive technologies such as Cloud Computing, Edge Computing, AR, and VR • Enhanced (IoT) connectivity: a massive number of sensors • Remote controlling and monitoring	(Tang et al., 2021) (Attaran M. & Attaran S., 2020)
Public-Safety	• Obtaining accurate and reliable data • Faster emergency response • Enhancing the quality of communications to make coordination for response teams. • Video Surveillance and analytics • Intersection and Pedestrian Safety • Traffic management	(Attaran M. & Attaran S., 2020) (Tealab et al., 2020) (Quinn, 2020) (Gomez-Barquero et al., 2020) (Joshi H. and Joshi S., 2022) (Maroufkhani et al., 2022)

Digital Industry/ Field	Impact of 5G and beyond networks on Different Industries Productivity	References
Education	• Digital Learning • Distance Learning • Increase availability of education • Equal opportunities for education • AR as a new educational model • Digitized and Digital Medical and employee education: Distance and Online Learning (AR/VR/3D Videos)	(Attaran M. & Attaran S., 2020) (Nakao, 2020) (Morimoto et al., 2022) (Xu et al., 2020) (Joshi H. and Joshi S., 2022) (Maroufkhani et al., 2022)
Smart Cities and Intelligent Buildings	• Smart air conditioning • Intelligent Elevators, • Smart Ventilation, heating • Intelligent Traffic Management: Intelligent Navigation and Routing • Smart Transportation, Healthcare, Education, Governance • Intelligent and digital urban planning: Efficient Energy Distribution • Green Infrastructure • Fully connected environment	(HPE, 2018) (Tealab et al., 2020) (Rusti et al., 2019) (Ahrend et al., 2019) (Joshi H. and Joshi S., 2022) (Gohar and Nencioni, 2021) (Turkalj, 2021)
Retailing	• Heavy-duty big data predictive analytics • Customization • Augmented store experiences using AR/VR/XR • Optimized Intelligent logistics and operations in the store	(Attaran M. & Attaran S., 2020) (Maroufkhani et al., 2022) (Hitachi solutions, 2022)
Manufacturing	• Enhanced Machine type communication, • Seamless and fully connectivity • Automation • Smart production, factory • Performing Internet of Things applications • Agile manufacturing • Improved Business Intelligence	(Attaran M. & Attaran S., 2020) (HPE, 2018) (Lundgren et al., 2022) (Nguyen et al., 2022) (Wang and Gao, 2020) (Kerroum et al., 2020)
Financial Sector	• Highly secure and reliable platforms • Cost-effective customer processes • Mobile and online applications for customer transactions • Personalized financial responses • Digital Banking • Automation • Robotizing • Digital investment recommendation applications	(Szasz and Varga, 2022) (Lee et al., 2021) (Garcia, 2021) (Agafonova et al., 2021) (Seow et al., 2021)

Digital Industry/ Field	Impact of 5G and beyond networks on Different Industries Productivity	References
Media and Entertainment • Evolutionary consumer and media interaction: Virtual Reality • Capability for Big Data processing and analytics • Dynamic and real-time responses to significantly increased demands • Enhanced quality of service • High-speed downloading and uploading • Highly interactive and embracing meetings: Game streaming • Evolved digital content offered by different platforms: 4K/8K displays, 3D/4D videos, high-speed voice • Seamless and Ubiquitous Connectivity • (Attaran M. & Attaran S., 2020) • (HPE, 2018) • (Guarda et al., 2021) • (Turkalj, 2021)		
Smart Grids	• Efficient edge computing solutions • 5G connectivity • 5G distributed network infrastructure • Less bandwidth requirement and minimum latency • Highly secure 5G-enabled smart grids • Efficient distributed smart grids	(Chen et al., 2021) (Borgaonkar et al., 2021) (Sun, 2021) (Han et al., 2022)
Utilities and Energy	• Less energy consumption • Backward compatibility • Processing Big Data • Remote monitoring and controlling • Efficient smart grid solutions • Edge Computing Ability	(Attaran M. & Attaran S., 2020) (Tealab et al., 2020) (Ahrend et al., 2019) (Dutta and Hammat, 2020) (Turkalj, 2021) (Shunxin et al., 2020) (Gustavsson et al., 2021)

Healthcare

The health sector highly affected by digital transformation is rapidly developing today. This process gains even more speed, especially with what 5G and beyond networks provide. Here we can list some of them as follows:

- It allows efficient, reliable, and effective collection, storage, and instant processing of patient data produced in huge sizes.
- With the rapid processing of critical medical data, information can be sent to end users, for example, to a mobile application. It can provide real-time action to take new action with suggestion systems.
- It makes the digital medical systems widely accessible.
- It facilitates the control of remote devices in various operations.

- It allows utilizing wearable technology to prevent and control diseases.
- By enabling the use of virtual and augmented reality technology and effective remote management, it also paves the way for distance education. It facilitates the reproducibility and accessibility of the training provided.
- Telehealth, telenursing, telesurgery, and pharmacy are important digital health services, and 5G plays a significant role in implementing them.

Telemetry

Telemetry is defined as an automated system consisting of a control unit, physical input, and a communication channel, which is a remote measurement process to make data transfer possible between receiving devices and remote locations (Marin, 2020). Since 5G and beyond networks tend to enable communication anywhere between anything, it facilitates the usage of telemetry as a remote automated system. In addition, real-time monitoring and communication are easily applicable because 5G and beyond networks enhance the spectrum and provide seamless and full connectivity (Sampson, 2019).

Remote Control

Technological enhancements and new paradigms such as 5G networks, the Internet of things, and Industry 4.0 all over the world increase the remote-control necessity. Recently, especially after the COVID-19 Pandemic, industries have begun to utilize remote control heavily. Digital transformation in the remote control is considered obviously because of increasing sector/industry/user demands and the number of automated machines. Since 5G and beyond networks provide higher bandwidth and lower latency with more reliability and safety, the intensive data and a massive number of machines, industries/sectors /users can perform remote control very fast and efficiently.

Intelligent Transportation

With a fully digital connected world paradigm which 6G networks suggest, some technological innovations such as automotive, Vehicle-to-Everything (V2X), highly available Smart Public Transportation, which have optimized routes and fleets, and Connected Vehicles are key applications of the digital transformation in the transportation sector. Each of the features of 5G and beyond networks will contribute to the digital transformation of applications in transportation. At this point, it is possible to classify these contributions in three parts:

- Improvements in the connectivity of vehicles with each other and other objects that already exist will go much further,
- Increases in the ubiquity of interconnected vehicles and devices,
- Enhanced data availability to manage and operate the transportation issues.

In addition, 5G, 6G, and beyond network-based applications and improvements are critical for transportation systems such as Artificial Intelligent, High Mobility, Interoperable Connectivity, Quantum Computing and Communication, Blockchain-based information management and sharing.

Logistic

Logistics is another sector that is as important as the transportation sector. In this sector, 5G and beyond networks offer new solutions that can be classified into three categories

to produce efficient solutions. To make the autonomous vehicle paradigm widespread for sea and air as well as on land, to increase the number of connected vehicles by reducing the cost by making communication between vehicles effective and efficient, to reduce costs and environmental pollution by reducing energy consumption. These approaches aim to facilitate logistics management and product tracking, monitor the infrastructure, and ultimately increase overall productivity.

Agriculture/Farming

Smart agriculture can be defined as the ability to obtain more and better-quality products in a short time and at the most affordable cost by using digital technologies. In smart agriculture, with 5G's features such as device density, ultra-low latency, ultra-reliability, and security, with the ability to instantly process real-time data from thousands of IoT devices, as well as with video streams transferred from unmanned aerial vehicles or mobile robots, effective data analytics can be done (Tang et al., 2021).

Public-Safety

5G and beyond networks can widely provide many smart city applications for public safety, such as video surveillance, pedestrian and intersection safety, and traffic management based on some key technologies including artificial intelligence, big data, and the Internet of Things to make accurate and fast monitoring, biometrics for access control, broadband communications, and mobile applications. 5G and beyond networks enhance the response times for emergencies such as disasters, so a real-time reaction and monitoring system can be used.

Education

With 5G and beyond networks, Digital Learning and Distance Learning opportunities have become increasingly widespread. Any education opportunities can now be easily accessible by every student or everyone. These developments provide an applicable education with equal opportunity. In addition, augmented reality as a new educational model can be easily used in courses and training.

Smart Cities and Intelligent Buildings

A smart city is a digital urban area consisting of information and communication technologies such as sensors, intelligent devices, and real-time data collected using digital and electronic methods. Different algorithms process the collected data by using edge and cloud technologies. This information is utilized to manage smart city applications such as smart transportation, traffic management, navigation, smart air-conditioning, and smart education. Smart city applications consider energy efficiency, so any action may consume less energy. Thanks to the infrastructure suggested by 5G and beyond networks, a fully connected world is possible in a smart city where people and everything are connected. One of the most critical objectives of digital transformation for any smart city is to make the life quality of the tenants' and residents' life better so that the productivity of their life increases.

Retailing

Digital transformation of the retail sector can be divided into four parts such as customer participation, worker empowerment, optimized operations, and designing a brand-new

customer product. Since 5G and beyond networks provide high-speed data, predictive analytics is performed using Artificial Intelligence and Machine Learning techniques. Retail digital transformation powered by big data analytics aims for customer satisfaction, creating new products based on customer demands collected via following the customer behaviors and shopping patterns. With AR/VR/XR applications that are much more efficient with 5G and beyond networks, store experiences such as analyzing different scenarios responses, worker empowerment, and monitoring store operations can be improved.

Manufacturing

With the 5G-based digital transformation applications, the factories and workplaces can optimize the production and sale costs and manage the production process that is always desired to be agile. In an intelligent factory with 5G and beyond infrastructure, the production process and the operations can be monitored and controlled in real-time by gathering and processing all connected IoT devices and their communications.

Financial Sector

5G and beyond networks increase the data transmission efficiency, enable connection for many devices by providing high bandwidth and low latency, and allow real-time communication. With these characteristics offered by 5G and beyond networks, the digital economy and digital finance sector have become safer and more efficient. Especially the concept of digital banks and digital transformation in finance have made and will make severe progress with the automation of transactions and their independence from human errors. It has also increased the reliability of digital applications by managing transactions in real-time, very quickly and reliably. The understanding of banking and investment has changed with this transformation. With the rapid performance of big data analytics offered by 5G and beyond networks that facilitate this transformation in addition to cloud computation, investment recommendations can now be made with intelligent applications.

Media and Entertainment

5G and beyond networks make an evolutionary media and entertainment experience possible with high-speed data transmission and lower latency, 3D/4D videos, 4K/8K displays, and high-speed voice. With the opportunity of 5G and beyond network connectivity, users can access their desired content anywhere and whenever they need it. Since Big data belonging to millions of users can be analyzed, platforms can recommend content based on users' profiles. Because of the high-speed streaming capability of 5G and beyond networks, higher interactive meetings are possible.

Smart Grids

Smart Grid can be defined as a digital technology that is an electricity network allowing for two-way communication. Along the transmission lines, sensing capability makes the grid technology smart. Recently, this technology has suffered from coverage problems because of scattered distribution and a massive number of nodes. This problem sometimes results in a barrier problem for grid operations. 5G and beyond networks can overcome this challenge by enabling the deployment of edge nodes that are served by terminal access networks. With the network slicing ability of 5G, smart grids can be

logically divided into isolated networks so that different parts can serve with better coverage. With the implementation of edge computing, 5G makes the gateway deployment distributed so that local traffic can be processed by reducing the bandwidth requirement and latency. With 5G security solutions, the smart grid provides a more secure service.

Utilities and Energy

With the rapid technological improvements, user and city demands are significantly increasing. Researchers focus on using 5G and beyond network capabilities to develop energy-efficient solutions, lessen energy consumption, and diminish carbon emissions. The most recent technologies can be integrated with the existing infrastructures when the digital transformation is performed. 5G applications such as network slicing and edge computing can lessen energy consumption. Since 5G has high-speed data transmission and low latency, large volumes of data can be processed concisely to reduce energy consumption.

How does 5G-enabled Digital Transformation Affect Business Productivity?

Digital transformation has paved the way for new approaches and unconventional solutions to emerge or become more widespread in business and industry, especially with the effect of the COVID-19 pandemic. For example, the digital transformation of workplaces has brought evident innovation and change. The way of remote working is at the forefront of this change. To increase the productivity of their employees, employers can now take steps such as increasing the employee's commitment to the workplace and his/her job, ensuring the fastest access to the data he/she needs, sharing the results obtained in the fastest way, with the conveniences brought by the new generation networks, regardless of location, freely chosen. They try to earn their employees with platforms. At this point, there is a need for mobile-oriented, real-time, collaborative solutions to increase employees' productivity. 5G and beyond networks provide the necessary communication technologies infrastructure at this point. With the technological developments in recent years, workplace change has evolved from analog solutions to digital solutions. In addition, the pandemic also affected this change with positive momentum. In this way, workplaces had to keep up with this trend to meet market demands, increase work and worker productivity, and maintain a strong presence in the market. Employees can now use more mobile applications, especially with the benefits of 5th generation networks, and they can monitor their work and performance thanks to these mobile applications. In addition, to provide real-time solutions, the video conferencing method, for example, has been widely used as a suitable solution to ensure communication between employees and business continuity. The ability to access fast data anytime and the working principle anywhere will become even stronger with the spread of 5G. Let us look at a few situations where 5G and beyond communication networks will provide us and affect productivity in the business world as presented in Table 4:

Table 4. 5G and Beyond Networks-Enabled Business Management and Productivity

Most Prominent Enabler - 5G and beyond Characteristics	Enabler – Digital Technology or Approach	How affects Productivity
Low latency High speed date rate Reliability	• Augmented Reality • Virtual Reality • Distance management • High quality Video Streaming	5G and beyond networks provide more bandwidth and low latency so that users can access and send the data faster. Video conference systems and augmented reality, the next-generation networks' features, provide an essential concept for anyone to consider anywhere as their office via these opportunities. Information management becomes more and more easily thanks to these possibilities.
High bandwidth High connection density High throughput	• Business Intelligence • Automation • Smart Interactions	5G and beyond networks facilitate new solutions, including intelligent conference systems, artificial intelligence approaches, and office and workplace automation so that maximum productivity of a workplace can be achievable.
Ubiquitous connectivity Increased network energy efficiency High connection density High throughput	• Virtual reality, augmented reality, extended reality • Cloud technology and edge computing	In a digital workplace supported by 5G and beyond, it is inevitable that the work plan of employees should be made according to remote working and flexible working models, collaborative communication and workplace opportunities, and connection with any person or object anywhere, anytime. While 5G and beyond will do this, they will do so by enabling almost real-time and ubiquitous connectivity with possibilities such as virtual reality, augmented reality, extended reality. It also makes distributed workforce possible with new technologies such as cloud and edge computing. Combining all these possibilities means it will have severe productivity-enhancing effects in the business world.
Decreased latency Improved spectral efficiency	• Shared resources • Synchronization • Remote access • Real-time video interaction	Thanks to the 5G and beyond communication networks, it is possible to provide access by sharing enormous processing power using Cloud technology and with the real-time synchronization approach. By providing real-time video interaction, 5G enables remote problem solving, business meetings, and conferences and enables businesses to reduce operational costs with these facilities.
Fully connectivity Increased network energy efficiency High throughput	• Fully autonomous • Smart Systems • Energy Efficiency • Public Safety	The concept of the Internet of Things, which was started to be implemented with 4G, and the adoption of a fully connected and digital world approach with 5G and beyond, helps smart technologies such as smart buildings, smart transportation, smart agriculture, and many more. There is an expectation to support fully autonomous approaches in similar areas, which will bring many benefits. For example, 5G and beyond networks, one of the crucial pillars in the implementation of autonomous and connected vehicle technology, will contribute to reducing traffic accidents, reducing fuel consumption, and allowing drivers to spare more time for themselves to increase efficiency.
Higher speed and bandwidth	• Interactive Communications	Thanks to 5G and beyond networks, employees' communication with each other and customers in smart buildings and workplaces have become highly interactive.

Now let us examine the productivity gains of 5G and beyond networks in another area, namely the industry. Digital transformation in the industry is an inevitable reality behind it; many reasons are similar and different to the business world. Among these, there are factors such as increasing income by providing better service to the sector, increasing

efficiency and effectiveness by reducing production, sales, and marketing costs, on the other hand, trying to survive in the competitive environment to stay in the market and even being a pioneer, while preventing risks by increasing security.

Conclusion

The rapid advancement of technology and the ever-increasing growth of the needs of users who use many state-of-the-art products have rendered the existing communication and network technologies inadequate. Not only mobile users but also the business world, health sector, automotive, intelligent transportation, logistics, education, smart urbanization, retailing, production and manufacturing sector, finance sector, media and advertising, intelligent networks, and digital learning have significantly increased demands. In the face of emerging these needs and increasing demands, 5G and beyond networks have been developed to create not only technological innovation but also a paradigm shift, and especially 5G networks have started to be used as of 2020. This chapter explains how 5G affects productivity in the sectors mentioned above and areas. In addition, digital and disruptive technologies and approaches are known as enabling technologies in the digital age, such as artificial intelligence, deep learning, machine learning, big data, distributed mobile edge computing, multi-access edge computing, network slicing, virtualization of network functions, haptic internet, augmented and virtual reality. , advanced reality, blockchain, digital twin, and many other technologies were examined in a way that considers the aspects that increase the efficiency of the relationship between 5G. Finally, the efficiency of 5G in the business world, which is the most effective and can be changed by the next-generation networks, is discussed. In particular, the characteristics of 5G networks such as low latency, high bandwidth, high spectral efficiency, fast data transmission, high reliability, and security are considered accelerator and problem-solving paradigms for the above-mentioned digital approaches and technologies. While 5G networks have started to be deployed worldwide and various standards are being established, the implementation of 6G networks will coincide with the year 2030. With 5G, the concept of the Internet of Things will be implemented much more efficiently, and a fully connected digital world will be created with 6G networks. 5G and beyond networks are of vital importance in terms of increasing efficiency in many areas. At this point, it is essential for the states to expand these networks within themselves and with each other, to take the steps that local governments and citizens should take, and to ensure the transition of existing technology by making cost and time comparisons.

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