Overview of 5G+ Industrial Internet

Rucheng Fan(✉)

Nanjing University Jingling College, Nanjing, China
2019020800047@jlxy.nju.edu.cn

Abstract. 5G is one of the indispensable technologies in the new era of informatization and even industry 4.0, and it is the focus of competition among countries. The industrial Internet, or the industrial Internet of things, was proposed as early as 2012. It was originally used for predictive maintenance of aeroengines. Due to the promotion of the United States, it has been used in medical, biopharmaceutical, chip production and other industries. At present, 5G + industrial Internet is the top priority for the development of various industries in various countries. This paper first expounds the concept, application scenarios, key technologies of 5G and the concept of industrial Internet, then it puts forward the concept of 5G + industrial Internet by combining the two and explains the integration mechanism, and puts forward the application scenarios of 5G + industrial Internet. The last part is to put forward the problems in this field and the solutions. In general, this paper expounds the division of 5G + industrial Internet into 5G and industrial Internet, explains the advantages and disadvantages of 5G + industrial Internet, and finally puts forward suggestions to solve the existing problems.

Keywords: Industrial Internet · 5G · Time Delay · Bandwidth · Intelligence

1 Introduction

5G is the fifth generation of new broadband mobile communication technology after 4G. Compared with 4G, it has been expanded in almost every aspect. For example, in terms of download rate, 5G is at least 100Mbps, while 4G is only 10Mbps. And it has made great progress in capacity, bandwidth, delay and so on. Industrial manufacturing is composed of closed islands with distinct levels. In the process of industrial production, the type and amount of data are very large, so the requirements for data transmission and storage are naturally high. It is the powerful features that make 5G play an irreplaceable role in the current industrial development. This paper will explore the characteristics and reasons for the combination of the two, explain the inevitability of 5G + industrial Internet, and finally put forward the remaining problems and gives solutions.

2 Introduction of 5G

The 5th generation mobile communication technology, referred to as 5G for short, is a new generation of broadband mobile communication technology with the characteristics of high speed, low delay, and large connection. 5G communication facilities are

G. Ali et al. (Eds.): ISEMSS 2022, ASSEHR 687, pp. 1031–1039, 2022.
https://doi.org/10.2991/978-2-494069-31-2_120

the network infrastructure to realize man-machine and object interconnection.5G has the characteristics of high speed, low delay, and low power consumption, and makes it possible to interconnect everything [1]. Of course, the requirement to reach 5G is also very strict. It can be called 5G only if the following conditions are met: the peak rate needs to reach 10-20Gbit/s to meet the transmission of high-definition video, virtual reality and other large amounts of data; the air interface delay is as low as 1ms, meeting the real-time applications such as autopilot and telemedicine; it has the equipment connection capacity of millions of connections / square kilometers to meet the Internet of things communication; the spectral efficiency is more than 3 times higher than LTE. With continuous wide area coverage and high mobility, the user experience rate reaches 100Mbit/s; In terms of mobility, it supports high-speed mobility of 500km/h [2].

3 Three Application Scenarios of 5G

3.1 eMBB

Enhanced mobile broadband (eMBB) is a people-centered application scenario [3], which is concentrated on ultra-high data transmission rates, mobility guarantee under wide coverage, etc. At present, eMBB mainly focuses on the following five aspects: (1) 8K cloud VR live, 5G can provide uplink live image transmission rates of more than 100Mbps. (2) VR cloud games.[4] VR games, real-time media processing on edge computing units, GPU image rendering, etc. by setting up the cloud and putting commands on the cloud for processing, users do not need to configure VR game consoles, but only need VR display units. (3) Smart Tourism: there is a face recognition camera in the scenic spot, and the face recognition information is returned through 5G for authentication and track tracking. (4) AR remote collaboration: through front-end and back-end cameras, the headset AR device realizes high-definition video two-way communication with the help of 5G to achieve real-time collaboration assistance [5]. (5) HD remote teaching: it also realizes remote synchronous education, remote letters and visits and other specific services with the help of 5G. In this COVID-19 era, this function is particularly reliable. In general, eMBB is mainly responsible for the propagation rate and coverage, and its peak value can reach 10Gbps.

3.2 mMTC

Mass machine communication (mMTC) has millions of connections per square kilometer.5G's strong connectivity can quickly promote the deep integration of various vertical industries (smart city, smart home, etc.). People's lifestyles will also undergo disruptive changes with the interconnection of all things. In this scenario, the data rate is low, the delay is insensitive, the connection covers all aspects of life, the terminal cost is lower, the battery life is longer, and the reliability is higher [6]. Typical application scenarios also include wearable devices, traffic control, the smart grid, intelligent monitoring, etc.

3.3 uRLLC

The Ultra-high-reliability and low-delay communication (uRLLC) has high reliability and low delay.[7] In this scenario, the connection delay should reach the level of 1ms, and support the reliable (99.999%) connection in the case of high-speed mobile (500km/h). This scenario is more oriented to special applications such as the Internet of vehicles, industrial control and telemedicine. Such applications have high potential value in the future. In the future, society will move towards intelligence, so we must rely on the network in this scenario. In terms of intelligent transportation, it can remind the vehicles with faults, and remind the approaching vehicles when overtaking. In the medical industry, it can collect data from wearable medical devices for real-time transmission, surgical picture broadcasting, telemedicine, etc.

5G accelerates the arrival of Industry 4.0 and plays an important role in industrial automation, data aggregation, production process visualization, quality management, predictive maintenance, equipment testing, etc.

4 5G Key Technologies

4.1 High Band Transmission

Millimeter wave [8] technology is one of the main 5G technologies. Sufficient available bandwidth, miniaturized antennas and equipment, and high antenna gain are the main advantages of millimeter wave mobile communication, but they also have some disadvantages, such as short transmission distance, poor penetration and diffraction ability, and easy to be affected by climate environment. It needs to solve the problems of RF devices, system design, and so on. The higher the frequency, the more the electromagnetic wave tends to propagate in a straight line, so the diffraction ability is poor, and the greater the attenuation in the propagation process. Due to its high frequency, the millimeter wave has the following characteristics: wide spectrum, combined with the use of various multiple access multiplexing technologies, it can greatly improve the channel capacity. It is suitable for high-speed multimedia transmission services, with high reliability. The higher the frequency, it is less disturbed, and can better resist the impact of rain weather, It provides a stable transmission channel with good directivity. The millimeter wave is greatly absorbed by various suspended particles in the air, which makes the transmission beam narrow and increases the difficulty of eavesdropping. It is appropriate for point-to-point, short-range communication. It is simple to incorporate a large-scale antenna array in a compact space due to the extremely short wavelength and the small size of the needed antenna.

4.2 New Multi Antenna Transmission Technology Massive MIMO(Multiple-In Multipleout) Technology

Using higher frequency signals in 5g, the higher the frequency, the shorter the wavelength, which means that the received power will be much lower than the current communication system. Antenna length = wavelength /10 to wavelength /4. Through space division multiplexing, many antennas are plugged to realize large-scale MIMO technology. Massive MIMO can increase the energy by more than 10 times and radiant energy efficiency by about 100 times.

4.3 Simultaneous Same Frequency Flexible Full Duplex Technology

Compared with Time Division Duplex(TDD) and Frequency Division Duplex(FDD) in traditional duplex mode, the spectrum efficiency of air interface can be doubled theoretically.[9] The traditional duplex mode can effectively avoid the interference of the transmitter signal to the receiver signal in the frequency domain or time domain, but it wastes the frequency band resources. The emerging simultaneous same frequency full duplex technology can save the frequency or time slot resources and improve the spectral efficiency by adopting the methods of self interference and mutual interference elimination.

4.4 D2D Technology

D2D(Device to Device) refers to a technology that allows one mobile terminal device to communicate directly with another mobile terminal device without data transmission through the base station. When the base station fails or is in an area that cannot be covered by the poor signal quality of the wireless network, the device can still communicate through the terminal direct communication technology, which expands the coverage of the cell and improves the communication quality of the wireless network. A new technology that allows terminals to communicate directly through multiplexed cell resources is under the control of the system.. It can increase the spectral efficiency of cellular communication systems, reduce the terminal transmission power, and solve the problem of a lack of spectral resources in wireless communication systems to a certain extent [10].

4.5 Heterogeneous Ultra Dense Networking Technology

Ultra dense networks can improve network coverage, greatly increase system capacity, and divert services. It has more flexible network deployment and more efficient frequency reuse. In the future, it will adopt a more dense network scheme for the high-frequency band and large bandwidth. Increase the density of small base stations in a unit area and realize hotspot enhancement, eliminate blind spots, improve network coverage and improve system capacity by introducing super large-scale low-power nodes into heterogeneous networks.

4.6 New Network Architecture

5G adopts C-RAN access network architecture. The fundamental concept of C-RAN is to directly transmit wireless signals between distant antennas and centralized central nodes by fully utilizing a low-cost high-speed optical transmission network, in order to construct a wireless access system covering hundreds of base station service areas, even hundreds of square kilometers. It uses end-to-end network slicing technology to divide the network into multiple logically independent slices to achieve the best experience in each specific business or scenario. Network slicing technology can realize resource sharing between different services and networks, so as to improve efficiency. The new network architecture is based on technologies such as software defined networks, network function virtualization, mobile edge computing and fog computing.

5 Industrial Internet

5.1 Concept of Industrial Internet

The industrial Internet refers to a technology that closely connects equipment, production lines, employees, factories, warehouses, suppliers, products and customers through an open and global communication network platform, shares various element resources of industrial production processes, and makes them digital, networked, automated and intelligent, so as to improve efficiency and reduce costs. It has six typical application modes: platform design, intelligent manufacturing, networked collaboration, personalized customization, service extension and digital management. Through these six typical application modes, industrial Internet has promoted enterprise development and technological innovation and laid the foundation for Industry 4.0 [10].

5.2 Development Trend of Industrial Internet

Since the birth and development of PLC in the 1960s, it has achieved global 5G business in 2020. In 2022, the industrial Internet has formed multiple systems such as industrial network security, industrial software and cloud computing, and the prototype of the industrial Internet has been formed. The United States, Europe and the Asia Pacific region are the key areas of the industrial Internet. Among them, the United States Group has significant advantages, Microsoft, Amazon and other giants are actively deployed, and various start-ups are focusing on cutting-edge innovation, which is expected to help the United States maintain its leading position in the industry. Due to the impact of the epidemic in 2020, the growth rate of the global industrial Internet scale slowed down, but the overall growth trend showed an upward trend. The integrated development of information technology and all facets of life has great prospects and limitless potential in the latest wave of the world's industrial transformation and scientific and technological revolution. The industrial Internet has become an irresistible trend, among which the industrial PON technology based on all-optical connection is the most promising.

6 5G+ Industrial Internet

6.1 The Inevitability of 5G Application in Industrial Internet

5G has the characteristics of high speed, low delay and large connection, which will greatly increase the scale of the industrial Internet, comprehensively improve industrial production efficiency, help form a production system with more complete and intelligent manufacturing lines, and achieve efficient decision-making and flexible production. The industrial Internet is the product and carrier of the deep integration of the new generation of information and communication technology and the real economy. It is one of the best application scenarios for 5G advanced achievements. The integrated development of 5G and the industrial Internet will accelerate the building of an efficient and intelligent new generation information network, improve the intelligence level of traditional infrastructure, and support the high-quality development of the real economy.

6.2 Integration Mechanism of 5G + Industrial Internet

As mentioned above, digitalization, networking and intelligence are the development trends of the industrial Internet, and also the three paradigms of intelligent manufacturing. Digitalization is the basic work for the development of the industrial Internet. Digitalization can realize the integration of online and offline, and promote the cooperation and coordination of production units. The plug-and-play intelligent industrial module of the 5G chip module realizes direct and efficient communication between devices with the help of D2D technology, which is convenient to reduce costs. At the same time, the 5gmmtc feature can meet the communication requirements of massive IoT; Networking refers to the interconnection and collection of human, machine, material and other element data with the industrial Internet platform, and the use of effective mechanisms for sharing, so as to reconstruct the entire production mode and management system. Advanced network support is a necessary condition for the interconnection of all things. 5G's urllc feature will provide perfect support in scenarios such as human-computer interaction and industrial control. In addition, 5G + mec is an important element of 5G Internet of things, which will significantly increase computing-related applications requiring large-scale processing, such as VR or AR; Intellectualization is based on big data and centered on model and algorithm innovation to provide all aspects of intelligent application services for various production and operation. While 5g technology can provide factories with a large number of industrial data collection and uploading, and realize independent learning, intelligent judgment and conscious implementation through the ability of cloud computing, so as to improve the efficiency of key industrial fields [11].

6.3 Typical Application Scenarios of 5G + Industrial Internet

6.3.1 Smart Home

There are five smart home connection modes: WiFi, Bluetooth, Bluetooth Mesh, ZigBee, and traditional infrared. For convenience, most homes will use Bluetooth to open an app to find the corresponding furniture. After setting, the password of the router will be given to him to connect to WiFi. Even if he is not at home, he can control the operation. Although WiFi is fast, it consumes power, so it is generally used in power-consuming products. Bluetooth Mesh is used in more intelligent furniture. Compared with traditional Bluetooth single point connection, Bluetooth Mesh can achieve multi-point connection and give instructions one to many; ZigBee is usually used on the switch. It can still operate even if the network is disconnected. The connection is to transmit the WiFi secret key to the wireless gateway through the app so that the gateway can identify all smart products, so that all appliances can be connected to the network through the gateway, so that they can be operated and controlled through the mobile phone [12].

6.3.2 Driverless Cars(5G Drive)

Compared with 4G, the 5G channel is wider and supports massive mechanical communication connections, providing a guarantee for the interconnection between cars and

everything. To realize automatic driving and other functions, one is the perception function, by installing high-definition cameras, millimeter wave radar, laser radar, etc. on the car; the other is decision-making. The data transmitted by the perceptual radar will be identified by AI, and the decision will be made by the intelligent chip through the algorithm to help the driver control the vehicle. However, it is impossible to effectively respond to emergencies only based on one vehicle [13] Therefore, it is necessary to realize mutual detection between vehicles within 100 m and generate correct response methods through 5G ultra-low delay, so as to truly realize automatic driving through the networking of people, vehicles and traffic conditions. There are many ways to connect vehicles to the Internet of vehicles. Among them, C-V2X is divided intoLTE-V2X andNR-V2X based on 4G or 5G. The difference between the two is firstly the ability to support vehicle speed, which is 350km/h and 500km/h respectively. Secondly, it is the communication delay, which is less than 50ms and 3ms respectively. This shows the importance of 5G for 5G + vehicles.

6.4 Problems and Challenges Faced by 5G + Industrial Internet Development

6.4.1 5G Deployment and Application Costs Are High

Compared with the 4G network, the 5G network works in a higher frequency band, and the signal attenuation is faster. In order to achieve the same coverage, more indoor and outdoor base stations need to be deployed, which greatly increases the cost of 5G network construction and operation. Most of the wireless devices of 5G base stations use large-scale active antennas, which not only have a high equipment cost, but also have high power consumption. According to the data of relevant manufacturers, the power consumption of 5Gbase stations is about twice that of 4G. Therefore, before the new applications based on 5G are fully launched, operators are faced with huge construction cost and operation cost pressure in the process of promoting 5G commercial use.

6.4.2 Industrial Network Cannot Meet the Requirements of Intelligent Development

In the traditional factory network, wired network access is the main access method. In the existing industrial network composition, more than 50% is based on Industrial Ethernet, and nearly 40% is based on industrial buses. Only a small amount of wireless technology is used for instrument data collection. There are many technical standards involved, which are poorly interconnected and compatible with each other, limiting large-scale network interconnection, and it is difficult to meet the high real-time and highly reliable direct collection of field level data.

6.4.3 The Business Model Is Not Mature Yet

At present, the model of the 5G+ industrial Internet is not clear. Firstly, the market demand is not clear, and the products cannot be reproduced and produced on a large scale. Therefore, the profit model is not clear, the network investment and construction model needs to be developed, and the ecological industry needs to be further improved.

6.4.4 Immature Technology

Although the 5G transmission rate is fast, the propagation loss is too large; The signal distance becomes shorter, but the number of 5G base stations laid in the same area is several times that of 4G base stations, and the laying progress will take longer. In terms of security, the network architecture of 5G networks and industrial Internet is relatively open, with a large amount of data transmission and wide coverage. It is inevitable to encounter security problems such as information leakage.

6.5 Solutions

6.5.1 Strengthening Technology Research and Development

The development and application of 5G + industrial Internet are inevitable. We should work together with leading-edge enterprises and scientific research teams to promote 5G + industrial Internet, work hard on the current main problems, solve the problems of high cost and insufficient intelligent cost, and then gradually promote further development.

6.5.2 Improving Industrial Structure and Business Model

Promote the improvement of cooperation mode among enterprises, combine different industries such as factories and shopping malls, jointly promote the mass production of 5G products, and form a new industrial ecology of 5G + industrial Internet and Applications.

7 Conclusion

The development of the 5G + industrial Internet has formed an irresistible trend, which will become the core of competition among countries and an indispensable part of people's lives. At present, the development of the 5G + industrial Internet has taken shape, but there are still many problems to be solved. This paper analyzes the relevant technical knowledge of 5G and the current situation of the industrial Internet, summarizes the prospects and existing problems of 5G + industrial Internet, and puts forward some opinions on the solutions to the problems. However, 5G + industrial Internet is a very complex thing. This paper only analyzes the basic knowledge of 5G, industrial Internet and the products of the combination of the two, and does not analyze the deep-seated knowledge too much; 5G + industrial Internet is still an immature technology and has not been widely used. Therefore, the problems raised in this article are only limited to the current bottleneck of this technology. It is hoped that this technology can make great progress in the future and benefit human society.

References

1. Gundall M, Strufe M, Schotten H D, et al. Introduction of a 5G-enabled architecture for the realization of industry 4.0 use cases. IEEE access, vol. 9, 2021, pp. 25508–25521.
2. Hui H, Ding Y, Shi Q, et al. 5G network-based Internet of Things for demand response in smart grid: A survey on application potential. Applied Energy, vol. 257, 2020, p. 113972.

3. Popovski P, Trillingsgaard K F, Simeone O, et al. 5G wireless network slicing for eMBB, URLLC, and mMTC: A communication-theoretic view. Ieee Access, vol. 6, 2018, pp. 55765-55779.
4. Alshahrani A, Elgendy I A, Muthanna A, et al. Efficient multi-player computation offloading for VR edge-cloud computing systems. Applied Sciences, vol. 10(16), 2020, p. 5515.
5. Elvezio C, Sukan M, Oda O, et al. Remote collaboration in AR and VR using virtual replicas//ACM SIGGRAPH 2017 VR Village. 2017, pp. 1-2.
6. Bockelmann C, Pratas N K, Wunder G, et al. Towards massive connectivity support for scalable mMTC communications in 5G networks. IEEE access, vol. 6, 2018, pp. 28969-28992.
7. Park J, Samarakoon S, Shiri H, et al. Extreme URLLC: Vision, challenges, and key enablers. arXiv preprint arXiv:2001.09683, 2020.
8. Odell, Laura A. 5G and Next-Generation Mobile Communications. Institute for Defense Analyses, 2019. JSTOR, Retrieved from: http://www.jstor.org/stable/resrep22688. Accessed 12 Jun. 2022.
9. Sharma S K, Bogale T E, Le L B, et al. Dynamic spectrum sharing in 5G wireless networks with full-duplex technology: Recent advances and research challenges. IEEE Communications Surveys & Tutorials, vol. 20(1), 2017, pp. 674-707
10. Boyes H, Hallaq B, Cunningham J, et al. The industrial Internet of things (IIoT): An analysis framework. Computers in industry, vol. 101, 2018, pp. 1-12
11. Li J Q, Yu F R, Deng G, et al. Industrial internet: A survey on the enabling technologies, applications, and challenges. IEEE Communications Surveys & Tutorials, vol. 19(3), 2017, pp. 1504-1526.
12. Akpakwu G A, Silva B J, Hancke G P, et al. A survey on 5G networks for the Internet of Things: Communication technologies and challenges. IEEE access, vol. 6, 2017, pp. 3619-3647
13. Kutila M, Kauvo K, Aalto P, et al. 5G Network Performance Experiments for Automated Car Functions//2020 IEEE 3rd 5G World Forum (5GWF). IEEE, 2020, pp. 366–371.