Benchmark
5G in the US

Overview

The United States will be one of the first countries to launch 5G in the world. The deployment of 5G represents an important growth opportunity for the US economy as well as an essential tool to develop innovation in the areas of energy, transport, public safety, healthcare and manufacturing, highly important for the US. Therefore, US public authorities are facilitating and fostering the research and development of 5G mainly driven by the telecom and technology industries.

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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
SDN	Software-Defined Networking
TMT	Technology, media and telecoms
US	United States of America
USCIB	United States Council for International Business
VR	Virtual Reality

Executive Summary

5G is the next telecommunication generation, the fifth generation. It succeeds the 4G systems and should answer the needs of a high increase of data and the society's connectivity. 5G should be faster (10 times more than 4G), enable low latency and high reliability, allow to connect more people and more devices, to use more connected objects (such as IoT devices), and it should 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 the 5G technology is the use of high frequencies in the spectrum which is more powerful but has less reach then previous telecommunication generations (4G, 3G). Therefore, an important number of cellular sites have to be implemented[1]. Today, 5G is in the development phase: no country has yet implemented 5G on a large scale, only tests have been implemented in some cities at the end of 2018 and others have been planned for 2019. All major world economies are aiming at an early and strong implementation of 5G in their country – and they are thus either competing or collaborating on this topic. Multiple countries are implementing diverse strategies for the 5G development and launch – whilst some focus on acquiring the largest amount of licences and spectrum, others aim at a wide-spread integration in different applications.

In the USA, the term "5G" is not used as in the EU - a comparable term is "advanced wireless". In the US, government funding only supports pre-commercial research and experimentation – as the 5G research is considered done and commercialisation is approached, "advanced wireless" is the chosen terminology that describes "5G beyond" in the US. It is of importance to know the difference in comparison to the EU to be able to understand the different approach. Nevertheless, for the ease of reading, it has been chosen to speak about "5G" or "5G Networks" throughout this document.

The Global5G.org project is 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 supports in particular the implementation of EU-supported 5G projects, their collaboration and outreach, it also looks at international initiatives: as seen above, the 5G development is a global one. To this regard benchmarks are undertaken on the 5G Network in selected countries in order to compare their strategies and implementation modes to the one in the EU. In this context, the information gathered in this benchmark is of relevance for the project since it allows to identify some good practices and important information related to the 5G implementation in the US. More specifically, this analysis allows to:

» Identify the potential benefits and advantages the 5G's implementation will enable in the next years
» Understand how the development process of this technology is defined in a country like the United-States
» Have an overview of the 5G's driving forces (trends, public authorities, industrial players and Universities) in the United-States
» Identify the verticals prioritized by the US and which applications of the 5G they foresee
» Understand the link between vertical industries, standardisation and research in an important country as the USA
» 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

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1   The 5G era in the US (2018) GSM Association

Introduction

From the "1G" to the today widely used "4G" and the debut of "5G", a lot has changed and notably in the way p ople work, live and play. The following figure gives an overview of the shifts and changes across the various generations.
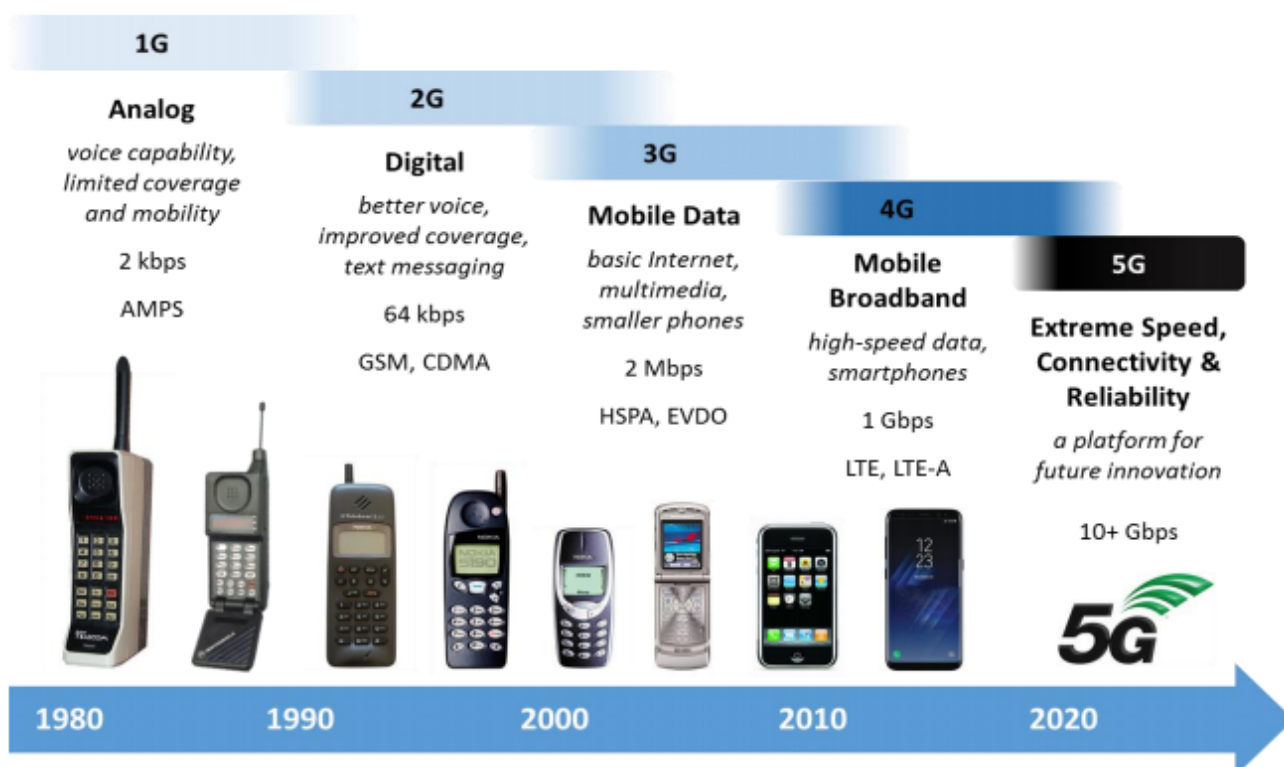
Figure 1: EVOLUTION AND KEY DEVELOPMENTS IN CELLULAR TECHNOLOGY FROM 1G TO 5G

With the 3G appeared the possibility to use basic mobile Internet service. Further mobile equipment improvements allowed to catalyse this Internet service and the 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.

After the 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:

» 1000 times more capacities
» 10 to 100 times more connected objects
» 5 times more responsiveness
» 90% energy savings
» Everywhere the same efficiency[2]

The various countries are at different levels of development regarding the 5G. The ambition of the US, as it was the case for the 4G, is to be the first country to launch 5G commercial services. Indeed, Verizon has indicated that it will launch 5G-based fixed wireless services in three to five US markets in the second half of 2018. AT&T and Verizon are expected to launch mobile 5G services based on industry standards in late 2018. 5G phones will be ready in 2019 and by then the four mobile operators

2   5G PPP Video: youtu.be/bfNmiYtG9Cg

in the US – AT&T, Sprint, T-Mobile and Verizon – will provide mobile 5G services.[3]

This document will describe in a first part the 5G market in the US followed by an analysis of the US market environment through a PESTEL analysis. A third part will describe the US market trends using 5G and the projected increase through the nationalisation of 5G use. The driving forces of the 5G in the US will be explained in a fourth part including the initiatives from the public authorities and the industry that offers to the 5G a favourable environment for development. The fifth part will focus on the 5G implementation strategy followed by the US key telecom providers. The challenges that will have to be faced regarding the 5G implementation will be discussed in a sixth part. Finally, a conclusion will allow to identify the differences regarding 5G between the US and the EU. Good practices will be presented throughout the whole document.

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3   Iacopino P. & Hudson A. (2018). *The 5G era in the US,* GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

1. The 5G market in the US

The US technology, media and telecoms (TMT) industry is changing. The telecom and media domains are increasingly converging, while the technology domain with the Internet of Things (IoT) and Artificial Intelligence (AI) are moving towards mainstream adoption and offer opportunities for innovation, growth and productivity improvements. Over the next decade, 5G will be the instrument of these major trends' development. 5G is expected to:

» Deliver an increasingly integrated video on mobile customer experience
» Spur further developments and scale in IoT
» Support growth in augmented reality, virtual reality (VR), industrial automation and AI
» Increasingly serve as an alternative for fixed broadband connectivity

The US environment is especially favourable for the development of the 5G:

» The US government make continuous efforts to support 5G progress through new spectrum allocations, infrastructure deployment
» The US is the leading country concerning consumer digital engagement and speed of adoption of new technology
» The US is also the leading country in R&D, financing tech innovation and digitalisation of industries and businesses
» Continued and significant investment by the telecom operators in fibre infrastructure and 4G network upgrades

1.1 The planned deployment of 5G in the US

US mobile operators are planning on initiating a phased approach to 5G network deployments: at the beginning, 5G will not be based on a standalone architecture (4G and 5G radio access technologies in tandem) and then eventually will be transferred into a standalone architecture (5G radio access technology only). Moreover,

US 5G stakeholders believe that co-investment network involving financing from companies which will benefit from 5G is not required to develop the 5G network in the US.[4]

The US mobile operators plan the deployment of the 5G as follows:[5]

Through to 2021: a non-standalone model

› Implementation on existing macro cell sites
› Installation of small cells
› Further virtualisation of the RAN

› Existing macro sites and LTE spectrum used as anchor connection
› High-speed data transmissions facilitated through densified network of small cells and the use of upper band mmWave spectrum

4   Iacopino P. & Hudson A. (2018). *The 5G era in the US,* GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download
5   Iacopino P. & Hudson A. (2018). *The 5G era in the US,* GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

Through to 2021: a non-standalone model
New-build sites in urban and suburban areas (complementing the densified small cells)

Beyond 2025 : a standalone network
5G core and new radio will be used (requiring the largest investment)

Figure 2: THE DEPLOYMENT STRATEGY OF 5G IN THE US

1.2. Market size and growth

Worldwide, 5G is expected to take 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%[6]. The following figure is illustrating the fast evolution of the mobile telecommunication technologies worldwide.
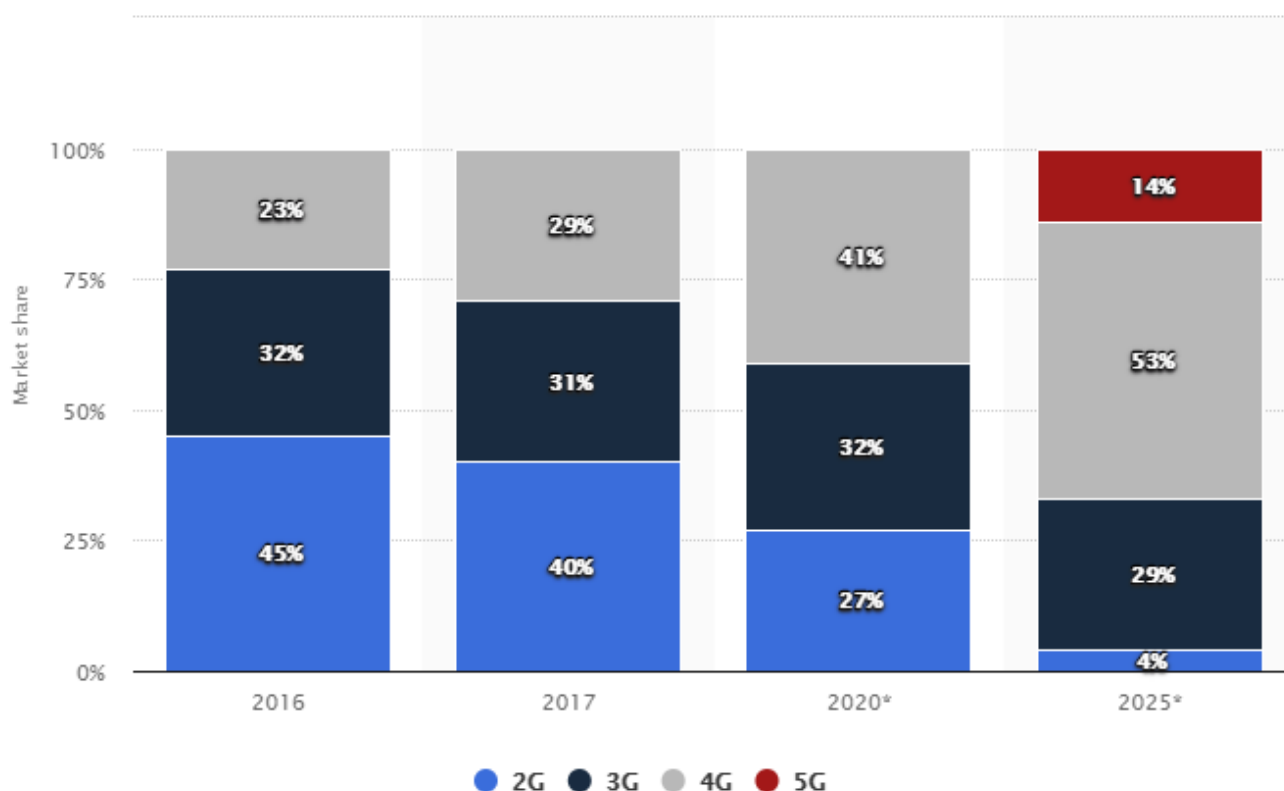
Figure 3: Market share of mobile telecommunication technologies worldwide from 2016 to 2025 by generation

In the US, the worldwide trend is expected to be followed, except for the 4G. The share of mobile connections from all other generations are expected to decrease and the one from 5G is expected to increase rapidly. In the US, it is projected that 5G connections will reach 40% of all mobile connections by 2023 and 60% by 2025[7].

6   www.statista.com/statistics/740442/worldwide-share-of-mobile-telecommunication-technology/

7   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download
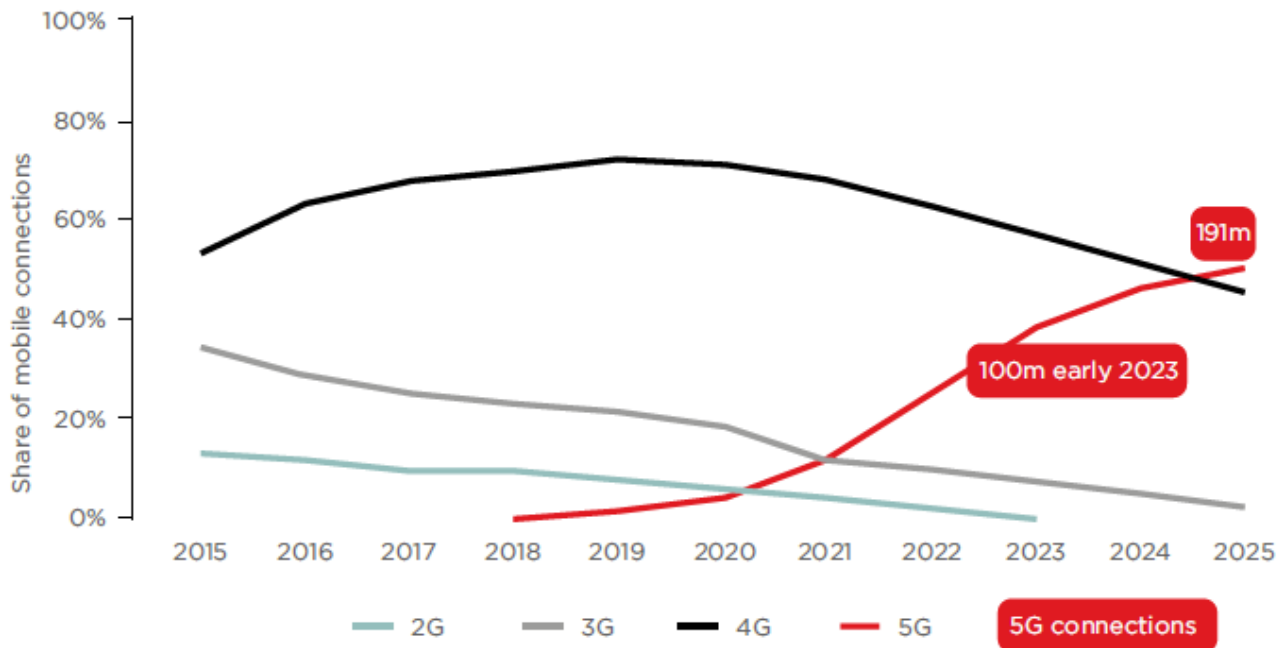
Figure 4: Mobile connections by technology, excluding cellular IoT in the United-States (Source: GSMA Intelligence)

More precisely, it is expected that in the US there will be a lot of early adopters of the 5G technology as it was the case when the 4G was launched in 2010. Indeed, 58% of smartphone users were considered "early adopters" of the 4G technology and 35% were considered as the early majority[8].

hese figures are higher than in any other region in the world (see following figure). These consumers represent the addressable market for 5G services in the first years after commercial launch.


SMARTPHONE USER SEGMENTATION BY ENGAGEMENT PATTERN (PERCENTAGE OF TOTAL SMARTPHONE USERS)			
	AFICIONADOS EARLY ADOPTERS	PRAGMATISTS EARLY MAJORITY	NETWORKERS LATE MAJORITY	TALKERS LAGGARDS
North America	53%	36%	5%	6%
US	58%	35%	3%	4%
Europe	46%	42%	5%	7%
Middle East & North Africa	34%	33%	25%	8%
East Asia/Pacific	26%	36%	24%	14%
Latin America	12%	45%	31%	12%
Sub-Saharan Africa	14%	18%	49%	19%
South Asia	9%	24%	32%	35%

Addressable market for 5G services

Figure *5*: Consumer mobile engagement (Source: GSMA Intelligence Global Mobile Engagement Index)

As the new technology will mature, 5G consumers are expected to become more numerous. Indeed, in the US alone, 200 million 5G connections are expected by 2025 which will represent more than 50% of total mobile connections[9].

8   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download
9   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

5G mobile connections excluding cellular IoT

Figure 6: 5G customer adoption in the US (Source: GSMA Intelligence)

On the offer side, US mobile operators plan to invest around $275 billion in infrastructure which could create up to 3 million jobs and boost the GDP by $500 billion[10].
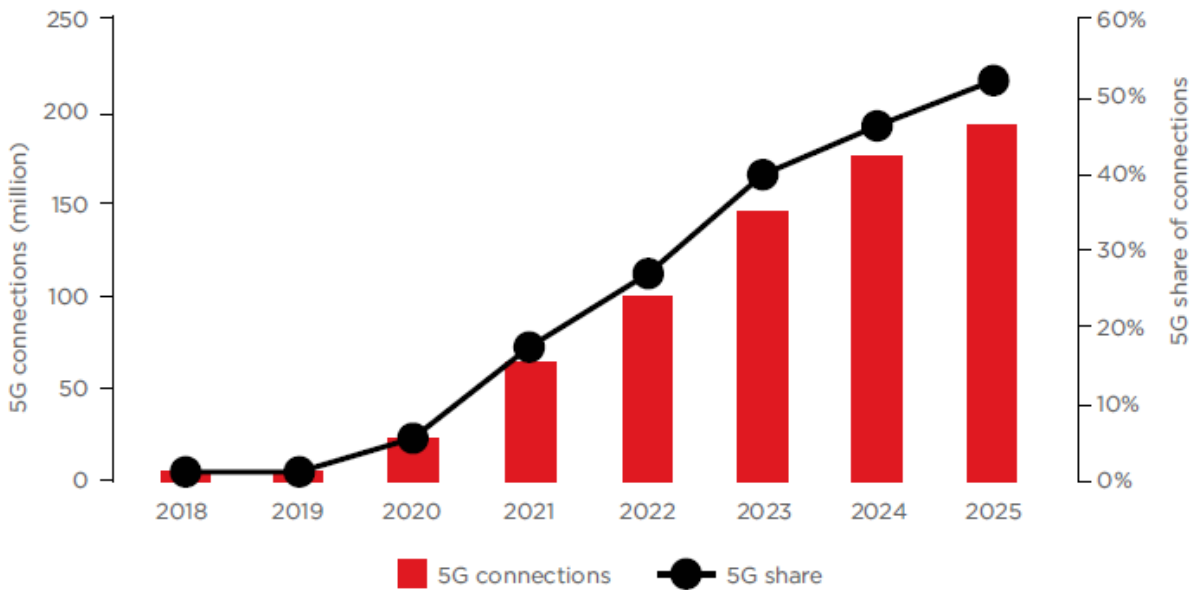
Accenture, in a strategy report, estimates that approximately 50 000 new construction jobs for the deployment of the 5G infrastructure will be created each year over the 7-year buildout period of 5G. Moreover, the effects on suppliers and other partners and their spending in the economy will allow the creation of 120 000 jobs each year during those first 7 years[11].

Thanks to the 5G, users will be able to use video applications for telecommuting or participate in e-learning courses which will allow their employability and earning power to increase and create more competitive workforce in different localities. This aspect would allow an additional $90 billion GDP growth and 870 000 job growth.

Moreover, small to medium-sized cities could see 1 000 jobs created thanks to 5G and larger cities as Chicago could see the creation of 90,000 jobs. Over the longer term, 5G will allow the US communities to remain competitive by ensuring

the latest wireless communications technology is available to citizens and businesses.
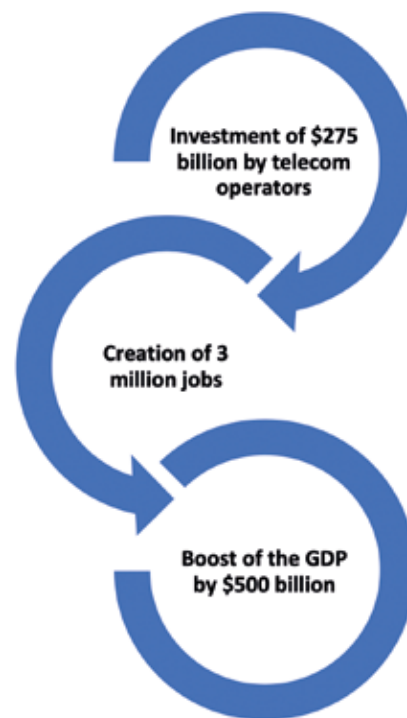
Figure 7: EXPECTATIONS REGARDING THE 5G IN THE US (Source: Accenture Strategy)

10   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

11   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

Moreover, because of the growing demand for process automation in various industries, the market for industrial automation is expected to grow at a high rate between 2020 and 2026 thanks to the implementation of a 5G network enabling a high speed with the minimal delay process.

The growth of the market is attributed to various factors such as increasing automation in different industries, rising number of subscribers owning more than one connected device, advanced technologies such as Internet of Things (IoT), high growth rate of connected/autonomous cars, increase in cellular M2M connections, high demand for on-demand video services, and growing trends of smart cities. In these applications, 5G network connectivity will be critical to carry out different tasks such as data transfer, data process, and communication. Thus, the growth of these applications in North America is the major driving factor for the growth of the 5G infrastructure market[12].

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12   www.marketsandmarkets.com/PressReleases/5g-technology.asp

2. PESTEL Analysis

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

2.1 Political

The political environment is full of risks for the telecom sector. The traditional political risks for telecom are the ones related to regulations, network licensing, national radio spectrums.

However, one factor that worked in the favour of the telecom industry in the US was privatisation and deregulation. For some time, the telecom industry enjoyed relative freedom based upon its importance in the process of globalisation.

National security and human rights issues are another major source of political pressure on the telecom sector. The US have launched measures to monitor and control communications motivated by political and security reasons. These measures have grown tougher in the aftermath of the terrorist attacks on US and hacking attempts on the US government's databases. All these factors show that political risks are going to sustain. Moreover, a large number of countries have maintained trade barriers against the US telecom companies. According to a USCIB 2016 report, there is an extensive list of countries that maintain trade barriers against the US telecom companies. Argentina, Australia, Brazil, Germany, Russia for example are part of this list (of 37 countries)[13].

In October 2018, the US government announced that the American Secretary of Commerce will lead the National Spectrum Strategy which consist in ensuring that there is sufficient spectrum or radio airwaves used to ferry wireless data, across a broad vase, with a particular focus on the use of wireless networks for military purposes. The ultimate goal of this strategy is to have more spectrum in the hands of carriers (in particular rural carriers) to deploy the cellular service and that the spectrum is used efficiently and effectively as spectrum is a critical component of the technological capabilities that enable economic activity and protect national security. In a first step, the federal agencies will have to submit a report to the Commerce Department on anticipated future and current spectrum needs[14]. The Commerce Department will gather those inputs and will share them with D. Trump, current US president. In a second step, the Commerce Department working through the National Telecommunications and Information Administration and in consultation with the Office of Management and Budget, the Office of Science and Technology Policy, the Federal Communications Commission (FCC) and other Federal entities will submit to the US President a long-term National Spectrum Strategy including legislative, regulatory or other policy recommendations[15]. For D. Trump, this strategy will provide a playbook for developing innovative technologies in the years to come:

» It will examine how to improve spectrum management and assess research and development priorities to create next technologies and improve the US competitiveness

» It will provide a comprehensive roadmap for policy makers on all levels, so that the US government can successfully lead the way to a connected future

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13   www.uscib.org/uscib-identifies-foreign-telecom-and-other-trade-barriers/

14   www.cnet.com/news/trump-reveals-plan-for-5g-wireless-network-strategy/

15   www.whitehouse.gov/presidential-actions/presidential-memorandum-developing-sustainable-spectrum-strategy-americas-future/

» For the US president it is essential that military and Federal agencies have the necessary tools to protect the US. Therefore, he understands that in the modern era, national security is dependent on technological superiority, as the military and Federal agencies rely on spectrum to carry out their missions[16].

Moreover, the US government is supporting the fast development of 5G in the US, particularly to be the first country to deploy it on a large scale, through different initiatives in 2018. For example, in January, the White House announced its plans for a national 5G network coverage; in March, D. Trump blocked the proposed acquisition of San Diego-based Qualcomm from the Singapore-based Broadcom because of Qualcomm's importance in the development of 5G; and in September the White House held a 5G summit in September[17]. D. Trump highlighted the importance of 5G, "We're on the verge of new technological revolutions that could improve virtually every aspect of our lives, create vast new wealth for American workers and families, and open up bold, new frontiers in science, medicine and communication"[18].

Nevertheless, the US government has also been engaging in activities which complicates the relationships with the Asian countries and compromises the security of technology companies' high executives. For example, in Canada, at the behest of US officials, Meng Wanzhou, the chief financial officer of the Chinese telecom company Huawei has been arrested. The US government has also given a $1 billion fine for violating trade rules to the telecom maker, ZTE[19]. For many experts and journalists, one of the key reasons behind the trade war between the US and China is the US's desire to get ahead in 5G. This trade war manifested itself through threats over billions of dollars of tariffs between the US and China. According to Declan Ganley, CEO of communications company Rivada Networks, the trade war "is about who is going to define and control the model, the architecture and the agenda of 5G, and why that matters is because 5G is the deep blue ocean of the cyber domain[20].

16   www.whitehouse.gov/briefings-statements/president-donald-j-trump-leading-way-wireless-technology-empowering-american-innovation-2/

17   www.cnet.com/news/trump-reveals-plan-for-5g-wireless-network-strategy/

18   www.whitehouse.gov/briefings-statements/president-donald-j-trump-leading-way-wireless-technology-empowering-american-innovation-2/

19   www.nytimes.com/2018/12/07/opinion/huawei-meng-wanzhou-china-arrest.html

20   www.cnbc.com/2018/07/06/a-major-factor-behind-the-us-china-trade-war-is-winning-in-a-crucial-t.html

2.2 Economic

Since the economic recession has passed, consumer spending on telecom has been back on track. Globally, it depends on the economy: the higher the economy is, the higher will be consumer spending on any product or service.

The American GDP growth rate being high in the second semester of 2018 and growing constantly since several years (illustrated by the figure below)[21], this represents a favourable environment for the consumer spending on telecom products and services.

SOURCE: TRADINGECONOMICS.COM | U.S. BUREAU OF ECONOMIC ANALYSIS
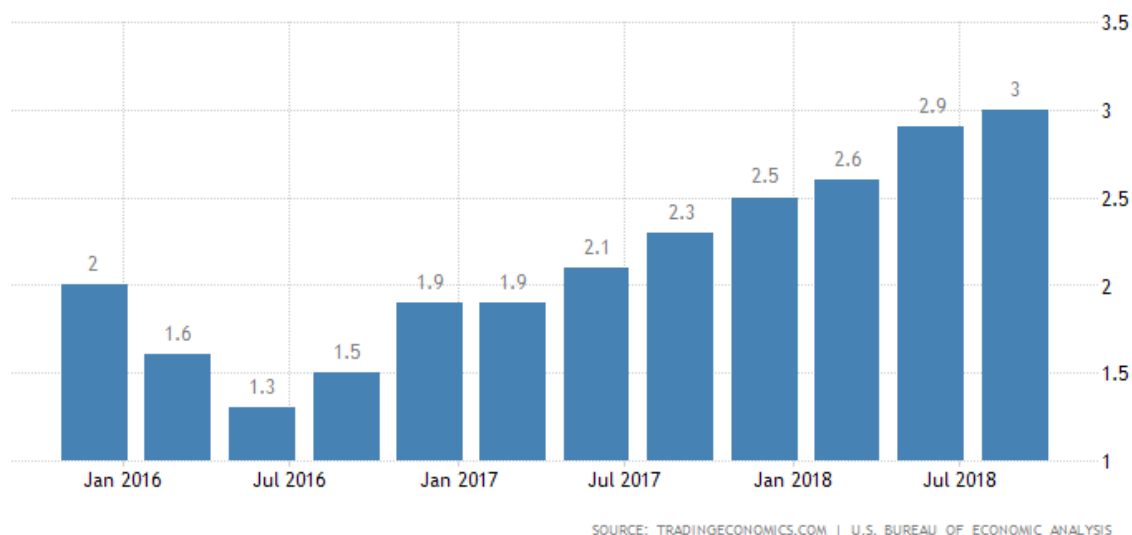
Figure 8: GDP Growth Rate in the US (Source: tradingeconomics.com)

In the US, in 2018 the growth of the mobile subscriber base is strong with a penetration rate of about 127%[22]. There is a decline in revenue from voice services, but it is compensated by the high growth in mobile data use. Moreover, the smartphone penetration in the US is the 7th strongest in the world with a rate of 71.5% representing more than 235 million Smartphone users in 2018[23].

The economic trends are also supported by technological changes. Moreover, the fewer trade barriers are, the better growth rate for the US based network providers will be.

2.3 Social

Globally, the use of internet-based services has grown. A higher number of people are using the social media for entertainment and business. From YouTube videos to Netflix, video streaming services require a very good connectivity. This is a reason why the use of 4G has grown globally. Moreover, people want to stay connected all the time with their family and friends and work.

The use of mobile computing has grown quite fast and many features in these smartphones and tablets cannot be used without a very good connection. In addition, more and more people are growing health conscious and are using wrist bands to track their physical activity. Overall, these trends have proved high favourability regarding the telecom industry.

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21 tradingeconomics.com/united-states/gdp-growth
22 www.budde.com.au/Research/USA-Mobile-Infrastructure-Broadband-Operators-Statistics-and-Analyses?r=51
23 newzoo.com/insights/rankings/top-50-countries-by-smartphone-penetration-and-users/

Indeed, the US is one of the countries in which the people spend the more time on the Internet and using apps (36% of total usage of the phone in the US; 25% of total usage of the phone in Europe). The following figure shows the position of the US compared to other countries in the world regarding the use of their mobile phones and the digital purchasing intensity.
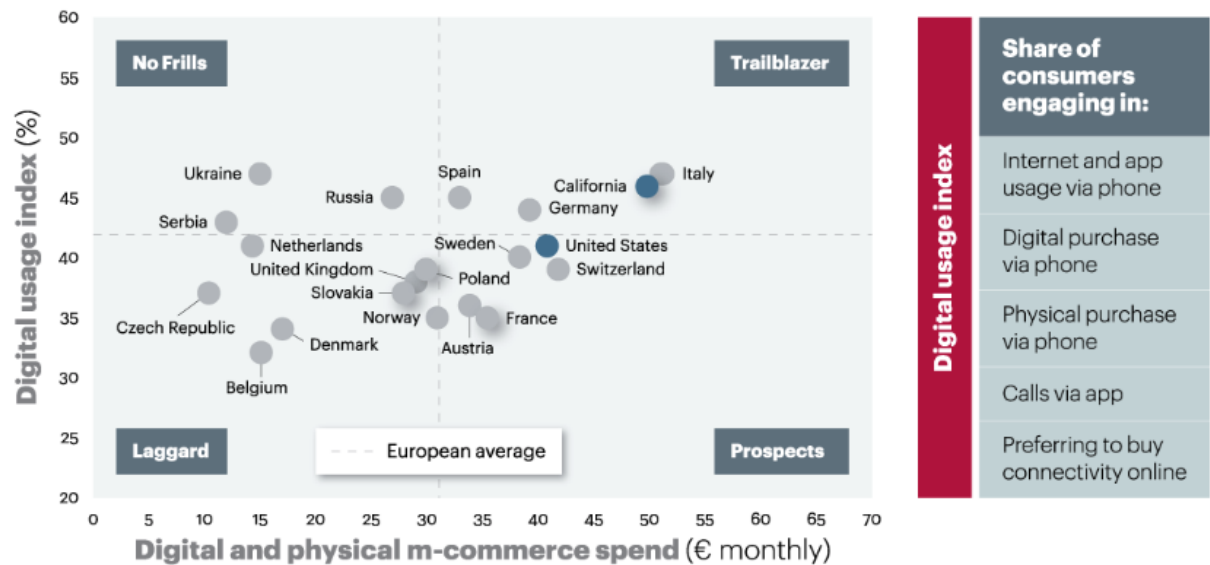
Figure 9: Mobile digital usage and m-commerce spending (Source: A.T. Kearney analysis)

2.4 Technological

According to the National Science Foundation's (NSF) Science and Engineering Indicators 2018 report, the US is the global leader in science and technology[24]. Moreover, according to the Global Competitiveness Index 2017-2018[25], the US ranks second in the category "Innovation and sophistication". It is because the US want to stay the leader that they are highly invested in the development of 5G and are battling to win the 5G race.

5G is a technology and is therefore influenced by the technological changes. Smartphone sales in the US have decreased in 2018 but are expected to grow again in the next years[26] and since none can be used fully without a fast connection, 5G has already risen a lot of excitement.

24   www.nsf.gov/news/news_summ.jsp?cntn_id=244271
25   www.weforum.org/reports/the-global-competitiveness-report-2017-2018
26   http://nymag.com/intelligencer/2018/12/global-u-s-growth-in-smartphone-growth-starts-to-decline.html

Figure 10: Growth in Smartphones Sales (Source: Intelligencer)
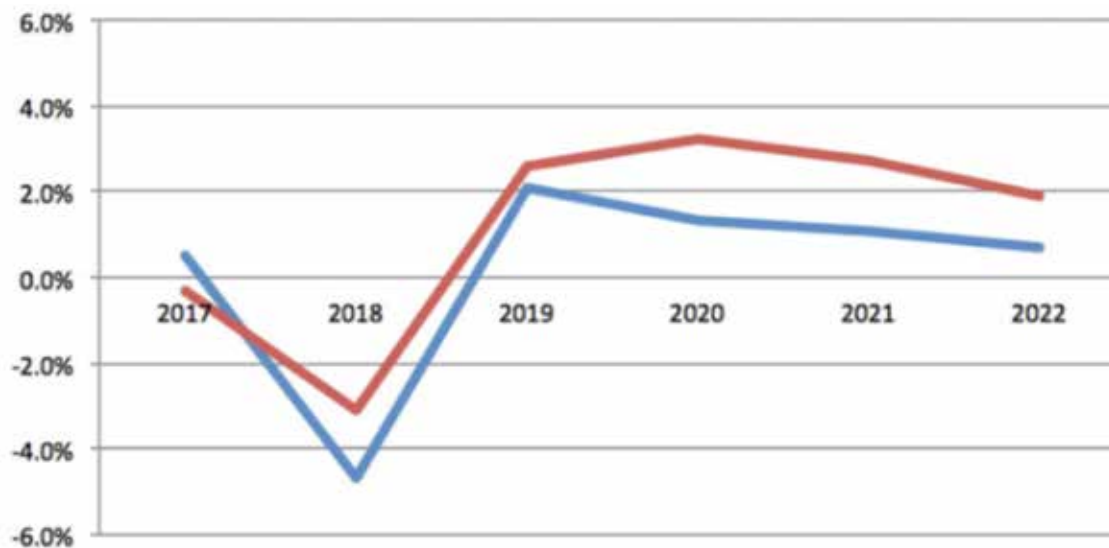
Moreover, autonomous driving, IoT, connected cars, smart homes and businesses, smart cities will have connectivity at their core. 5G is expected to take things ahead by reducing costs for the providers and speeding up their connections.

2.5 Environmental

People have become more and more environmental conscious, even though the current US Government is not particularly sensitive to environmental issues. Indeed, as shown in the figure below most US Americans report feeling concerned about the environment[27]. The 90% energy savings in Smart Cities for example that are intended to be offered by the use of the 5G, are therefore well embraced by the population[28].
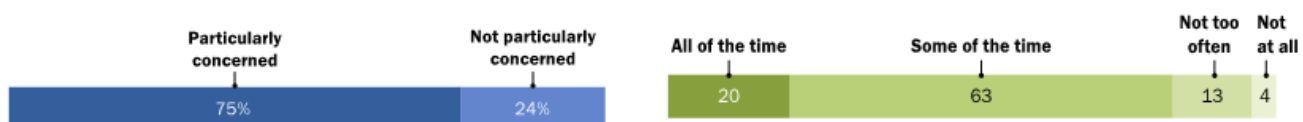
Figure 11: Americans concern about the environment (Source: PEW Research Center)

Moreover, 5G combined to IoT (with other required technologies such as big date, AA) are expected to be an essential tool to create Smart cities (as described in the following chapter). According to a survey conducted by CompTIA, 60% of Americans want to live in smart cities. In line with this trend, the smart city market is expected to grow from $425 billion in 2017 to $1.2 trillion in 2022 and it is estimated that the smart cities component of the IoT market will range between $930 billion to $1.7 trillion by 2025[29].

Apart from some concerns about cybersecurity, an important part of the Americans seems well embracing the new technology when it allows to live in a cleaner and energy saving environment.

27 http://www.pewresearch.org/fact-tank/2017/04/20/for-earth-day-heres-how-americans-view-environmental-issues/

28 Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

29 www.techrepublic.com/article/60-of-americans-want-to-live-in-a-smart-city/

2.6 Legal

In the US, the broadcasting regulations are overseen by the Federal Communications Commission (FCC) which was established by the Congress in 1934. There are several laws including those related to telemarketing and privacy that the providers must comply with. Several changes took place in the aftermath of the 9/11 attacks that gave rise to additional pressures for the telecom providers.

In 2018, to "Facilitate America's Superiority in 5G Technology", the FCC implemented a new strategy promoting 5G wireless communications investment and innovation, the 5G FAST plan[30]. The three main aspects of this plan are the following:

» Freeing up spectrum
» Promoting wireless infrastructure
» Modernising regulations

Concerning spectrum, the FCC has decided to take actions to free up additional spectrum for 5G in:

» High bands: 5 GHz of spectrum will be made available. An auction of 24 and 28 GHz frequencies have been organised in November 2018 and an auction of 37, 39 and 47 GHz frequencies are scheduled for 2019
» Mid-bands: 884 MHz will be freed up in 5, 3.5 and 3.7-4.2 GHz frequencies
» Low bands: The use of 600, 800 and 900 MHz frequencies will be improved
» Unlicensed spectrum: 6 GHz and above 95 GHz will be used for Wi-Fi

The second major component of the 5G FAST plan concerns infrastructure and is composed of two main topics:

» Speeding Up Federal Review of Small Cells: new rules were adopted in order to reduce federal regulatory impediments to deploying the small-cell infrastructure needed for 5G and to expand the reach of 5G[31].

» Speeding Up State and Local Review of Small Cells: this reform aims at banning short-sighted municipal roadblocks that have the effect of prohibiting deployment of 5G and at giving the states and localities a reasonable deadline to approve or disapprove small-cell siting applications[32].

Concerning regulations, the FCC is pushing to adopt the following new rules:

» Restoring Internet Freedom: to encourage investment and innovation while protecting Internet openness and freedom, this rule sets a consistent national policy for Internet providers. This would go against the "Title II" Framework to Spur Investment, Innovation and Competitions since it had a negative impact on the broadband deployment and on the investments in high-speed networks. Indeed, under the "Title II", broadband network investment dropped more than 5.6%[33].
» One-Touch Make-Ready: the aim of this rule is to update the FCC's rules governing the attachment of new network equipment to utility poles and to reduce cost and to speed up the process for 5G backhaul deployment[34].
» Speeding the IP Transition: this rule's goal is to make it easier for companies to invest in next-generation networks and services (networks of the past were fading)[35].
» Business data services: to incentivise investment in modern fibre networks, the FCC updated the rules concerning high-speed, dedicated services and lifted rate regulation where appropriated[36].
» Supply-chain integrity: this rule prohibits universal service spending on equipment and services from companies threatening national security[37].

The FCC has passed those regulations without regard to the health issues the small cells could cause, to the authority of the different cities and

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30 www.fcc.gov/5G
31 www.fcc.gov/document/fcc-acts-speed-deployment-next-gen-wireless-infrastructure
32 docs.fcc.gov/public/attachments/DOC-353927A1.pdf
33 www.fcc.gov/restoring-internet-freedom
34 www.fcc.gov/document/fcc-speeds-access-utility-poles-promote-broadband-5g-deployment
35 www.fcc.gov/document/fcc-acts-enable-investment-next-generation-networks-0
36 www.fcc.gov/document/business-data-services-report-and-order
37 www.fcc.gov/document/fcc-proposes-protect-national-security-through-fcc-programs-0

to the property rights of the US population[38]. Numerous cities have prosecuted the mobile operators and the FCC in justice regarding several of these issues. Since several months, it is a legal struggle between the municipalities and the FCC[39].

38   www.citylab.com/life/2018/10/fcc-5g-wireless-broadband-regulations-city-government/571921/
39   www.smartcitiesdive.com/news/cities-and-counties-sue-fcc-over-5g-vote/540889/

3. Key market trends impacting the 5G market

In early 5G deployments, 5G will be valued thanks to the enhanced mobile broadband. Moreover, massive IoT, ultra-reliable and low-latency communications will be the core of the mobile operators' proposition. They may be used in numerous emerging areas such as industrial and vehicular automation, autonomous vehicles, remote medical surgery, advanced manufacturing, virtual reality, etc. The following figure describes the highest priority use cases in early 5G deployment.
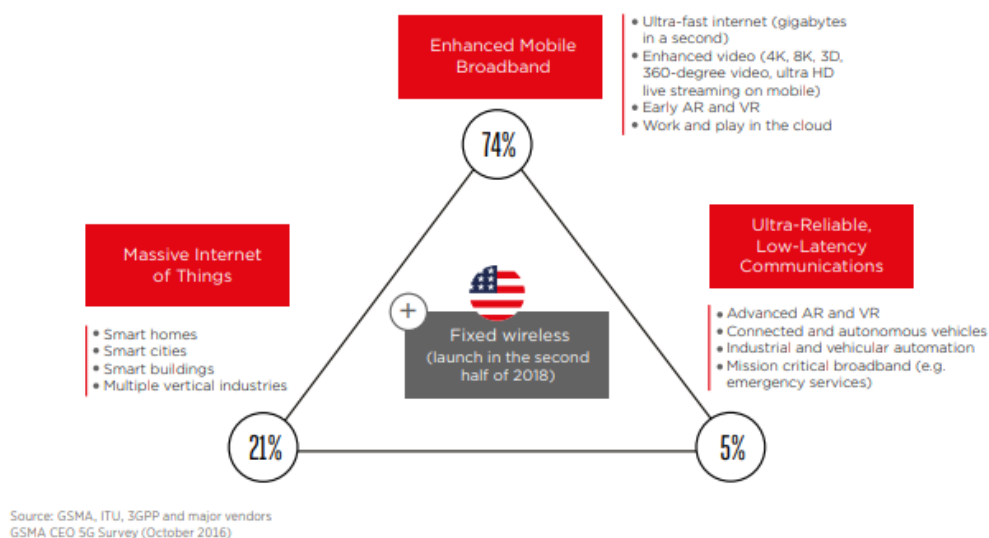
Figure 12: THE USE CASE PRIORITY IN EARLY 5G DEPLOYMENT

The following sub-chapter will specify current key market trends but of course this information can only be seen as a forecasting.

3.1 Mobile content and video

Mobile content and video are some of the most significant consumer use cases for 5G. For the companies seeking to grow, they will extend their business towards content aiming to enable the delivery of content to any screen through wireless distribution[40].

Moreover, the US streaming video market continues to increase in terms of formats and features. Hardware manufacturers are responding to anticipated demand growth by increasing the component production capabilities. For example, Foxconn plans to produce "8K+5G" displays which have the latest ultra-sharp 8K definition and can accommodate ultra-fast 5G wireless speeds.

Telecom operators are also working to meet this

40 www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/telecommunications-industry-outlook.html

demand – and not only in the US: For example, AT&T launched 5G trials in which participants could stream premium live TV via DirecTV Now. Netflix and Amazon Video are expected to expand their content libraries with 8K recording taking place in Hollywood by the time 5G

launches. The Japanese public TV company, NHK is expected to broadcast the 2020 Tokyo Olympics in 8K. And personal 8K video cameras are already available from some manufacturers such as GoPro[41].

3.2 Virtual reality

Augmented Reality (AR) and Virtual Reality (VR) are expected to benefit from the introduction of 5G thanks to its superior data streaming capabilities and lower latencies. The US is one of the first markets to experience AR and VR application, one of the leading markets in terms of adoption over time and is the home to many innovative companies in this domain already releasing products into the market.

Major tech companies are building AR capabilities into their platforms in anticipation of market development as Facebook with its Oculus Rift (in late 2016), Google and its Daydream headset and mobile content platform (in early 2017), Microsoft with its HoloLens headset and surrounding ecosystem (in late 2006), Apple and its AR Kit toolkit for developers (in 2017) and Amazon with its Lumberyard game development platform (2016).

The four major US telecom operators – AT&T, Sprint, T-Mobile and Verizon – are also engaged in AR and VR through a number of trials and showcases. In February 2018, Verizon streamed live in a 180-degree stereoscopic video the Super Bowl field in Minneapolis directly to VR headsets in New York City over 5G. In 2016, at the Copa América Centenario tournament in Santa Clara, California, Sprint demonstrated 5G capabilities for VR applications and advanced video by enabling spectators to experience a live streaming VR system from VideoStitch and view live stream video in 4K ultra high-definition.

While the range of potential applications is diverse (e.g. entertainment, gaming, translation, mapping/ schematics) and the potential to combine AR and VR with cloud services and AI will increasingly be explored, a considerable boost in the content available will be required to stimulate demand for AR and VR services[42].

3.3 Handset

Smartphones are expected to be the principal 5G device in the US. The first smartphone models will be costlier than the latest 4G devices available, as they will offer enhanced features, like 4K and 8K displays, additional cameras, advanced cloud functions and sensors for AR and VR applications[43]. As seen in the first chapter describing the 5G market in the US, Americans are generally early

adopters of new technologies. Indeed, 58% of current American smartphones users are expected to use those new technologies[44].

Worth noting here that as it did for 4G, Apple will wait before releasing 5G-compliant phones. Indeed, first 5G phones from Apple are expected to be produced in 2020[45], to avoid facing issues with early 5G deployments. However, its main

41   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

42   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

43   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

44   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

45   www.telegraph.co.uk/technology/2018/12/03/apple-will-wait-least-2020-release-5g-iphone/

competitors from China and South Korea, Huawei and Samsung, are excepted to to launch their own 5G phones in 2019.

3.4 Internet of Things (IoT)

IoT will become a critical engine for future growth. The connected cars are this far one of the most popular applications of IoT. In addition, other categories of IoT applications will continue to meet important growth, like connected consumers and connected home monitoring and control, entertainment, wearables, etc. Moreover, IoT will also enable application on the enterprise market, like for connected vehicle fleets, predictive maintenance, factory automation, workforce training and field support, etc.

IoT will continue to gain scale in both the consumer and industrial segments and will reach a total of more than 5 billion connections in the US only by 2025[46].

Key IoT markets are the following:

» Smart cities
» Connected vehicles
» Digital health
» Smart homes
» Energy/utilities
» Manufacturing and logistics
» Autonomous vehicles

3.5 Smart cities

In the US, implementation of smart city technology is gaining momentum, driven by public and private funding, and an increasing number of companies engaged throughout the value chain. The four most important US American mobile operators are engaged in smart city projects through partnerships with governments and urban planners[47].

5G will enable connectivity and computing capacity which will bring the power of Smart City solutions to municipalities across the US. The reductions in energy usage, traffic congestion and fuel costs and the vehicle traffic and electrical grids management enabled through Smart City solutions will result in $160

billion in benefits and savings. Moreover, it will enable cities to reduce commute times, improve public safety and generate significant smart grid efficiencies[48].

The key attributes of 5G that will benefit Smart Cities include higher speeds, more connections, quicker and more adaptive response times that support time-sensitive applications (for example, vehicle-to-vehicle communications) and ultra-low-power connections (for example, sensors for leak detection in water mains. The following figure illustrates the most important need of smart cities to which 5G will respond[49].

46   GSMA Intelligence IoT forecasts. Cellular and non-cellular IoT connections
47   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download
48   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf
49   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

5G: Technology to Meet the Growing Demands of Smart Cities

Source : Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart" Cities"

Figure 13: 5G TO MEET GROWING DEMANDS OF SMART CITIES

4. Applications of 5G: Verticals

The implementation of 5G will allow for a lot of transformation. 3G and 4G particularly increased the usage of mobile devices and transformed how they are used and what it enables. 5G will allow the transformation of several vertical industries. In particular, 5G will propose ultra-reliability which will effectively eliminate any element of risk but also low-latency which will enable people to control objects remotely, ensure the ultra-rapid responsiveness of objects and a lot more. The following figure show what the 5G is expected to enable and which verticals will emerge through these opportunities.
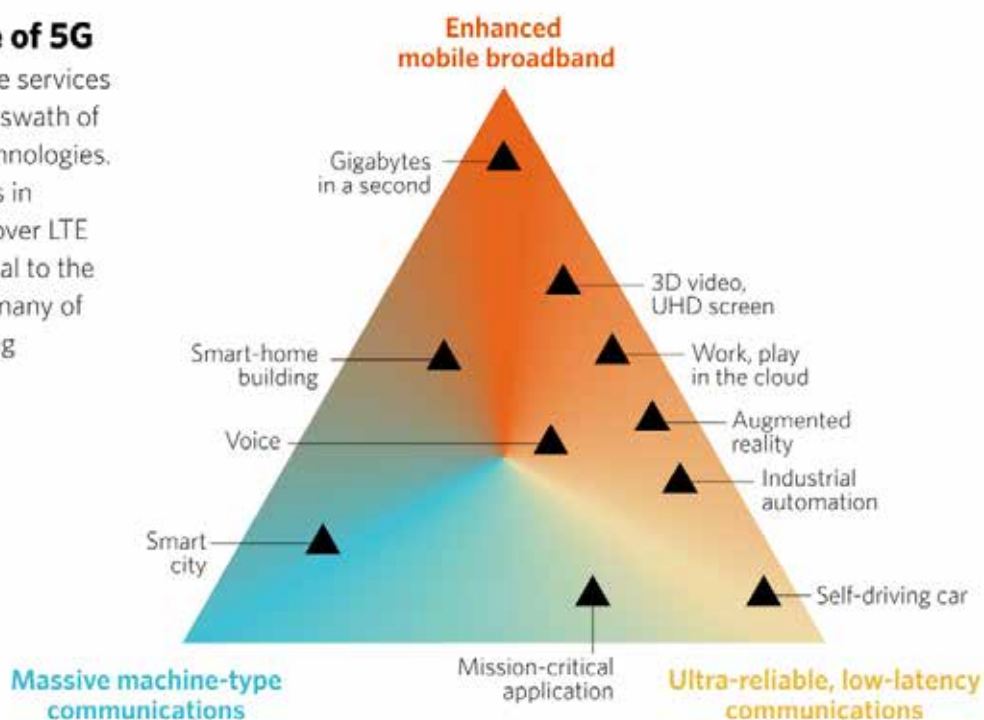
Figure 14: THE FUTURE USE OF 5G

4.1 Energy and utilities

4.1.1 Smart Grid

Through 5G, Smart Grid will be taken to a next step. According to the Electric Power Research Institute, Smart Grid will engender benefits of $2 trillion dollars over 20 years across the US[50].

5G will enable unconnected, energy consuming devices to be integrated into the grid and to be more accurately monitored and support better forecasting of energy needs. Moreover, these will allow to support the load balancing, will help reduce electricity peaks and in fine, reduce energy costs.

In the case of power failure, the smart grid

50 Electric Power Research Institute, "Estimating the Costs and Benefits of the Smart Grid", March 2011, Accessed July 30th, 2018

technology powered by 5G will enable precise and real-time diagnosis which will speed the repair processes and reduce the downtime. Smart grid had already without 5G allowed the EPB (Electronic Parking Brake) Chattanooga in Tennessee to save $1.4 million in operational costs for just one storm by reducing the duration of outages by 50%[51]. With 5G, the savings could even be more considerable.

Moreover, in general, 5G is considered more cost effective and energy efficient than previous wireless technology and will allow energy savings[52].

4.1.2 Smart Lighting

Smart lighting will include automatically dimming of public lighting when no pedestrians or vehicles are present. Smart lighting has already proven its efficiency: as part of a Smart City Initiative, San Diego and Barcelona have already installed Smart lighting and engendered estimated savings of respectively $1.9 million[53] annually and $555,000 annually[54]. Across the US, the savings through Smart lighting installations are estimated to be more than $1 billion per year.

Moreover, Smart lighting can also monitor local air quality and the lighting system's maintenance costs[55].

Nevertheless, it's worth noting that for such use case, 5G has many competing technologies like for instance LoRa or NB-IoT which might be more efficient when neither a low latency nor a wide bandwidth are required.

4.1.3 Smart cities

"Smart cities" are in the centre of numerous communities' focus in the US. Indeed, the four major telecom operators in the US (Verizon, AT&T, Sprint and T-Mobile) are engaged in smart city projects through partnerships with governments and city planners.

5G combined to IoT solutions can enable significant cost savings. For example, in Los Angeles, 215 000 street lights have been converted to LED smart lights which generated savings of $9 million[56]. In San Diego, IoT is used to monitor energy usage in a baseball park and is expected to reduce by 25% the operational costs over the next five years[57]. Moreover, the 5G enabled technology will allow the smart management of energy (see 1.1 Smart Grid and 1.2. Smart Lighting).

4.2 Transportation/Automotive industry

One of the fundamental societal challenges for the next decade is to improve efficiency of private and public transportation. In the US, this issue is of importance since the country is the world leader in traffic jams and costs US American motorists nearly $305 billion in 2017 (in average $1,445 per driver)[58]. Indeed, according to a report from INRIX, a leader in transportation

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51   Tweed, Katherine, "Smart Grid Saves EPB Chattanooga $1.4M in One Storm, Greentech Media, August 1, 2013, Accessed July 30th, 2018

52   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

53   Berg, Nate, "The Secret Energy Drain on Cities: Streetlights", April 30, 2012, Accessed July 30th, 2018.

54   Adler, Laura, "How Smart City Barcelona Brought the Internet of Things to Life", Data-Smart City Solutions, February 18, 2016, Accessed July 30th,2018

55   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

56   Maddox T., "How LA is now saving $9M a year with LED streetlights and converting them into EV charging stations" (2016) www.techrepublic.com

57   Hartje E., "The home of the San Diego Padres, Petco park, becomes an IoT connected smart city with Snapdragon TM technology" (2016) www.inforcecomputing.com

58   mobilitylab.org/2018/02/06/u-s-is-the-world-leader-in-traffic-jams/

analytics and connected car services, five of the top ten most-congested cities in the world are in the US. Key components identified to solve this challenge are connectivity and automation of cars. Besides the cars, the roads, the roadside infrastructure and the traffic information systems will have to be adapted for more efficiency and safe transportation. Currently, to reduce accidents and support drivers, advanced driver assistance systems are being implemented which sense nearby vehicles, road conditions and pedestrian activities. With 5G, this can ultimately be replaced by fully autonomous vehicles capable of both monitoring the surrounding environment and performing the driving functions. The vehicle-to-vehicle communication will allow cars to communicate on the environment and in fine, allow car convoys of thousands of cars. The benefit of fully autonomous cars will be numerous:

enhanced public transportation, reduced traffic congestion, reduced rider wait-times, optimized bus inventory and routing.

The connected and automated driving research is strongly encouraged by federal initiatives from the US Department of Transportation, US Department of Defence and the National Science Foundation in the US like the Smart and Autonomous Systems initiative, the Efficient Transportation Technologies initiative or the Micro Autonomous Systems and Technology initiative. The US automotive private industry and technology companies involved in internet related services also play a key role in connected and automated driving research. Companies like Google, Uber and General Motors for example have established synergies with universities and research centres to undertake important research in the field.

4.2.1 Connected automated vehicles

To have fully autonomous driving, the vehicle should be able to sense its environment and navigate without human interaction under all circumstances. To do so the cars will use a combination of numerous technologies including wireless communication technologies (5G), laser and radar sensing, GPS, and others. Information from those technologies will be processed by an artificial intelligence and deep

learning computer systems.

Today, automated driving trials rely on sensors on vehicles to enable emergency braking and collision avoidance. 5G, thanks to its low latency capabilities, will enable the communication between thousands of vehicles on a large scale with high reliability and high performance and enable fully autonomous driving.

4.2.2 Traffic/Commuting

Fully autonomous driving will improve considerably the in-town traffic by 40% and will allow savings of $100 million annually[59]. Cars will be able to move in convoys which will increase

the road vehicle capacity and the energy savings for the drivers. The following figure shows the mechanisms of those convoys and how they will allow cost savings.

59 Data from Texas A&M Transportation Institute, tti.tamu.edu/

Figure 15: CAR CONVOY ENABLED ENERGY SAVINGS (Source: Accenture Strategy Report)

4.3.3 Public Parking

Through real-time information available concerning empty parking spaces, vehicles will no longer need to circle to find an available space but instead would directly go to an available one identified through the system (could be a low-cost 5G sensor on a street lamp). This could increase parking revenue by 27%[60] and reduce traffic and slow driving[61].

4.3.4 Key telecom operators' action in the automotive industry

Two of the four US key telecom providers have started to take action concerning the automotive industry, Verizon and AT&T.

Verizon has developed a strategy towards this industry. It acquired numerous companies (in 2016, Fleetmatics and Telegis, in 2017, Skyward and in 2018, Movildata International) which placed Verizon as the largest provider of built-in telematics and mobile applications for commercial vehicles in the world. Moreover, Verizon has invested in Renovo, a start-up specialised in autonomous vehicles, and in Veniam, the worldwide provider of mobile Wi-Fi and data solutions for commercial fleets.

AT&T has developed 25 partnerships with automotive brands (including General Motors, Ford, Honda and American Centre for Mobility). Moreover, AT&T is part of the consortium with Ford, Nokia and Qualcomm for the C-V2X (vehicle-to-everything) trials at the San Diego Regional Proving Ground[62].

4.3 Public Safety

5G can be an important means to improve public safety: in Smart Cities it will enable all video surveillance in ultrahigh definition and so to use facial recognition to identify known criminals and to spot missing persons.

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60 Martens, Jon and Turoff, Steffen, "Mensa Meters", International Parking Institute, May 2013, Accessed July 30th, 2018, http://www.parking. org/2016/01/15/tpp-2013-05-mensa-meters/

61 Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

62 Daniels G., "San Diego to host cellular V2X trials with Ford, AT&T, Nokia and Qualcomm" (2017) www.telecomtv. com/content/automotive/san-diego-to-host-cellular-v2x-trials-with-ford-at-t-nokia-and-qualcomm-16136/

Figure 16: GUNSHOT DETECTION

Gun-related deaths is one main issue of the US. Indeed, in 2016, 37,200 people dies due to a gun use, representing the second highest rate in the world[63]. 5G will enable precise location in real-time of firearm discharge by a triangulation of the location and by sometimes an identification of the type of gun[64]. The authorities will be immediately alerted. In San Francisco, this location system has already been implemented based on 4G/LTE and has reduced gun crime by 50%[65]. The following figure illustrates how the gun shots will be detected.

Concerning flooding, in many communities in the US, emergency warning systems are already implemented and provide alerts about tornados and other weather events. 5G flood sensors could also provide vehicle drivers with route guidance and so reduce the primary cause of death during flooding (people choosing routes that are in flooded areas).

63   www.pbs.org/newshour/health/theres-a-new-global-ranking-of-gun-deaths-heres-where-the-u-s-stands
64   Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf
65   Ebi, Kevin, "Smart street lights shine spotlight on violent crimes", Smart Cities Council, October 2, 2015, Accessed July 30th, 2018, http:// smartcitiescouncil.com/article/smart-street-lightsshine-spotlight-violent-crimes

4.4 Healthcare

One of the most important challenges of the US regarding health concerns the important amount of money spent for healthcare. This amount is expected to reach 20% of the GDP by 2025[66]. The US is one of the countries spending the most important amount of money in healthcare[67].
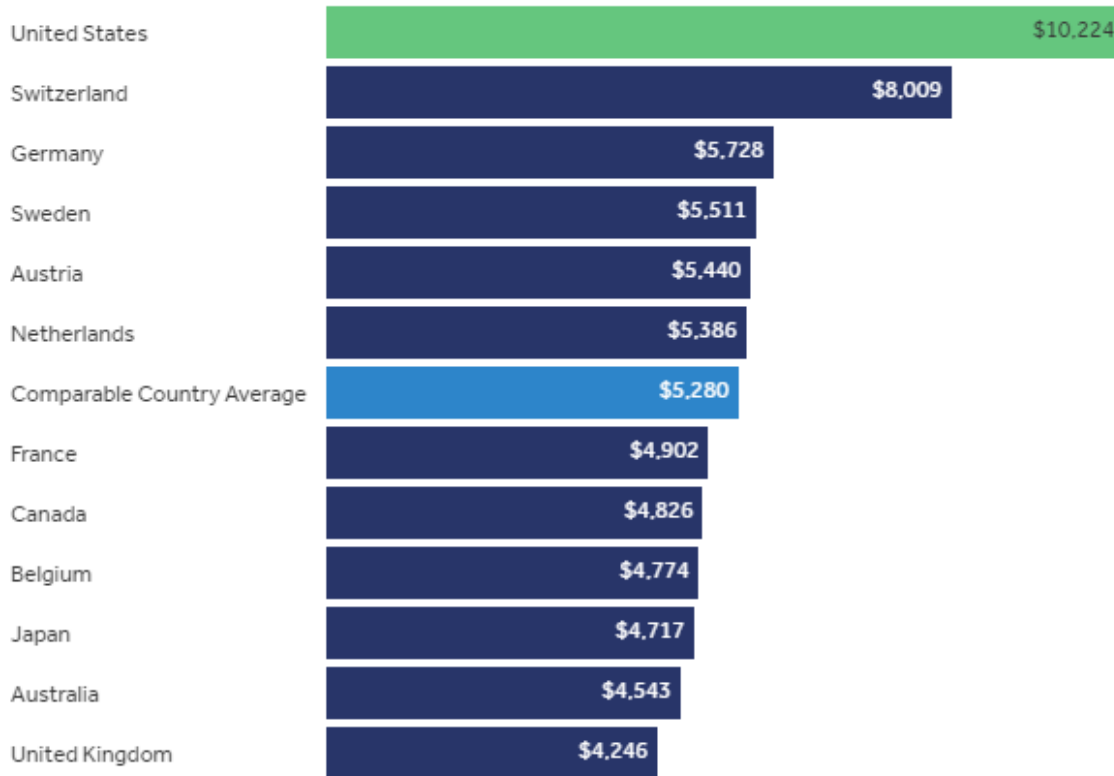

Figure 17: Healthcare expenditures per capita in 2017 (in US dollars and PPP adjusted) (Source: KFF analysis of data from National Health Expenditure)

The challenge for the US is to limit the cost of healthcare and to provide more effective care. 5G is expected to allow the US to create self-management capabilities and facilitating access to healthcare to minimize costs through the increased application of mHealth (the application of mobile phones, other wireless technology, information and communications technologies in medical care) and of eHealth (the delivery of health services and information through the Internet to reach people via mobile wireless technologies and broadband connections). Moreover, 5G also has an important potential to enhance the capabilities of the surgeons through the use of robots for remote applications.

5G could in particular impact the following areas:

» Remote Health Monitoring

Currently, short range communication technologies (e.g. Bluetooth, Wi-Fi) are used to connect sensors and wearable devices smartphones and apps to collect data to monitor and manage wellness indicators. With 5G, the Big Data acquired through those devices could be monitored by public health services to detect the onset and spread of epidemics (by combining with geographic data and other data sources. Moreover, 5G could counter the issues due to the support of massive increased connections per square meter, while still maintaining the requisite Quality of Service.

» Remote Healthcare

Remote Healthcare would enable individualized consultations, treatment and patient monitoring

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66 National Health Expenditure Fact Sheet, Centers for Medicare and Medicaid Services. 2015
67 www.healthsystemtracker.org/chart-collection/health-spending-u-s-compare-countries/#item-average-wealthy-countries-spend-half-much-per-person-health-u-s-spends

and not necessarily located in traditional healthcare establishments like hospitals and clinics. Remote Health Monitoring and remote Healthcare used in a complementary way could enable treatments using smart pharmaceutical devices that would administrate approved dosages of a drug on a specific schedule fixed by the practitioner. Moreover, this combined use of remote Health Monitoring and Healthcare could allow practitioners to remotely monitor

progress of treatment in real-time and quickly adjust the treatment as necessary.

» Remote Surgery

Through 5G and its enabled high reliability and very low latency, surgeon could remotely operate through the use of a surgical robot. Thus, the access to talented surgeons will be more uniform and their skills will be better utilized. Moreover, the surgeon could receive real-time information of the patient.

1. Manufacturing (Factories of the Future)

Improvements in manufactories and factories will be achieved through the increase of the efficiency of the production lines based on robotic automation and connecting distributed production sites, suppliers and logistics. Those will need 5G technology to be reliable. According to Accenture, the industrial Internet of Things is forecasted to add about $14.2 trillion to the global economy by 2030 and will generate an economic impact of $1.2-3.7 trillion per year by 2025[68]. In the US, its economy will gain $6.1 trillion in cumulative GDP by 2030 and it could even reach $7.1 trillion if the US's broadband infrastructure is improved for example or by taking additional measures. This could increase the American GDP by 2.3 percent compared to the trend projections in 2030[69].

In general, factory automation is used in the part of the factory where the products are assembled, tested or packed. In-time delivery of messages and high reliability are very important to avoid interruptions in the manufacturing process. Every step involved many sensors and actuator nodes which should be connected through effective wireless technology, 5G, to improve the productivity and increase the availability (compared to wired sensors/actuators at difficult locations).

5G is expected to improve:

» Industrial Process Automation

Through the automation of industrial processes which will ensure quality, consistency and cost-effective production of goods or services.

» Automated Production Lines

Devices such as sensors, robots, actuators for example in the production line need to communicate through wireless technology with low latencies to enable efficient production.

» Inventory and Supply Chain Optimization

Inventory and supply chains management leverage a large number of connected sensors and platforms that provide big data analytics to automate inventory and supply chain management decisions.

» Inter- and Intra-Enterprise Communication

This communication will need real-time coordination. For example, suppliers and logistics managers will need to interact seamlessly to maximize operational efficiency and ensure maximum value creation.

» Remote-Human IoT

New technologies will be used to provide guidance in tasks related to product assembly, maintenance or fault identification but also to conduct measurements, handle hazardous material, dig and tele-operate industry vehicles[70].

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68 Winning with the Industrial Internet of Things, Accenture. 2015.
69 Winning with the Industrial Internet of Things, Accenture. 2015.
70 5G Americas Whitepaper – 5G services and Use Cases (2017)

5. Driving forces of the 5G market

Internet access and the wireless networks provide important economic benefits to the US economy. The traffic of wireless networks has grown consequently since several years: today there is 100 000 times more traffic than in 2008. With this heighted traffic a need for more broadband infrastructure has emerged. The Recovery Act has announced the Government's investment of $4 billion in broadband including 114 000 miles of broadband infrastructure (especially in under-served areas). Moreover, tax incentives have been implemented to encourage wireless companies to invest in infrastructure and services.

Before starting with the 5G, the US was a leading country in terms of 4G deployment and covered with 4G/LTE more than 98% of the US American citizens. This allowed a traffic speed 10 times higher than in 2012. The mobile operators have since 2010 invested nearly $150 billion which include $85 million investment in advanced wireless testing platforms. These platforms allow academics, entrepreneurs and the wireless industry to test and develop advanced wireless technology ideas.

The success of the US in 4G has been fostered thanks to a clear and flexible policy strategy which allowed:

» The enhanced and early availability of spectrum;
» Innovators and entrepreneurs to define the future of wireless technologies and applications;
» An open competition and development of technologies on the marketplace;

» Sustained Federal investments in fundamental academic research that lead to technology breakthroughs (e.g. new channel access, antenna, modulation, and other technologies that contributed to the 3G and 4G revolutions, the broad deployment of Wi-Fi, mmWave technologies and spectrum-sharing arrangements).

Moreover, parallelly to the success of the 4G, several other societal factors have been driving the 5G development as for example demographic changes, the growing population (which for example puts an incentive on the agricultural sector to increase production), secure, clean and efficient energy to reduce energy consumption and smart, green and integrated transport to reduce congestion, accidents and pollution.

It can be expected that the success factors and results of 4G in the US, and the need to face those societal challenges are also the strongest driving forces for the 5G development and later deployment in the country. Therefore, the US industry has shown keen interest in the 5G research and development and is strongly driving it, supported by advantageous policy measures that are implemented through several initiatives and key public authorities.

The following subchapters describe some examples of initiatives that are fostering the development of 5G technologies in the US from the public sector as well as from the industrial sector and the research sector.

5.1 Public authorities/Initiatives

5.1.1 MOBILE NOW Act

The US Senate Committee on Commerce, Science, and Transportation approved the MOBILE NOW Act on the 1st of March 2016. This initiative aimed at boosting the development of 5G wireless broadband: it expanded the amount of the spectrum available for commercial licensing and helped streamline infrastructure development for 5G services. It was followed by the Advanced Wireless Research Initiative.

5.1.2 Advanced Wireless Research Initiative

In 2016, under the government of Barack Obama, the Advanced Wireless Research Initiative with $400 million investment from the National Science Foundation (NSF) and American Telecom providers (AT&T, Intel, Sprint, T-Mobile, Qualcomm and Verizon) was adopted. This Initiative aims at boosting the 5G deployment by establishing four city-sized testing platforms (Salt Lake City and New York City have been part of the Round I Platforms; it is not public which will be the two other cities[71]) and at supporting the growth in connected smartphones (370 million smart phones) which have doubled over the past decade and which are expected to reach 200 billion including other connected devices by 2021 (25 connected devices per person). The Internet of Things is expected to be a major driver to this increase in connected devices since it is expected to add 50 billion connected devices by 2020. Globally, data traffic is North America is expected to grow by 42% between 2015 and 2020.

Regarding the spectrum, the initiative is supporting the US strategy in this field which consists in making large amounts of high-frequency millimetre wave spectrum available for both licensed and unlicensed use. The spectrum in question is on the 28 GHz, 37 GHz and 39 GHz. Regulation was also updated allowing for an easier transition from older telephone networks to newer wireless and internet-based voice networks for telecom providers.

In the initiative, some potential application areas for 5G are cited:

» Mobile phones and tablets can download full length HD movies in less than 5 seconds (100 times faster than with 4G)
» Doctors will obtain information of the patient vitals and medical records before the patient arrives at the hospital door (through real-time video and sensor data from police vehicle, ambulances and drones)
» Semi- or fully-autonomous vehicles
» Factories with always-connected smart manufacturing equipment that self-diagnose

and repair themselves
» Gigabit-speed wireless broadband available in many public places
» Virtual reality training and simulators to develop and demonstrate skills in high-demand fields

More than twenty private-sector companies and associations in the US wireless industry have pledged more than $100 million in cash and in-kind support to the design, development, deployment, and ongoing operations of the testing platforms[72]. This includes design support, technical networking expertise, networking hardware, including next-generation radio antennas, software-defined networking switches and routers, cloud computing, servers, and experimental handsets and devices, software, and wireless network testing and measurement equipment. Some examples of contributions by the telecom industry – as planned when the initiative was launched[73]:

» **AT&T** will provide on-site mobile connectivity in the cities selected.
» **Carlson Wireless Technologies** will contribute equipment, technology, and expertise in TV white spaces and dynamic spectrum sharing
» **CommScope**, will contribute connectivity solutions such as antennas, RF cabling, cabinets, small cells, and fiber optics.
» **HTC** will provide technical expertise, mobile devices, IoT sensors and virtual reality systems.
» **Intel** will assist in research on mmWave, multi-antenna array, steerable beamforming, novel radio interface techniques, and anchor-booster architecture.
» **InterDigital** will contribute financial support and provide tools for spectrum and bandwidth management, heterogeneous networks and backhaul.
» **Juniper Networks** will contribute software, systems, and expertise to advance orchestration and authentication of massively-scalable, massively-distributed IoT networks, as well as new approaches to secure these networks.
» **Keysight Technologies** will provide a range

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71   www.advancedwireless.org/
72   advancedwireless.org/partners/
73   techcrunch.com/2016/07/15/us-to-put-400m-into-advanced-wireless-research-initiative-for-5g-networks/?guccounter=1

of current and next-generation cellular and WLAN hardware and software products and also consulting and testing assistance.

» **National Instruments** will support next-generation wireless communications research in areas like mmWave and Massive MIMO.

» **Nokia** (with **Nokia Bell Labs)** will provide financial contributions, research collaborations, governance, and product platform support, and will focus on software-defined radios, the Internet of Things, remote sensing, mmWave, security, new use cases and applications, and dynamic spectrum sharing.

» **Oracle** will provide core network controls, analytics, and network orchestration to researchers and help them understand the impact of subscriber behaviours, enhance orchestration, and bolster security.

» **Qualcomm** will contribute financial support as well as engineering equipment and guidance to explore new and innovative communication systems.

» **Samsung** will contribute research design and engineering expertise, with a particular emphasis on technologies for future wireless networks in the 28GHz and other millimetre wave bands, as well as continued enablement for the Internet of Things.

» **Shared Spectrum** will provide technical expertise in dynamic spectrum sharing to support the design and architecture of research platforms.

» **Sprint** will support research and development and technical expertise on network design, use cases, and architecture requirements for core and radio access networks and the devices that will access them.

» **T-Mobile USA, Inc.** will provide technical expertise, including staff engineering assistance or advice in the design and deployment of the testing platforms.

» **Verizon** will contribute technical expertise, such as staff engineering assistance in the design and deployment of the testing platforms, and in fixed and mobile systems, indoor and outdoor environments, and residential and commercial buildings.

» **Viavi Solutions** will provide test, measurement, assurance, and optimization solutions for lab and field trials for network and services to enable next-generation technologies for the always-connected society and Internet of Things.

» The **Alliance for Telecommunications Industry Solutions (ATIS)** will provide technical assistance and staff time on the design and deployment of the testing platforms. ATIS will also identify potential opportunities for research to be conducted on the platforms.

» **CTIA** will contribute engineering and technical assistance to help align industry R&D and university research with next-generation wireless networks, devices, and applications.

» The **Telecommunications Industry Association (TIA)**, will provide technical and engineering expertise in wireless network deployment, Internet of Things, interoperability, and software-defined networking. TIA will also assist with expanding industry awareness of the testing platforms.

5.1.3 National Science Foundation

The National Science Foundation (NSF) is part of the previous mentioned Advanced Wireless Research Initiative and has invested $5m million over 5 years to design and build the four city-scale advanced wireless testing platforms. Each platform will deploy a network of software-defined radio antennas city-wide to imitate the existing cellular network. This will allow academic researchers, entrepreneurs, and wireless companies to test, prove, and refine their technologies and software algorithms in a real-world setting. The aim is to allow "at-scale experiments" and perform proof of concept work.

A further $350 million will be invested over the next 7 years in fundamental research on advanced wireless technology projects that will exploit these platforms. Additionally, NSF will fund two prize challenges to enhance wireless broadband connectivity. The first challenge will focus on providing rapid, large-scale wireless connectivity to restore critical communication services in the aftermath of a disaster. The second will seek innovative solutions to provide low-cost, seamless connectivity in urban areas using fibre optics in overhead light poles. Jointly with Intel Labs NSF will provide $6 million for research on information-centric wireless edge networks, with the goal of developing the ability

to process very large quantities of information with response times of less than one millisecond.

5.1.4 National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST) is establishing a Future Generation Communications Roadmap by creating a multi-disciplinary working group. It aims at identifying key gaps and R&D opportunities related to the 5G systems and standards.

The NIST is also performing a coordinated channel measurement, verification, and comparison campaign for indoor environments through the 5G mmWave Channel Model Alliance. This Alliance brings together researchers from different sectors (communication technology companies, academia and government) in the ultimate goal to accelerate 5G innovation.

Moreover, the NIST has launched the "5G and Beyond" programme which aims at providing the wireless industry with the maximum metrological impact as it develops new technology, standards and instrumentation[74]. In this programme are included the following projects:

- » Millimetre-Wave Transistor and NL Device Measurements
- » Millimetre-Wave Signal Characterization
- » Channel Measurement and Modelling
- » Over-the-Aire Test for Massive MIMO
- » Radio Resource Allocation and Beamforming Algorithms

5.1.5 National Telecommunications and Information Administration

In April 2018, the National Telecommunications and Information Administration (NTIA) signed a cooperative research and development agreement for a five-year period with the University of Colorado Boulder (CU) to develop a wireless test bed. The NTIA's Boulder-based Institute for Telecommunications Sciences (ITS) will collaborate with the university in order to install spectrum monitoring sensors throughout the CU Boulder campus and to explore a campus-scale wireless network, the share of spectrum and mobile applications[75]. With the Centre for Advanced Communications, ITS will demonstrate the Measured Spectrum

Occupancy Database (MSOD) project at the International Symposium on Advanced Radio Technologies in Colorado. MSOD has been recording spectrum utilization 24 hours a day, seven days a week, over several years, using data from multiple sensor installations. ITS will also expand its Urban and Indoor Radio Frequency (RF) Propagation Measurement campaign by using the four city test sites to provide additional data to improve the accuracy of RF propagation models in urban terrain. Electro Magnetic Compatibility (EMC) analyses and tests will also be performed at the test beds.

5.2 Research Initiatives in 5G from the Industry

The American industry is a high contributor to the development of 5G. Unlike in the European Union in which research and development are often conducted by the universities and public research organisations, in the US research and development activities are often conducted

by the industry. As explained in the previous chapter a lot of industry players contributed to the Advanced Wireless Research Initiative. This chapter will describe examples of other research initiatives conducted by the industry.

5.2.1 T-Mobile and Ericsson US

T-Mobile US, Inc. and Ericsson are working together and are jointly evaluating the

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74 ttps://www.nist.gov/programs-projects/5g-beyond
75 www.ntia.doc.gov/press-release/2018/ntia-signs-agreement-wireless-test-bed-study-partnership-university-colorado

performance and applicability of potential 5G key technologies[76]. An aim is to develop a pre-standards 28GHz 5G test system for lab and field trials in the United States. The work builds upon Ericsson's long-standing partnership with T-Mobile for LTE-Advanced and network transformation. The two companies will develop and test selected 5G use-cases and services to enable T-Mobile to evaluate emerging 5G technologies, drive 5G technology development and standardization, and to explore new business opportunities. Notably Ericsson are predicting 150 million 5G subscriptions by the end of 2021. T-Mobile currently delivers Americas fastest 4G LTE network and the market is waiting for 5G consumer smartphones and standards. Ericsson has announced more than 20 agreements to test 5G with operators across the globe and Ericsson 5G Radio

prototypes, designed for operator field trials, are already achieving more than 25 Gbps mobile throughput. Since 2018, the two companies have been implementing 5G in New York, Los Angeles and Las Vegas using 5G New Radio (NR) radios and baseband[77]. At the beginning of the year 2019, T-Mobile and Ericsson partnered with Intel to conduct the world's first 5G data call and video call on 600 MHz (including successful uplink and downlink communication), both on a live commercial network. The 5G signal covered more than a thousand square miles from a single tower. T-Mobile also accomplished a tri-band 5G video call with three users on different spectrum bands, 600 MHz, 28 GHz and 39 GHz. This represent an important step forward for the multi-band spectrum strategy used by the companies to implement 5G in the US[78].

5.2.2 Verizon

Verizon is planning field trials of 5G networks in 2017 at their Basking Ridge headquarters with a planned entry into service date of 2020 with 1GBps. The 5G network will provide speeds 200 times faster than the 5 Mbps generally available today on Verizon's LTE network. Verizon is also working with Alcatel-Lucent, Ericsson, Cisco, Nokia, Qualcomm and Samsung to test 5G in

their innovation centres. Verizon has set up a 5G Technology Forum that includes venture capitalists and the company has created "sandbox" testing areas for 5G technology, in its innovation centres in Waltham, Massachusetts, and San Francisco. Verizon has also opened 5G Labs to support entrepreneurs and innovators as they build the 5G adapted applications[79].

5.2.3 Other industry players

AT&T is one of the four major telecom providers in the US, as are T-Mobile, Verizon and Sprint. AT&T has invested between 2013 and 2017 more than any other public company: more than $135 billion (including capital investment and acquisitions of spectrum and wireless operations).

Sprint has spent in 2018 $6 billion in capex on the upgrade and infrastructure of its network. $1 billion has been spend in purchase orders for equipment related to its massive MIMO deployment[80]. Moreover, T-Mobile and Sprint will be merging in the first half of 2019 in order

to be a stronger competitor of Verizon and AT&T and to accelerate their 5G deployment.

T-Mobile, Verizon, AT&T and Sprint's 5G deployment strategies will be described in the next chapter (VI. Implementation strategy of key vendors).

Other technology players are designing solutions to aid enterprises and the government to make the most of 5G evolution and are helping the telecom providers to deploy 5G with suitable infrastructures. The most notable companies are Qualcomm, Qorvo, Skyworks Solutions, Ericsson, LG, Cisco and Intel.

76   http://hugin.info/1061/R/1988513/730155.pdf

77   www.ericsson.com/en/press-releases/2018/2/ericsson-and-t-mobile-to-deploy-multi-band-nationwide-5g-network

78   www.thefastmode.com/technology-solutions/13968-t-mobile-completes-world-s-first-5g-call-on-600-mhz-with-ericsson-and-intel

79   www.verizon.com/about/news/when-we-say-5g-we-mean-5g

80   www.sdxcentral.com/articles/news/sprint-spent-1b-on-massive-mimo-for-its-5g-network-in-q2/2018/06/

5.2.4 5G Americas and 5G Forum USA

5G Americas (which changed its name from 4G Americas on February 12, 2016) is an industry trade organisation headquartered in Bellevue, Washington, composed of leading telecommunications service providers and manufacturers. The organisation's mission is to advocate for and foster the advancement and full capabilities of LTE wireless technology and its evolution to 5G. 5G Americas' key aim is to develop a connected wireless community while leading 5G development for all of the Americas. The organisation is addressing the following areas:

» Standards recommendations, technical requirements and advocacy for LTE, LTE-Advanced and LTE-Advanced Pro technologies and beyond

» Supporting the 3GPP technology path as it evolves to 5G technology

» Serving as a resource for information on LTE wireless technology and 5G throughout the Americas

5G Americas organises a 5G Forum in the US every year where the world's leading 5G organisations discuss the latest research and development achievements and views on 5G.

5G Americas was also supporting the Global 5G Event in Beijing, China on May 31-June 1, 2016 collaborating with The Fifth Generation Mobile Communications Promotion Forum (5GMF) (Japan), 5G Forum (Republic of Korea), IMT-2020 (5G) Promotion Group (China) and the 5G Infrastructure Association - Public Private Partnership (5G PPP) (Europe). Since then, the Global 5G Event has become a biannual event: 5G Americas has organised five other Global 5G Events all over the world (Rio de Janeiro, Seoul, Italy, Tokyo and Austin), the latest one being held in Rio de Janeiro, Brazil in November 2018 with representatives from Mavenir, Nokia, FCC and Ericsson.

5G Americas publishes regularly white papers and in October 2015, they published a white paper on 5G Technology Evolution Recommendations, expanding upon 4G Americas' view of 5G recommendations in 2014. A key recommendation from this was that the US should invest in a national programme in 5G in order to compete with the rest of the world which led to the Advanced Wireless Research Initiative.

5.3 Research initiatives from Universities

5.3.1 University of Texas at Austin

The Wireless Networking and Communications Group (WNCG) is an interdisciplinary centre for research and education at the University of Texas at Austin with an emphasis on industrial relevance. Founded in 2002, the group includes 20 faculties from the departments of Electrical and Computer Engineering, Aerospace Engineering, Mathematics, and Computer Sciences. The group is addressing mmWave research to demonstrate the viability of the technology for 5G systems. The research is investigating data rates, blockages, system coverage, sensitivity to interference and antenna arrays. Approaches to hybrid beamforming transmission strategies are being developed to adaptively configure arrays at the transmitter and receiver. Ways for propagation channel estimation are also being developed, which can aid the beamforming process. Five technologies that could lead to both architectural and component disruptive design changes have been identified: device-centric architectures, mmWave, massive MIMO, smarter devices, and native support for machine-to-machine communications. UT Austin and Stanford work together in this area and they have recently been awarded an NSF grant of $978,000[81].

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81   www.ece.utexas.edu/news/profs-de-veciana-shakkottai-and-collaborators-received-nsf-grant-work-5g-wireless-networks

5.3.2 Stanford University & Berkeley

Stanford University in collaboration with Berkeley are working on Software-Defined Networking (SDN) and Network Functions Virtualization (NFV) which are two key pillars for 5G. The concept for SDN arose out of the graduate work of Martin Casado at Stanford in collaboration with Nick McKeown, also at Stanford, and Scott Shenker at Berkeley. The Open Networking Research Center (ONRC), was set up to develop and support open source SDN tools and platforms for OpenFlow and SDN. This is sponsored by CableLabs, Cisco, Ericsson, Google, Hewlett-Packard, Huawei, Intel, Juniper, NEC, NTT Docomo, Texas Instruments and VMware.

The ONRC is made up of the networking research groups at Stanford University and UC Berkeley and an independent, non-profit Open Networking Laboratory (ON.Lab). The ONRC collaborates with the Open Networking Foundation (ONF) on the Open Networking Summit, bringing a cross-section of industry engineers, business leaders and researchers together for tutorials and keynotes.

5.3.3 New York University Wireless

New York University Wireless was established in 2012 as a multi-disciplinary research centre, focusing on 5G wireless research in the medical and computer science fields. The centre is funded by the National Science Foundation and has an Industrial Affiliates board of 10 major wireless companies. NYU WIRELESS has conducted and published channel measurements that show that mmWave frequencies are viable for multi-Gigabit per second data rates for future 5G networks.

5.3.4 Rutgers University

The Cyber-Physical System (CPS) Lab at Rutgers University, funded by NSF, are working on dynamic provisioning and allocation under the Cloud Radio Access Network (C-RAN). They have shown that the dynamic demand-aware provisioning in the cloud will decrease the energy consumption while increasing the resource utilization. They have also implemented a testbed to demonstrate the feasibility of C-RAN and developed new cloud-based interference cancellation techniques.

6. Implementation strategy of key vendors

In the US, there are four main telecom providers: Verizon Wireless, AT&T, T-Mobile and Sprint.

Top U.S. Wireless Carrier Metrics Q1 2018 (ranking by subscribers, retail + wholesale)

		Subscribers (millions)	Net Adds (millions)	Postpaid Smartphone Net Adds (mil)	Blended Churn (Avg Monthly)
1	Verizon Wireless	151.482	1.025	0.220	1.28%
2	AT&T	143.832	2.630	0.042	1.65%
3	T-Mobile	74.018	1.433	0.760	2.22%
4	Sprint	53.600	-0.019	0.185	2.33%
5	US Cellular	5.063	-0.033	-0.010	1.65%
6	C Spire*	n/a			
7	Shentel	1.025	0.009	0.038	2.44%

Source: *www.fiercewireless.com/wireless/how-verizon-at-t-t-mobile-sprint-and-more-stacked-up-q1-2018-top-7-carriers*
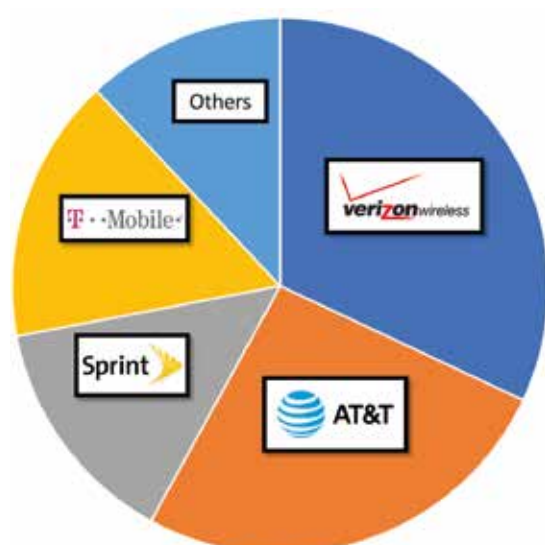
Figure 18: MAIN TELECOM PROVIDERS IN THE US

Figure 19: THE EXPECTED US RETAIL WIRELESS SUBSCRIPTION MARKET SHARE IN 2020

Those operators hope to deploy 5G very soon and make the US one of the first (if not the first) country to deploy it. The telecom operators are deploying 5G for a broader launch in 2019. But it is still unclear how broad those services will be launched and if the early experience will meet the global expectations[82].

The previous chapter identified the main efforts of the telecom and technology industry to develop 5G on a global level where as this chapter will describe the four telecom operators' strategies concerning the commercialisation of 5G in the US.

82 www.cnet.com/news/china-not-the-us-is-most-ready-for-5g/

6.1 Verizon Wireless

In 2016, Verizon established its 5G Technology Forum including Apple, Cisco, Ericsson, Intel, LG, Nokia, Qualcomm and Samsung and completing and releasing its 5G radio specification. These specifications were used for early 5G trials and the development of the 3GPP NR standard.

Moreover, Verizon has acquired spectrum in the 28 GHz and 39 GHz bands and has tested them through a number of trials successfully. Verizon expects to use them as part of its 5G ecosystem.

The company already has delivered pre-commercial 5G services in 11 metropolitan areas (Ann Arbor, Atlanta, Bernardsville, Brockton, Dallas, Denver, Houston, Miami, Sacramento, Seattle and Washington DC) in 2017. It allowed the company to test their mmWave 5G service. In the second half of 2018, Verizon targets a 20-30% penetration rate with the launch of 5G-based fixed wireless services in three to five

US markets (including Los Angeles, Boston and Sacramento). By 2019, it expects to rollout a broader fixed wireless network.

In parallel, Verizon Wireless is upgrading its 4G network and is also preparing for mobile 5G. It has completed a successful FDD massive MIMO trial in partnership Ericsson and Qualcomm with a compatible customer device. Verizon considers MIMO as a key technology component for its evolution and will potentially enhance the customer experience by raisin network spectral efficiency and customer speeds.

Moreover, Verizon has commercialised the first 5G compatible mobile phone in January 2019[83].

Success story: in February 2018, the chairmen and CEOs of Verizon (in Minneapolis, US) and KT (in Seoul, South Korean) conducted the first-ever pre-commercial 5G video call on two prototype 5G tablets developed by Samsung.

6.2 AT&T

Already in 2016, AT&T conducted 5G field trials using mmWave spectrum and tested 5G services with residential customers, small and large businesses, and retail locations. In 2017, the company launched pre-standards 5G fixed wireless trials in a number of areas (Austin, Texas, Waco, Texas, Kalamazoo, Michigan and South Bend, Indiana).

In June 2018, AT&T conducted one of the US first fixed 5G trials using mmWave spectrum in South Bend making 71 metros nationwide where their ultra-fast internet service in available. A full end-to-end 5G network architecture, including the 5G radio system and core, demonstrating extremely low latency was observed[84]. It received positive feedback from the families enabled to stream their favourite shows, research online archives and download movies, textbooks and

research materials in an instant and all at the same time[85].

The trial in Kalamazoo, Michigan allowed AT&T to observe that there were no impacts on 5G mmWave signal performance due to rain, snow or other weather conditions. Moreover, the company discovered that mmWave signal can penetrate materials such as significant foliage, glass and even walls better than initially anticipated[86].

The third trial in Waco, Texas consisted in providing 5G mmWave service to a retail location more than 150 meters away from the cell site and. AT&T observed wireless speed of approximately 1.2 Gbps in a 400 MHz channel and latency rates at 9-12 milliseconds. It was also the occasion for them to test their infrastructure which supported hundreds of simultaneous

83 www.lesmobiles.com/actualite/26127-le-premier-telephone-compatible-5g-est-commercialise.html
84 European 5G Observatory
85 Press Release "A glimpse of the 5G future – starting in South Bend, Indiana" (June 2018) about.att.com/innovationblog/5g_south_bend
86 European 5G Observatory

connected users using the 5G network[87].

The president of AT&T Indiana said "Our fibre expansions across the nation will help allow AT&T to achieve its plans to be the first US carrier to provide mobile 5G service, which we plan to begin introducing in 12 cities by the end of this year (2018). Our customers expect and deserve rapid information at their fingertips, and we are constantly working to transform the way they experience technology. In addition, we're thrilled South Bend was chosen as one of four cities nationwide where AT&T is currently doing a fixed 5G trial." Moreover, AT&T plans on bringing their 5G network to parts of 13 additional metro areas (Amarillo, Beaumont, Bowling Green, Evansville, Florence, Gainesville, Hattiesburg, Lake Charles, Northeast Mississippi, Panama City, Pensacola, Springfield, Il. and Waco) using their LTE Advanced Pro technologies. They also plan on reaching at least 14 million locations across at least 84 metro areas by mid-2019[88].

The first 5G devices implemented in 2018 are working as mobile hotspots while waiting for early 5G phones to be ready in 2019. In the meanwhile, AT&T is upgrading well towers with network upgrades that include ultra-fast LTE Advanced features such as 256 QAM, 4x4 MIMO and three-way carrier aggregation. These features aim to provide faster speeds and a better entertainment and connectivity customer experience on mobile devices. AT&T's target is using multiple technological architectures to deliver 1 Gbps speeds in the US using 39 GHz and 28 GHz[89].

One of the driving forces behind their overall network transformation is Network AI, their framework for using software-defined networking, artificial intelligence and edge computing to create an autonomous network based on open source efforts[90]. Moreover, AT&T is making significant progress with its network virtualisation: 55% of its network was virtualised in 2017 and plans of virtualising 75% of it by 2020.

6.3 T-Mobile

T-Mobile is focused on delivering a truly transformative 5G experience and plans on delivering 5G in 30 cities during 2018. New York, Los Angeles, Dallas and Las Vegas customers will be the first to experience 5G when the first 5G smartphones will be launched in early 2019. T-Mobile also uses simultaneously its 4G and 5G networks to deliver 5G. T-Mobile's goal is to deliver a nationwide network that will also continue to work even when the customer moves from one place to another. That is why the company uses its LTE network which is the most advanced LTE network in the US and on the less populated spectrums.

Moreover, T-Mobile has built out 5G not on

mmWaves but on 600MHz spectrum primarily and will use 29 and 39 GHz frequencies in a second stage in order to get high speeds with a broad coverage[91]. The company deployed 25 000 small-cells allowing to add extra capacity and speed, while paving the way for 5G[92].

In June 2018, T-Mobile in collaboration with Nokia announced the first successful completion of a bi-directional over-the-air 5G data session on a 3GPP-compliant 5G new radio system in T-Mobile's lab. This is a major milestone in delivering mobile 5G since it shows that is will work on actual smartphones. The 5G data transmission was conducted with the Nokia AirScale baseband and radio, AirFrame server,

87   European 5G Observatory
88   Press Release "Ultra-Fast Internet Powered by AT&T Fiber Now Available in South Bend, Ind." http://about.att.com/story/5g_and_att_fiber_in_south_bend.html
89   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&downld
90   Press Release "Behind the Scenes of our Journey to 5G (June 2018) http://about.att.com/innovationblog/behind_the_scenesat
91   European 5G Observatory
92   Press Release "T-Mobile building out 5G in 30 cities this year… and that's just the start" (February 2018) www.t-mobile.com/news/mwc-2018-5g

and AirScale Cloud RAN running 5G new radio 3GPP-compliant software[93].

6.4 Sprint

Sprint has announced that by early 2019 the company plans to provide 5G commercial services and devices and deploys 2.5 GHz massive MIMO radios slated for commercial use in 2018. These radios will allow Sprint to support both LTE and 5G simultaneously without additional cell tower. This is enabled thanks to the hold of more than 160 MHz of 2.5 GHz spectrum available in the top 100 US markets.

In June 2006, Sprint demonstrated a 5G trial using 73 GHz frequencies in collaboration with Nokia. They observed a peak download speed delivered reaching 2 Gbps by streaming a live, highly responsive, virtual reality system and a live video in 4K ultra HD[94]. In 2018, Sprint has announced that they will be launching 5G in selected markets (Chicago, Dallas, Los Angeles, Atlanta, Houston and Washington DC) in the first half of 2019. In May 2018, Sprint expanded the list of the selected markets and included Kansas

City, New York City and Phoenix[95]. The customer in these cities will be the first to experience 5G-like capabilities. Moreover, Sprint expects to deploy thousands of massive MIMO radios that would increase data speeds and network capacities for millions of customers in 2018 and 2019[96]. Sprint is also upgrading its existing towers and is building thousands of new cell sites to expand its coverage footprint and reach more cities. Sprint has already installed more than 100 000 "Magic Boxes" in about 200 cities in the US and plan on deploying more than 1 million in the next years.

Moreover, Sprint will be one of the first to launch the mobile 5G services in partnership with Ericsson[97] and Qualcomm[98] since it is planned for the first half of 2019. Sprint has developed a mobile 5G strategy and key enabling technologies including 5G applications and services[99].

6.4.1 Sprint and T-Mobile merger

Sprint and T-Mobile announced in June 2018 their merger which is for many the most important merger in US history. This merger aims to create the best nationwide 5G network and to bring a lot of other benefits to consumers, create jobs and to position them as the leader

in mobile 5G. Without this merger T-Mobile and Sprint separately would not have the necessary

funding and network capacity to enable nationwide 5G network[100]. More specifically it is expected that the merger will enable them to

93 Press Release "Nokia and T-Mobile achieve nation's first 3GPP-compliant bi-directional 5G new radio data transmission" (June 2018) www.t-mobile.com/news/nokia-and-t-mobile-achieve-nations-first-3gpp-compliant-bi-directional-5g-new-radio-data-transmission
94 opean 5G Observatory
95 Press Release "Sprint announces New York City, Phoenix and Kansas City among first to experience Sprint 5G" (May 2018) http://newsroom.sprint.com/sprint-announces-new-york-city-phoenix-and-kansas-city-among-first-to-experience-sprint-5g.htm
96 Press Release "Sprint unveils six 5G-ready cities; significant milestone toward launching first 5G mobile network in the US" (February 2018) http://investors.sprint.com/news-and-events/press-releases/press-release-details/2018/Sprint-Unveils-Six-5G-Ready-Cities-Significant-Milestone-Toward-Launching-First-5G-Mobile-Network-in-the-US/default.aspx
97 Press release "Ericsson a key partner in Sprint's 5G-ready Massive MIMO deployments" (February 2018) www.ericsson.com/en/news/2018/2/ericsson-a-key-partner-in-sprints-5g-ready-massive-mimo-deployments
98 Fierce Wireless News "Sprint promises to launch nationwide mobile 5G network in first half of 2019" (February 2018) www.fiercewireless.com/5g/sprint-promises-to-launch-nationwide-mobile-5g-network-first-half-2019-and-to-raise-unlimited
99 News Release "Sprint executives Austin-bound to talk 5G" (May 2018) http://newsroom.sprint.com/sprint-executives-austin-bound.htm
100 Press Release 9to5Mac "T-Mobile and Sprint announce $26B merger, plan powerful nationwide 5G

rollout ultra-fast 4G LTE – twice as fast as Verizon and three times faster than AT&T. The merge will enable:

» To combine the capacity of Sprint and the coverage of T-Mobile for a robust 5G network delivery and an improve LTE service
» To provide faster access to more cell sites
» To become more competitive and to force their competitors AT&T and Verizon to accelerate and increase investment in their 5G network plans
» To offer lower prices, better service and new offerings to more consumers through an increased network capacity

» To offer access to high-speed mobile LTE broadband and retail service also to the rural communities
» To create thousands of new jobs: they announced the creation of more than 3 000 direct jobs initially and in a few years to increase this number to more than 11 000 jobs and with the installation of 5G to thousands of more jobs to support it[101.]

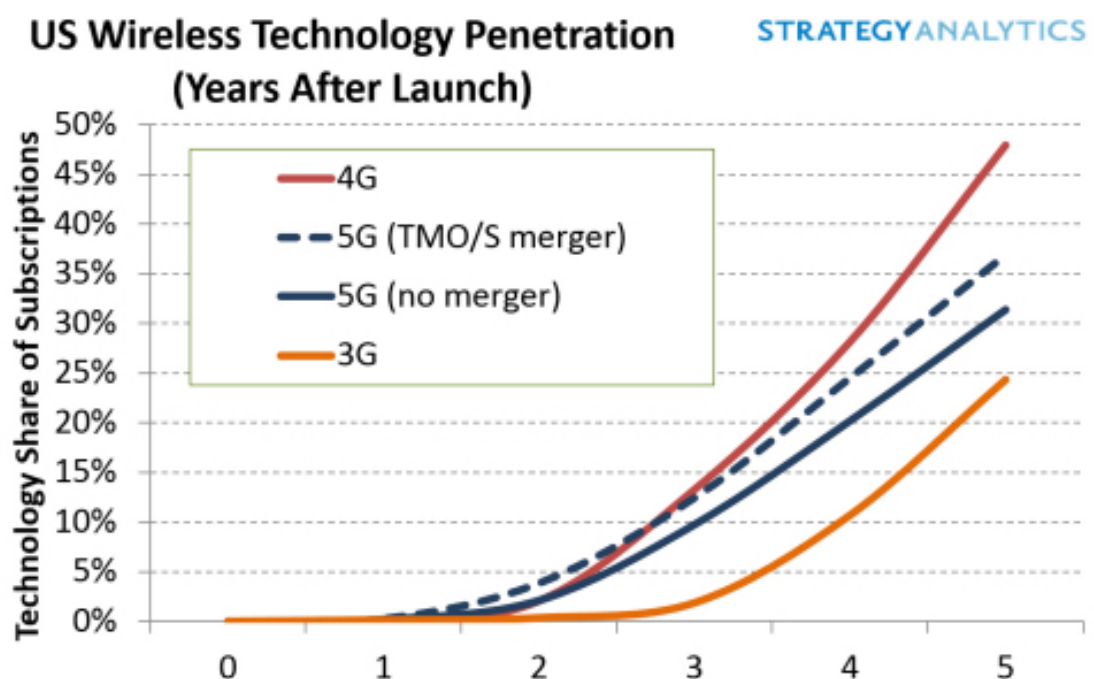Moreover, this merger is expected to accelerate the 5G penetration as it is shown in the following figure[102].

Figure 20: US 5G penetration (Source: Strategy Analytics)

The merged company will be named T-Mobile and will be led by the T-Mobile CEO. It is a $26 billion merger.

network" (April 2018) 9to5mac.com/2018/04/29/t-mobile-sprint-merger-confirmed/
101 Press Release "Why Sprint + T-Mobile = Great for competitiveness, consumers and jobs" (June 2018) newsroom.sprint.com/why-sprint-t-mobile-great-for-competitiveness-consumers-and-jobs.htm
102 www.businesswire.com/news/home/20180530005854/en/Strategy-Analytics-T-Mobile-Sprint-Merger-Accelerates-5G

7. Challenges of the 5G market

7.1 Monetisation of 5G

One of the key challenges for the telecom operators is the monetisation 5G commercially over time.

With 5G, the telecom operators plan on proposing innovative enhanced mobile and video customer experience to drive 5G consumer adoption. Moreover, to market 5G the operators will emphasise the speed and capacity of the 5G to early consumers. They will promote the greater end-user experience compared to 4G through videos, AR and VR gaming and immersive entertainment services[103] . 5G will also be promoted for businesses as it will allow a large use of IoT in different verticals.

But it will take a few years for US telecom providers to have these revenue streams. Mobile phones with 5G chips are not commercialised yet and the first usages of 5G are the hotspots. It will be hard for telecom providers to strongly commercialise 5G in the first years.[104] By 2023, 5G revenues are expected to overtake 3G/4G revenues in the US and total net new revenues coming from 5G are expected to account for $67bn in the US[105].

7.2 Sufficient investments

Investment in research and development by companies, allocation of additional radio frequencies to wireless companies by the government are needed.

The operators need to invest a lot in the deployment of small-cells. The small-cells in itself accounts for only 10% of the total costs of deployment in the US. The rest of the costs are required for acquiring the ownership of the place where the small-cell is going to be implemented (place, fees, connexions, etc.). Not many telecom providers can afford such an investment. Even the biggest telecom providers in the US struggle making this amount of investment. This is why, Sprint and T-Mobile are merging. The aim of this merger is to be able to provide competitive 5G services. Moreover, AT&T has bought Time Warner in order to drive its growth and to be able to propose integrated services.

7.3 Municipalities' support

To deploy 5G the telecom operators need to install numerous small cells and the municipalities need to encourage those operators to invest in their next-generation infrastructure. For example, operators will need approvals for the small-cells and an appropriate adjustment in the permitted areas. To benefit entirely from the 5G and to support the deployment of new small-cells, municipalities should strive to be among the first to streamline permitting, change their

103   Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

104 www.rcrwireless.com/20180722/opinion/reality-check/5g-presents-the-biggest-opportunity-for-u-s-operators-but-poses-the-most-challenges-reality-check-tag10

105 newsroom.intel.com/wp-content/uploads/sites/11/2018/10/ovum%E2%80%93intel%E2%80%935g%E2%80%93ebook.pdf

fee structures and reduce regulatory barriers.

More specifically the deployment of small-cells will have the following benefits:

» Speed to deliver: as there will be more small-cells they will be located closer to the destination, and thus provide faster delivery and enable large amounts of data to be more readily delivered to users

» Capacity to serve: a higher number of small-cells (compared to one big centre) can help provide the service demanded even if there is too much traffic demand due to a major event for example; if one smart cell has too much demand another one nearby can take over

» Specialisation and diversification of fulfilment: with the availability of more small-cells, wireless networks can support both specialized transportation solutions (for example, vehicle-to-vehicle communication) and specialized public safety solutions (for example, gunshot detection sensor), while ensuring the best quality of service to other highly critical applications (for example, nearby hospital which requires highly reliable communications for remote surgery).[106]

With the new 5G FAST plan from the FCC (described in the previous chapter, II PESTEL analysis 6. Legal), the development of small cells across the country are more streamlined since local government control over the installation of wireless equipment is override. Since the FCC published this plan, major US cities revolt against the proposed rules and claiming that they should remain in charge of the costs and timelines associated with small cell deployments. Some of those cities are for example Philadelphia, San Francisco, Chicago and Lakewood where the telecom providers have planned to deploy the smart cells by 2019. The city of Philadelphia argued in a writing to the FCC that "the City's ability to manage its right of way is essential in order to effectively protect the health, safety and welfare of the City's over 1.5 million residents and 43 million annual visitors".[107] One of the main challenges for the US is to find an arrangement regarding this issue that will allow the fast deployment of 5G and smart cells without overriding the cities' authority.

7.4 Policy and regulation

The full potential of 5G can only be reached if certain developments regarding the policies and regulations are done. There are 3 main domains that could influence the development of 5G:

1. **Spectrum**: to prioritise and support the timely and sufficient availability of spectrum (sub-1 GHz, 1-6 GHz, above 6 GHz, mmWave frequencies, licensed and unlicensed bands).

2. **Infrastructure**: to reduce existing barriers to deploy infrastructure (small cells) that could develop organically and commercially.

3. **Economics**: to provide a long-term greater predictability, effective competition among companies in the ecosystem, and to encourage innovation. These regulations would help fuel investments in the infrastructure and increase business activity in other major industries.[108]

The FCC's 5G FAST plan described in a previous chapter (II. PESTEL analysis 6. Legal) was designed to make more spectrum available, to ease the 5G infrastructure deployment and to foster investment in the 5G infrastructure. The challenge of the US is to ensure the implementation of the 5G FAST Plan.

106 Accenture Strategy Report, "How 5G can help Municipalities become vibrant Smart Cities" newsroom. accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf

107 www.fiercewireless.com/wireless/major-u-s-cities-revolt-against-fcc-s-proposed-small-cell-deployment-rules

108 Iacopino P. & Hudson A. (2018). The 5G era in the US, GSM Association Report. www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

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.

As it was the case for the 4G, the ambition of the United States of America (US) is to be the first country to launch 5G commercial services but China is also battling to the be first and is even beating the United States with regards to the 5G infrastructure (China has already built 350 000 cell sites necessary for the use of 5G, while the United States has built fewer than 30 000 cell sites) and the investments (China spent $24 billion more than the US).

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. South Korea is also on one of the top positions. It seeks to be the world's first nation to offer commercial 5G services by March 2019. The country has already tested its 5G technology during the Winter Olympics in February 2018 with self-driving cars, virtual reality games and a motion detection system to ward off menacing wild boars.

The US is third in this 5G race. Tests in several cities have already been implemented. The next step will be to turn those tests into commercial offerings. Other large countries/regions are targeting a commercial 5G roll out within the next two years: Japan, Russia and Europe plan to introduce commercial 5G in 2020 and India in 2022. This race is motivated by the huge lead in hiring and investment, and a cache of valuable data from connecting all kinds of devices the first 5G implementing country will obtain.

In the US, the research and development of 5G is highly driven by the industry and fostered by public authorities. In Europe, it is less the case since in Europe there are many different telecom operators (up to 3 or 4 in some countries) which causes issues regarding the investment capacity of each one for a large-scale 5G and small cells deployment.[109] The research and development of 5G has to be driven by the European Union, numerous countries and operators working together.

For this purpose, the 5G Infrastructure Public Private Partnership (5G PPP) has been created in the EU. The 5GPPP is a joint initiative between the European Commission and European ICT industry (ICT manufacturers, telecommunications operators, service providers, SMEs and research institutions) with the joint aim to deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade. A comparable organisation has been created in the US, the 5G Americas which also includes South America. It is an industry trade organisation composed of leading telecommunications service providers and manufacturers aiming at advocating for and fostering the evolution of LTE wireless technologies to 5G throughout the ecosystem's networks, services, applications and connected devices in the Americas. The 5G PPP focuses on the following applications of 5G which are areas where Europe is strong or where there is potential for creating new markets: smart cities, e-health, intelligent transport, education or entertainment and media.[110] In Europe, the verticals are highly important. Indeed, according to Colin Willcock, chairman of the Board of the 5G Infrastructure Association, "the promise of 5G is the verticals; if we can't successfully bring

109 www.usine-digitale.fr/article/5g-pourquoi-la-chine-et-les-etats-unis-sont-loin-devant-l-europe-selon-nokia.N658174

110 5g-ppp.eu/

5G to the verticals we would have failed".[111] In the US, the following sectors are the most attractive sectors for the 5G applications are: media and entertainment, automotive and public transport, energy and utilities, health and industrial automation[112][113].

Moreover, to address investment issues in Europe (due to the many different operators), the European Investment Bank has shown its support. The European Investment Bank has signed a €250 million loan with Ericsson[114] and a €500 million loan with Nokia to develop 5G in Europe[115]. This investment is seen as minor when considered to the profit that will be generated. In Europe, 5G is expected to generate 225 billion euros per year until 2025.[116] In the US, the investments are coming from the telecom providers which have already invested $1.6 trillion in network infrastructure between 1996 and 2016[117].

Moreover, Europe has to overcome the challenge of available spectrum for 5G. While other countries like the United-States and China are pushing ahead and making spectrum available for 5G, Europe is fragmented on the issue. European lawmakers decided to free up 5G radio frequencies for a 20-year time period which is according to the industry not enough. They asked for a minimum of 25-year time period arguing that it would spur more investments. Moreover, regulations regarding 5G spectrum are different from one European country to another.[118]

Nevertheless, research and development of 5G in Europe are advancing and numerous trials have been announced and launched. Indeed, in Europe 63 trials are planned in 38 cities whereas in the US only 25 trials have been planned by the 4 main telecom providers.

All in all, the US's strategy consisting in facilitating and fostering the large-scale deployment of 5G across the country is enabling a fast evolution of the LTE infrastructures towards a 5G infrastructure. The US is advancing on its objective to be the first country to deploy 5G on a large scale, but the country has to face several issues (political environment, municipalities suing the FCC, etc.). Nevertheless, the 5G large-scale deployment in the US is expected in the first half of 2019 making the US the first country to deploy 5G.

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111   5G PPP Youtube channel

112   http://www.5gamericas.org/files/9615/1217/2471/5G_Service_and_Use_Cases__FINAL.pdf

113   http://www.5gamericas.org/files/1115/4213/2248/5G_Americas_URLLLC_White_Paper_Final__updateJW.pdf

114   http://www.eib.org/fr/infocentre/press/releases/all/2018/2018-133-ericsson-finances-research-into-5g-telecom-technology-with-eu-backing.htm

115   ec.europa.eu/commission/news/digital-investment-eu500-million-eu-financing-5g-development-nokia-2018-aug-27_en

116   www.monpetitforfait.com/telephonie-mobile/49703-500-millions-euros-pour-la-5g-europe-veut-battre-chine-a-tout-prix

117   www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download

118   www.cnbc.com/2018/03/06/5g-europe-could-fall-behind-china-and-the-us.html

Figure *21*: 5G trials in Europe (Source: 5GPPP)

Figure 22: 5G trials in the US (Source: Light Reading 5G)