5G Opening up New Business Opportunities

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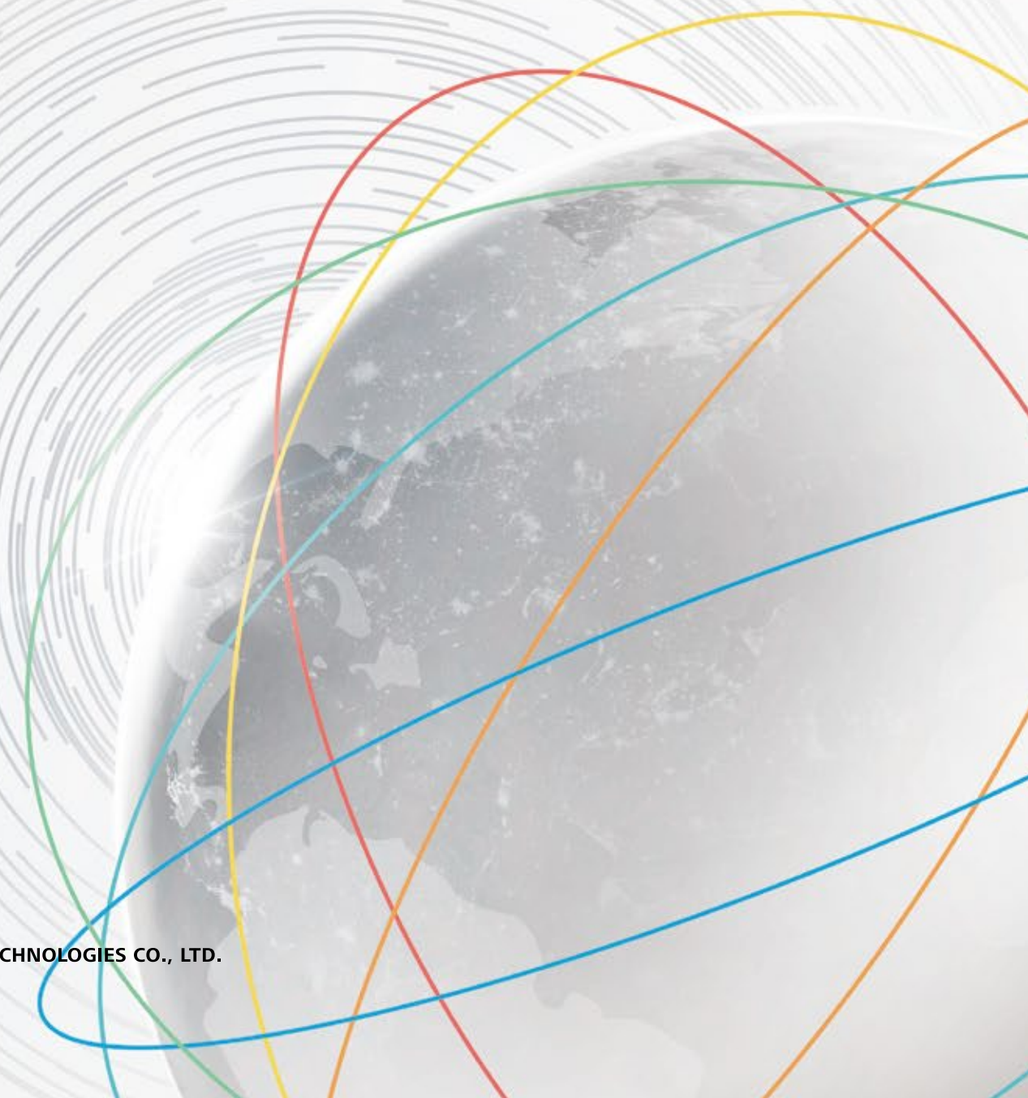

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Content

Executive Summary

Society and industry are undergoing a digital transformation, and it is apparent that existing mobile networks will not be able to satisfy future communication needs. New technology is required. According to a 5G white paper[1] newly released by Forbes, over 80% of executives believe that 5G, a new generation of mobile broadband (MBB) network, has the potential to provide a range of benefits. Industrial managers have begun to realize that MBB networks **provide a path and platform for the upgrade and transformation of multiple aspects of their operations**. The connection platform enabled by 5G network infrastructure must be leveraged to release the full potential of digitalization.

Key findings

- **Enhanced mobile broadband (eMBB) services will both drive 5G development and facilitate its success. The need for eMBB** will encourage the rapid development of 5G technology and 5G networks.
- The value of digitalized information lies not only in the information itself but also in the new services that can be created by linking information sources. Widespread **5G connectivity will eliminate information islands, boost the prosperity of a digitalized sharing economy, promote changes to existing production methods and lifestyles, and finally improve people's quality of life**.
- A 5G MBB network, delivered as platform as a service (PaaS), can drive the process of full digitalization through the integration of wireless connections, mobility, Internet of Things (IoT), cloud computing, and big data. **Based on a 5G infrastructure platform, the MBB network will facilitate the transformation of diverse industries**.
- 5G, featuring outstanding air interface performance as well as fully cloud-based and flexible network architecture, delivers a better and more comprehensive set of capabilities than other communication technologies. 5G is the best **enabling platform with the potential to achieve the aim of enabling multiple industries with a single network**.
- **A unified 5G standard will make cross-industry connection possible, accelerate industry application development, and improve the production efficiency of society as a whole**.
- **The greatest benefit of 5G to vertical industries is that digital transformation, through unparalleled connectivity, can be implemented in the production, product and service provision, sales, and ongoing support processes**. This will ultimately increase benefits and experience for consumers, as well as the industry suppliers themselves.
- **5G will provide new business opportunities for telecom operators**, ranging from provision of eMBB services to supply of applications to vertical industry customers. As well as supporting new consumer services 5G provides operators with the opportunity to increase their presence in industrial markets.
- As the providers and operators of 5G wireless network, **telecom operators have the potential to become the best enablers and trustworthy business partners for industry customers**.

[1] Forbes Insights , The Mobile Industrial Revolution: Anticipating the Impact and Opportunities of 5G Networks on Business, June 2016, http://www.forbes.com/forbesinsights/huawei/index.html

Introduction

As more information becomes digitalized, public and private sectors are undergoing tremendous change, and this change is resulting in the rapid development of mobile broadband (MBB) and the Internet of Things (IoT). It is expected that by 2025, there will be 100 billion connections worldwide, between people, things, and organizations. This interconnectedness results in new requirements for communication networks.

- Digitalized information becomes valuable when it becomes connected. Islands of individual and enterprise information are becoming interconnected, and this in turn is enabling more interconnection. This generates more network traffic – and more concurrent data processing. High bandwidth, multiple connections, high reliability, and low latency are now recognized as the most important new demands on network connectivity.
- Visual input has become the most important way that we acquire information, and network requirements for business and consumer services are becoming more demanding. Mobile applications based on video and using new virtual reality (VR), augmented reality (AR), and mixed reality (MR) terminals will become early important applications for 5G networks. The need to provide these services anytime and anywhere will drive the way operators build their networks.
- All business and social activities are being transformed. An MBB network based on 5G infrastructure will improve people's communication experience, and will also be a driving force for change in production and operating systems, through the connections between things, and between people and things.

5G networks will develop alongside the new services that the technology enable. Enhanced mobile broadband, as an early application, will in turn enable rapid development of 5G networks. With its huge technology improvements, the 5G network will become a network platform that will accelerate new industry applications.

To further explain the diverse and specific industry application requirements for 5G, this white paper examines five areas that will have a significant influence on socioeconomic infrastructure and people's livelihoods, including enhanced MBB services, smart driving, smart grid, mobile healthcare and smart manufacturing. The paper studies the application of 5G technology in these fields and how 5G network can support transformation in each one.

Future research will look at fields such as smart transportation, precision agriculture and smart ports and will examine the relationship between the 5G network and these industrial markets to help facilitate cooperation between industry and operators, and highlight new business opportunities.

01

Enhanced Mobile Broadband: Early 5G Applications

Mobile broadband Internet has developed rapidly and smart devices have become very popular. As a result, mobile video accounts for nearly 50% [2] of operator's network traffic and the proportion is increasing. There is also a trend to more immersive services based on new VR and AR headsets, and consumers will want to experience these services wherever they are, so they must be capable of being used wirelessly. These services will become more important for MBB. Some might call high definition video and wireless AR and VR services the early “killer applications” for 5G. There are significant implications for network pipes, and this will drive rapid development of 5G.

1.1 Key drivers

- **Mobile video traffic increases rapidly** – Video services will become operators’ basic services. Mobile video accounts for 48% of operators' traffic volume by 2016. Providing high definition (HD) mobile video anytime and anywhere requires higher network throughput and capacity.
- **Immersive experiences become popular** – Visual input is becoming the dominant way that we receive information at work, at home and when we are out and about. The new VR and AR immersive experiences, such as panoramic and 360 degree videos, will be recorded and viewed anytime, anywhere – and not be restricted to a wired connection. This places extreme demands on network throughput, end-to-end (E2E) latency, and capacity.
- **Applications are migrating to the cloud** – As mobile office applications, interactive entertainment and games are deployed on cloud servers, network air interface performance must be improved and network architecture itself must be cloud native to ensure the high speed and reliability of data transmission.

1.2 Applications

Both VR and AR applications are developed on the basis of HD video. VR provides immersive user experience by creating a virtual world, or simulating the real world, making use of sensors built into a headset to provide the interactivity with the virtual world. AR – Augmented Reality – is based on the real world, but offers more comprehensive perception of it by overlaying data. A wireless, untethered, immersive experience enables people to watch movies and live sports programs, play games, shop online and work remotely anytime and anywhere with convenience, freedom and efficiency. Such services also enhance cooperation and interaction in fields like education, training, construction, city planning and oilfield exploration.

- **Typical application scenarios for VR** include virtual games, live sporting events, remote presentation and remote equipment control.
- **Typical application scenarios for AR** include intelligent navigation, virtual tour guides, education and training.

1.3 Wireless technology requirements

Experiencing, sharing and interacting at any time and in any place are the primary characteristics of the application scenarios listed above. Large bandwidth and low latency are required for real-time, high-quality image processing and spatial location. HD image processing, scene identification and reconstruction, 3-demention (3D) audio dynamic tracking and gesture dynamic tracing are needed. In addition, mobile terminals must have low power consumption so that battery life is as long as possible. The network must help to enable low-energy design. Network throughput, latency and system capacity need to be improved, and network architecture must support the deployment of multiple applications on the cloud.

- Speed – In hotspots, the 5G mobile network must provide a throughput of Gbps to ensure a fully immersive wireless experience. In fast-moving vehicles, the video streams of AR for intelligent navigation and other on-vehicle MBB applications require a bandwidth up to 100Mbit/s.
- The bandwidth requirements of a mobile immersive experience are shown in Figure 1. These requirements support improved display quality (from a typical current resolution of 1200 x 1080 to the retina resolution of 5073 x 5707), a display position closer to eyes, widened field of view (from 110 degrees to 200 degrees), and 3D visual experience (with independent image processing for each eye), which doubles the data volume.

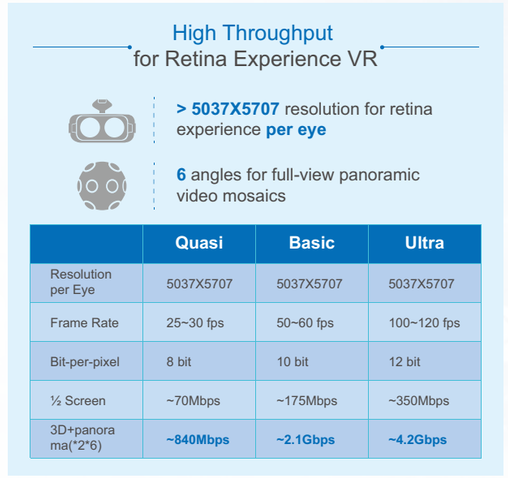


Fig 1: Wireless network bandwidth requirements of mobile immersive experience

- Latency – Generally, to ensure mobile immersive experience, E2E latency between the perception of an action and image display (“motion to photon” latency) must be less than 20ms to avoid disorientation and dizziness. Dizziness can be caused by the failure to deliver a fully immersive experience when interacting with a virtual world. Other complex tasks add to the processing latency. These include 3D image processing, correction of lens distortion and colours, dynamic tracing of 3D audio and echo strength, and AR scene identification and reconstruction. This means that latency on the network side must be within 5-9ms, as shown in Figure 2.

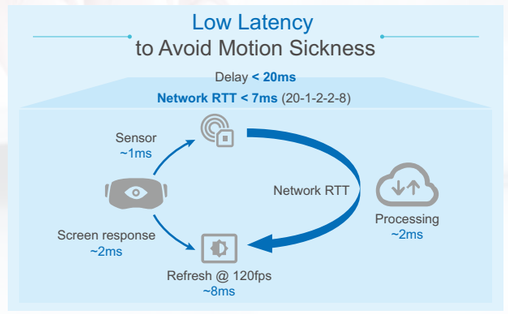


Fig 2: Wireless network latency requirements of mobile immersive experience

- 10 Tbps/km2 network capacity – In ultra-dense networks with high concentrations of users of AR / VR services, new handover and interference control algorithms will be required to ensure that users are able to have a consistent experience

[2] Huawei, Huawei Mobile Video Report, June 2016, http://www.huawei.com/en/industry-insights/huawei-voices

wherever they are. Attention must also be paid to power control and coverage, especially where users are moving at high speed, to avoid increasing the heat generated by VR/AR terminals as their power consumption rises.

- End-to-end sliced 5G cloud network architecture – As described above, eMBB terminals offering mobile immersive VR/AR experiences will be designed to support applications anytime and anywhere. Meanwhile, a large number of applications will be deployed on cloud servers, reducing the demands placed on terminal software and hardware and improving compatibility. In addition, to reduce data volume and further improve visual experience, only part of the image focused by the eyes will be displayed. The image is transmitted and adjusted according to real-time eye movements, and the operation is partially processed on the cloud servers. 5G is ideally suited to support the use of cloud resources required to deliver the VR/AR services. One of the main features of the 5G network architecture is its capability to support applications' migration to the cloud. The key technology elements concerned are separation of control plane from user plane, programmable forwarding capability of the user plane, deployment close to user plane, and dynamic migration of applications to the cloud side.

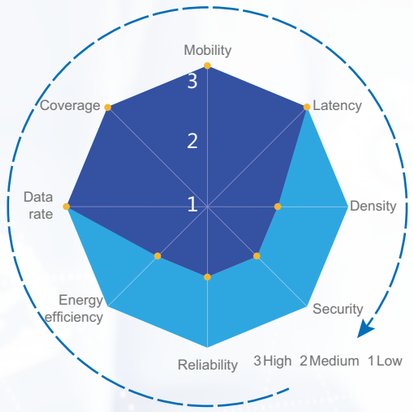


Fig 3: Wireless network requirements of mobile immersive experience

The requirements of VR/AR for the 5G network are shown in Figure 3.

1.4 5G enables VR and AR to form the foundations for next generation mobile social platforms

The VR and AR service experience based on the 5G mobile network will have no geographical boundaries. What's more, eye signals and physical gestures created in immersive VR/AR environments will take the place of characters and pictures, becoming the main information carriers on social platforms.

The industry supply chain for VR terminals and chip sets has already started to take shape. There are already successful VR and AR use cases in fields such as movies, gaming, retail, real estate, healthcare, education, building and engineering planning and design. In the future, with extensive development of mobile communication technologies, VR and AR applications will rapidly migrate to the wireless network.

Accessing live sports events and picture or video sharing regardless of time and place will all be as popular uses of the next generation of devices. 5G technology introduces improvements in uplink bandwidth, latency, network capacity, power control, and energy-saving design, and can effectively provide a ubiquitous mobile experience. Current efforts in the development of the 5G network and VR services will lead to the emergence of a large user base, and large scale development will in turn bring cost advantage. The combination of 5G with AR and VR will improve people's experience at work and in daily life.

02

Smart Grids: 5G will support national energy transformation

Smart grids integrate information, telecommunication and automation into traditional power systems, revolutionising the way energy is stored, delivered and sold. Smart grids are now regarded as an indispensable component of national energy strategies in many markets, including China, Europe and the United States. Smart grids are based on the principle that everything in the grid is connected, monitored and controllable. The data on usage, network status and performance, and energy supply from generation sources is collated centrally. Therefore, **the communications system for the smart grid is a crucial component which links all the power generation, transmission and distribution assets, as well as the management systems**. It enables two-way transmission of data between sensors and monitoring systems; between control systems and energy generation, storage and transmission assets; and between control systems and end users' smart meters.

2.1 Key Drivers

Digital transformation is challenging existing electricity generation facilities in terms of their types and scales, as well as energy management and control of the power system. At the same time, the conventional unidirectional energy transmission from power generators to consumers is changing. With the development of the sharing economy, power users can also serve as energy suppliers by sharing off-peak energy. This achieves bidirectional energy transmission and use. These transformations require real-time, safe, and stable smart grids with large capacity and high speed.

- **Diversified technical requirements**

A smart grid has different requirements for security and reliability, network bandwidth, latency, and coverage on its five stages (power generation, transmission, transformation, distribution, and consumption). Existing communication systems do not meet all the technical requirements.

- **Cross-regional coordinated control**

Energy and power distribution in China is extremely unbalanced. China is taking measures such as South-to-North energy transfer to schedule and manage resources across grids. Taking the automatic control of substations in smart grids as an example, replacing single-site-level transmission with grid-level transmission increases requirements for the transmission and security of the backbone transmission network in terms of distance, efficiency, and safety.

- **Sustainable, efficient, and sharing economy**

A standardized grid will help realize sustainable development of smart grids over the next two decades. Another advanced technology, remote intelligent metering and scheduling, not only reduces labor requirements, but also comprehensively reflects the power consumption and operating status. The sharing economy mode allows UEs to sell off-peak energy, saving energy and reducing problems of regional power shortage. The United States government surveyed 38 electricity companies and found that the popularization of intelligent metering and bidirectional energy transmission makes it easy to obtain overall energy consumption information. Users can then limit their consumption or avoid using power at peak hours, reducing power consumption by 11%.

The over-the-air connectivity on the 5G network eliminates the need for grid construction. With strong anti-disaster abilities, 5G networks are easier to construct and recover in mountainous areas or over water than fiber optic cable networks or other short distance networks. In addition, featuring ultra-large bandwidth, non-line-of-sight transmission, wide seamless coverage, and roaming, 5G technologies meet the diversified requirements of future smart grids and ensure the robustness of intelligent networks with high reliability and high bandwidth.

2.2 Applications

With respect to the five stages of a smart grid, wireless communication technologies can mainly be applied in the scenarios in Figure 4, which are explained as follows:

- **Distributed grid-tied management of new energy**

Featuring wide coverage, large capacity, real-time performance, reliability, and scalability, 5G networks allow grid-tied management of new energy such as hydraulic, wind, and solar power. 5G networks also address challenges to grid-tied management, such as random and intermittent new energy supply, unbalanced peak-load regulation capability, and bidirectional transmission.

- **Intelligent management of the power transmission and transformation network**

To promptly handle abnormal disturbance, the transmission network, voltage transformers, and other power devices are monitored real-time online. Furthermore, onsite operations and outdoor facilities are under video surveillance.

- **Intelligent management of power distribution network**

Online real-time monitoring and automated management of power distribution facilities improve device efficiency and provide timely dispatching and scheduling of power to different consumption areas.

- **Remote smart meter**

This technology collects and analyzes power consumption and quality, based on which other value-added services are provided, including remote control of home appliances, home security, and power sharing during off-peak hours. According to the UK government, installing intelligent meters in 26 million houses nationwide would save consumers and energy companies some 3 billion pounds over the next two decades. Energy consumption would be reduced by 3% to 15% relative to the base case. The measure will bring both social and environmental benefits.

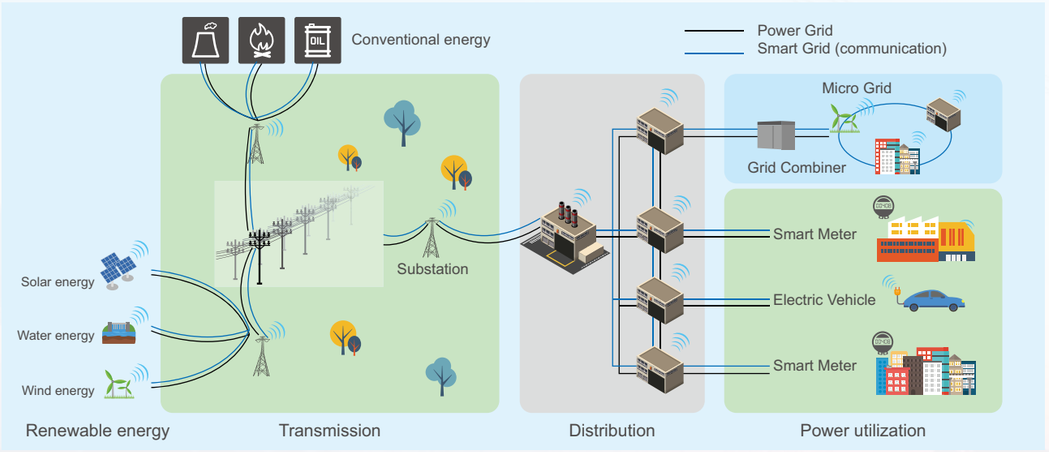


Fig 4: 5G applications of smart grid

2.3 Wireless Network Requirements

- **Wide coverage, high bandwidth, and massive connections**

The communication network provides long-distance consecutive communications across the country, and the data center implements real-time data processing. Both of them require high bandwidth and enormous data volume. In addition, the access and communication of massive user data recorded on intelligent or gateway meters raise high requirements on the coverage, bandwidth, and number of connections. For example, millions of intelligent meters are installed in large cities, and massive measurement data is transmitted from each meter to the concentrators and data center every day.

- **Milliseconds- to second-level latency**

Smart grids raise high requirements on the real-time performance of the power transmission and scheduling and the monitoring of power devices. On the 4G network, less than 20 ms latency can hardly be ensured when there are a huge number of concurrent connections. 5G networks, therefore, must be able to monitor the grid operating status in real time, isolate faults, and implement self-recovery, avoiding large-scale power failures. Table-1 shows the requirements of each scenario in the grid for the latency of the communication network.

Table-1: Smart grids' requirements for communication latency

Scenario	Latency	Description
Power transmission network	5 ms	The power transmission line of the backbone network and key power grid devices such as transformers and lightning sensors require 24/7 safe and reliable operation. Therefore, real-time monitoring of electric network communications must be ensured. For example, relay protection requires a latency less than 5 ms.
Power distribution network	10–50 ms	End to end (E2E) data transmission between power distribution stations, substations, and control centers requires low latency to achieve quick fault location and self-healing.
Power consumption network	< 1s	E2E data transmission between users' electric meters and control and metering centers requires low latency[3], so that power usage and grid operation can be monitored in a timely manner.
New energy merging network	1s	New energy, prone to unpredictability, intermittency, and peak-load surge, raises high requirements on real-time information collection, communication, and transmission of sensors. Renewable tidal, wind, and solar power may cause dramatic voltage increase or decrease in minutes or seconds because of rapidly changing natural conditions.

- **Gbit/s bandwidth**

Remote high definition (HD) video control, virtual reality (VR), and augmented reality (AR) provide visualized communications to identify faults in the electric power system, give warnings, and help rectify the faults. The backbone power supply network now delivers transmission bandwidths of Gbit/s or even higher, meeting the bandwidth requirements of substations and control centers on the transmission network. Generally, the bandwidth required by each intelligent substation is 0.2–1 Mbit/s, that required by every one million digital meters is 1.85–2 Mbit/s, and that required by every 10 thousand intelligent sensors is 0.5–4.75 Gbit/s.

[3] 5GPPP, 5G and Energy, September 2015, https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White_Paper-on-Energy-Vertical-Sector.pdf

• Flexibility, compatibility, and scalability

In response to the expansion and increased access to distributed energy, smart grids now support access to both traditional centralized and distributed energy sources.

• Carrier-class security

Eavesdropping or attacks on the power system would have significant societal and economic consequences. To ensure quick and accurate response to power system exceptions, more emphasis must be put on carrier-class data confidentiality and security.

Figure 5 visualises the range of networking requirements of smart grids.

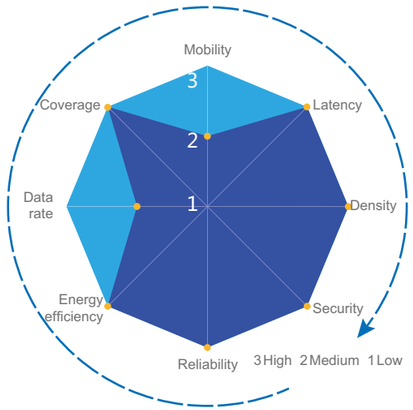


Fig 5: Wireless network requirements of smart grid

2.4 5G networks can free utilities from the need to deploy their own communications systems

By using 5G networks utilities can avoid building and maintaining their telecommunications systems. 5G networks will meet all their requirements, over a dedicated slice of the 5G network, with the cost based on ongoing network usage.

5G networks will match smart grid requirements for decades. They can also support backward compatibility as smart meters are already being deployed now. 5G operators will need to demonstrate progress on power consumption and battery life issues for user side components.

Running smart grid communications networks requires expert knowledge. **Network operators are ideally placed to provide this expertise and experience**. Meanwhile, energy companies could be important anchor tenants for mobile operators' 5G networks.

03

Smart Driving: 5G will increase automotive safety and efficiency

The automobile industry is at the start of a transformation that will take 15 to 20 years to realise. Billions of dollars are being invested in advanced vehicle technologies that will enable the introduction of new safety and efficiency systems, and ultimately, driverless cars.

These future generations of automobile will require sophisticated wireless telecoms capability in order to communicate with one another, with local traffic control systems, with manufacturers and with third-party service providers.

According to NAVIGANT RESEARCH's forecast, the number of autonomous vehicles will reach 95.4 million by 2035 as shown in Figure 6. All new cars will be connected by 2025 according to Accenture [4].

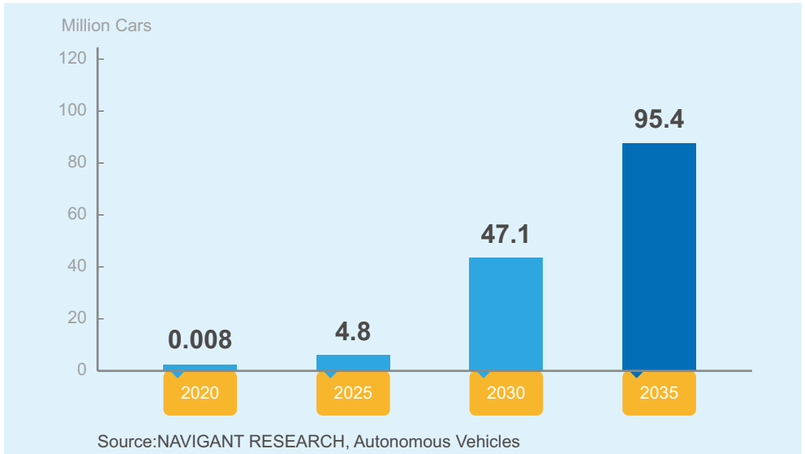


Fig 6: Number forecast of autonomous vehicles

[4] Accenture, Connected Vehicle, April 2016. https://www.accenture.com/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_21/Accenture-digital-Connected-Vehicle.pdf

3.1 Key Drivers

- **Enhanced safety**

Internet of Vehicles (IoV) is expected to reduce traffic accident rates, relieve congestion, save energy, and reduce pollution. It is estimated that if 90% of vehicles in the United States were automated, the number of traffic accidents would decrease by nearly 80% and the number of fatalities by about 60%. The US National Highway Traffic Safety Administration (NHTSA) predicts that light and medium-sized vehicles with vehicle-to-vehicle communications (V2V) can avoid 80% of accidents, and large vehicles with V2V can avoid 71% of the accidents. With a rapidly aging population and many accidents involving senior citizens, the automatic driving function will become a standard safety feature for future vehicles. This year, the European Union member states call for Vehicle-to-Everything (V2X) modules to be installed alongside roads to implement information exchange between vehicles and infrastructure. Korea and Singapore plan to deploy V2X modules in 2017 and 2018, respectively. V2X technology is maturing and being deployed in multiple countries. Emergency Call (eCall) and V2X are becoming standard features for vehicles and will reach a penetration of 30% three years from now.

- **Improved efficiency**

The IoV and smart driving can reduce traffic congestion by 60% and improve traffic capacity by two or three times. Vehicle stop time and running time can be reduced by 30% and 13–45%, respectively, cutting fuel consumption by around 15%. Manpower released from traffic congestion will increase economic production and give people more free time. The consulting firm McKinsey believes that commuters around the world will save up to one billion hours in total when driverless vehicles become mainstream. Driverless vehicles also free people's hands and eyes, allowing them to handle important business or entertain themselves while driving. However, existing networks cannot meet the requirements of future IoV or smart driving applications. 5G networks are expected to enable safe and efficient passenger experience through smart driving. 5G technology has aroused people's interest with its promise of flexible networking, high real-time performance, and extremely fast rate. In the telecommunication and automobile industries, integrating IoV and smart driving technologies with 5G has become an important research direction to ensure traffic safety and develop business applications.

3.2 Applications

V2X, considering vehicles as carriers, is applied in various scenarios to assist people's daily transportation, as shown in Figure 7.

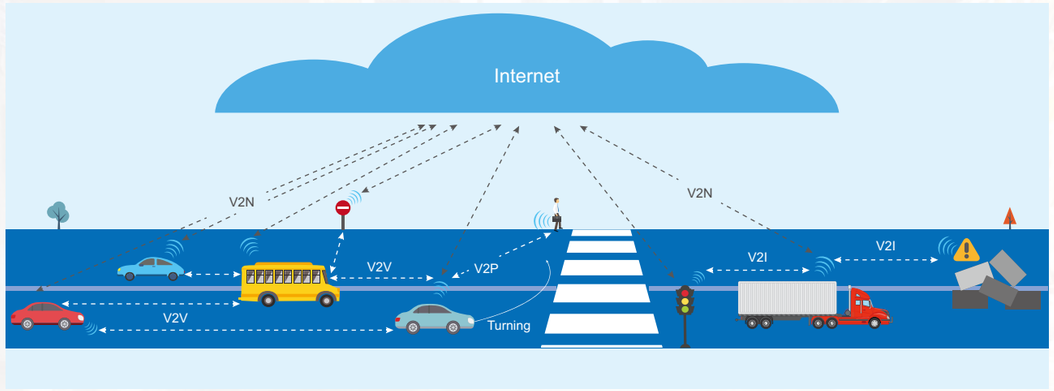


Fig 7: 5G applications of smart driving

Existing short-distance wireless networks can provide small-area communication in an ideal propagation environment. However, when the environment is not ideal or in NLOS scenarios with complex road conditions, it is difficult to obtain wide coverage panoramic traffic information, give quick warnings, and take anti-collision measures. In high-speed mobile scenarios, moving vehicles are sensitive to obstacle interference, frequency offset, and inter-cell handovers. To meet the communications requirements of smart driving, the propagation path of cellular networks will function as an indispensable connection channel. Table-2 describes the application scenarios of IoV and supported communication types.

Table-2: Application scenarios of IoV and smart driving

Application Scenario	Application Cases	Communication Type
Vehicle-to-Vehicle (V2V)	Lane-changing and braking notification sent by vehicles or fleets, autonomous driving, transportation information sharing, and anti-collision function	Short-distance networking and cellular communication
Vehicle-to-Pedestrian (V2P)	Vehicle-mounted entertainment for drivers and passengers, navigation, insurance, payment applications, and anti-collision function for vehicles and pedestrians	Short-distance networking and cellular communication
Vehicle-to-road infrastructure (V2I)	Information interaction between vehicles and roads, traffic lights, obstacles, and nearby buildings	Short-distance networking and cellular communication
Vehicle-to-Internet Network (V2N)	Communication between vehicles and Internet, taking vehicles as mobile telecommunication terminals allow web browsing, entertainment, navigation, searching, uploading, and downloading	Cellular communication

3.3 Wireless Network Requirements

The development of IoV and smart driving technology requires driving data collection and processing as well as interaction control. According to the vehicle automation level[5], ranging from 0 to 5, jointly defined by American Society of Automobile Engineers and the German Association of the Automotive Industry, level 0 indicates solely manual control while level 5 indicates highly intelligent autonomous driving. Table-3 describes the communication requirements of the automation levels.

[5]5GPPP, 5G Automotive Vision, October 2015. https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf

Table-3: Requirements of smart driving for the communication

Vehicle Automation Level	Automation Degree	Latency (ms)	Transmission Rate per Vehicle (Mbit/s)
1	Driver Assistance	100–1000	0.2
2	Partial Automation	20–100	0.5
3	Conditional Automation	10–20	16
4 & 5	High & Full Automation	1–10	100

Besides the latency and rate, smart driving has requirements for communication distance, the number of vehicles connected to the network, and the information security of insurance or payment services, as shown in Figure-8.

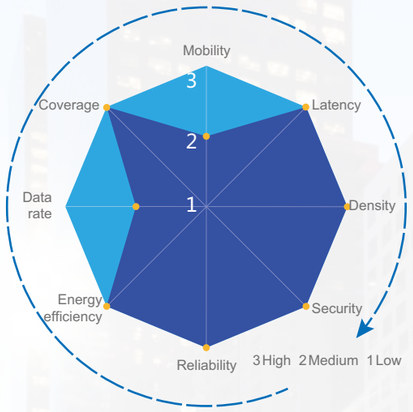


Fig 8: Wireless network requirements of smart driving

3.4 5G networks offer automotive manufacturers a tailor-made platform

It will be 10~20 years before widespread adoption by consumers of fully autonomous vehicles on public roads. 5G standards can be created with the automotive industry fully in mind, so made-for-measure networks are ready exactly when they are needed.

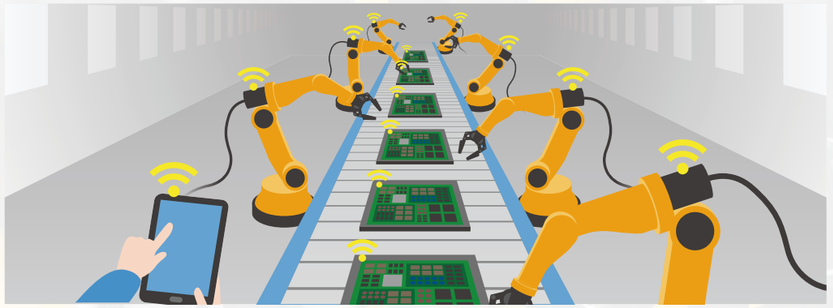
Automotive manufacturers will be able to use 5G networks as a platform to open up new revenue streams and business models such as charging for real-time in-car entertainment, basing rental charges on driving behaviour and route selection, or sale of road mapping data to third-party organisations.

Automotive manufacturers have no experience of building nationwide communications infrastructure. They can avoid the need to build their own networks, or to acquire complex skills, by buying managed 5G network services from operators.

04

Smart Manufacturing: 5G will drive manufacturing transformation

In the Industry 4.0 vision, factories of the future will be based on cyber physical systems. They will integrate computing, networking and physical processes to improve the ways in which manufacturing businesses are run. **The entire manufacturing supply chain will be interconnected**. Data will be shared between different locations about key business aspects such as design, manufacturing and distribution; information about equipment and products; and even data about customers and suppliers so that operations in all these areas can be improved. Products will become channels, sharing data about, and enabling subsequent sales to, customers. Data marketplaces will emerge to take advantage of the new insights available. The factories themselves will be populated with more capable manufacturing robots, and densely equipped with sensors and automated systems. On-demand manufacturing will increase. Production flexibility and efficiency will improve.



4.1 Key drivers

Manufacturing is also being revolutionised. Whilst the technologies and concepts are known, massive investment will be required to change factory equipment and systems. PwC's analysis[6] predicts that companies worldwide will invest $900 billion per year until 2020 in Industry 4.0 technologies with most spend on sensors, connectivity and software. That investment is expected to deliver annual cost reductions of 3.6%, and annual revenue growth of 2.9%. Cumulatively over five years these changes will mean significant efficiency advantages for investors.

Industry transformations will include the introduction of on-demand manufacturing, super-efficient supply chain and logistics operations, the emergence of data marketplaces, and the provision of new services to accompany and enrich products.

4.2 Applications

All this evolution will be based on extensive data sharing and analysis. **This information dissemination can only happen if there is a robust wireless telecom infrastructure, and if a wide variety of things (equipment, control systems and products) are given the ability to communicate**. Key applications for 5G in smart factories, as shown in Figure 9 will include:

- Constant on-site connectivity – to enable continuous transmission and sharing of manufacturing information. Use cases will include sharing of time critical sensor data and video, non-time critical information collection, and data to enable remote control of equipment and systems
- Constant inter-site connectivity – for tracking materials, components and products through the manufacturing process, for collation of data in data centres, and transmission of control instructions between sites
- Use of VR/AR technologies to enable virtual collaboration on complex designs by engineers in diverse locations
- Wide area connectivity – for employee, customer and partner collaboration, and for tracking/optimising goods following delivery. Use of wireless networks in product lifecycle management through end-to-end tracking, and supply chain enhancement - from the initial order, through materials buying and production processes, to the end consumers; and the creation of new services by analysing data collected from connected products.

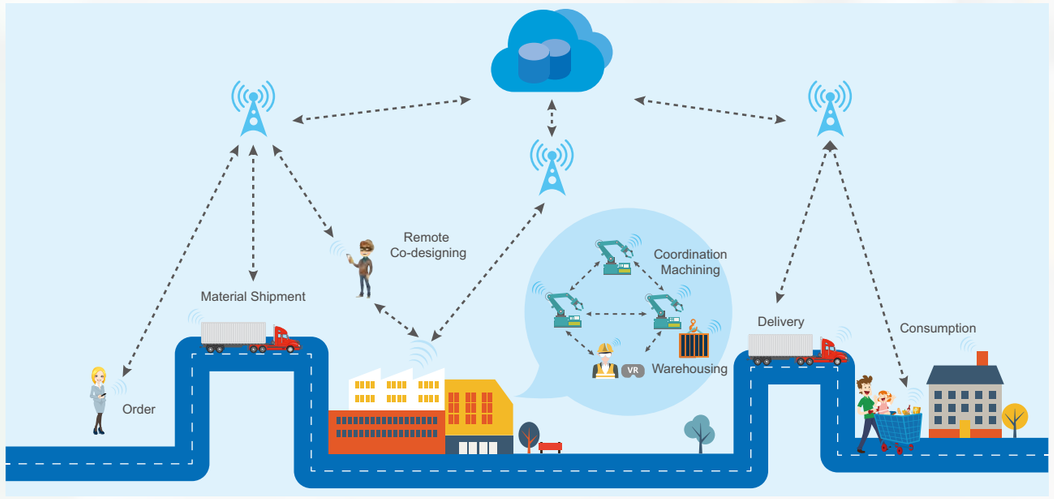


Fig 9: 5G applications of smart manufacturing

[6] http://press.pwc.com/News-releases/Industry-4.0--companies-worldwide-are-investing-over-US-900-billion-per-year-until-2020

4.3 Wireless network requirements

Employees and machines need to be connected anytime, anywhere; a requirement that can only be met by ubiquitous wireless networks. The figure above depicts the manufacturing environment, and shows where 5G would play an important role. Future factory networking requirements are particularly challenging:

- Latency – the latency requirements of future factories are likely to be very stringent. According to 5GPPP[7] motion control applications and factory automation applications can have latency requirements of 1ms to 10ms, and jitter of less than 1µs. Other applications such as transmission and non-time critical sensor data do not depend on particularly low latency.
- Speed – where video or complex industrial designs are being transmitted the bandwidth needs are likely to be of the order of many Mbit/s.
- Connection density and coverage – only 5G has the potential to provide ubiquitous coverage, and cope with the sheer number of connections that need to be maintained
- Availability and reliability – Availability and reliability will be extremely important, as factory downtime costs money. Dedicated 5G network slices designed to guarantee uptime will prevent expensive production delays.
- Security – Security of systems must be watertight. 5G infrastructures have the potential to offer managed secure slices of public infrastructure protected by experts.

Figure 10 illustrates potential networking requirements considering the full range of potential manufacturing applications.

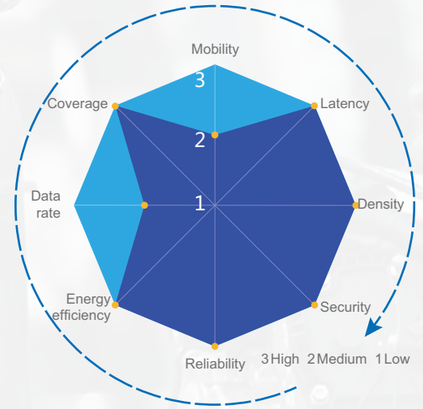


Fig 10: Wireless network requirements of smart manufacturing

4.4 5G systems have the potential to deliver global economies of scale

Standards will be critical for maximising the potential of future factories – If all smart factories are based on different technology approaches there can be no economies of scale in the components needed to build them. 5G networks have the potential to deliver **real economies of scale.**

5G can deliver when fixed networks cannot – There are many places where fixed infrastructure is not available or insufficient for inter-factory communications. This limits where factories and manufacturing operations might be deployed, or the ways they can be configured. 5G networks can solve this problem.

5G can offer certainty of technology supply – Factory investments are expected to last decades. 5G (with backward compatibility to LTE and 3G) can support manufacturing throughout that period.

[7] 5GPPP, 5G and the Factories of the Future, October 2015. https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Factories-of-the-Future-Vertical-Sector.pdf

05

mHealth: 5G can bring health to everyone

The pressures on global health systems are tremendous: growing and ageing populations mean it is becoming too expensive to continue to provide healthcare in traditional ways. Governments are responding to these trends by seeking new models of practice and new telehealth technologies that can assist in cutting costs, increasing efficiency of processes, and improving population health. Meanwhile, consumers are being offered an increasing array of commercial wireless health or wellness monitoring or tracking services.

5.1 Key drivers

Humanity is realising the potential of eHealth to increase the availability of medical services, and to reduce the cost of delivering them. According to Grand View Research's report[8], mHealth market scale will expect 49 billion dollars by 2020. Mobile devices are now being used as part of medical diagnosis or treatment all around the world. According to a survey[9] of 15,000 people in 15 countries undertaken by the Mobile Ecosystem Forum, 44% of people have seen a medical professional use a mobile device during treatment or diagnosis.

5.2 Applications

Applications as shown in Figure 11 for 5G networks in this context include:

- Telehealth services – including provision of remote diagnosis and advice via video link
- Personal health monitoring – using body area sensors to manage individuals' health, including monitoring and smart medicine administration

[8] Grand View Research, mHealth Market Analysis By Service (Monitoring Services, Diagnosis Services, Healthcare System Strengthening), By Participants (Mobile Operators, Device Vendors, Content Players, Healthcare Providers) And Segment Forecasts To 2020. August 2015 , http://www.grandviewresearch.com/industry-analysis/mhealth-market

[9] Mobile Ecosystem Forum, 2015. http://www.mobileecosystemforum.com/solutions/analytics/mef-global-mhealth-and-wearables-report-2015/

- Assisted living / home care automation – combining insights from cloud analytics with sensors and actuators in order to manage and manipulate the care setting automatically
- Asset management – using wireless technologies to track and monitor equipment
- Remote surgery – enabling surgeons to conduct operations remotely, using video feeds and robotics, and in the future using augmented reality
- Commercial wearables – devices bought by consumers to track their own health, or monitor their own activities or behaviours.

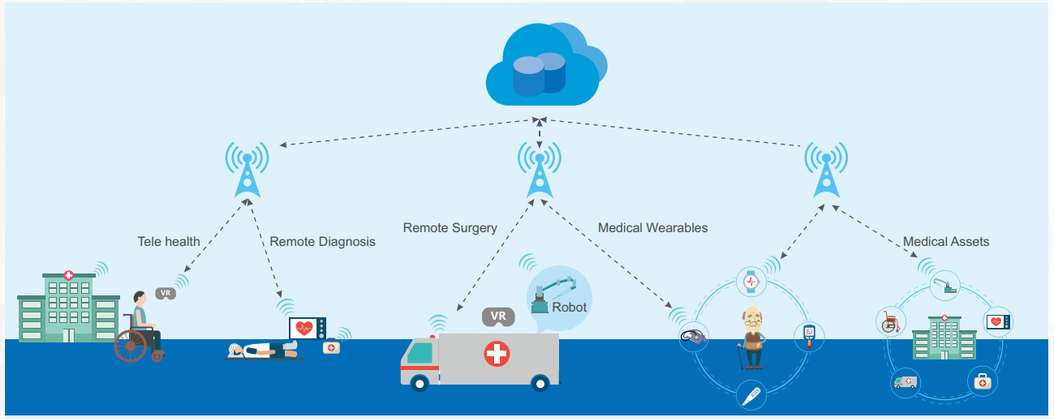


Fig 11: 5G applications of eHealth

5.3 Wireless network requirements

These solutions will all rely to some extent on the availability of wireless networking, or will be enhanced with access to 5G networks. The figure above shows how 5G networks could support e-Health service provision. Specific networking requirements depend upon the application.

- Latency – Remote surgery is very latency intolerant. According to 5GPPP[10] real-time connections will be needed between the surgeon, local sensors, robots, backend systems and other health professionals. End-to-end latency tolerances for communications between these end-points will need to be as low as 20ms.
- Speed – Remote surgery would also be very demanding in terms of bandwidth. The bandwidth requirements range from Mbps to as much as Gbps for some parts of the process.
- Coverage – Health monitoring solutions must provide 100% coverage within their targeted service area. By offering access to services with a range of frequencies, and by building mobile coverage cells around individuals, 5G can offer better coverage than other technologies.

[10] 5GPPP, 5G and e-Health, https://5g-ppp.eu/wp-content/uploads/2016/02/5G-PPP-White-Paper-on-eHealth-Vertical-Sector.pdf

- Availability and reliability – Health systems all need maximum possible availability and reliability. 5G infrastructure can offer slices of the networks with guaranteed SLAs and traffic prioritisation in emergency scenarios. 5G networks can ensure that mHealth services keep running.
- Security – Security is paramount in mHealth environments. 5G networks can offer dedicated virtual network resources designed to prevent unwanted system access.

Figure 12 illustrates potential networking requirements considering the full range of potential mHealth applications.

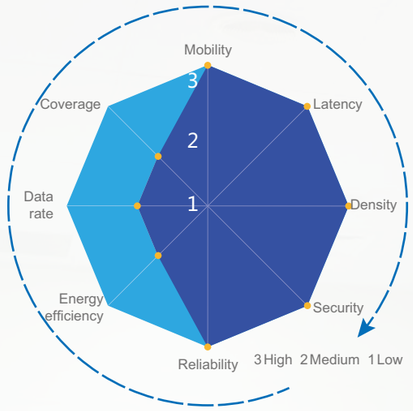


Fig 12: Wireless network requirements of eHealth

5.4 5G networks can provide a platform for healthcare innovation

The need to test and certify slows down adoption of new healthcare technologies, systems and models.

Experimentation with mHealth is happening all around the world, but is at a very early stage. The whole industry needs to work together to educate the public and government about the benefits of mHealth.

Healthcare providers expect the expertise or the resources to develop networks. They cannot rely on end-user-funded infrastructure (such as home broadband links). Publicly available 5G networks can offer the required performance and will be operating for years to come.

Crucially 5G networks can help providers to bring advanced healthcare to places that fixed networks and alternative technologies will never reach.

By working with the healthcare industry to appropriately configure 5G networks, network operators can provide the platform for ongoing experimentation, and ultimately, deployment.

5G Provides New Business Opportunities for Telecom Operators

The 5G network will drive disruptive change and transformation across all industries by bringing together wireless connectivity, mobility, IoT, cloud computing and big data. At the same time, **telecom operators have the opportunity to become the best enablers for industry applications and trustworthy business partners for industry customers; supporting them** through continuous technical innovation and industry cooperation.

Future market requirements are uncertain. To deal with this uncertainty, and to support diverse needs across industries, 5G introduces new generation technologies that improve the capabilities of mobile networks, and support flexibility of approach. These include a new generation air interface based on a new waveform, codec, multiple access technology, and large-scale antenna arrays; as well as fully cloud-based network architecture leveraging software defined network (SDN) and network functions virtualization (NFV). Different network slices can be combined and encapsulated on the network using a unified underlying physical infrastructure. Operators will be able to sell customized slices of their networks and provide professional maintenance and management for various industry applications.

With the combination of diverse innovative technologies, 5G offers a more comprehensive set of capabilities than other communication technologies. The 5G communication infrastructure will become a platform that realizes the target of **enabling multiple industries with a single network**. By taking advantage of the rapid and reliable communication capabilities of 5G networks, as well as the enormous number of connections 5G can support, 5G will enable operators to better serve customers in all industries. **Telecom operators will be able to position themselves as the 'best enablers' for industry applications**.

The development of eMBB services will accelerate the coming of the 5G era. User experience of early 5G services will set a good precedent and encourage the development of vertical industry applications. With the progress of communication technologies and in particular mobile Internet, boundaries of traditional industries will be expanded. This will provide a window of opportunity for telecom operators to become an integral part of industry developments. Using 5G infrastructure as an enabling platform, vertical industry applications will improve the productivity of the whole of society, as well as delivering growth opportunities for operators.