5G NETWORK IN SUPPLY CHAIN

Matthew N. O. Sadiku[1], Samuel A. Ajayi[2], & Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering

Prairie View A&M University, Prairie View, TX 77446

[2]Texas Southern University, Houston, TX 77004

[3]Juliana King University, Houston , TX

USA

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ABSTRACT

The fifth generation of wireless technology, or 5G, is the latest and most advanced wireless communication technology that offers faster Internet speeds, lower latency, and higher capacity than its predecessors. 5G is the 5th generation mobile network. 5G technology opens up many opportunities for mobile communication. 5G uses higher frequencies and a much broader portion of the radio spectrum than previous generations, which allows it to send more data more quickly and to more devices. With the promise of faster and more reliable connectivity, 5G is poised to transform the way we communicate, work, and live. 5G technology offers a solution to problems that plague warehousing logistics and supply chains around the globe. This paper explores the potential impact 5G on supply chains.

Key Words: 5G network, 6G, 7G, Supply chain, Supply chain management, SCM.

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1. INTRODUCTION

We are living in a world that is changing rapidly. Human society is moving towards digital technology from age-of-information technology. In light of this, digital leadership is a fundamental component to revolutionize the technology along with its capacity. Supply chains have become digital, keeping sync with consumer demands and preferences. It has been governed by technology in the past few years.

The advent of the fifth generation of wireless technology, commonly referred to as 5G, heralds a transformative era in communication and technology interaction. 5G is a new technology that has immense potential to revolutionize industries. It is among the new revolutions in the supply chain. 5G is spreading its roots and linking a pool of devices and systems across the supply chain to offer seamless connectivity, advanced speed and low latency. The deployment of 5G began in 2019 and is advancing speedily to cover the globe. 5G is born to give rise to robust connectivity, enhanced speed, broader coverage, and superior reliability [1,2]. Figure 1 shows the symbol of 5G [3].

5G is being hailed as a 5th generation technology in telecommunications as a successor of 4G technology. Every new generation of wireless networks is significantly faster and more capable than the previous ones. 5G is the fifth generation of wireless network technology that is expected to replace the 4G LTE connection. For example, current 4G technology allows over 10,000 devices per square mile. This is why dense population centers compete and struggle for bandwidth. With 5G, over one million devices can operate within the same area, implying a 250-times growth in capacity. Given these ground-breaking features, 5G is a critical enterprise tool to accelerate digital transformation across industries, particularly in their supply chain management initiatives. Figure 2 represents global supply chain [2].

2. OVERVIEW OF 5G NETWORK

5G is the fifth-generation wireless cellular technology that will provide faster and more reliable communication with low latency. Compared to its predecessor, it is estimated that the 5G mobile network allows 1,000 times more data transmission compared to 4G.

Like its predecessors—3G, 4G, and 4G —5G utilizes radio waves to transmit data.
Evolution from 1G to 5G is depicted in Figure 3 [4], while the relationship between 3G, 4G, and 5G is portrayed in Figure 4 [5]. Like any other cellular network, 5G
networks send data through radio waves and operate on a cellular infrastructure, where geographic regions are partitioned into cells, each supported by an antenna and a base station. Each cell is connected to a network backbone through a wired or wireless connection. 5G may transmit data over the unlicensed frequencies currently used for Wi-Fi. It promises a smarter, faster, and more efficient network. The goal of 5G is to have far higher speeds available, at higher capacity per sector, and at far lower latency than 4G. To increase network efficiency, the cell is subdivided into micro and pico cells [6]. 5G will be a new mobile revolution as it is expected to provide gigabit-per-second data rates anytime, anywhere. 5G uses towers, as typically shown in Figure 5 [7]. 5G towers are telecommunications sites capable of transmitting 5G signals for wide-area coverage. 5G cell towers use a combination of low, mid, and high-frequency bands for various connectivity use cases. Towers themselves are not 5G; it is the equipment on the tower that makes it 5G. Figure 6 shows how 5G works [8].

In a 5G wireless network, every mobile phone will have an IPv6 address depending on the location and network being used. 5G utilizes the user-centric network concept World Wide Wireless Web (WWWW) instead of operator-centric as in 3G or service-centric as in 4G [9]. WWWW will be capable of supporting applications and services and interconnecting the whole world. 5G includes the latest technologies, such as cognitive radio, the Internet of things, nanotechnology, and cloud computing.

The key features of 5G include high throughput, improved spectrum efficiency, reduced latency, better mobility support, and high connection density. 5G technology has the following advanced features [10]:

- Architecture will be device-centric, distributed, programmable, and cloud-based
- High data rates
- One to 10 Gbps connections to endpoints
- One millisecond end-to-end round trip delay
- Low battery consumption
- Better connectivity irrespective of location
- Larger number of supporting devices
- Lower cost of infrastructure development

Some of these features are illustrated in Figure 7 [11]. The development of 5G will not be from scratch but will gradually build on 4G LTE. Major technologies enabling 5G include:

- *D2D Communication*: Direct connectively is achieved through device-to-device (D2D) technology. 5G cellular network will implement D2D mm wave communication technology to provide high-speed data rate, improve coverage, and offer peer-to-peer services. Much research has been invested in characterizing D2D connections as part of LTE [12].
- *M2M Communication:* While D3D communication targets mobile radios, machine-to-machine (M2M) expands the scope and facilitates ubiquitous connectivity among mobile devices. It is estimated that there will be over 100 billion connected devices using M2M communications in the 5G backbone [13].
- *MIMO:* Multiple-input-multiple-output (MIMO) technology plays a crucial role in 4G and is expected to play an important function in 5G. Massive MIMO extracts the benefits of MIMO on a large scale by increasing the throughput and spectrum efficiency.

Other enabling technologies of 5G include mmWave communication, ultra-dense network (UDN), all-spectrum access (ASA), OFDM (orthogonal frequency division multiplexing), and the Internet of things. Industries that use 5G technology are shown in Figure 8 [4].

This section would be incomplete without mentioning the successors of 5G [14]:

- *6G Network:* Fifth-generation cellular technology is replaced by sixth-generation wireless or 6G. The bandwidth and latency of 6G networks will be significantly higher than those of 5G networks due to their ability to operate at higher frequencies. The main purpose of 6G internet is to provide communications with one-microsecond latency. 6G will employ satellites to connect the current 5G networks.

- *7G Network:* Globally, the 7G Network provides a faster means of communication. The advanced cellular technology that will be the successor for 5G and 6G. A 7G network is the quickest way to make a call, whether it is local or international. Voice over Internet Protocol (VoIP), or 7G, requires access to all local and international telecommunications. 7G will be able to satisfy the requirements of extremely high bandwidth, almost zero latency, and universal integration. Although 7G will not be generally available until 2030, a handful of countries are currently using it. These include Norway, Netherlands, South Korea, and Hungary. They are the nations in the world to provide the fastest Internet speeds.

3. 5G NETWORK IN SUPPLY CHAIN

5G is the fifth generation mobile network. With speeds up to 100 times faster than 4G, 5G technology is more reliable and can carry data at greater speeds with lower inactivity. It links people, things, data, apps, transportation systems, and cities in intelligent-networked communication environments. 5G allows for the expansion of the Internet of things and all things connected to it. It also allows us to automate many processes and improve track and trace visibility. 5G technology is upgrading the capabilities of supply chains by giving them the power of real-time communication. This level of connectivity allows businesses to monitor supply chain operations.

To boost supply chain performance, companies are venturing into the world of digitization. A 5G network in a supply chain enables real-time tracking and monitoring of goods throughout their journey, significantly improving visibility and efficiency. 5G gives businesses a way to predict supply shortages and give them time to find alternative sources for goods to mitigate potential shortages. 5G enhances warehouse automation due to its capacity to support one million connections within a given area.

4. APPLICATION OF 5G NETWORK IN SUPPLY CHAIN

The applications of 5G network refer to the various use cases and scenarios where the capabilities of 5G technology can be applied to deliver new services and enhance existing ones. Private networks using 5G technology offer a secure and reliable platform for various applications, such as industrial automation, remote monitoring, and mission-critical communications. Here are some of the common, current applications of 5G in supply chain [15-17]:

- *Asset Tracking*: 5G network enables precise location tracking of shipments and assets using IoT sensors, providing real-time updates on their status and movement. 5G networks have the speed and capacity to support IoT sensors in warehouses and in transit. This means that teams will have the capability to track the movement of goods and materials in real time with unprecedented accuracy and efficiency. This level of granular insight enables proactive decision-making, ensuring that goods arrive at their destinations in optimal condition while minimizing delays and disruptions. Today's warehouses are often so large that traditional organizational tools no longer work. Due to 5G, asset tracking is now more accurate than ever.

- *Warehouse Management:* IoT integration is not limited to using sensors to track inventory. IoT devices can alert managers when there are signs of theft, or when products are mis-shelved. Some IoT devices can track temperature and humidity, ensuring that warehouse conditions are optimal for your products. Labor is the costliest expense in warehousing. It can affect all aspects of warehouse logistics from receiving to shipping. The escalating cost of labor is driving many businesses to use automation. 5G is bringing forth smart warehousing by shifting how businesses consider inventory and warehouse management. It is expected to bring revolutionary changes to the way we manage warehouses. Ultimately, 5G will expand the availability of data from sensors and intelligent equipment in distribution centers and factories. 5G promises to transform

companies' approach inventory and warehouse management in supply chain operations. Here, 5G's high-speed network ensures the collection, delivery and archiving of goods and products is more transparent and efficient for enterprises.

- *Fleet Management:* Poor maintenance of fleet vehicles increases the risk of a malfunction. 5G networks can help in improving the driving efficiency through real-time vehicle condition monitoring based on the vehicle diagnostics data. A key 5G advantage of supply chain fleet management is its ability to allow real-time responses concerning vehicle safety status and collision avoidance. The network infrastructure not only becomes easy to deploy with 5G but also improves the potential automation capabilities in these vehicles. In fact, test vehicles with 5G prototyping have been found to be safer, as they can come to a complete halt from high velocities with faster-than-human reflexes due to their advanced sensors and high-speed low latency connectivity.

- *Smart Cities:* 5G networks can enable real-time monitoring and management of city infrastructure, such as traffic lights, parking, and public transportation systems, to improve efficiency and reduce congestion. The potential of 5G networks for IoT and smart cities refers to the capability of this technology to support a massive number of connected devices and sensors in urban areas, enabling the development of interconnected and intelligent systems that can enhance the quality of life for residents and improve the efficiency of city operations.

5. BENEFITS

5G technology offers several advantages that make it particularly well-suited for use with automation technologies. Low latency provides fast response times, making it ideal for time-sensitive tasks in industrial automation, robotics, and other automated systems. 5G networks are designed to be highly reliable and this is important for automation systems. Other key benefits of 5G in supply chain include the following [1,18,19]:

- *Automation:* Automation often refers to IoT-connected machines or robots that perform repetitive tasks, create efficiencies, and reduce costs. Many companies have already employed the Internet of things technology (IoT) for automation purposes. 5G empowers the deployment of autonomous vehicles and robots in warehouses and logistics operations, as illustrated in Figure 9 [20]. It offers a digital infrastructure to support the public endorsement of IoT technology. 5G technology can improve and automate robotic performance. 5G enables instant communication between machines, and this can be leveraged to automate warehouse robots, trucks, and cargo ships.

- *Speed:* Some 5G services will provide coverage areas with data speeds up to 100 times faster than 4G and almost instantaneous response times. The speed at which 5G technology operates offers supply chain new efficiency opportunities. Large amounts of data can be transferred quickly, allowing for detailed analysis and insights. 5G speed, capacity, and low latency can power a network of IoT devices, support AI solutions, and drive reliable communications. It is the perfect tool for a modern, connected supply chain. Because of its low latency, 5G allows us to get information as fast as a sensor detects it.

- *Enhanced Connectivity:* The potential of 5G networks to provide high-speed connectivity refers to the capability of this technology to deliver faster data speeds and greater bandwidth than previous generations of wireless technology. Organizations faced speed issues with 4G technology, particularly when connecting multiple devices, leading to reduced performance. Since supply chain management uses a pool of devices and systems, 5G is the best fit. 5G technology is dedicated to giving a faster and more reliable Internet speed, enhancing the connectivity between various devices and systems and allowing a seamless flow of information.

- *Low Latency:* With 5G technology, organizations involved in supply chain management can optimize their computer networks to process and transmit large amounts of data across systems with minimal delays. It enhances the customer experience by offering them real-time tracking and monitoring.

- *Network Segmentation:* 5G also introduces the concept of network segmentation, which allows network operators to create virtual, segmented network segments optimized for specific use cases. This customization

allows network parameters to be tailored to the specific needs of the automation application, ensuring optimal performance and resource allocation.

- *Edge Computing:* 5G networks require edge computing infrastructure, which is necessary to process and store data close to the user or device. This is necessary to reduce latency, improve reliability, and support new applications that require real-time processing and analysis of data. Naturally, 5G complements edge computing by bringing computing resources closer to the source of data generation. This is beneficial for automation applications that require quick decision-making and processing of data at the edge of the network, reducing latency and improving overall system efficiency.

- *Product Monitoring:* Detailed product monitoring is another key benefit of 5G. You can install 5G-connected sensors to track and trace your items. After installing 5G tracking devices, you will get access to each item's location and critical information, like temperature and humidity. Installing 5G sensors can help you protect units from counterfeiting and other damage.

- *Visibility:* Supply chain visibility refers to how companies track products from point of production to delivery to the end customer. 5G technology provides a resilient network that can adapt to the scalability of varying internet loads and the need for faster speed. It helps provide granular data into the various aspects of supply chain operations, including inventory, order status, and shipping routes. Complete visibility allows the supply chain management system to allocate and distribute resources wisely throughout the supply chain.

- *Operational Efficiency:* It becomes more accessible for the supply chain management system to collect and analyze immense amounts of real-time data to draw in beneficial insights that can help improve the supply chain operations. It helps in improving the productivity and profitability of the supply chain.

- *Data Privacy:* 5G networks generate large amounts of data, which can include sensitive personal information. This data needs to be protected from unauthorized access, theft, or misuse. In addition, the use of edge computing and distributed processing raises new privacy concerns, as data may be processed and stored in multiple locations.

- *Network Slicing Security*: 5G networks use network slicing to partition the network into multiple virtual networks. However, ensuring the security of each network slice can be challenging, as different slices may have different security requirements and vulnerabilities. As shown in Figure 10, each network in 5G has its own protection [20].

- *Improved Collaboration:* 5G facilitates seamless communication between different stakeholders in the supply chain, including manufacturers, distributors, and retailers.

6. CHALLENGES

Unreliable suppliers, transportation delays, and communication breakdowns are just some of the headaches faced by logistics and transport professionals every day. The challenges of 5G networks include infrastructure investment, technological complexity, and lack of standards for certain applications. Before implementing any 5G-enabled technology, you may need to strengthen your security and data infrastructure. Other potential challenges of using 5G in supply chain include the following [16]:

- *High Cost:* The deployment of 5G networks requires significant investments in new infrastructure, such as base stations and fiber optic networks. This can be a major challenge for operators, especially in areas with low population density. Initial implementation cost is high. The cost to install the infrastructure and upgrade technology will be significant. So far, billions of dollars are being spent to acquire spectrum availability and to convince consumers about the benefits of the technology. Switching to 5G will increase costs. 5G costs vary depending on your provider, location, and the size of your operation, but for now, at least, the costs are higher than 4G. However, the ROI is significant enough to make up for the initial investment.

- *Cybersecurity:* 5G networks are vulnerable to various types of cyber threats, such as hacking and data breaches. Supply chain cybersecurity attacks are the most notorious. They cost companies and their suppliers millions of dollars and tarnish the victims' reputations for years. 5G's high speed and low latency makes it an attractive target for cybercriminals, and users need to be on their guard for potential data breaches or ransomware attacks. It is imperative to protecting sensitive data collected through connected devices. A strong security system can overcome this challenge easily. Using firewalls and VPNs can help keep your network safe from attack.

- *5G Limited Coverage:* 5G is still new technology; it does not yet cover every area of the globe. The technology is firmly in place across most parts of North America, western Europe, and much of Latin America.

- *Interoperability:* Interoperability is the ability of different systems to work together seamlessly, allowing devices to connect and communicate across different networks and technologies. Interoperability between 5G networks and existing networks is crucial for accessing full range of services and reducing deployment cost. The deployment of 5G networks requires collaboration and interoperability between different stakeholders, such as operators, vendors, and regulators. However, there may be differences in technical standards, business models, and regulatory frameworks that can create barriers to interoperability.

7.CONCLUSION

It is important to keep in mind that 5G is still in its infancy. 5G is expected to bring a wave of new applications and technologies to optimize supply chain management in the near future. There is no doubt that as enterprises begin adopting 5G, they need to reimagine and reinvent some of their existing data infrastructures and adopt analytics solutions suited to the task ahead. By making use of 5G technologies to digitize their warehousing and supply chain processes, companies are creating value and mitigating risks, while increasing profitability. As 5G supply chain technologies develop, they will be able to produce data in nearly every segment of supply chains. More information on the implementation of 5G networks in the supply chain industry is available from the books in [21-24].

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ABOUT THE AUTHORS

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics, computer networks, engineering education, and marriage counseling. He is a Life Fellow of IEEE.

Ajayi A. Samuel is currently a graduate student in the Department of Computer Science at Texas Southern University, Houston, Texas. He holds a master's degree in mechanical engineering from Hanbat National University, South Korea (2024) and earned his bachelor's degree in mechanical engineering from Ladoke Akintola University, Nigeria (2018). His research areas include heat and mass transfer, programmable logic controllers, cybersecurity, thermodynamics, condensation, and energy systems.

Janet O. Sadiku holds bachelor degree in Nursing Science in 1980 at the University of Ife, now known as Obafemi Awolowo University, Nigeria and doctoral degree from Juliana King University, Houston, TX in December 2023.

She has worked as a nurse, educator, and church minister in Nigeria, United Kingdom, Canada, and United States. She is a co-author of some papers and books.

Figure 1   The symbol of 5G [3].
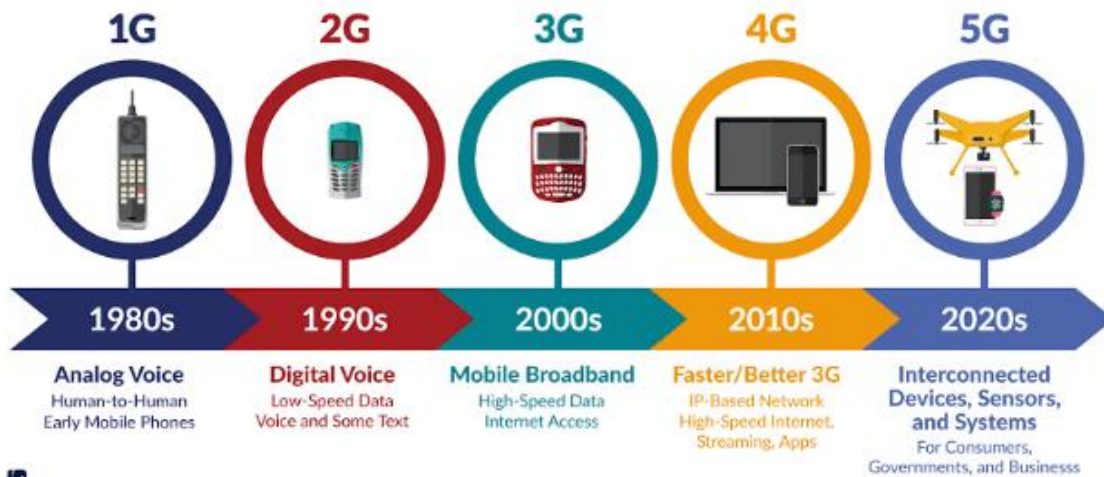

Figure 2   Representation of global supply chain [2].

Figure 3   Evolution from 1G to 5G [4].

Figure 4   Relationship between 3G, 4G, and 5G [5].

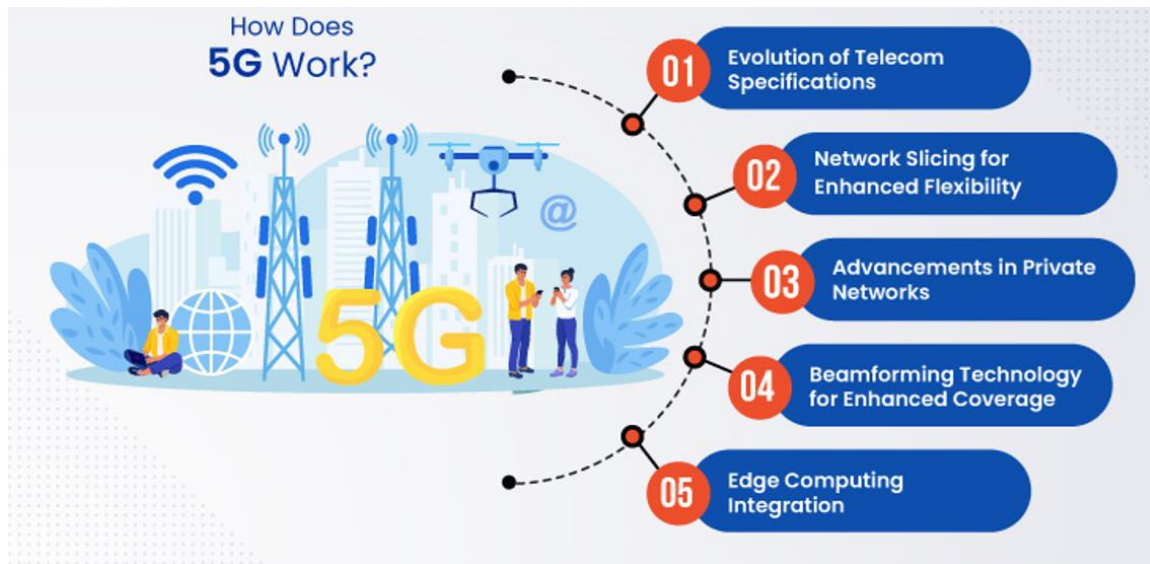

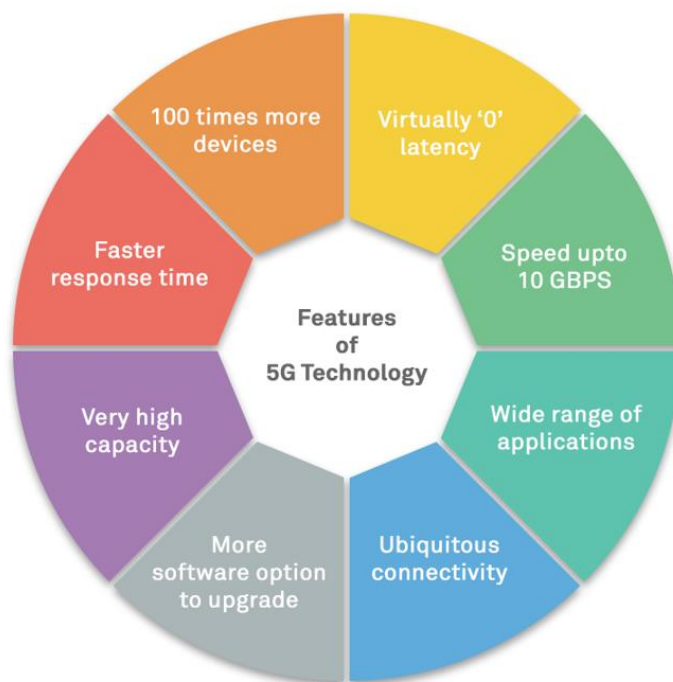**Figure 5   A typical 5G towers [7].**

Figure 6   How 5G works [8].

Figure 7   Some of the features of 5G [11].
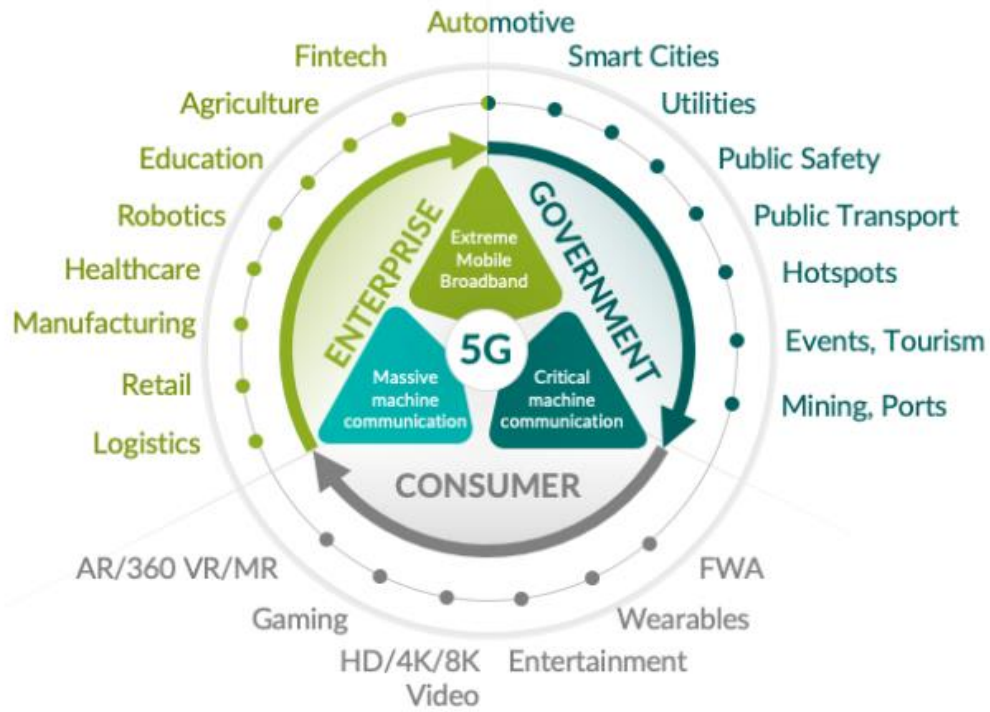
Figure 8   Industries that use 5G technology [4].
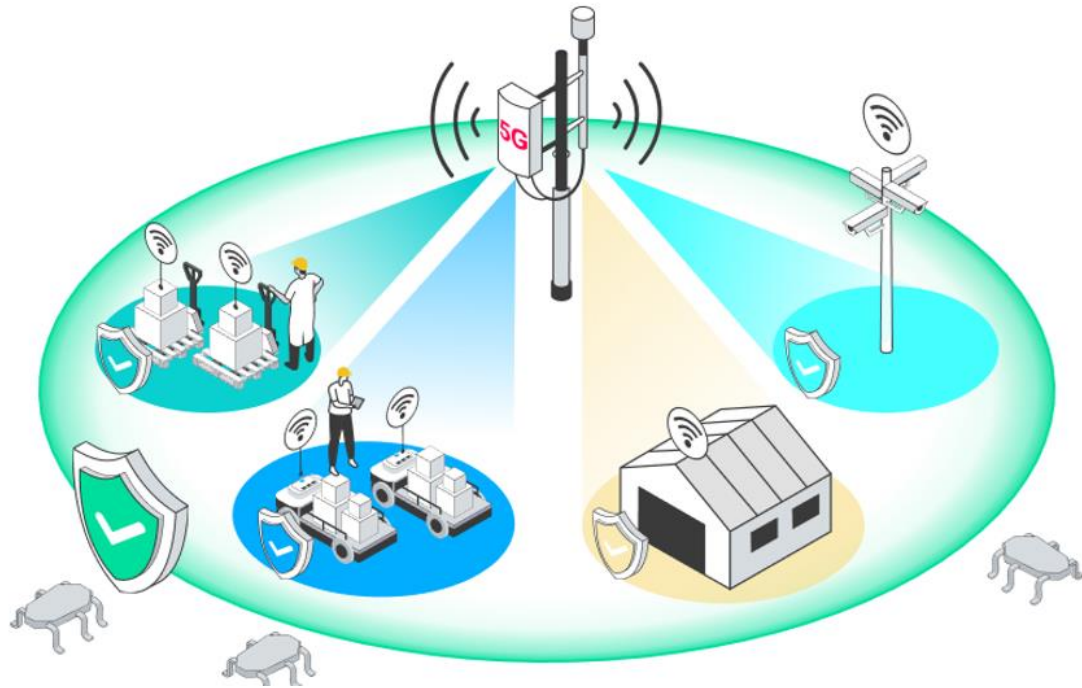

Figure 9   Use of robots in warehouse [20].

Figure 10   Each network in 5G has its own protection [20].