Benchmark
5G in China

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Overview

China is one of the first countries in the world to launch 5G. The deployment of 5G is an important growth opportunity for the Chinese economy, as well as an essential tool to drive innovation across vertical industries and market sectors as diverse as automotive, transport, logistics, energy and utilities monitoring, security, finance, healthcare, industrial automation and farming, which are all highly important for China. Therefore, telecommunication operators are creating partnerships with the broader mobile ecosystem and vertical industry players to develop new services and business models that will make intensive uses of 5G networks.

This benchmark report is part of a Global5G.org series covering 5G in China, Japan and the USA coordinated by Trust-IT. The reports are highly complementary to its focus on 5G for vertical industries across Europe and globally. GlobaThis work entails investigating market trends and forecasts as part of a Market Watch (IDC)

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Glossary of Terms

3GPP	3rd Generation Partnership Project
4G	Fourth Generation of mobile network technology
5G	Fifth Generation of mobile network technology
AI	Artificial Intelligence
AR	Augmented Reality
ASIC	Application-Specific Integrated Circuit
CAGR	Compound Annual Growth Rate
CEO	Chief Executive Officer
C-RAN	Centralized Radio Access Network
CU	University of Colorado Boulder
EPB	Electronic Parking Brake
FC	Fiber Channel
FCC	Federal Communications Commission
GBps	Gigabits per second
GDP	Gross Domestic Product
GHz	Gigahertz
IoT	Internet of Things
ITS	Institute for Telecommunication Sciences
LTE	Long-Term Evolution
M2M	Machine-to-Machine
MEC	Multi-access Edge Computing
MHz	MegaHertz
MIMO	Multiple Input, Multiple Output
mmWave	Millimetre Wave
MSOD	Measured Spectrum Occupancy Database
NFV	Network Functions Virtualization
NIST	National Institute of Standards and Technology
NL	Nonlinear
NSF	National Science Foundation
NTIA	National Telecommunications and Information Administration

ONF	Open Networking Foundation
ONRC	Open Networking Research Center
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RFIC	Radio Frequency Integrated Circuit
SASAC	State-owned Assets Supervision and Administration Commission
SDN	Software-Defined Networking
TMT	Technology, media and telecoms
URLLC	Ultra-reliable low latency communications
USCIB	United States Council for International Business
VR	Virtual Reality
WTO	World Trade Organisation

Executive Summary

5G is the next telecommunication generation, the fifth generation. It succeeds 4G systems and is expected to meet the societal needs such as enhanced connectivity and growing data rates. 5G should be faster (10 times faster than 4G), enable low latency and high reliability communications (URLLC), connecting more people, devices and objects (such as IoT devices), and be more cost-effective. Major innovations are expected to come from vertical industries, from automotive and transport to health and energy. The key element of 5G technology is the use of high frequencies in spectrum which is more powerful but has less reach then previous telecommunication generations (4G, 3G). Therefore, a large number of cellular sites have to be implemented[1].

5G rollouts are already taking place in several countries: Estonia, Finland, Germany, Italy, Spain, United Kingdom, Switzerland, South Korea, Bahrein, Qatar, Kuwait, Lesotho, the United Arab Emirates, the US and Australia. All major world economies are aiming for an early and widespread implementation of 5G in their country, sometimes on a competitive basis, sometimes through collaboration. Diverse strategies underpin these 5G rollouts, with some focusing on large amounts of spectrum, and while others are aiming for extensive usage in a variety of applications.

In China, a trial network of 350,000 cell sites were built in 2018 and are continuing to expand in 2019. With investments of USD 400 billion, China is forecast to be the largest 5G market with 430 million users by 2025[2].

The Global5G.org project (July 2017-December 2019) focuses its efforts on vertical industries 5G standardisation across Europe and globally. Its wide-ranging analysis looks at dedicated to international technology advances in 5G, with a focus on standardization, regulations, market verticals and identification of existing gaps in technology. Whilst the project particularly supports the implementation of EU-supported 5G projects and their collaboration and outreach, it also looks at international initiatives: as seen above, the 5G development is a global one. In addition to the Global5G Mapping Tool released on the project's website, Benchmarks are undertaken on the 5G Network in selected countries in order to compare their strategies and implementation modes to those in the EU. In this context, the information gathered in this benchmark is relevant for the project because it allows the identification of some good practices and important information related to the 5G implementation in China. More specifically, this analysis allows you to:

› Identify the potential benefits and advantages the implementation of 5G will enable in the next years;

› Understand how the development process of this technology is defined in a country like China;

› Have an overview of the 5G's driving forces (trends, public authorities, industrial players and Universities) in China;

› Identify the verticals prioritized by China and which applications of the 5G they foresee;

› Understand the link between vertical industries, standardisation and research in an important country as China;

› Understand how the 5G's implementation is enabled, which are the key actors of this implementations and what is their strategy;

› Understand the potential challenges of this technology's development and implementation;

› Identify which aspects could potentially be applicable in Europe.

Introduction

From the 1G to the now widely used 4G and the debut of 5G, a lot has changed, notably in the way people work, live and play. The following figure gives an overview of the shifts and changes across the various generations.

1G	2G	3G	4G
Analog *Voice capability, limited coverage and mobility*	**Digital** *Better voice, improved coverage, text messaging*	**Mobile Data** *Basic internet, multimedia*	**Mobile Broadband** *High-speed data, smartphones*
2 kbps	64 kbps	2 Mbps	1 Gbps
AMPS	GSM, CDMA	HSPA, EVDO	LTE, LTE-A

5G *Extreme Speed, Connectivity & Reliability*

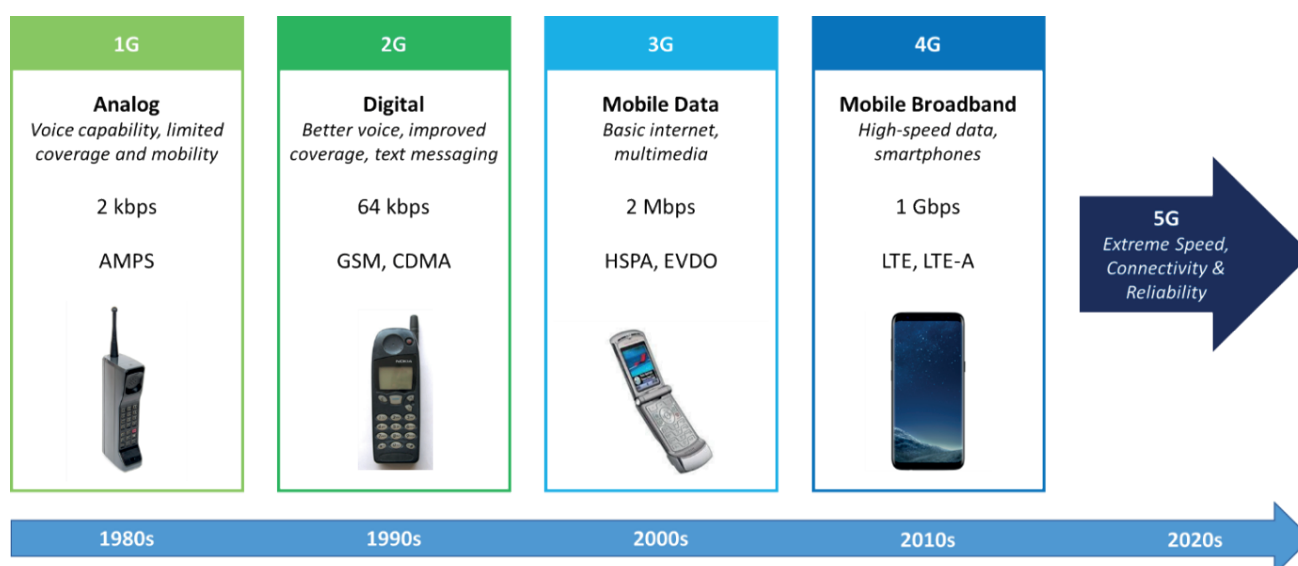| 1980s	1990s	2000s	2010s	2020s

Figure 1: Evolution and key developments in cellular technology from 1G to 5G

With the arrival of 3G came the possibility to use basic mobile Internet service. Further mobile equipment improvements capitalized this Internet service and text messages (through phone displays of higher quality, advanced chipsets, digital cameras integration). 4G has capitalized on smartphones and increased consequently the data speeds. Moreover, it enabled the development of a mobile broadband service which is capable of delivering streaming video and multimedia experiences.

Post 4G, a new area is about to arrive: the 5G Network. The ambition of the future 5G Networks is to increase usage, speed and services of telecommunication whilst reducing energy consumption. 5G should allow:

› 1,000 times more capacities

› 10 to 100 times more connected objects

› 5 times more responsiveness

› 90% energy savings

› Everywhere the same efficiency[3]

Countries are at different levels of development regarding the 5G. Europe plans on deploying 5G by 2022 whereas China, the US, Japan and Korea are planning on deploying it this year, 2019.

This document describes in the first part the 5G market in China followed by an analysis of the Chinese market environment through a PESTEL analysis. The third part describes the Chinese market trends using 5G and the projected increase through the nationalisation of 5G use. The driving forces behind 5G in China is explained in the fourth part and includes initiatives from the public authorities and the industry that offers to the 5G a favourable environment for development. The fifth part focusses on the 5G implementation strategy followed by the Chinese key telecommunication providers. The challenges caused by the 5G implementation are then discussed in the sixth part. Finally, the conclusion identifies differences between 5G in China and 5G in the EU. Good practices are presented throughout the whole document.

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3   5G PPP Video: https://youtu.be/bfNmiYtG9Cg (accessed 19/08/2019)

The 5G market in China

During the past decade, as the largest developing country in the world[4], China has experienced a remarkable transformation and growth in its telecommunication industry. Indeed, today the Chinese telecommunication market is the largest in the world in terms of subscribers[5] as illustrated in the figure below. More than two thirds (69%) of mobile connections in China are made by smartphones, with smartphone adoption expected to reach 88% of the connections by 2025[6].

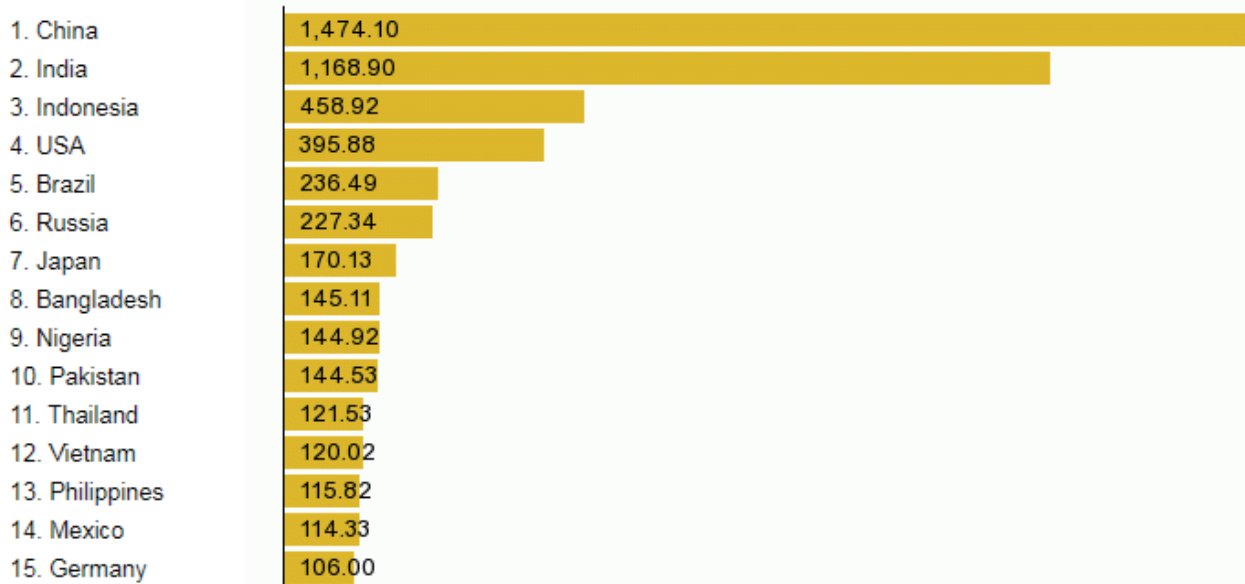|	
1. China	1,474.10
2. India	1,168.90
3. Indonesia	458.92
4. USA	395.88
5. Brazil	236.49
6. Russia	227.34
7. Japan	170.13
8. Bangladesh	145.11
9. Nigeria	144.92
10. Pakistan	144.53
11. Thailand	121.53
12. Vietnam	120.02
13. Philippines	115.82
14. Mexico	114.33
15. Germany	106.00

Figure 2: Mobile phone subscribers in million in 2017 (Source: The International Telecommunication Union, TheGlobalEconomy.com)

China's mobile ecosystem added 670 billion euros in value to the country's economy in 2018, equivalent to 5.5% of China's GDP in 2018. This ecosystem directly and indirectly supported 8.5 million jobs in 2018 and made a tax contribution to the public finances of government of 75 billion euros[7].

In regard to 5G, the country has made it a top priority to lead wireless technology developments[8] striving to take a leadership role in the global landscape. The country's ambition is to be one of the main players participating in the development of the international 5G standard[9] and to make the Chinese tech companies become the next innovative global giant like Apple or Microsoft, after spending years of producing copycat products[10].

Therefore, the country has implemented some key elements to provide a favourable environment for the development of 5G, notably:

› The Nation's 5G capital expenditure is expected to hit 193 billion euros between 2019 and 2025;

› Proactive government support and big-

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4   https://www.encyclopedia.com/international/applied-and-social-sciences-magazines/chinas-telecommunications-industry-transformation-and-challenges (accessed 19/08/2019).

5   https://www.budde.com.au/Research/China-Telecoms-Infrastructure-Operators-Regulations-Statistics-and-Analyses (accessed 19/08/2019).

6   https://www.rcrwireless.com/20190320/5g/telecom-sector-represens-china-gdp-2018-gsma-says (accessed 19/08/2019).

7   https://www.rcrwireless.com/20190320/5g/telecom-sector-represens-china-gdp-2018-gsma-says (accessed 19/08/2019).

8   https://www.technologyreview.com/s/612617/china-is-racing-ahead-in-5g-heres-what-it-means/ (accessed 19/08/2019).

9   http://www.chinadaily.com.cn/a/201811/08/WS5be37c24a310eff303287440.html (accessed 19/08/2019).

10   https://www.technologyreview.com/s/612617/china-is-racing-ahead-in-5g-heres-what-it-means/ (accessed 19/08/2019).

ticket investments have helped shape a self-sustainable 5G environment in China;

› The country plans on being among the first batch of countries to issue 5G licenses in the world. China will issue 5G licenses in the second half of 2019 and the first half of 2020;

› Frequency bands have been distributed to Chinese telecommunication providers already in 2018 which accelerated the construction of the 5G network[11]

The Chinese government has been very pro-active in the deployment of 5G for the several years. Indeed, the government controls all three major mobile operators in the country – China Mobile, China Telecom and China Unicom – and has been encouraging them to focus on 5G and to deploy large-scale 5G test networks in several big Chinese cities. Moreover, under the government direction, Chinese companies began conducting research on 5G already in 2013 and holding technical trials of related technologies already in 2016.

11   http://www.chinadaily.com.cn/a/201811/08/WS5be37c24a310eff303287440.html (accessed 19/08/2019).

The planned deployment strategy of 5G in China

Unlike in USA, where telecommunication operators are planning to deploy 5G on a non-standalone architecture (4G and 5G radio access technologies work in tandem) in the first part of the 5G implementation, Chinese telecommunication operators are planning on adopting a standalone architecture (5G radio access technology only) from the beginning despite the costs to build a 5G base station being at least 1.5 times higher than the costs for a 4G base station12. Admittedly, a non-standalone infrastructure offers a quicker route to market but a standalone infrastructure offers large economies and high performance, as well as less complexity from legacy LTE integration13. A standalone architecture includes the new building of a network with new base stations, backhaul links and core network.

Through proactive government support and industrial capital investments, China is shaping a self-sustained 5G environment. China is one of the pioneers in 5G R&D and is the world's first country to test 5G, being guided and planned by the Government. The aim being to get pre-commercial 5G products ready by mid-2018, the country has followed the timetable illustrated below.
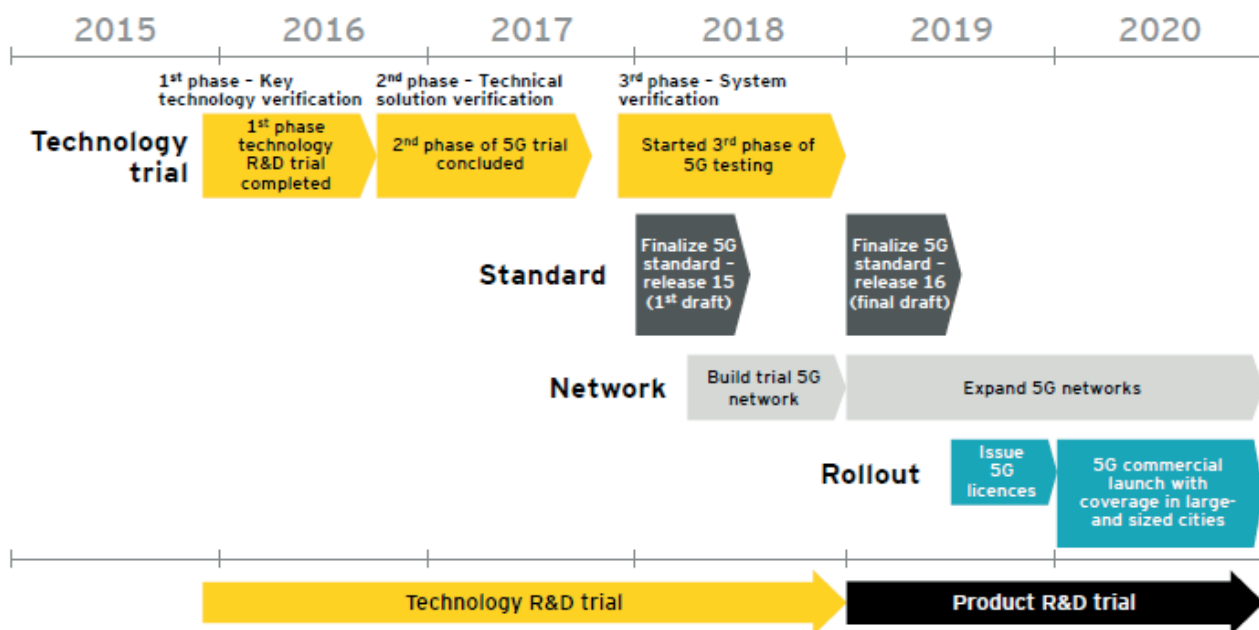
Source: MIIT, SCMP, China Daily

Figure 3: Timetable for China's 5G development (Source: Ernst and Young)

Market size and growth

Worldwide, 5G is expected to represent a rapidly growing market share. According to Statista, the worldwide market share of 5G is expected to be of 14% in 2025, whereas 4G will have a market share of 53%, 3G of 29% and 2G of 4%14. The following figure is illustrating the fast evolution of the mobile telecommunication technologies worldwide.

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12 http://www.chinadaily.com.cn/a/201811/08/WS5be37c24a310eff303287440.html (accessed 19/08/2019).

13 https://www.gsmaintelligence.com/research/?file=67a750f6114580b86045a6a0f9587ea0&download (accessed 19/08/2019).

14   https://www.statista.com/statistics/740442/worldwide-share-of-mobile-telecommunication-technology.com (accessed 19/08/2019).
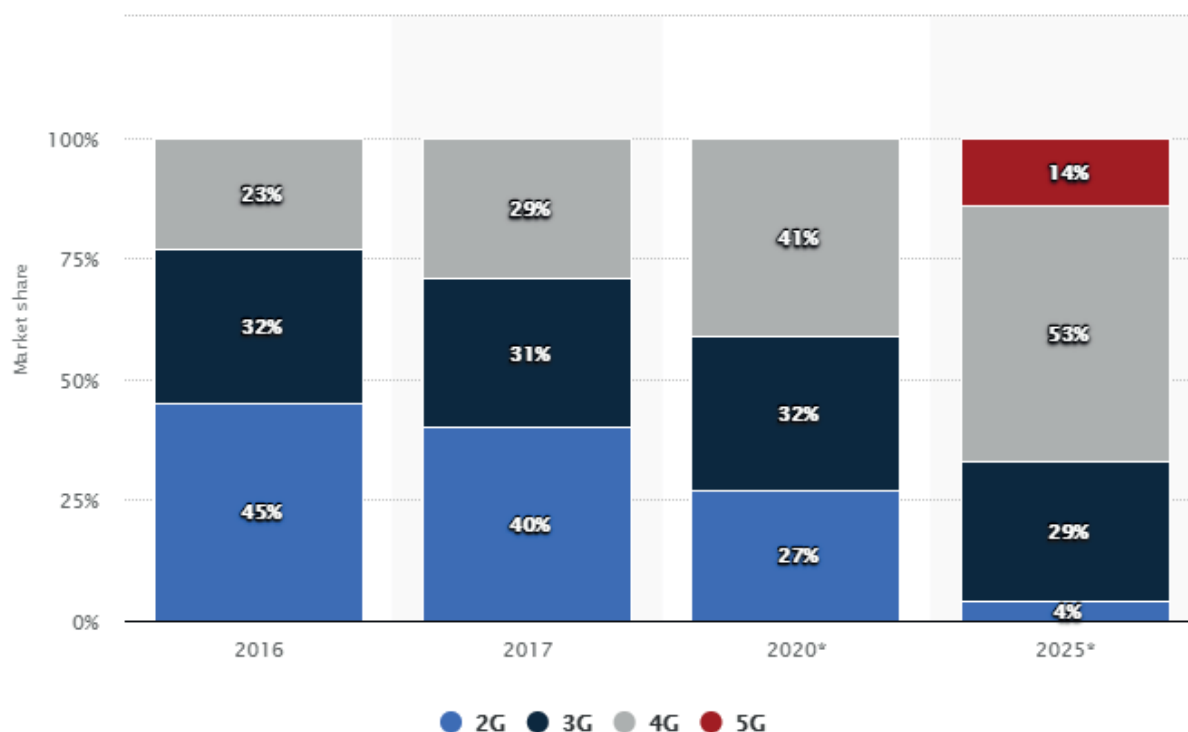
Figure 4: Market share of mobile telecommunication technologies worldwide from 2016 to 2025 by generation

In China, the percentage of 5G connections among the total number of connections by 2025 is expected to surpass these percentages. Indeed, it is expected that 5G connections by 2025 will account for 28% of China's total connections15 (taking into account consumer connections). In comparison with other countries also in the race for being the first countries to implement 5G on a large-scale, this rate remains low (as illustrated in the figure below) because of several reasons16:

› LTE advanced speeds are high enough to blur the difference with 5G for all but the ultra-low latency services which makes 5G less of a necessity;

› There are a lot more potential 5G customers in Korea and Japan since most of the population live in cities whereas in China the population is dispersed.

15   https://www.rcrwireless.com/20190320/5g/telecom-sector-represens-china-gdp-2018-gsma-says (accessed 19/08/2019).

16   https://www.gsmaintelligence.com/research/?file=077db5d3e96e47d392f6f48c808be526&download (accessed 19/08/2019).
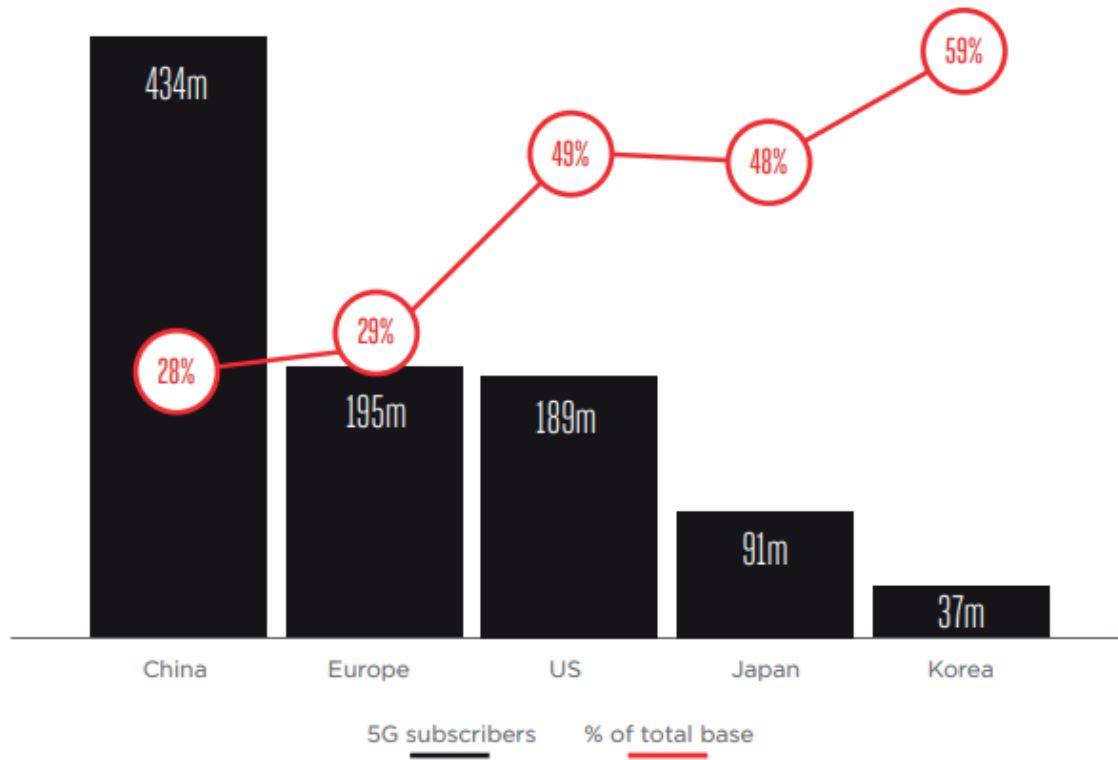
Figure 5: Projected 5G share of the total mobile subscriber base in 2025 (Source: GSMA)

According to the GSMA forecasts in its report on 5G in China[17] 5G is expected to roll out slower than 4G since the 4G rollout was very aggressive and serving a demand for high-speed mobile data services. Nevertheless, the number of 5G connections is expected to reach 428 million by 2025. The following figure illustrates the expected number of 5G connections in the coming years.
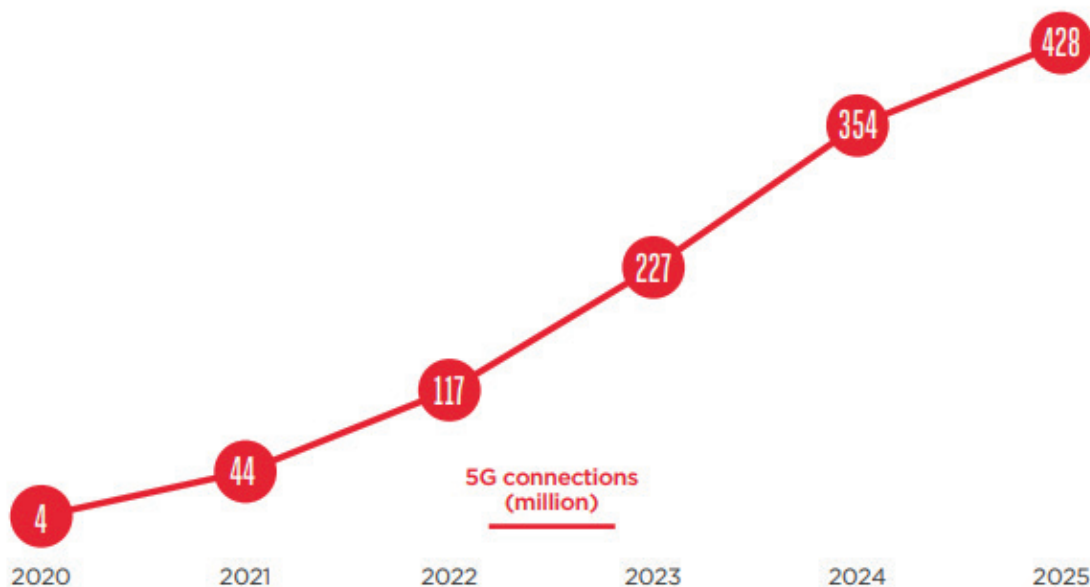

Figure 6: Forecast of the number of 5G connections (Source: GSMA)

17 https://www.gsmaintelligence.com/research/?file=67a750f6114580b86045a6a0f9587ea0&download (accessed 19/08/2019).

Moreover, the 5G adoption by users is expected to be slower than it was with 4G. It was due to the transfer of subsidies from 3G to 4G and the wide availability of 4G devices that increased the 4G adoption (as illustrated in the following figure).
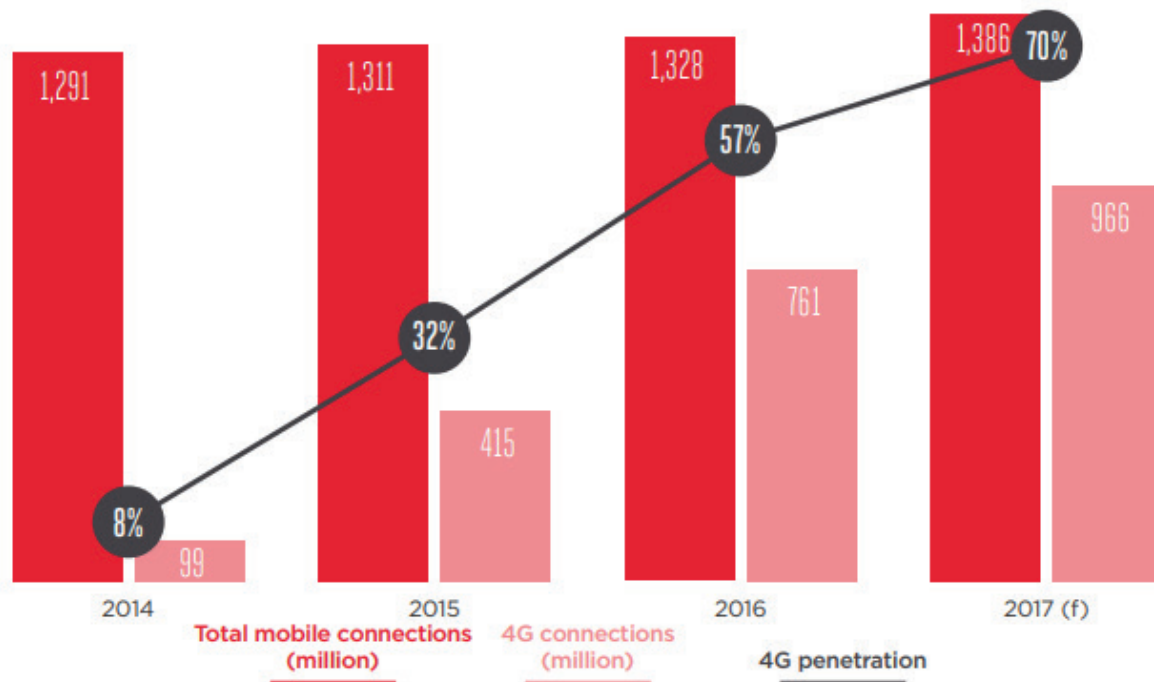

Figure 7: 4G evolution in China (Source: GSMA)

On the contrary, early 5G networks will be deployed principally as hot-spot technology to supplement the current networks. Moreover, China is an early launch market and it will initially face a less mature device ecosystem than was the case when 4G was launched. The price of 5G devices is also expected to decrease slower than it was the case for 4G given the hardware requirements to support 5G speeds[18].

China is expected to have 576 million 5G users by 2025, over 40 percent of global consumption[19]. The Nation's 5G capital expenditure is expected to hit 193 billion euros between 2019 and 2025[20]. According to the China Academy of Information and Communications Technology (CAICT), 5G will create more than 8 million jobs domestically by 2023 and major industries, including energy and health care, will spend billions of dollars collectively on 5G equipment and wireless service during that period[21].

18 https://www.gsmaintelligence.com/research/?file=67a750f6114580b86045a6a0f9587ea0&download (accessed 19/08/2019).

19 http://www.chinadaily.com.cn/a/201811/08/WS5be37c24a310eff303287440.html (accessed 19/08/2019).

20 http://www.chinadaily.com.cn/a/201811/08/WS5be37c24a310eff303287440.html (accessed 19/08/2019).

21 https://www.technologyreview.com/s/612617/china-is-racing-ahead-in-5g-heres-what-it-means/ (accessed 19/08/2019).

PESTEL Analysis

A PESTEL analysis allows you to identify the environment in which the 5G research and deployment in China are evolving. The analysis includes the description of the political, economic, social, technological, environmental and legal aspects.

Political

To understand the current specificities of the telecommunication market in China, a brief history of this market is necessary.

In 1949, when the People's Republic of China was founded, its Ministry of Posts and Telecommunications controlled the public telecommunications and post sector, with the State Council at the highest level, thus combining the functions of a public operator with that of a regulator. The Directorate General of Telecommunications, a department of the Ministry of Posts and Telecommunications, was responsible for the operations of public telecommunications[22].

Before the macro-reforms of 1976, revenue from telecommunications operations was turned over to the central government and the industry received a set percentage of the budget for development. With the end of the reign of Mao Zedong in 1976, China's reformers placed economic development at the top of the new regime's agenda and realized the importance of telecommunications in this development. Therefore, the government listed posts and telecommunications as a preferential construction item and allowed the industry to use funds derived from its operations at national, local and collective levels to supplement its development. In addition, the government adopted a set of favourable policies toward telecommunications. In 1979, the State Council allowed the Ministry of Posts and Telecommunications to adopt the policy concerning the collection of initial installation fees for telephones and three years late decided to adopt the "Three Revers 90 percent Policies". This included that local postal and telecommunications branches could retain 90% of their profits, keep 90% of their foreign exchange earnings and be exempted from repaying 90% of their state loans. In 1986, a tax refund policy for telecommunications equipment imports was approved by the State Council. All these measures allowed the Ministry of Posts and Telecommunications to raise enough funds to develop public telecommunications[23].

Since 1995, the public became dissatisfied with the telecommunications sector mainly because of the high prices and the low quality of its services. This is when competition into China's telecommunications market was established, notably through two operators: China Jitong, focusing on Internet services, and China Unicom, focusing on fixed telephone services and mobile telephone services. China Unicom was established in July 1994 as a joint venture with stakeholders from the Ministry of Electronic Industry, the Ministry of Railway, the Ministry of Electrical Power and 13 other corporations. China Jitong was established as a corporation in June 1993, with one aim of seeking joint ventures with overseas companies. Stakeholders include China International Trust and Investment Corporation and 30 other state-owned enterprises and research institutes[24].

Moreover, in the same year, the Directorate General of Telecommunications was changed from a functional department of the Ministry of

22 https://www.encyclopedia.com/international/applied-and-social-sciences-magazines/chinas-telecommunications-industry-transformation-and-challenges (accessed 19/08/2019).

23 https://www.encyclopedia.com/international/applied-and-social-sciences-magazines/chinas-telecommunications-industry-transformation-and-challenges (accessed 19/08/2019).

24 https://www.hindawi.com/journals/misy/2017/2358618/ (accessed 19/08/2019).

Posts and Telecommunications to an enterprise responsible for operating and managing the Ministry of Posts and Telecommunications' fixed and mobile telephone networks, named China Telecom[25].

In 2000, the China Telecom's services were divided into four activities, thus ending the initial monopoly. These four activities were ran by different companies: China Unicom was responsible for paging services, China Telecom was responsible for fixed lines, China Mobile for mobile services and China Satellite for satellite services[26].

In 2001, China entered the WTO which provided significant opportunities for China's telecommunications development. Notably, in terms of national services, they were widely improved through the introduction of competition in an open market. In March 2003, China's State-owned Assets Supervision and Administration Commission (SASAC) was established. It accelerated the change of management and development of the state-owned China Telecom. Since then, ownership, manufacturing rights and management were separated from each other. This is why the development of China's telecommunications was better regulated[27].

Since 2013, the Chinese telecommunication market has developed from 1G to 5G and is now driven by the government agencies, the operators or manufacturers, as well as by users.

For example, customers request very high speed and uninterrupted usage scenarios. Nevertheless, the Chinese government still has a strong hold on the industry through its strong position in the regulatory systems[28].

Today, the political climate in China is pushing forward the country's digitisation journey and has made the 5G deployment a top priority in the country. The state is also investing in a range of emerging technology industries such as Artificial Intelligence, robotics, autonomous cars, etc[29]. Indeed, the Chinese government has launched supporting policies under its national strategy:

› Made in China 2025: launched in 2013, which supports industry R&D and strives for 5G commercialization in 2020;

› 13th Five-Year Plan (2016-2020): decided upon in 2015, which has the same goals as the Made in China 2025 Initiative;

› National 863 Program (2014-2015) and the National Science and Technology Major Project (2015-2017): which describes how National major projects aimed to promote 5G key technologies development as well as aim at verifying and improving 5G technical schemes and which supports the global unified 5G standardization.

These initiatives will further be described in the section 5.1. Public initiatives.

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25 https://www.encyclopedia.com/international/applied-and-social-sciences-magazines/chinas-telecommunications-industry-transformation-and-challenges (accessed 19/08/2019).

26 https://www.hindawi.com/journals/misy/2017/2358618/ (accessed 19/08/2019).

27 https://www.hindawi.com/journals/misy/2017/2358618/ (accessed 19/08/2019).

28 https://www.hindawi.com/journals/misy/2017/2358618/ (accessed 19/08/2019).

29 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019).

Economic

As illustrated in the following figure, China is second largest economy in the world and has the second largest gross domestic product (GDP) growth[30]. China's economy accounts for almost a fifth of the global GDP[31].
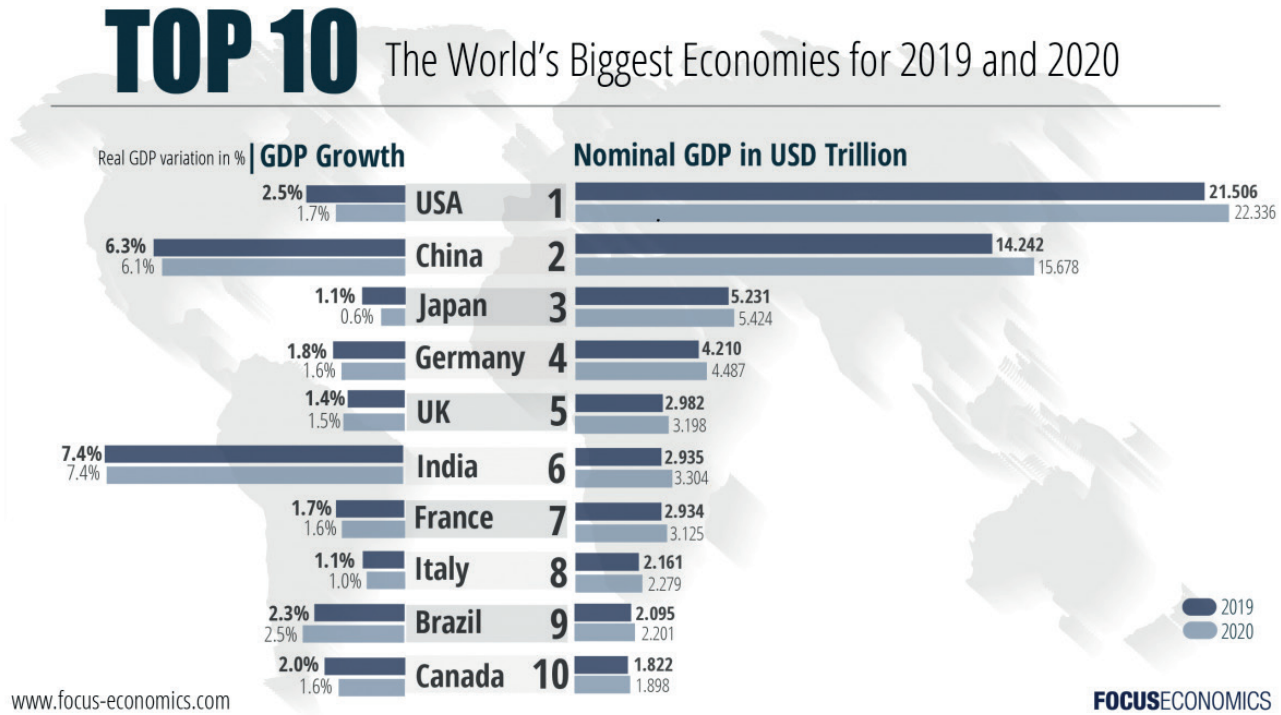
Figure 8: The 10 world's largest economies for 2019 and 2020 (Source: FocusEconomics)

Since the late 1970s, government policies and market forces have allowed the Chinese economy to expand massively and rapidly, notably in the steel, automotive and telecom industries. Today, the Chinese digitization strategy is supported by a broad and diverse mobile ecosystem in the country and has an important impact on consumers, businesses and wider society[32].

With more than 1.6 billion subscribers in 2018, China is the largest mobile market[33]. Particularly notable is the high rate of growth in mobile Internet penetration which reached 58% in the late 2018 – three times higher than 10 years before. As a consequence, China's growing middle class are purchasing more and more goods online which increases the already important e-commerce market. Moreover, there are many millions of tech-savvy consumers who are keen adopters of social media and users of a variety of apps, placing greater demands on operators for improved network performance[34].

However, and as noted in the EXCITING white paper on Future Internet policy[35], the Chinese economy, previously export-dependent is now more tied to domestic consumption. That's a drastic change as China's growth, which has been driven by shifting workers from agriculture

30 https://www.fa-mag.com/news/the-world-s-biggest-economies-in-2018-39645.html (accessed 19/08/2019).
31 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019).
32 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019).
33 https://www.theglobaleconomy.com/China/. (accessed 19:08/2019).
34 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019).
35 https://static.martel-consulting.ch/wp-content/uploads/sites/27/2019/03/EXCITING-Future-Internet-policy-white-paper-2019.03.19.pdf (accessed 5/11/2019).

to manufacturing is now approaching the Lewis Turning point[36] (when such shifts no longer raise overall productivity). In such situation, the government made a concerted effort to foster science research and innovation to provide another vector for growth[37].

The economic environment in China is favourable for the development of 5G. Therefore, the number of 5G subscribers is expected to reach 434 million representing 65% of the population in 2025 with a penetration rate of 28%[38].
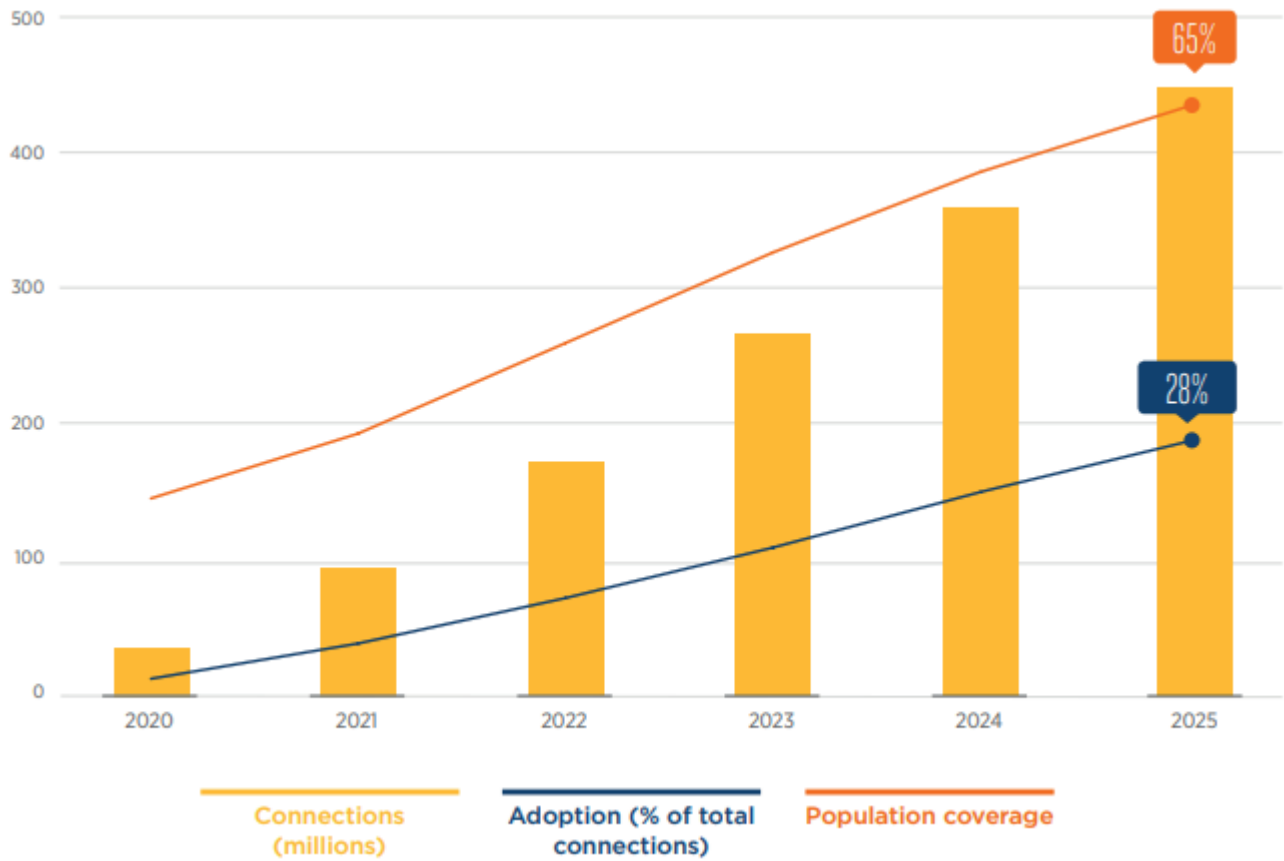

Figure 9: 5G forecast in China (Source: GSMA)

The shift from one telecommunication generation to the next one, including 5G, is expected to be fast with a complete replacement of 2G and 3G by 4G and 5G by 2024 (as illustrated in the figure below)[39.]

36 https://en.wikipedia.org/wiki/Lewis_turning_point.

37 https://www.bloomberg.com/opinion/articles/2018-09-12/chinese-researchers-are-outperforming-americans-in-science (accessed 5/11/2019).

38 https://www.gsmaintelligence.com/research/?file=67a750f6114580b86045a6a0f9587ea0&download (accessed 19/08/2019).

39 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019).
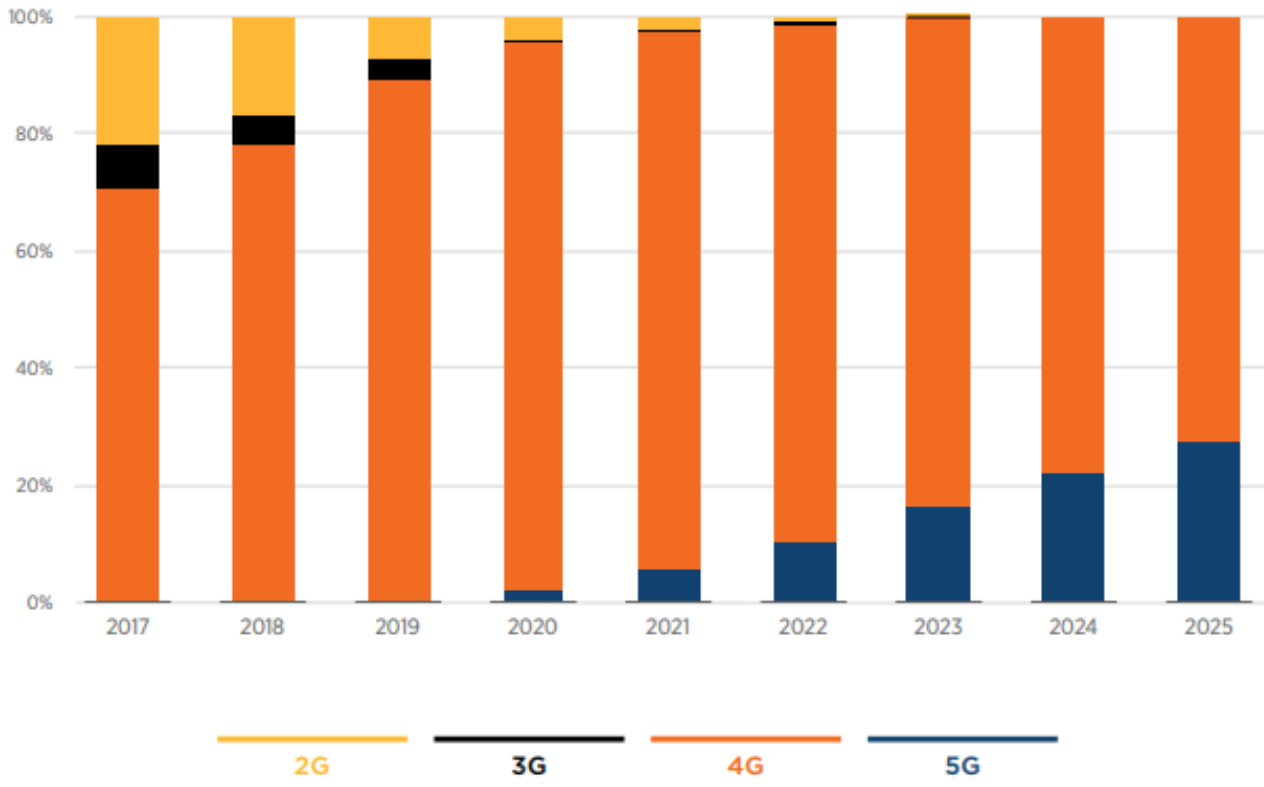
Figure 10: Connections by telecommunication generation in China (Source: GSMA)

Social

In China, the increasing smartphone adoption and the wide availability of 4G has led to a surge in mobile Internet use, supporting the country's movement up the digital society value chain. According to Statistica, the number of mobile Internet users is expected to grow by 4% between 2018 and 2019 is expected to reach 904.2 million by 2023 (corresponding to a growth of 19% between 2018 and 2023)[40.]
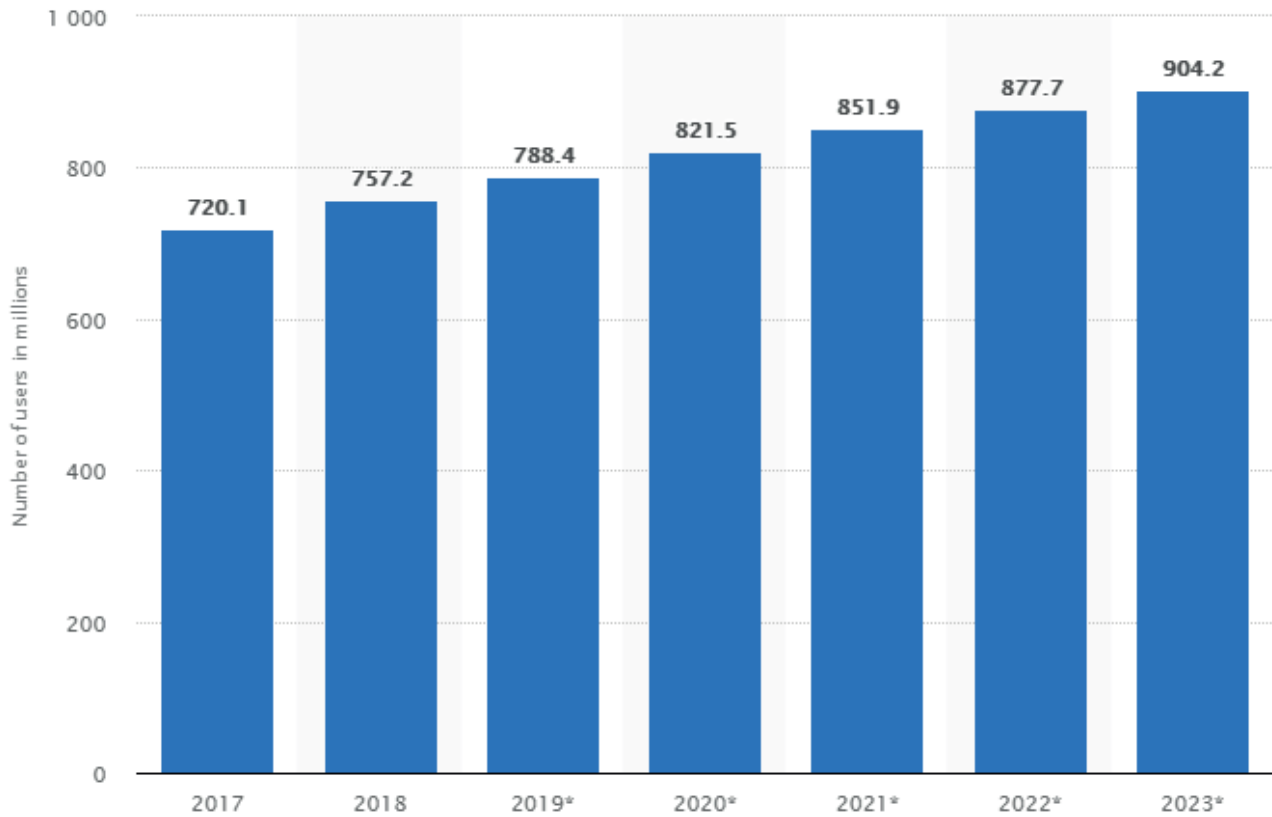

Figure 11: Number of mobile Internet users in China (Source: Statistica)

According to the forecasts by Cisco[41,] Internet traffic in China will reach 23.3 Exabytes per month in 2020, up from 7.3 Exabytes per month in 2015 which represents a growth of 219%. On a daily basis, this represents an Internet traffic of 765 Petabytes per day in 2020, up from 240 Petabytes per day in 2015. Internet Video represents already a large share of Internet traffic and this share is expected to increase by next year: total Internet video traffic (business and consumer) will represent 84% of all Internet traffic in 2020, up from 72% in 2015.

The Chinese population spends a large amount of time on the Internet, according to the World Atlas[42,] Chinese people spend, on average, 13.5 hours per month on the Internet which ranks China 10th in the list of countries who spend the greatest amount of time online. How Chinese people access the Internet has evolved these past few years towards a mobile driven Internet use. In 2014, 50% of time spend on the Internet was done through the mobile whereas in 2018 it reached 70.5% clearly making the mobile the favourite device to access and spend time on the Internet. This share is expected to steadily grow in the next years, reaching 76% in 2020 (as illustrated in the following figure)[43.]

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40 https://www.statista.com/statistics/558731/number-of-mobile-internet-user-in-china/ (accessed 19/08/2019).

41 https://www.cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast-highlights/pdf/China_2020_Forecast_ Highlights.pdf (accessed 19/08/2019).

42 https://www.worldatlas.com/articles/top-countries-which-spend-the-greatest-amount-of-time-online.html (accessed 19/08/2019).

43 https://www.chinainternetwatch.com/24439/media-time-spend-2018/ (accessed 19/08/2019).

CIW

Share of Average Time Spent Per Day with Internet by Adults in China by Device (% of total)

■ Mobile   ■ Desktop/laptop   ■ Other

Year	Other	Desktop/laptop	Mobile
2014	6.5%	43.5%	50.0%
2015	7.2%	37.8%	55.0%
2016	8.7%	30.8%	60.5%
2017	8.7%	25.3%	66.0%
2018	8.7%	20.8%	70.5%
2019	8.7%	17.7%	73.6%
2020	8.8%	15.2%	76.0%
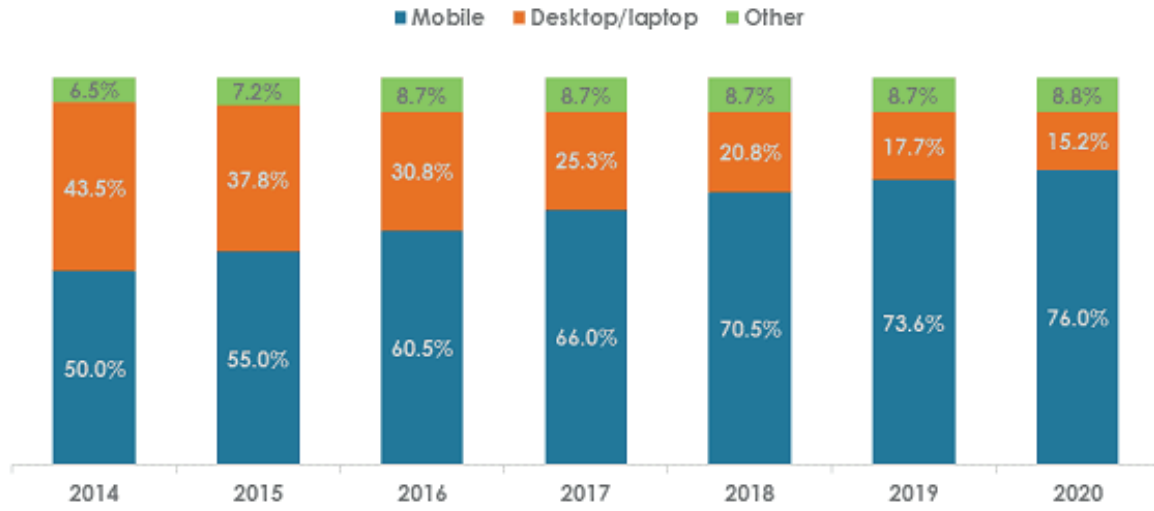
China Internet Watch

Source: eMarketer, Apr 2018

Figure 12: Internet use by devices in China (Source: eMarketer)

Technological

As the Wall Street Journal44 cited "China's technology sector is reaching a critical mass of expertise, talent and financial firepower that could realign the power structure of the global technology industry in the years ahead." The article also quoted a partner at PricewaterhouseCoopers saying, "Traditionally, Chinese companies were fast followers, but we are starting to see true innovation...".

Statistics from the OEC[45] shows that R&D spending as a share of GDP has largely increased in China, from 0.89% in 2000 and reaching 2.13% in 2016. This can explain this important change cited in the Wall Street Journal.
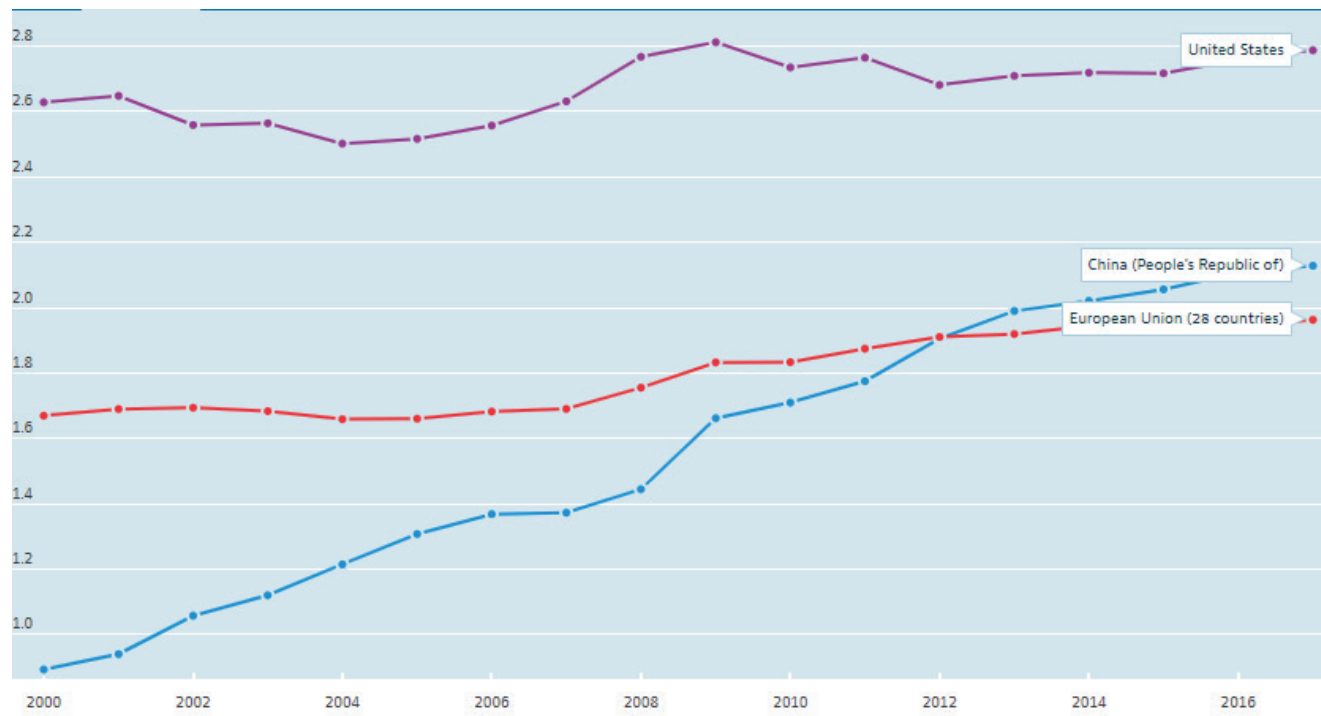

Figure 13: Gross domestic spending on R&D in China (Source: OECD)

Moreover, government initiatives like the 13th five-year plan and the "Made in China 2025" plan have been initiated to catch up in strategic and selected industries. These initiatives are supported by an unprecedent amount of fiscal and financial resources, generating sufficient funds to be channelled toward expanding R&D, hiring overseas Chinese experts as well as foreign experts, importing high-tech capital goods, acquiring foreign technological patents and licenses, and merging with or buying out foreign high-tech companies (especially by state-owned Chinese corporations[46].

44 https://www.wsj.com/articles/the-rise-of-china8217s-innovation-machine-1389900484 (accessed 19/08/2019).

45 https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm (accessed 19/08/2019).

46 https://thediplomat.com/2018/08/understanding-chinas-technological-rise/ (accessed 19/08/2019)

Environmental

The growing population and rapid industrialisation of China has had a disastrous impact on the environment and resources in the country, leading to a serious environmental crisis. China is the world's largest source of carbon emission[47], and the air quality of many of its major cities fails to meet international health standards. More than 50% of China's surface water is not fit for human consumption, and approximately 60% of the groundwater under Chinese cities is considered to be "severely polluted"[48]. This is caused by the large industrial base, the millions of motor vehicles and most of all by the country's numerous coal-fired power plants. China is responsible for 47% of the world's coal burning, which is more than all other countries in the world combined[49].

China's ruling Communist party has admitted that regulatory steps need to be taken to resolve the country's numerous environmental issues. One of the first solutions proposed was in 2013, a regulatory roadmap released by China's economic planning agency, the Air Pollution Action Plan. Since then 15,000 factories are required to publicly report real time data regarding their air emissions and water release. The Chinese government also pledged USD275 billion over the next five years toward cleaning up the country's air pollution[50].

In 2018, a new version of the Air Pollution Action Plan was released, the 2018-2020 Three Year Action Plan for Winning the Blue Sky War. Unlike the previous plan which only applied to specific cities, this plan focused on reducing the emissions of volatile organic compounds and nitrogen oxides by 10% and 15% respectively by 2020. This new plan includes the following measures[51]:

› Strengthen end-of-pipe treatment;
› Improve transition in energy, industry and transportation;
› Cleaner heating furnaces;
› Tackle small-scale coal burning;
› Improve district heating in northern industrial cities.

Recent investments into China's research and development of clean technology has been much larger compared to similar investments that have been made in both the United States and the European Union. The Chinese government has been embracing clean technologies more and more in recent years[52]. The energy savings enabled through the introduction of 5G in various verticals as for example in Smart Cities can be therefore interesting for the Chinese government.

Legal

The regulatory system in China includes the Ministry of Information Industry, the Ministry of Science and Technology, the Science and technology commission of the Beijing municipal government, the State Administration of Radio, Film and Television and the State-owned Assets Supervision and Administration Commission of the state council. The Chinese government has a strong system to supervise and operate the industry in every aspect, including intellectual property rights protection, innovation encouragement and asset value management[53].

As the 5G deployment is a priority for the Chinese government, it is taking the necessary legal actions in order to pave the way for 5G. For example, spectrum is an enabler for growth and

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47 https://www.visualcapitalist.com/all-the-worlds-carbon-emissions-in-one-chart/ (accessed 19/08/2019)
48 https://www.economist.com/analects/2013/03/12/a-bay-of-pigs-moment (accessed 19/08/2019)
49 https://www.nytimes.com/2013/01/31/world/asia/beijing-takes-emergency-steps-to-fight-smog.html?ref=environment (accessed 19/08/2019)
50 https://www.azocleantech.com/article.aspx?ArticleID=546 (accessed 19/08/2019)
51 https://www.azocleantech.com/article.aspx?ArticleID=546 (accessed 19/08/2019)
52 https://www.azocleantech.com/article.aspx?ArticleID=546(accessed 19/08/2019)
53 https://www.hindawi.com/journals/misy/2017/2358618/ (accessed 19/08/2019)

competitiveness in the digital age: assigning the right frequencies, at the right time and under the right conditions is a prerequisite for enabling the investments needed to deliver 5G and the next wave of mobile innovation for Chinese citizens and businesses. Both the government and the Ministry of Industry and Information Technology recognise the need to ensure the timely release of spectrum and promote its efficient use. Indeed, the Ministry of Industry and Information Technology has issued test licences for 5G trials in the 2.6, 3.5 and 4.9 GHz bands, signalling its commitment to support pre-commercial deployments and the maturity of China's 5G value chain[54]. The ministry will make more spectrum available at low frequencies (below 3GHz) for 5G and will likely free up 3.6-4.2GHz for future 5G allocation[55].

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54 GSMA https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019)

55 https://www.ey.com/Publication/vwLUAssets/ey-china-is-poised-to-win-the-5g-race-en/$FILE/ey-china-is-poised-to-win-the-5g-race-en.pdf (accessed 19/08/2019)

Key market trends impacting the 5G industry

Telecommunication technologies are driving the innovation capacities in each country. In this chapter, the main market innovation that are pushing forward for the 5G large deployment are described.

Internet of Things

In late 2018, the number of IoT connections in China reached 672 million which represents more than 90% of all IoT connections in Asia Pacific and 60% of IoT connections globally. It is expected that by 2025, this number will reach 1.9 billion IoT connections through growth driven by various industry/vertical applications[56].

One of the key pillars of the government's plan is industrial modernization which the aim to retool factories with connected machinery to allow for advanced robotics and to conduct skills training for staff with augmented reality. For example, Ericsson has placed real-time motion sensors to narrowband IoT modules across its manufacturing plant in Nanjing in order to improve the calibration process of expensive, high-precision screwdrivers. Moreover, China Telecom, Hebei Wuvei Avionics Technology and Yantai Hendyuan Intelligent Technology have launched a digital management transformation project using narrowband IoT networks and real-time data analysis to shorten product manufacturing cycles, accelerate manufacturing speeds and reduce costs[57].

From around 70 million smart manufacturing connections in the late 2018, there is expected to be more than 530 million smart manufacturing connections in 2025 in Asia Pacific (which represents more than 50% of the global total)[58].

This emerging trend for the IoT is pushing forward the deployment of 5G. It is however worth noting here that in this domain, 5G has strong competitors (NB IoT, but also 6LoWPAN, LoRa, SigFox, …).

Smart cities

China is striving to develop smart cities to offset the environmental issues and to leverage economic growth in the country. 5G, a key technology for smart cities, is highly awaited in this industry.

56 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019)

57 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019)

58 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download(accessed 19/08/2019)

Applications of 5G: Verticals

Transportation/Automotive industry

The global automotive industry has experienced a significant transformation in these last years and will experience even more important transformations in the next few decades through notably autonomous driving which will mainly be enabled by 5G.

For China, the automotive industry is one of the targeted key sectors in the "Made in China 2025" Plan, aiming at making China a leading country in high-tech industries. Moreover, China is a key player in the sector developments and linking between ICT and automotive industries. The three Chinese mobile operators – China Mobile, China Telecom and China Unicom – have been working on vehicle telematics, connected cars and the "Internet of Vehicles" for the past several years. These operators have been investing heavily in R&D and have conducted numerous LTE and 5G autonomous driving demonstrations. They are now working on developing new solutions such as Cellular Vehicle-to-Everything for remote driving, vehicle platooning and autonomous vehicles. In order to access the needed technologies, the three operators have been supporting cooperation in the ecosystem. For example, China mobile has launched the 5G Joint Innovation Centre and Baidu's Apollo open source software platform for autonomous driving; China Unicom, Tsinghua ZTE, Datang, Ford and FAW have been working together on pre-crash warning for pedestrians; China Mobile and China Unicom have joined the 5G Automotive Association (5GAA), a global and cross-industry organisation including vendors, automobile manufacturers and suppliers for cars and trucks[59].

Three automotive use cases in China have been identified defined by the level of the vehicle autonomy:

Connected vehicles

Connected vehicles require a lower vehicle autonomy than the other two use cases and the new functions listed in figure 14 can already be provided by the 3G and the 4G networks. Nevertheless, with the launch of 5G, it is expected that the new functions are increasingly served in China.

Early autonomous driving

The new functions presented in this use case are already covered by the 4G network, but with 5G network, remote driving will increasingly be tested and used to complement driverless autonomous vehicles as it will be the case of vehicle platooning[60] mainly tested for trucks with the aim to improve traffic safety, reduce fuel consumption and CO2 emissions. In China, several demonstrations have already been conducted: China Unicom and Chery demonstrated automated driving at the World Internet of Things Exposition in Wuxi; China Mobile, SAIC Motor and Huawei demonstrated 5G-based remote driving with a passenger car located more than 30km away.

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59 https://www.gsmaintelligence.com/research/?file=4ac41ce0d0e94cd567ed0d19289a3d7d&download (accessed 19/08/2019)

60 Platoon = a group of vehicles that travel very closely together; the lead vehicle controls the speed and direction while all following vehicles respond to the lead vehicle's movement.

Truly autonomous vehicles

For this use case, 5G is required as it will allow communication type on which autonomous vehicles is based with low latencies: Cellular Vehicle-to-Everything Communication. This type of communication includes Vehicle-to-Vehicle communication, Vehicle-to-Road Infrastructure communication and Vehicle-to-Road Users communication. 5G is notably needed because a very large amount of data will the processed including wide-area information, data captured by car sensors, cameras, radar and LIDAR.

The following figure illustrates the enabled functions for each use cases[61].
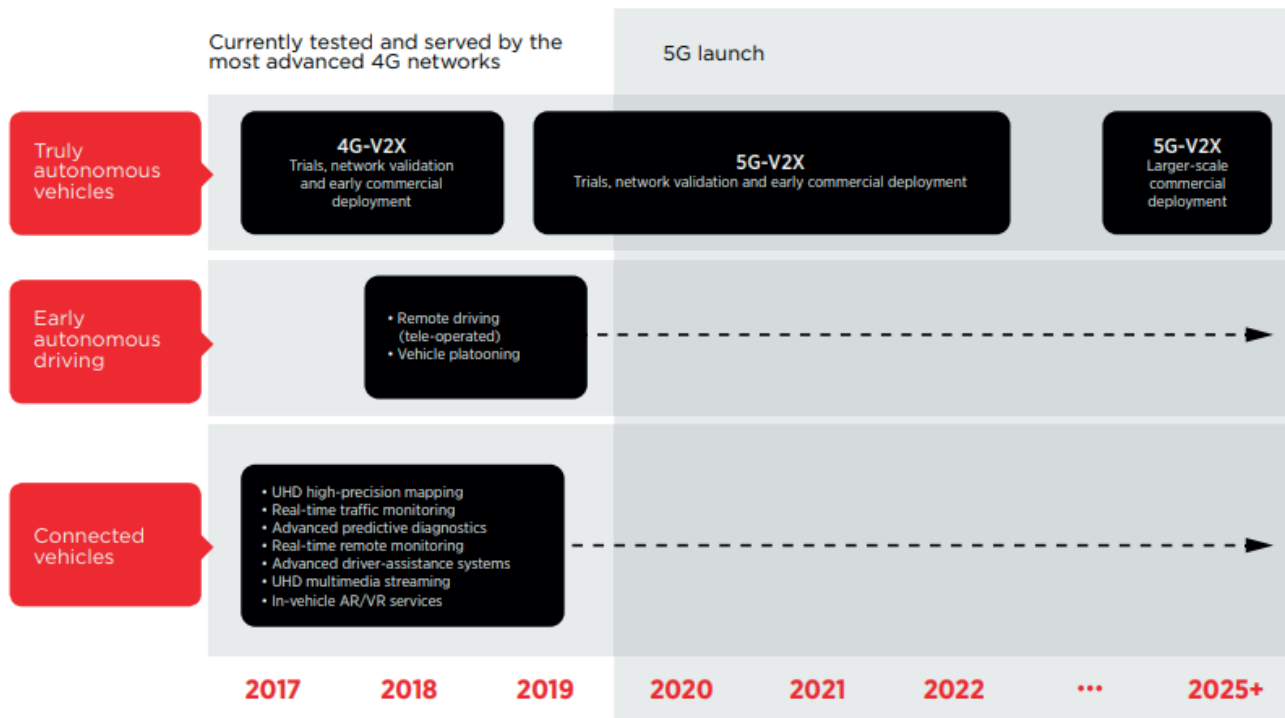
Figure 14: 5G automotive use cases (Source: GSMA)

Drones (UAVs)

For the last several years, the drone market developed outside its military roots into civil applications. In China, the civil drone market (including consumer and industrial applications) is estimated to reach RMB 80 billion ($13 billion) by 2025.

China Unicom has developed an industrial drone cloud platform at a test facility in Yunnan that is recognised by the Civil Aviation Administration. The central platform handles data flows and management from drones in all provinces[62].

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61 https://www.gsmaintelligence.com/research/?file=077db5d3e96e47d392f6f48c808be526&download (accessed 19/08/2019)

62 https://www.gsmaintelligence.com/research/?file=077db5d3e96e47d392f6f48c808be526&download (accessed 19/08/2019)

Manufacturing

The Industry 4.0 continues to gain momentum across the globe with numerous manufacturing companies increasingly adopting robots, machine learning, sensors and a range of industrial IoT solutions with the aim to optimise their production processes, increase productivity and efficiency, drive product innovation and new revenue opportunities.

The manufacturing sector is part of the "Made in China 2025" Plan. Therefore, the Chinese government has been intensifying national efforts to run pilots and implement projects in smart manufacturing across a number of key verticals including raw materials, equipment, consumer goods and electronics. Numerous consortia have been formed in China in order to accelerate the development of industrial lower Internet through industry cooperation (as for example, the Alliance of Industrial Internet (AII)).

5G is a key driver of future developments in smart manufacturing because large-scale adoption of automation and AI adds new requirements in terms of latency and network reliability. 5G will also enable unprecedented levels of interaction and coordination between machines, devices and robots, making manufacturing more tech-based and data-driven. In late 2017, the Wireless Connected Factory Special Interest Group (SIG) was created including Huawei and several industry partners and research institutions with the aim to stimulate developments and innovation, and to explore manufacturing use cases that can be supported by 5G and promote 5G application in future smart manufacturing. Four main use cases have been identified[63]:

› **Robots and Robotics**: 5G will replace Wi-Fi-based connectivity and allow real-time robot collaboration and integration throughout the production line as well as cloud-based wireless robotics;

› **Remote real-time or near-real-time manufacturing**: 5G coupled with industrial AR will enable workforce training and will increase human skills as well as high precision simulations of human-machine interaction in various manufacturing situations;

› **Labour augmentation**: 5G will enable live remote monitoring and reconfiguration of robots and processes and remote quality inspections;

› **Connected operational intelligence and analytics**: 5G coupled with AI will enable real-time data gathering to inform immediate manufacturing decisions and 5G based, large-scale data analytics in various areas.

But there are other verticals such as agriculture, health care, energy and utilities sectors that are likely to benefit early from 5G in China (as illustrated in the following figure)[64] through the implementation of IoT[65].

63 https://www.gsmaintelligence.com/research/?file=077db5d3e96e47d392f6f48c808be526&download (accessed 19/08/2019)
64 http://www.chinadaily.com.cn/a/201806/15/WS5b2328b2a310010f8f59d2bf.html (accessed 19/08/2019)
65 http://www.chinadaily.com.cn/a/201806/15/WS5b2328b2a310010f8f59d2bf.html (accessed 19/08/2019)

Smart buildings
Smoke detectors
Alarm systems
Home automation

Utilities
Smart metering
Smart grid management

Smart cities
Parking sensors
Smart bicycles
Waste management
Smart lighting

Environment
Flood monitoring/alerts
Environmental monitoring
(water, air, noise, etc.)

Agriculture
Climate/agriculture
monitoring
Livestock tracking

Massive IoT

Health care
Emergency rescue
Health monitoring
Online doctor appointment
and health information
services

Transport and logistics
Fleet management
Goods tracking

Industrial
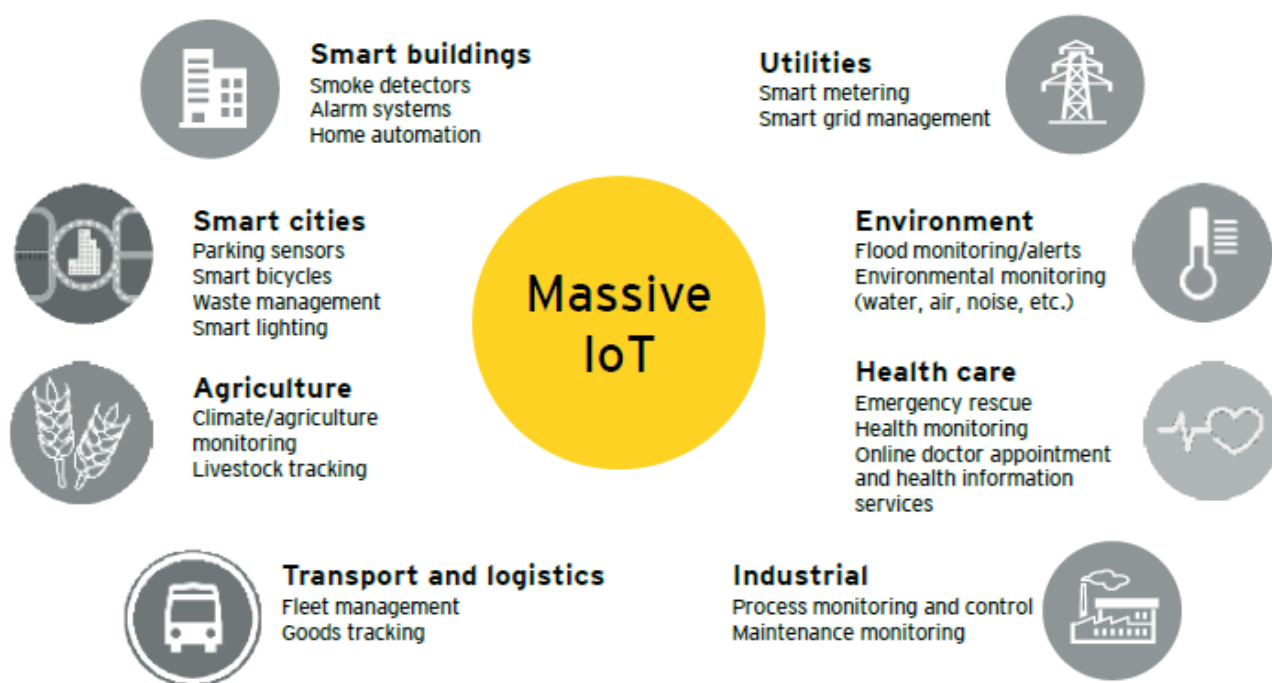Process monitoring and control
Maintenance monitoring

Figure 15: 5G technology enables massive IoT verticals (Source: E&Y)

› **Logistics**: 5G will mainly allow, through low latency, high speed and wide availability, to track packages in real time which will offer real-time insights and boost efficiency between warehouses and distributors, giving customers a clearer visibility of their deliveries. Moreover, it could enable a certain upgrading through the use of robot workers in warehouses and drones for deliveries;

› **Energy and utilities monitoring**: 5G technology has the potential to dramatically enhance the way utility companies network their grid assets and systems, therefore maintaining balanced energy supply and demand in grid[66], which is a crucial issue in China;

› **Finance**: the low latency, high data capacity and reliability of 5G will help create a new platform for the delivery of innovative mobile services consumers want, virtually wherever the customer is. Moreover, wearable devices could become an important channel for mobile payments;

› **Healthcare**: the high reliability and low latency of 5G can be applied in health care to make complex, remote diagnosis and robotic assisted surgery possible for patients in the Chinese rural areas;

› **Agriculture industry**: 5G can transform the agriculture industry further, making it possible for connected drones to stream live footage of animals to their owners, while also surveying the surrounding landscape. A Chinese vendor recently demonstrated how 5G-enabled drone could transmit high-definition images to the cloud and generate topographic maps in seconds[67].

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66 http://www.chinadaily.com.cn/a/201806/15/WS5b2328b2a310010f8f59d2bf.html (accessed 19/08/2019)
67 http://www.chinadaily.com.cn/a/201806/15/WS5b2328b2a310010f8f59d2bf.html (accessed 19/08/2019)

Driving forces of the 5G market

Public initiatives

The Chinese government policy supports both the development of 5G standards and the commercial deployment of 5G networks through a range of policies and initiatives. Four major initiatives are the "Made in China 2025" plan, the 13th Five Year Plan, the National 863 Program and the National Science and Technology Major Project.

"Made in China 2025" Plan

On 19 May 2015 the "Made in China 2025" Plan was adopted in the framework of president Xi Jinping's economic policy, which aims at enhancing the performance of the Chinese companies. Its aim is to transform China from a giant manufacturer to a global manufacturing leader by 2025. The priority will be to enhance manufacturing innovation, to integrate information technologies into the industry, to consolidate the manufacturing fundamentals, to promote the Chinese brands, to reinforce green manufacturing industry, to promote key innovation findings in ten keys sectors to foster the reconstruction of the manufacturing sector, to promote service oriented production and service linked to production, and to internationalize the manufacturing sector[68]. This document also prioritised ten key sectors[69]:

› Numerically controlled machine tools

› Robots

› New information technology

› Aircraft equipment

› Oceanic engineering equipment and high-tech ships

› Rail equipment

› New energy vehicles

› New materials

› Biomedicine

› Agricultural machinery.

The "Made in China 2025" Plan also financially supports sectors that boost manufacturing innovation according to the Ministry of Industry and Information Technology, including the Internet of Things, smart appliances and high-end consumer electronics. The total funding available is around USD1.34 billion[70].

For the Chinese government, an important part of the Plan's success will be enabled through the deployment of 5G as it will offer manufacturers and telecommunication operators the chance to build smart factories and take advantage of technologies such as automation, artificial intelligence, connected robots, augmented reality for troubleshooting and the IoT.

The 13th Five Year Plan

The 13th Five-Year Plan (2016-2020), adopted in March 2016 by the People's National Assembly in China defines priorities for the next 20 years and provides a roadmap to a harmonious society. It focuses on six paramount objectives[71]:

› **Shift from capital accumulation-led growth to innovation-led growth**: in order to enhance total factor productivity and release the huge potential of consumer spending;

› **Integrated urban-rural development**:

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68 https://portail-ie.fr/analysis/1273/made-in-china-2025-lambition-chinoise (accessed 19/08/2019)

69 https://www.chine-magazine.com/la-nouvelle-economie-made-in-china-2025/ (accessed 19/08/2019)

70 EU-project EXCITING https://cordis.europa.eu/project/rcn/205946/factsheet/en (accessed 19/08/2019)

71 http://www.cepii.fr/PDF_PUB/pb/2016/pb2016-12.pdf (accessed 19/08/2019)

through a reform of the social welfare system to equalize basic public services among regions and among rural and urban areas;

› **Green development**: through a shift to renewable energy, recycling, low-carbon transportation systems, and tighter regulation and supervision of emissions;

› **Inclusive development**: by adopting reforms on the universal social insurance system, improved public health through medical reforms, lifting an additional 55.75 million people out of poverty, and the implementation of a two-child policy to counter the ageing population;

› **Finance and State-owned Enterprise-(SOE) reform**: focusing on the resolution of the problem of over indebtedness to strengthen the banking system, and on the reformation of the state-owned enterprises (SOEs);

› **Opening up to the world**: with the aim to attract foreign investments and encourage Chines enterprises to invest abroad and become global competitors.

In the Plan, there are also determined quantitative targets, notably to achieve 6.5% annual average growth GDP from 2016 to 2020, to reach a R&D expenditure of 2.5% GDP in 2020 and to reduce emissions per unit of GDP by 40 by 2020, to 45% compared to 2005 levels[72].
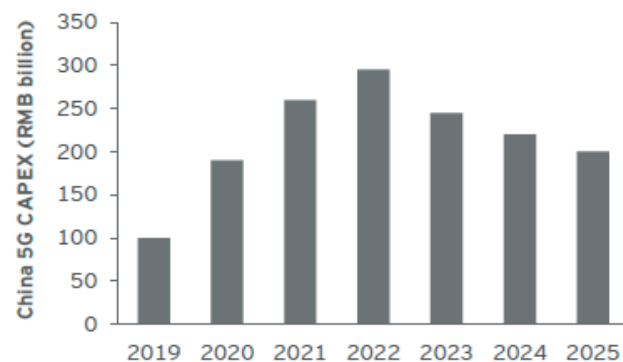
In this document, 5G is described as a "strategic emerging industry" and "new area of growth". It specifies that "we will drive forward research in key technologies for 5G mobile networks and ultra-wideband applications and develop commercial applications of 5G technology. We will adopt a forward-thinking approach in planning for the next generation of Internet and move to upgrade to IPv6 across the board"[73].

IMT-2020 (5G) Promotion Group

In 2013, The Ministry of Industry and Information Technology, the National Development and Reform Commission and the Ministry of Science and Technology established the IMT-2020 (5G) Promotion Group. It is the major platform to promote 5G research in China. The aim is to combine the power of industry-academia-research-application cooperation in mobile communication, promoting 5G technology research, standards formulation, industrial development, and international cooperation. Leading operators, equipment manufacturers, chip and instrument enterprises, universities and research institutes in the field of mobile communications are members on this platform[74].

The industry

To be ready for the commercialization of 5G, the telecommunication industry has been taking the necessary steps. Mainland telecommunication equipment manufacturers are investing heavily in 5G research and patent development-related projects. Their active engagements with global operators in supplying pre-5G mobile infrastructures shows that they are making way to spearhead the 5G equipment market. Moreover, all Chinese operators have announced plans to invest in 5G network deployment from 2019 onwards and are building out 5G innovation centres and conducting external field tests in major cities in preparation for 5G. The investments are expected to be progressive over a longer period of time as illustrated in the following figure.

72 http://www.cepii.fr/PDF_PUB/pb/2016/pb2016-12.pdf (accessed 19/08/2019)

73 http://en.ndrc.gov.cn/newsrelease/201612/P020161207645765233498.pdf (accessed 19/08/2019)

74 Eu-project EXCITING https://cordis.europa.eu/project/rcn/205946/factsheet/en (accessed 19/08/2019)

Implementation strategy of key vendors

There are three main telecom operators in China: China Mobile, China Telecom and China Unicom. China Mobile is the largest player, with a 46% market share. China Unicom is the second largest with 29% followed by China Telecom with 25% market share. The following figures illustrated the market share per telecom operators. These Chinese carriers are forecast to invest $184 billion on 5G by 2025, according to GSMA[75].
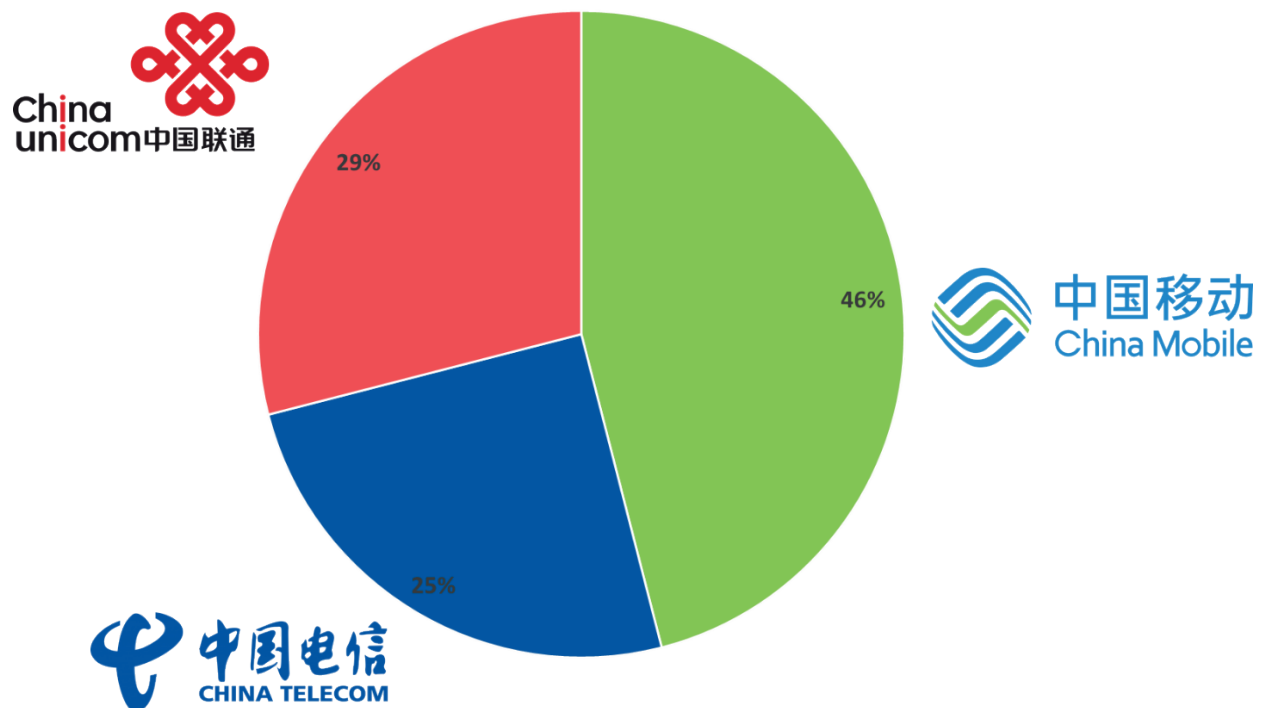

Figure 17: Market Share of Chinese Telecom providers

1. China Mobile

China Mobile is the world's biggest mobile phone operator with nearly one billion subscribers. In 2015, China Mobile set up a 5G base station with Ericsson and a month later it launched another 5G trial network in Beijing. Since then, the company has also implemented a 5G network in the Hongqiao railway station[76].

At the MWC (Mobile World Congress) 2018, China Mobile released the largest end-to-end communication solution based on 3GPP standards, including nine manufacturers involved in base stations, terminal chips and test instruments. China Mobile also released 5G commercial product prototype and test results and published the technical requirements for end-to-end large-scale 5G testing[77].

In 2019, China Mobile has been testing 5G in several cities on a non-standalone infrastructure: Hangzhou, Shanghai, Guangzhou, Suzhou and Wuhan. The company plans to build 100 5G base stations in each of these cities by 2020. Moreover, the company will offer 5G services and

75 https://www.rcrwireless.com/20190626/5g/china-mobile-launch-5G-50-cities-china-end-2019 (accessed 19/08/2019)
76 https://www.lifewire.com/china-5g-4178852 (accessed 19/08/2019)
77 https://pandaily.com/chinas-three-major-telecom-operators-confirm-5g-schedules-and-6g-in-the-works/ (accessed 19/08/2019)

application demonstrations in 12 cities: Beijing, Xiong'an, Tianjin, Fuzhou, Chongqing, Chengdu, Nanchang, Nanning, Shenzhen, Zhengzhou, Shenyang and Lanzhou[78].

In May 2019, China Mobile tested its first call through a 5G network in Beijing using 5G compatible mobile phones[79]. Several months earlier, according to the Chinese media, a doctor practiced the very first brain surgery via 5G network supported by China Mobile and technology by Huawei. The doctor testified that "the 5G network has solved many problems such as video lag and remote control delays that were present when using the 4G network, which enabled a near-real-time operation [...] And you hardly feel that the patient is 3,000km away"[80].

China Mobile joined 20 terminal partners to launch the 5G Terminal Pioneer Program. The Program aims at creating an open 5G ecosystem and develop applications in sectors such as healthcare and transportation[81]. Among those 20 terminal partners are[82]:

› 6 major chip manufacturers: Qualcomm, Huawei, Mediatek, Tsinghua Unigroup, Intel and Samsung

› 10 major terminal manufacturers: OPPO, Vivo, Xiaomi, ZTE, Lenovo, HTC, Hisense and TCL

› 4 component companies: Qorvo, Skyworks, Taiyo Yuden and Feixiang

At the MWC 2019, the company announced that it will deploy 5G commercially in over 50 cities and 50 000 5G base stations across China by the end of the year, 2019. Moreover, the company plans to expand the 5G commercial service to all Chinese cities by 2020[83].

The company's future plan is to combine 5G with artificial intelligence and cloud technology for an ultramodern network. Shang Bing, chairman of China Mobile, said: "We will focus on the standalone 5G network structure, push forward the cloud deployment of the superfast technology and build an intelligent network by boosting the operational efficiency with AI"[84].

2. China Unicom

China Unicom is the world's fourth-largest mobile service provider and is owned by the Chinese government. In the early 2019, China Unicom launched 5G on the Tiananmen Square.

In 2018, the company has launched 5G test projects in the following cities: Beijing, Tianjin, Qingdao, Hangzhou, Nanjing, Wuhan, Guiyan, Chengdu, Shenzhen, Fuzhou, Zhengzhou and Shenyang. The plan is to build 100 5G base stations in each of these cities[85]. At the end of the same year, the Ministry of Industry and Information Technology awarded China Unicom with 3500-3600 MHz band to conduct nationwide trials. The company plans to expand the scale of trial as appropriate based on the

testing results and maturity of equipment. China Unicom is taking an active approach in researching and driving network co-building and co-sharing of 5G with various cooperation modes to lower the network construction cost. It will simultaneously use non-standalone and standalone infrastructure[86].

In 2019, China Unicom covers seven key cities (Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou and Xiong'an) with its 5G network and has hotspot coverage in 33 Chinese cities[87].

Moreover, in the same year, China Unicom and China Telecom signed an agreement in order to mutualise their network for the deployment of

78 https://pandaily.com/chinas-three-major-telecom-operators-confirm-5g-schedules-and-6g-in-the-works/ (accessed 19/08/2019)

79 https://french.peopledaily.com.cn/Economie/n3/2019/0415/c31355-9566940.html (accessed 19/08/2019)

80 https://french.peopledaily.com.cn/Economie/n3/2019/0415/c31355-9566940.html (accessed 19/08/2019)

81 (accessed 19/08/2019)

82 https://pandaily.com/chinas-three-major-telecom-operators-confirm-5g-schedules-and-6g-in-the-works/ (accessed 19/08/2019)

83 https://www.rcrwireless.com/20190626/5g/china-mobile-maunch-5g-50-cities-china-end-2019 (accessed 19/08/2019)

84 http://www.chinadaily.com.cn/a/201811/08/WS5be37c24a310eff303287440.html (accessed 19/08/2019)

85 https://www.lifewire.com/china-5g-4178852 (accessed 19/08/2019)

86 https://www.chinaunicom.com.hk/en/ir/faq.php (accessed 19/08/2019)

87 https://www.asiatimes.com/2019/06/article/china-unicom-to-build-5g-networks-on-belt-and-road/

5G until 2026. This agreement will allow China to deploy 5G even faster and will allow the two operators to save €47 billion between 2019 and 2026[88].

3.China Telecom

In 2017, China Telecom launched the 5G Innovation Demonstration Network in Xiong County, Xiong'an, Hebei Province and 5G pilot programs (including the deployment of 5G base stations) in the following cities: Shenzhen, Shanghai, Suzhou, Chengdu, Xiong'an and Lanzhou[89]. The company has implemented six to eight base stations in each city in the 3.5 GHz frequency band. In December 2018, China Telecom was awarded the 3.5 GHz band to conduct nationwide 5G network trials. The company is expected to accelerate 5G deployment proactively and pragmatically. This means to accelerate industry chain maturity and conduct scale trials, to adjust investment plan and expand trial subject to technology maturity, licensing, market competition and results of scale trial, and to actively explore network co-building and co-sharing to reduce network construction and maintenance cost. Moreover, persisting in a market-oriented and demand-driven approach, China Telecom will appropriately manage the momentum, propel the development of non-standalone and standalone concurrently, and progressively expand the scale of network trials and the pilot project of 2B/2C applications[90]. Indeed, China Telecom signed an agreement with the China Academy of Information and Communications Technology to collaborate on several areas related to 5G including smart manufacturing, IoT, smart cities, Big Data and networking. In addition, the company also announced it is also looking into the use of cellular networks of emerging areas such as augmented reality, virtual reality and the Internet of vehicles[91].

China Telecom released in 2018 the first industry's white paper. According to this paper, the company's network evolution strategy will comprehensively consider factors such as service requirements, user experience, maturity of technologies, terminal ecosystem and construction cost. Therefore, its strategy will follow 3 principles[92]:

› Multi-network convergence principle: 4G, WLAN and 5G are expected to coexist for many years, which can meet diversified demands and provide seamless service to users;

› Phase-by-phase migration principle: guarantee for stable network operation and avoid large-scale and frequent network upgrades;

› Cost efficiency principles: costs are considered when choosing 5G technologies and solutions, and the full use of existing resources for network construction and achieve fixed mobile convergence to form a differentiated competitive advantage.

Moreover, China Telecom is expected to launch commercial 5G services in 2020. At the Beijing Expo 2019, China Telecom demonstrated all the 5G applications the company is looking forward to introducing in the market. On their 5G pavilion, China Telecom installed a 5G network which covered every corner of the pavilion. Visitors were able to get connected to the 5G-based WIFI hotspots via their cell phones and experience the connection speed of the 5G network. The company exhibited the following 10 items:

› 5G AI Robot: the robot simulated, almost without any delay, any movement made by another person who wore a costume equipped with sensors. The robot's application is particularly suited for some highly dangerous operation scenarios;

› 5G City of the Future: an inductive sand table which represented four application scenarios (environmental monitoring, intelligent

88 https://www.lesechos.fr/tech-medias/hightech/la-chine-se-met-en-ordre-de-bataille-pour-la-5g-1130461

89 https://www.ctamericas.com/china-telecom-adds-5g-testing-sites/

90 http://techblog.comsoc.org/2019/03/19/china-telecom-to-accelerate-5g-deployment-100-fiber-network-coverage-gigabit-fiber-broadband-deployment/ (accessed 19/08/2019)

91 https://www.ctamericas.com/china-telecom-adds-5g-testing-sites/

92 http://www.chinatelecom.com.cn/2018/ct5g/201806/P020180626325685163826.pdf (accessed 19/08/2019)

sanitation, intelligent irrigation and water quality monitoring) placed at corresponding sensing locations of the Beijing Expo 2019 allowed the visitors to touch the locations on the screen and watch videos on relevant solutions;

› 5G Cloud Class: through a pair of MR glasses, visitors could see two virtual robots explaining what is 5G. This could be used for students in remote areas to enjoy quality educational resources;

› 5G AI Patrol Robot: the robot could transmit the videos it captured to the monitoring screen of the pavilion. This could provide new types of safety monitoring solutions for large-scale events like the Beijing Expo;

› 5G Cloud Games: computer games could be calculated and rendered via servers of relevant cloud platforms. The users no longer need to equip their computers with pricy high-end graphics cards and processors and can enjoy games unimpededly with an ordinary computer monitor;

› 5G Dream Life: a CAVE VR showcased the scenes of family life in the future;

› 5G Expo Tour: Wearing a pair of 4K or 8K VR glasses, visitors could watch videos of the Expo site taken by UAVs and remote cameras which are sent back in real time via the 5G network.

› Time Travel: an interactive and transparent screen displayed the history of China's telecommunication sector. Moreover, visitors could experience interactive photography;

› 5G AI Experience Zone: Visitors were able to play the finger-guessing game with a robotic arm, enabling them to experience the unprecedented intelligence of 5G;

› 5G Equipment Exhibition Zone.

Challenge of the 5G market in China

Despite the fact that the Chinese telecommunication market is the largest in the world in terms of subscribers, there are some deficiencies that will impede further development of China's telecommunication sector. Current telecommunication consumption shows important geographical differences: eastern China is experiencing a considerable growth in advanced telecommunications services (such as mobile telephones and Internet access), while many villages in the central and western China are still striving for basic telecommunications services. Such a wide digital gap is likely to hinder the overall advancement of China's telecommunications industry and has become a critical challenge for China.

To illustrate this gap between eastern China and the rest of China, the following figure shows the differences in terms of GDP per person and Internet infiltration.

Economist.com

Conclusions and comparison with other countries

The US, China and South Korea are currently racing to know which one will be the first to deploy 5G at a large-scale. Whereas in Europe the large-scale deployment is not expected before 2020-2021.

The deployment of 5G is of high priority for the Chinese government as it wants to be part of the formulation of the international 5G standards and to allow the Chinese technology companies to become the next innovative global giants like Apple or Microsoft – after spending years of producing copycat products. The potential of the Chinese telecommunication market is very high when compared to other countries. Indeed, the Chinese mobile market is the largest in the world with 1.6 billion subscribers in 2018.

According to a study by Analysys Mason, in terms of readiness, the first major player in 5G is, indeed, China thanks to proactive government policies and industry momentum. China started trials in 13 major cities at the end of 2018.

Additionally, China has the hand on a lot of 5G commercial licences and spectrum and plans to propose the 5G services on a large scale and for commercial application by 2020.

One of the main characteristics of Chinese telecommunication market is the high implication of the Chinese government marked by the history of Chinese telecommunication operators, China Unicom, China Telecom and China Mobile – initially owned by the Chinese state. Indeed, the government has provided the telecom operators with the necessary environment to deploy 5G as it is a governmental priority. This proactive government and its policies are particular to the Chinese country. Indeed, in the US, for example, the deployment of 5G is highly industry driven or in Europe where as there are many different telecom operators (which causes issues regarding the investment capacity of each one for a large-scale 5G and small cells deployment) the deployment of 5G is more driven by the European Union.