The 5G era in the US

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The GSMA appreciates the important insights provided by the four national mobile operators in the US – AT&T, Sprint, T-Mobile and Verizon.

Contents

1 Executive summary

The mobile industry continues to make progress with 5G, with successful trials around the globe and the approval of the non-standalone 5G new radio specifications in December 2017. Early 5G commercial launches are expected over the next three years in North America and major markets across Asia-Pacific and Europe.

This GSMA report looks at the 5G era in the US, with a particular focus on network deployment, spectrum, use cases, and policy and regulation. The analysis of use cases includes 5G-based fixed wireless, an area where the US is playing a pivotal role. The report also presents GSMA Intelligence forecasts for the number of 5G mobile connections over the period to 2025.

The GSMA appreciates the important insights provided by the four national mobile operators in the US – AT&T, Sprint, T-Mobile and Verizon. In this report, we refer to these as "mobile operators" or "operators".

This report follows previous GSMA research on 5G in China (which included comparisons with Japan and South Korea), published in 2017.[1]

[1] 5G in China: Outlook and regional comparisons, GSMA Intelligence, 2017

The US mobile industry is rapidly moving to 5G commercialisation

The US will be one of the first countries to launch 5G commercial services, as was the case for 4G. Fixed wireless – the use of 5G as a last-mile technology for fixed broadband connectivity – will be an initial use case in 2018, following successful pre-commercial trials in 2017. To that end, Verizon has indicated that it will launch 5G-based fixed wireless services in three to five US markets in the second half of 2018. Mobile 5G services based on industry standards are expected to launch in late 2018 by AT&T and Verizon, with AT&T targeting 12 markets for this phase. The first 5G devices are anticipated to work as mobile hotspots while waiting for early 5G phones to be ready in 2019. All four mobile operators in the US – AT&T, Sprint, T-Mobile and Verizon – will provide mobile 5G services by 2019; this represents a major milestone for the US mobile industry.

Market context: the US provides a unique backdrop to 5G

The advent of 5G coincides with a period of significant transformation in the wider US technology, media and telecoms (TMT) industry. While telecoms and media are increasingly converging, 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 instrumental in the development of these major trends – a view largely shared by all four mobile operators in the US. 5G is expected to deliver an increasingly integrated mobile/video customer experience, and spur further developments and scale in IoT. It will also support growth in augmented reality (AR), virtual reality (VR), industrial automation and AI. Finally, 5G-based fixed wireless will increasingly serve as an alternative for fixed broadband connectivity.

A number of factors make the 5G outlook in the US distinctive. As well as continuous efforts from US government institutions to support 5G progress through new spectrum allocations (including mmWave bands) and work to enable infrastructure deployment, it is a leading country when benchmarking consumer digital engagement and speed of adoption of new technologies. While 4G has been driving the transition from *connected* to *digital* consumers during 2010–2020, 5G will play a key role in the transition to the *augmented* consumer in the longer term. Continued, significant operator investment in both fibre infrastructure and 4G network upgrades also represents a solid foundation for the upcoming 5G network deployment. Meanwhile, the US leads on R&D, financing of tech innovation, and the digitisation of industries and businesses – these create a more favourable environment for exploring incremental revenue opportunities, particularly in the enterprise market.

5G network deployment will follow a phased approach in the US

In the US – as in many other markets around the globe – mobile operators are targeting a phased approach to 5G network deployments, beginning with a non-standalone architecture (where 4G and 5G radio access technologies will be used in tandem) before eventual transition to a standalone model (use of 5G radio access technology). This offers a quicker route to market. Importantly, 4G and 5G networks will likely coexist and remain complementary for many years; as such, operators can service a significant share of data traffic on 4G networks, leaving 5G with the dual remit of absorbing overflow capacity and underpinning consumer and enterprise services that require higher speeds and/or lower latencies.

While there is little guidance currently on total operator investment in 5G, US mobile operators believe that a co-investment network model involving financing from companies expected to increasingly benefit from 5G (those from across the wider digital ecosystem, IoT companies, and large organisations in key verticals) is not required to deploy the physical 5G network in the country.

5G use cases in the US: opportunities in fixed wireless and mobile consumer/enterprise

The provision of enhanced mobile broadband to the consumer market will be the core proposition in early 5G deployments, with massive IoT and ultra-reliable, low-latency communications gaining scale at a later stage. Innovative and segmented consumer propositions targeting an enhanced mobile/video customer experience could play a key role in driving 5G consumer adoption. To that end, the range of mobile "companions" has never been greater. It includes entertainment content delivered through advanced video capabilities, AR/VR devices and applications for gaming and immersive TV, and multi-device subscriptions that include IoT services (e.g. connected cars).

5G-based fixed wireless as well as 5G-based services targeted at the enterprise sector represent major opportunities for incremental operator revenue in the US. In the fixed market, 5G offers a potentially lower cost and faster means – compared to FTTH – of expanding high-speed offerings to households and businesses, bringing the opportunity to gain market share and incremental revenue. In the enterprise segment, operators are already working with other tech players and industrial companies to bridge ICT and vertical industries, and establish new solutions that can be initially tested and implemented on 4G networks with a view to exploiting enhanced 5G capabilities in the future. However, long-term monetisation may require greater maturity of the 5G ecosystem – particularly for the more innovative and mission-critical services, such as autonomous vehicles and facets of smart cities.

5G adoption in the US: the main mobile network technology by 2025

According to GSMA Intelligence forecasts, the US will experience one of the fastest customer migrations to 5G in the world. As such, 5G will reach 100 million mobile connections in early 2023 and will become the leading mobile network technology in the country by 2025, with more than 190 million 5G connections (accounting for around half of total mobile connections). This forecast does not include 5G-based fixed wireless.

Policy and regulation: further developments are key to realising the full potential of 5G

Streamlining regulation as well as further developments in three main areas could influence the development of 5G over the next decade:

- **Spectrum –** US mobile operators believe there is a need for a regulatory framework that prioritises and supports the timely and sufficient availability of spectrum for 5G, both in the short term (2018–2019) and beyond. This applies to all frequency ranges (sub-1 GHz, 1–6 GHz and above 6 GHz), including the mmWave frequencies, as well as licensed and unlicensed bands. The FCC is currently focusing on getting the mmWave spectrum to auction.
- **Infrastructure –** US operators believe regulators must aim to reduce existing barriers to deploying infrastructure, particularly small cells which are expected to be widely utilised in 5G networks. Moreover, policymakers should allow any infrastructure sharing arrangements to develop organically and commercially over time – if they are viable – rather than introduce rules that could slow down the pace of deployment.
- **Economics –** While the long-term economics of 5G for the mobile industry are uncertain at this stage, in the US (and around the globe), there is a shared view among the US mobile operators that the investment needed to deploy 5G networks and deliver mobile connectivity for all use cases should be supported by a long-term policy environment that provides greater predictability, effective competition among companies in the ecosystem, and encourages innovation. Pro-investment reforms – such as the US tax reform signed into law in late 2017 – will help fuel investments in US infrastructure and increase business activity in other major industries; this could in turn spur additional demand for services provided by US operators.

To make further progress with 5G, operators and other mobile players should continue to work closely, and collaborate with the US government and institutions at the federal, state and local levels. Ultimately, the way 5G is deployed, funded, regulated and commercialised will determine the development of the wider mobile ecosystem over the next decade.

2 US market context

2.1 Unprecedented evolution of the TMT ecosystem

Four major trends are shaping the US TMT ecosystem and its competitive landscape (see Figure 1). AT&T and Verizon are driving the current phase of telecoms and media convergence as they look to diversify away from core telecoms services and compete more effectively with the internet players. T-Mobile is also targeting a key role in the rising convergence of mobile and video; earlier in 2018, the company announced the completion of its acquisition of Layer3 TV, a TV tech company that attracted significant investor funding during 2014–2016. This acquisition will drive T-Mobile's initiative to launch a new streaming TV service in 2018.

Meanwhile, IoT continues to gain scale in both the consumer and industrial segments, and will reach a total of more than 5 billion connections in the US by 2025.[2] New technologies are also emerging, including AI, AR and VR, driven by rising financing and a supportive ecosystem for innovation. Cross-sector mergers and acquisitions (M&A) and partnerships are playing a key role across all the major trends, with larger mobile, internet and technology companies targeting a bigger presence in a fast evolving ecosystem. AT&T and Verizon are among the most active cross-sector acquirers in the US (by size of acquisitions), along with other technology companies such as Google, Facebook, Amazon, Apple and Microsoft.

[2] Source: GSMA Intelligence IoT forecasts. Cellular and non-cellular IoT connections

Figure 1

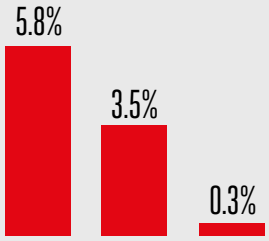
Four major TMT ecosystem trends in the US

Unprecedented pressure on traditional revenue

Mobile
- Smartphone penetration rate approaching saturation
- Unlimited data plans
- Effective competition*

TV
- OTTs** are winning in consumption model (e.g. Netflix, Amazon Prime) and new formats
- Traditional pay-TV declining for the first time

Mobile revenue (CAGR)



Telecoms and media convergence

	Acquisitions	Entertainment/ Digital Media revenue***
AT&T	DIRECTV	~$40 billion
	Time Warner (Pending****)	~$30 billion
VERIZON	AOL + Yahoo → Oath	~$7 billion

Internet of Things is gaining scale

Over 5 billion IoT connections in the US by 2025

Key IoT markets

- Smart cities
- Connected vehicles
- Digital health
- Smart homes
- Energy/Utilities
- Manufacturing and logistics
- Autonomous vehicles

The rise of new technologies and horizontal platforms*****

- Robotics
- Voice-based home devices
- Data analytics
- Blockchain
- Augmented reality
- Drones
- Edge computing
- Next-generation vehicles
- Virtual reality
- 5G
- Network slicing
- Machine learning

Big tech players are becoming horizontal platforms

Google Microsoft Facebook Amazon Apple

* FCC's 20th Wireless Competition Report. September 2017.

** Over-the-top (OTT) refers to delivery of audio, video and other media content over the internet.

*** Annual revenue. Sources: full-year 2017 figures for AT&T; Verizon's announcement made in July 2017 for Oath.

**** The AT&T/Time Warner deal is subject to regulatory approval.

***** Not exhaustive lists.

Source: company data and GSMA Intelligence

While the US mobile industry rapidly prepares for early 5G commercialisation, discussion around how this next generation network technology fits into the wider evolution of the TMT and digital ecosystems continues. There is widespread recognition among the US mobile operators that, over the next decade, 5G will increasingly enable and support the developments in the ecosystem, especially if successfully coupled with innovation in products, services and business models.

2.2 A unique backdrop to 5G

While most of the four TMT ecosystem trends highlighted are also occurring in other developed markets across Asia-Pacific and Europe, the following factors make the 5G outlook in the US particularly distinctive. These factors will play a key role in driving 5G deployment and customer adoption, with the US expected to be one of the leading 5G markets in the world.

Scale of mobile and telecoms/media convergence

With about 250 million mobile internet users by the time 5G launches[3], the US boasts one of the world's largest consumer bases in the digital era. The ongoing convergence of telecoms and media is also unique, and represents a major focus for the 5G era. As video consumption on mobile devices continues to grow[4], video technology further evolves (e.g. 4K, 8K, 3D video, 360-degree video) and newer AR and VR applications make content even more immersive and data intensive, 5G networks will be key to supply the mobile data traffic capacity required, and deliver a superior mobile/video customer experience.

The US consumer leads in digital engagement

In the US, the transformation of mobile customers from *connected* (those connected to mobile internet) to *digital* (those consuming digital services and content on a regular basis, with heavy data usage) has been one of the fastest in the world. Indeed, the majority of US mobile subscribers use their LTE smartphones frequently to access not only internet-based messaging and social media but also entertainment content (e.g. music, movies, sports, games), e-commerce and a range of digitally delivered services.[5] Many of these will become tomorrow's *augmented* customers in the 5G era; they will increasingly adopt or consume a range of new technologies, including those that are expected to benefit from the faster speeds and/or lower latencies promised by 5G networks such as advanced video, AR, VR, tech solutions for smart cities, as well as autonomous cars.

Significant operator investment in fibre and LTE network upgrades

The US leads on broadband investment; according to USTelecom, US broadband providers (e.g. mobile operators, fixed operators and cable companies) have invested a total of $1.6 trillion in network infrastructure between 1996 and 2016[6], and the broadband capital investment per capita in the US is greater than in Europe. AT&T and Verizon are the top two companies in the US by capex across major industries[7], with Sprint and T-Mobile also investing significantly in their networks.

Investment in fibre and LTE networks is key for 5G as US mobile operators are targeting a phased approach to 5G network deployments. To that end, there continues to be significant investment in fibre networks by US operators – both organically and via acquisitions – which can backhaul data and provide a competitive edge in the move to 5G and denser networks.

For example, Verizon acquired XO Communications' fibre business in 2016, and recently completed the purchase of fibre network infrastructure in the Chicago market from WideOpenWest. In April 2017, Verizon also announced an agreement with Corning to purchase up to 20 million kilometres (12.4 million miles) of optical fibre each year between 2018 and 2020, with a minimum purchase commitment of $1.05 billion. Meanwhile, AT&T increased the number of locations passed by its fibre-to-the-premises (FTTP) offering to more than 7 million at the end of 2017, as part of a plan that targets 14 million locations over the next two years. Over the last few months, Sprint has also announced multi-year strategic agreements with US broadband infrastructure companies Altice USA (in November 2017) and Cox Communications (in January 2018) to accelerate its deployment of small cells and the densification of its network.

All US mobile operators have also invested to further expand the capabilities of their existing mobile broadband networks, including small cells, distributed antenna systems, in-building solutions, and LTE Advanced features, such as 4×4 MIMO, carrier aggregation and 256 QAM.

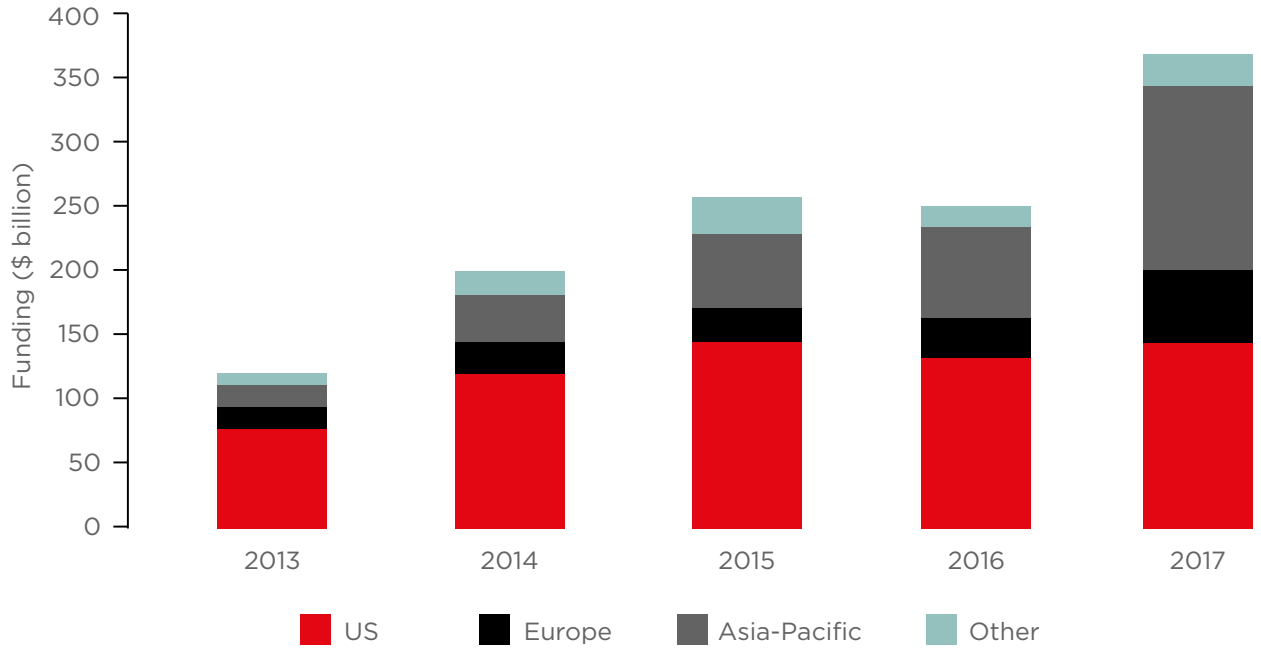
[3]Source: GSMA Intelligence mobile forecasts
[4]Source: Cisco. Mobile data traffic will grow fivefold in the US between 2016 and 2021. Video will account for nearly 80% of mobile data traffic in 2021, up from over 60% in 2016
[5]Source: Global Mobile Engagement Index 2017 Survey, GSMA Intelligence
[6]Source: USTelecom, Research Brief, 31 October 2017
[7]Source: PPI's Investment Heroes 2016 report (published in October 2016), based on 2015 capex. Sectors covered: telecom/cable, energy production/mining, internet/technology, utility/energy distribution, transportation, automotive/industrial, retail

Leading on R&D and tech innovation, and a more favourable economy and business environment

Financing of tech innovation and development reached an all-time high globally in 2017, with the US leading the way (see Figure 2).[8] Private equity companies, venture-capital firms and corporates have invested more than $600 billion over the last five years in the US to finance start-ups and fast-growth companies in a range of sectors, including TMT. Along with a strong focus on R&D, this supports innovation and growth in various tech areas, including consumer and industrial IoT, AR, VR, autonomous vehicles and AI. The US could lead the way on the 5G enterprise opportunity as the digitisation of industries and businesses in this market is occurring faster than in other developed countries across Europe and Asia-Pacific.[9]

Figure 2

Private investor financing by region



Source: CB Insights and GSMA Intelligence analysis

[8]Source: CB Insights. Industry analytics
[9]Source: McKinsey Global Institute. Rate of digitisation for key verticals and countries

3 5G deployment

3.1 The US mobile industry is rapidly moving from trials to commercialisation

The accelerated schedule agreed to by the 3rd Generation Partnership Project (3GPP) in 2017 has seen some operators around the globe – including the US – bring forward their 5G commercial launch plans. Non-standalone 5G new radio (NSA 5G NR) specifications were officially approved in December 2017 as part of a wider plan that targets complete standardisation of the 5G system for both non-standalone and standalone (SA) models by mid-2018. With a first set of NSA 5G NR specifications now available, hardware manufacturers, chip makers and other suppliers can progress their tests further, and build and design components that implement the 5G new radio specifications, while awaiting final standardisation across all NSA and SA models.

AT&T, Sprint, T-Mobile and Verizon have been key contributors into 3GPP's work on 5G standards since the start of 2016. The impact is not just based on the number of contributions to standards for all radio access network layers, but also on the progress they have helped lead in the development of standards. This includes the ability of 5G to co-exist on the same spectrum as LTE, an energy- and battery-efficient physical layer, and a framework for massive MIMO.

5G progress in the US is being led by both the mobile industry and government agencies. US mobile operators have announced some details of their 5G plans (shown in Figure 3) and are undertaking a number of projects and initiatives. These include participation in technology forums and industry-wide associations; collaboration on setting 5G NR specifications; trials; and spectrum purchases, including acquisitions of companies for their high-frequency mmWave bands holdings. Some operators are already showcasing potential applications for 5G, such as VR and AR, 360-degree video as well as use cases for autonomous vehicles. Meanwhile, government institutions – including the Federal Communications Commission (FCC), the National Telecommunications and Information Administration (NTIA), Congress and some states – are supporting 5G progress through initiatives that set the stage for the mobile industry to move forward, including consultations and decisions on spectrum allocations and work to streamline siting requirements of facilities.

Figure 3

US mobile operators' plans for 5G

AT&T

- AT&T started conducting 5G field trials with mmWave spectrum in mid-2016 and tested 5G service with residential customers, small and large businesses, and high-traffic retail locations. These extensive real-world trials will drive commercial deployments in 2018.
- In 2017, AT&T launched pre-standards 5G fixed wireless trials in a number of areas.[10] AT&T expects to introduce mobile 5G services in 12 markets by late 2018, including parts of Dallas, Atlanta and Waco, Texas, based on industry standards for 5G.[11] This is a year earlier than previously announced. The company will announce additional cities in the coming months. The first 5G devices in 2018 are anticipated to work as mobile hotspots while waiting for early 5G phones to be ready in 2019.
- Meanwhile, the company is making progress with its "5G Evolution", with launches in 23 major metropolitan areas.[12] In 2018, AT&T plans to continue to enhance its network with 5G Evolution technology in hundreds of additional metro areas. This initiative is laying the foundation for 5G, by utilising LTE Advanced Pro technologies.
- In these markets, AT&T is upgrading cell towers with network upgrades that include ultra-fast LTE Advanced features such as 256 QAM, 4×4 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.
- AT&T is also making significant progress with its network virtualisation. After hitting its goal of 55% for year-end 2017, the company plans to virtualise 75% of its network by 2020.

SPRINT

- Sprint has announced plans to provide 5G commercial services and devices by the first half of 2019, through the deployment of 2.5 GHz massive MIMO radios slated for commercial use in 2018. These radios are software-upgradable to 5G NR, allowing Sprint to support both LTE and 5G NR modes simultaneously without additional tower climbs. Sprint holds more than 160 MHz of 2.5 GHz spectrum available in the top 100 US markets.
- Sprint recently announced that, from April 2018, its customers in select US markets will begin experiencing 5G-like capabilities, as the company rolls out massive MIMO. Chicago, Dallas and Los Angeles will be the first three cities, with Atlanta, Houston and Washington, DC following later in the year. In 2018 and 2019 Sprint expects to deploy thousands of massive MIMO radios, significantly increasing data speeds and network capacity for millions of customers across the country.
- Sprint is also upgrading its existing towers to leverage all three spectrum bands (800 MHz, 1.9 GHz and 2.5 GHz) and is building thousands of new cell sites to expand its coverage footprint and reach more popular customer destinations. As far as small cells are concerned, Sprint has deployed more than 100,000 Sprint Magic Boxes in about 200 cities across the US and aims to deploy more than 1 million as part of its multi-year roadmap.

Source: company announcements.

[10] Austin, Texas; Waco, Texas; Kalamazoo, Michigan and South Bend, Indiana
[11] Source: AT&T's press releases on 5G (January 2018 and February 2018)
[12] Atlanta; Austin; Boston; Bridgeport, Connecticut; Buffalo, New York; Chicago; Fresno; Greenville, South Carolina; Hartford, Connecticut; Houston; Indianapolis; Los Angeles; Louisville; Memphis; Nashville; New Orleans; Oklahoma City; Pittsburgh; San Antonio; San Diego; San Francisco; Tulsa, Oklahoma and Sacramento, California

T-MOBILE

- T-Mobile aims to achieve 5G nationwide coverage by 2020, utilising the 600 MHz spectrum holdings it acquired in April 2017. According to the US operator, this spectrum band will allow rural areas to experience the latest mobile network technology at the same time as urban areas. In late February 2018, T-Mobile announced its plans to build out 5G in 30 cities in 2018. New York, Los Angeles, Dallas and Las Vegas will be the first cities to experience 5G; the first 5G smartphones will be available in early 2019. In addition to deploying 5G-ready equipment and lighting up 5G in 600 MHz spectrum, T-Mobile plans to begin building out 5G on mmWave spectrum in 2018.
- T-Mobile has engaged with broadcasters to accelerate FCC spectrum clearance timelines, entering into approximately 40 agreements with several parties. These agreements will, in aggregate, bring the total clearing target to over 100 million PoPs expected by the end of 2018.
- In addition to spectrum clearing, T-Mobile started deployments of 600 MHz spectrum, lighting up spectrum in 586 cities and towns in 28 states across the country, covering 300,000 square miles by the end of 2017. Two 600 MHz compatible devices were available for the 2017 Christmas holiday season, and more than a dozen compatible smartphones are expected to be rolled out in 2018.
- On top of its nationwide 5G network deployment, T-Mobile aims to enable high bandwidth and massive throughput in urban areas using a combination of mid band and mmWave spectrum.
- T-Mobile also continues to expand its network capacity through the refarming of existing spectrum and implementation of new technologies including voice over LTE (VoLTE), carrier aggregation, 4x4 MIMO, 256 QAM and License Assisted Access.

VERIZON

- Verizon established its own 5G Technology Forum that included Apple, Cisco, Ericsson, Intel, LG, Nokia, Qualcomm and Samsung, subsequently completing and releasing its own 5G radio specification in 2016. This radio specification has informed early 5G trials and the development of the 3GPP NR standard.
- Based on the FCC focus on mmWave spectrum for 5G, Verizon has acquired spectrum in the 28 GHz and 39 GHz bands. The company has successfully tested these bands through a number of trials and expects to utilise them going forward as part of its 5G ecosystem.
- Having delivered pre-commercial 5G services to pilot customers in 11 metropolitan areas across the country in 2017[13], Verizon will launch 5G-based fixed wireless services in three to five US markets in the second half of 2018, targeting a 20–30% penetration rate in these markets.[14] Broader fixed wireless rollout is expected in 2019 (see Section 4.1 for more details).
- Verizon is also continually evolving and upgrading its 4G network and preparing for mobile 5G. For example, in 2017, Verizon, Ericsson and Qualcomm completed a successful FDD massive MIMO trial with a fully compatible customer device. Massive MIMO is a key technology component in Verizon's evolution towards 5G and has the potential to significantly enhance the customer experience by raising network spectral efficiency and customer speeds.
- In early February 2018, the chairmen/CEOs of Verizon and KT successfully conducted the first-ever pre-commercial 5G video call on two fully functioning prototype 5G tablets developed by Samsung. They participated from Minneapolis, US and Seoul, South Korea respectively.
- Verizon plans to launch mobile 5G services based on industry standards in late 2018.

[13] Ann Arbor – Michigan; Atlanta – Georgia; Bernardsville – New Jersey; Brockton – Massachusetts; Dallas – Texas; Denver – Colorado; Houston – Texas; Miami – Florida; Sacramento – California; Seattle – Washington; and Washington – DC
[14] Source: Verizon's press release (November 2017)

3.2 Spectrum to be available across various bands

The US is moving fast on 5G spectrum. The FCC, in collaboration with the NTIA and other government agencies, has made available a range of low-, mid- and high-frequency spectrum bands that could be used for 5G. In particular, the FCC's Incentive Auction has given carriers access to low-band spectrum while the Spectrum Frontiers proposals and the latest consultation on bands between 3 GHz and 24 GHz are opening up mid- and high-band ranges. As a result, 5G trials in the market are currently using – or are expected to use – all three ranges of spectrum band: sub-1 GHz, 1–6 GHz and above 6 GHz.

Sub-1 GHz

T-Mobile plans to use its 600 MHz spectrum to provide nationwide 5G rollout by 2020. This band provides wider-area coverage compared to some of the higher frequency 5G bands. At the end of 2017, T-Mobile owned a nationwide average of 31 MHz of 600 MHz spectrum covering 328 million PoPs. At least 10 MHz of this 600 MHz spectrum – covering over 1.2 million square miles and approximately 62 million PoPs – was clear and available for deployment as of the end of 2017. T-Mobile expects to reach a clearing target of 250 million PoPs by the end of 2019.

1–6 GHz

Sprint holds more than 160 MHz of 2.5 GHz spectrum (Band 41) available in the top 100 US markets, and aims to use this band to provide 5G commercial services and devices by the first half of 2019. For the 3.5 GHz band (3550–3700 MHz in the US), the country has taken a different approach compared to the rest of the world. Following the 2010 National Broadband Plan and the President's Council of Advisors on Science and Technology report issued in 2012, the FCC adopted rules for allowing expanded commercial service in a band primarily used by the federal government. The Citizens Broadband Radio Service (CBRS) initiative is opening up 150 MHz of spectrum using a novel spectrum management approach. This new spectrum sharing model offers access to spectrum for a larger number of users, while preserving the rights of incumbent users to access the spectrum with the highest priority when and where required. Access will be governed by a three-tier scheme, split as follows:

- **Incumbent** users (military radar systems, satellite ground stations, and wireless internet service providers) will be protected from interference from PAL and GAA users (see below) at all times.
- **Priority access licence (PAL)** users will have the next highest priority access and will be protected from GAA users. PALs will be assigned via auction, with each licence covering 10 MHz blocks and up to seven licences available (a total of 70 MHz), depending on demand.
- **General authorised access (GAA)** users will be permitted to access any portion of the band when not used by higher tier users.

Furthermore, in late 2017, the FCC proposed reforms of its licensing rules governing PALs in the 3.5 GHz band (FCC 17-134). In particular, the FCC proposed extending PAL licence terms from three to 10 years, with the possibility for renewal, and sought comment on increasing the PAL geographic licensing area. Further proposals included allowing portioning and disaggregation of PALs on the secondary market, and amending the rules governing assignment of PALs. In the same document, the Commission also proposed removing a rule requiring public disclosure of device registration information, and sought comment on changes to the technical rules to allow operation over wider bandwidths.

Within the 1–6 GHz range, the focus on the 3.7–4.2 GHz band is also particularly important as it offers the possibility of large swaths of spectrum in much lower frequencies, and could be harmonised for next-generation terrestrial mobile services around much of the world. The importance of this spectrum band is also demonstrated by the FCC's work on expanding flexible broadband use in mid-band spectrum (FCC 17-104). In late February 2018, the FCC Chairman announced that, in the coming months, he intends to propose the next steps needed to make the 3.7–4.2 GHz band available for commercial terrestrial use.

Above 6 GHz

The US is one of the first countries in the world to open up high-frequency spectrum bands for 5G networks and applications. In 2016, nearly 11 GHz of mmWave spectrum was made available for flexible wireless use, including new licensed spectrum located in the 28 GHz (27.5–28.35 GHz), 37 GHz (37–38.6 GHz) and 39 GHz (38.6–40 GHz) bands, as well as new unlicensed spectrum in 64–71 GHz. Furthermore, in 2017, the FCC made available an additional 1.7 GHz of mmWave spectrum for flexible wireless use in the 24 GHz band (24.25–24.45 GHz and 24.75–25.25 GHz) and the 47.2–48.2 GHz band (a segment of the wider 47.2–50.2 GHz band (47 GHz band)).

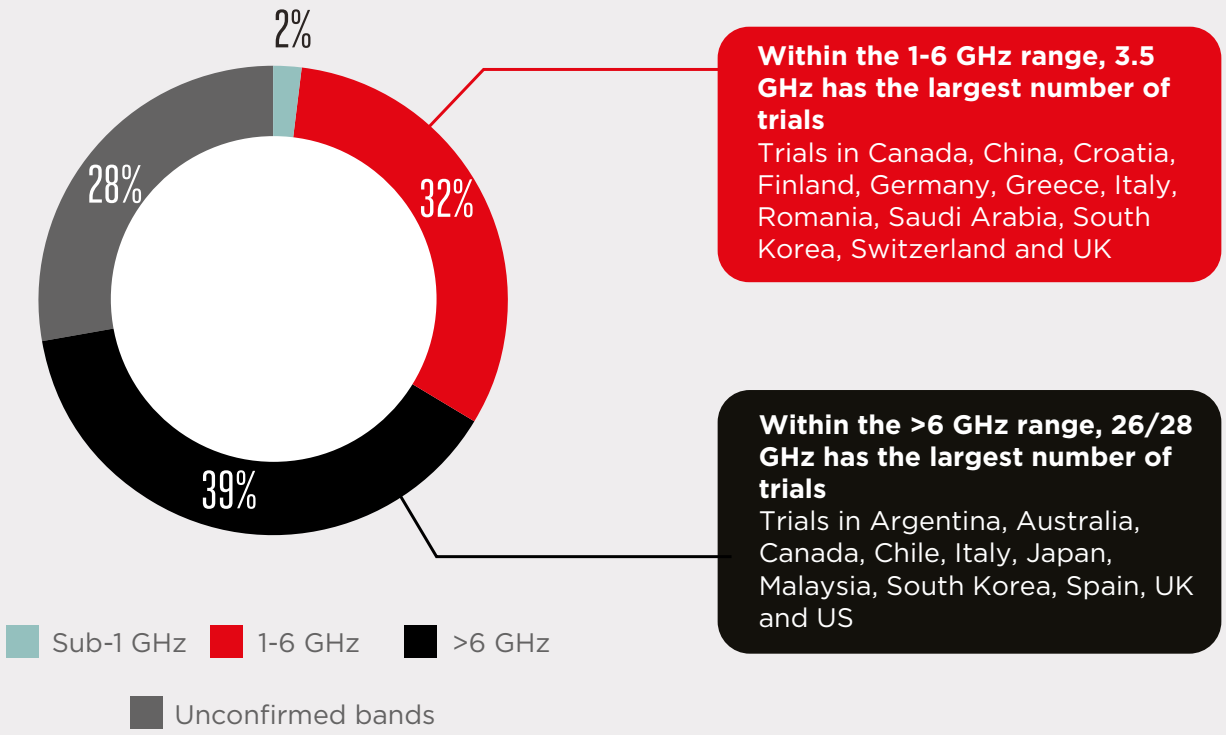
All four mobile operators in the US have access to high-frequency spectrum bands. Following several acquisitions, Verizon (through XO Communications and Straight Path Communications) and AT&T (through FiberTower) own a large amount of the licensed mmWave spectrum. Both operators have announced that such spectrum will underpin their planned 5G networks. T-Mobile also holds spectrum in the 28 and 39 GHz bands in a number of major metropolitan areas, and, in February 2018, it announced an agreement to buy some 1150 MHz of Local Multipoint Distribution Service (LMDS) spectrum (28-31 GHz) in Ohio, for 5G use.

As discussed earlier, the FCC intends to auction spectrum in the 28 GHz, 37 GHz and 39 GHz bands not currently licensed to any single operator. In addition, it is likely that FCC auctions will include the newly allocated bands (24 GHz and 47.2-48.2 GHz).

To that end, in late February 2018, the FCC Chairman announced plans to hold an auction of spectrum in the 28 GHz band in November 2018, followed immediately by an auction of spectrum in the 24 GHz band. In Spring 2018, the FCC will ask for public input on the right procedures for these auctions. However, to start the auctions in November, the US Congress needs to pass legislation by May 13 addressing the handling of upfront payments.

Figure 4

Global view: 5G trials in a range of spectrum bands



Percentages of total number of trials worldwide.
Trials completed in 2017 (or before) or active (as of end of 2017). 77 operators have trialled – or are trialling – 5G technology across 49 countries
Source: GSMA Intelligence

3.3 Network deployment through a phased approach

5G rollout is unlikely to be a one-size-fits-all story around the world; different approaches are being considered – or will be considered – by different operators at different stages in the 5G rollout timeline. Current industry indications suggest that most operators across many markets will opt for a non-standalone (NSA) approach in the early stage, which, if not a permanent configuration, could serve as a bridge to eventual standalone (SA) 5G networks. Interest in the NSA model has also been confirmed by the collaborative work that led to the approval of the NSA 5G NR specifications in December 2017.[15]

In the US, mobile operators intend to use a phased approach beginning with a non-standalone architecture before eventual transition to a standalone model. We have divided this phased evolution into three possible stages – early, ramp-up and long term; for each stage, we provide an indication of the most likely timeline and considerations for other mobile operators around the world.

[15] Source: 3GPP (December 2017). List of operators and vendors participating at the work plan: Alcatel-Lucent Shanghai-Bell, Alibaba, Apple, AT&T, British Telecom, Broadcom, CATT, China Telecom, China Unicom, Cisco, CMCC, Convida Wireless, Deutsche Telekom, NTT DoCoMo, Ericsson, Etisalat, Fujitsu, Huawei, Intel, Interdigital, KDDI, KT, LG Electronics, LGU+, MediaTek, NEC, Nokia, Ooredoo, OPPO, Qualcomm, Samsung, Sierra Wireless, SK Telecom, Sony, Sprint, Swisscom, TCL, Telecom Italia, Telefonica, TeliaSonera, Telstra, T-Mobile USA, Verizon, Vivo, Vodafone, Xiaomi, ZTE

Early: through to 2021

In early 5G deployments, a non-standalone model involves selective implementation of 5G equipment on existing macro cell sites, supplemented by a significant increase in small cells to facilitate transmission in high-density metropolitan areas and further virtualisation of the RAN. In this scenario, US mobile operators are able to use existing macro sites and LTE spectrum as an anchor connection (including voice over LTE), with a densified network of small cells and use of upper band mmWave spectrum to facilitate high-speed data transmissions.

For example, NTT DoCoMo has articulated how such an architecture could work through a so-called phantom cell approach (see Figure 5). An existing LTE macro cell establishes and maintains the network connection with the user (control plane), while a separate set of smaller cells is overlaid to provide the data connection (user plane). The base connection would use sub-6 GHz spectrum, while the small cells would use higher frequency spectrum to generate faster speeds. Depending on the operator and its spectrum holdings, we would expect this first phase of deployment to occur through to 2021.

Ramp-up: 2021–2025

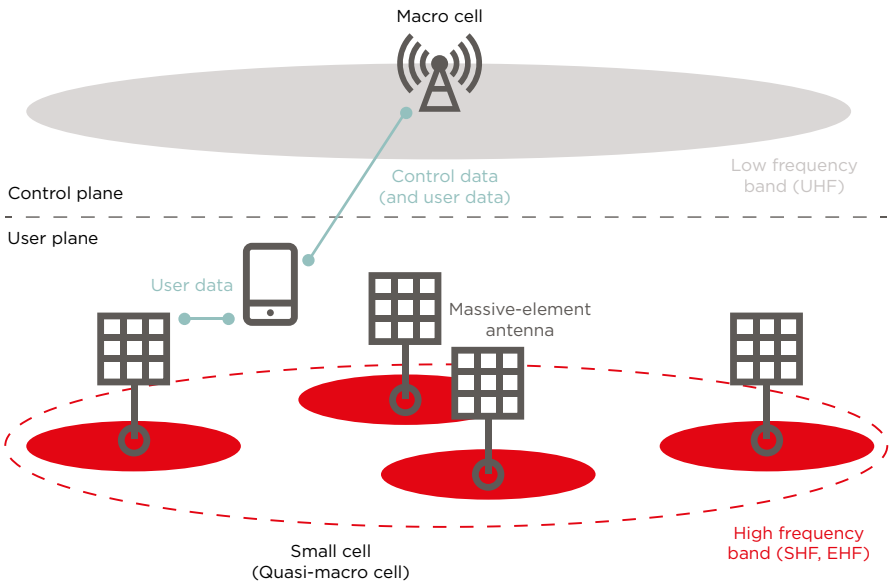
The second phase involves a hybrid approach, with selective new-build sites in urban and suburban areas complementing the densified small cell network used in initial deployments. The pace and extent of new-build sites in this phase will depend on the existence of international standards and, crucially, the investment returns from 5G services. This is the phase with the least certainty around timing given the variation in strategies to monetise 5G, tolerance for incremental network capex, and spectrum portfolios. Globally, for operators with nationwide LTE networks and sufficient sub-3 GHz spectrum holdings, a hybrid configuration could even be a long-term solution.

Long term: beyond 2025

The third phase involves standalone networks, including the use of a 5G core and new radio. Standalone networks are likely to require the largest investment outlay given the incremental site build, but the increased scale and efficiency gains through 5G network performance relative to 4G should translate into more favourable network economics over the long term. As with the hybrid phase, there will be variation among operators around the world as to when – and in some cases if – this eventual long-term state becomes de facto.

Figure 5

Phantom cell configuration



Source: reproduced by GSMA Intelligence based on illustration by NTT DoCoMo[16]

[16] Source: NTT DoCoMo Technical Journal Vol. 17 No. 4 (5G Multi-antenna Technology)

3.4 Investment outlook: 5G capex peak still to come post-2020

According to GSMA Intelligence, between 2010 and 2017, US mobile operators have invested nearly $250 billion in mobile networks (capex) – this accounts for 14% of the total mobile revenue generated throughout that period.[17] Operators have also invested heavily in acquiring wireless spectrum, particularly over the last three years, including some $60 billion for two major spectrum auctions ($41 billion for the AWS-3 auction concluded in 2015, and $19 billion for the 600 MHz auction concluded in 2017), as well as investments in secondary market transactions.

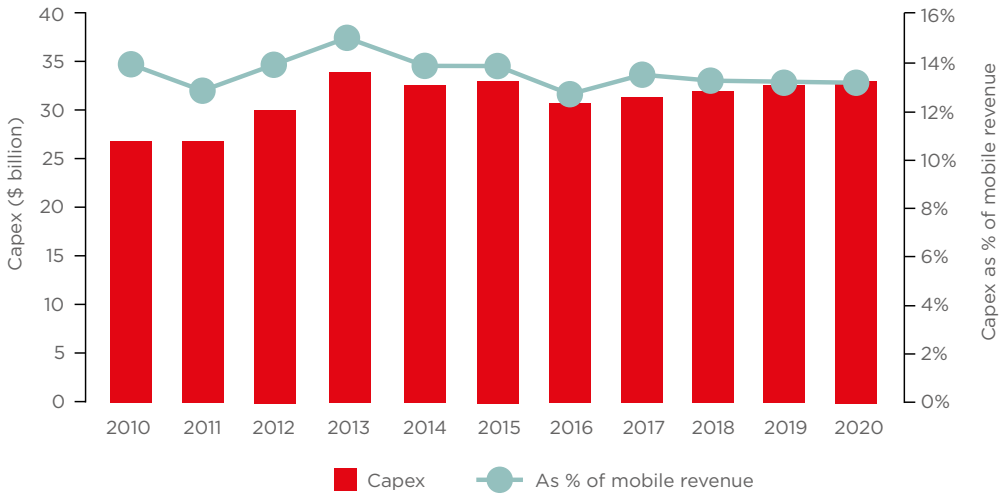
In the US, indeed around the globe, there is little guidance currently on operator 5G mobile capex. Ultimately, it will depend on a number of factors including the model (SA, NSA or phased approach) selected for deployment, the targeted network coverage, the range of spectrum bands in use, and the availability of fibre infrastructure and nationwide LTE networks. We believe it is also reasonable to assume a gradual rollout path; indications from the Chinese mobile operators are that 5G investment will follow a more gradual route and over a longer period than 4G, roughly seven years, between 2018 and 2025. In Japan, operators claim that the deployment of 5G will not lead to any significant spike in capex.

Between 2018 and 2020, GSMA Intelligence forecasts mobile capex to be about $100 billion in the US[18] (cumulative capex, excluding spectrum acquisitions), mostly driven by network maintenance, further upgrades of LTE networks, and early 5G investment. US mobile operators will need to continue to manage all three network generations (3G/4G/5G) until voice services are fully migrated from 3G to VoLTE and eventually 5G new radio.

Subsequent expansion of 5G to a larger footprint, especially in rural areas, could require incremental capex, above the $32 billion forecast in 2020. As the US mobile market faces unprecedented levels of pressure on traditional mobile revenue, any further capex increase beyond 2020 would push mobile capex as a percentage of mobile revenue closer to (or above) the 15% peak in 2013.

Figure 6

Mobile capex in the US



Source: GSMA Intelligence

[17] Source: GSMA Intelligence
[18] Source: GSMA Intelligence capex forecast

4 5G use cases and market opportunities

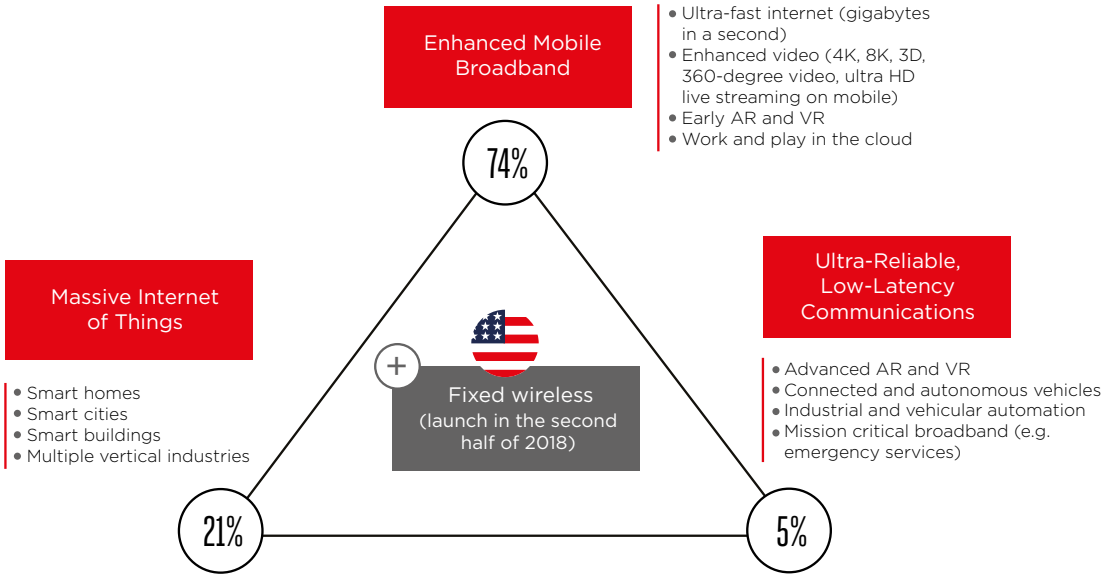
The majority of mobile operators around the world indicate that enhanced mobile broadband will be the core customer proposition in early 5G deployments, with massive IoT and ultra-reliable, low-latency communications gaining scale at a later stage (Figure 7). Ultra-reliable and low-latency communications may be utilised in a number of emerging or future areas such as autonomous vehicles, industrial and vehicular automation, remote medical surgery, and advanced AR and VR.

In the US, mobile operators agree that 5G networks, coupled with technology advancements in video, AR and VR, will help drive 5G consumer adoption at launch while awaiting greater scale in IoT and developments in AI and automation. Fixed wireless is an additional 5G-based use case, with early commercial launches in the second half of 2018.

Figure 7

Priority use cases in early 5G deployments

Question: What will be your highest priority use case in early 5G deployment?
Percentages add to 100% of respondents globally.



Source: GSMA, ITU, 3GPP and major vendors
GSMA CEO 5G Survey (October 2016)

4.1 5G-based fixed wireless – early commercial launch in 2018

AT&T and Verizon have made significant progress with their 5G-based fixed wireless strategies. The fixed wireless services will use radio signals, rather than copper or fibre cables, to provide last-mile fixed broadband connectivity.

Verizon announced details of its commercial 5G-based fixed wireless rollout in November 2017. It will launch in three to five US markets in the second half of 2018, with fixed wireless likely to be offered as part of dual- and triple-play bundles at market-competitive pricing. The company is targeting a 20–30% penetration rate in these markets, with an initial focus on the residential space. Verizon plans a broader rollout in 2019 and has indicated that over a three-year period the opportunity expands to around 30 million households outside of its existing fibre footprint, with more than a quarter of the national fixed broadband market (excluding that already covered by the company's Fios fixed broadband) potentially addressable by the 5G offering. Verizon announced that Sacramento will be the first city in which it will deploy 5G-based fixed wireless, building on its existing smart city partnership with the city. It is likely that other deployments will target areas where Verizon has extensive fibre infrastructure and small cell deployments.

From a practical perspective, 5G could work well as a fixed wireless solution, particularly in the mmWave frequencies. Work to address some of the challenges that these very high frequencies bring around propogation and power is also ongoing. For example, trials undertaken by AT&T have shown that beamforming capabilities have allowed 'bounced' signals to penetrate significant depths of foliage even where direct line of sight is not an option, although in some cases it proved necessary to replace infrared reflective glass with more traditional glass panes.[19]

[19]Source: AT&T Labs. Article on RCR Wireless News, July 2017

Verizon field testing with its 5G technology partners started in early 2016, covering a wide range of deployment scenarios. Fixed wireless and mobile 5G systems were connected to the Verizon network backbone and signals transferred between outdoor and indoor environments. Verizon performed tests both in residential and commercial buildings; these mimic real-world scenarios using mmWave bands. The propagation characteristics of these bands were stressed across multiple fixed and mobile deployments, providing throughput in the multiple Gbps range. Latency was measured in the ms range across varied distances, delivering a high standard of video quality. Based on the results of this testing, Verizon announced completion of its 5G radio specification in July 2016.

The interest from a number of mobile operators in 5G-based fixed wireless comes against the backdrop of increasing fibre investment in the US market. Fibre deployments announced include the following:

- **CenturyLink** has been investing in its network across the US, with a target to bring faster broadband speeds to 3 million homes and small businesses by the end of 2017 (half of those accessing speeds of 100 Mbps and higher).
- **Comcast** is deploying fibre deeper into its network as part of a DOCSIS 3.1 deployment across an increasing proportion of its footprint. This service allows Comcast to offer broadband speeds of up to 1 Gbps to corporate customers and some households.
- **Altice USA,** unlike other cable operators in the US, has announced an FTTH network deployment, with a target of passing more than 1 million homes by the end of 2018. The company is also continuing to roll out enhanced services to its customers via its existing HFC network.
- **AT&T** plans to increase the number of locations passed by its fibre-to-the-premises (FTTP) offering from over 7 million at the end of 2017 to 10 million at the end of 2018, and at least 12.5 million across 82 metro areas by mid-2019. Additionally, AT&T is the largest US-based provider of fibre for business services with more than 8 million business customer locations either on or within 1,000 feet of AT&T's fibre. FTTP and fibre for business are part of a wider portfolio of high-speed internet technologies (including VDSL and 5G) that will allow AT&T to reach more than 50 million unique locations with high-speed fixed connectivity beyond 2020 (company's target).
- **Verizon** entered an agreement with Corning in April 2017 to purchase up to 20 million kilometres (12.4 million miles) of optical fibre each year between 2018 and 2020, with a minimum purchase commitment of $1.05 billion. Also, in 2017, Verizon launched its One Fiber initiative in Boston, MA – this is a six-year programme that aims to replace all of the legacy copper cables with an all-fibre infrastructure throughout the city.

Fixed wireless market opportunity

The US fixed broadband market has more than 100 million connections and is currently dominated by the cable operators Comcast (26 million customers as of Q4 2017) and Charter (24 million). Both AT&T (16 million) and Verizon (7 million) have grown their fixed broadband customer bases over the last few years but their market shares remain comparatively low.[20]

For operators, fixed wireless offers a potentially lower cost and faster means – compared to fibre-to-the-home (FTTH) – of expanding high-speed offerings to households and businesses. FTTH solutions require operators to commit significant capex to pass buildings, and take-up rates may even then be relatively low. Crucially, a 5G-based fixed wireless solution allows US operators to expand their broadband offerings outside their existing fixed line footprints, bringing the opportunity to gain market share in the fixed broadband market and incremental revenue.

A rough estimate of the addressable 5G-based fixed wireless opportunity indicates that, at the current level of fixed broadband ARPU in the US, serving 30 million households with last-mile 5G-based connectivity solutions could generate annual fixed broadband revenue of up to $20 billion, excluding potential fixed voice and pay-TV revenues associated with double-play and triple-play bundles.[21] This incremental revenue for US operators would be the result of churn from existing technologies (e.g. cable) and gross additions at market level (households subscribing to home broadband services for the first time).

Figure 8

Main fixed broadband providers in the US

	MAIN TECHNOLOGY	HOMES AND BUSINESSES PASSED (MILLION)	FIXED BROADBAND CUSTOMERS (MILLION)*
Comcast	Cable	57.2	25.9
Charter	Cable	49.8	23.9
AT&T	FTTH/xDSL	>60	15.7
Verizon	FTTH/xDSL	14.6	7.0

* Includes business customers (the vast majority of customers are residential though). Q4 2017 figures.
Source: company data and GSMA Intelligence

[20]Source: OECD, company data and GSMA Intelligence analysis
[21]Source: GSMA Intelligence analysis of data as reported by Comcast, Charter, AT&T and Verizon

4.2 Consumer market – from launch to early majority in five years

5G will launch against a backdrop of a technologically more advanced consumer mobile market compared to when 4G launched. In 2010, mobile internet penetration was just about 40% of the US population, with smartphone adoption at an early stage. Ten years on, 5G will launch in a highly penetrated US smartphone market[22] with most mobile users highly engaged in the digital world.

A deeper look at the segmentation groups of smartphone users by their mobile engagement patterns (Figure 9) reveals that the "Aficionados" – an exclusive group of very tech-savvy mobile consumers, connected primarily to 4G networks – are predominant in the US and account for 58% of all smartphone users (2017).[23] Such penetration is higher than in any other region in the world. These consumers represent the addressable market for 5G services in the first years after commercial launch.

Figure 9

Consumer mobile engagement

	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

Source: GSMA Intelligence Global Mobile Engagement Index

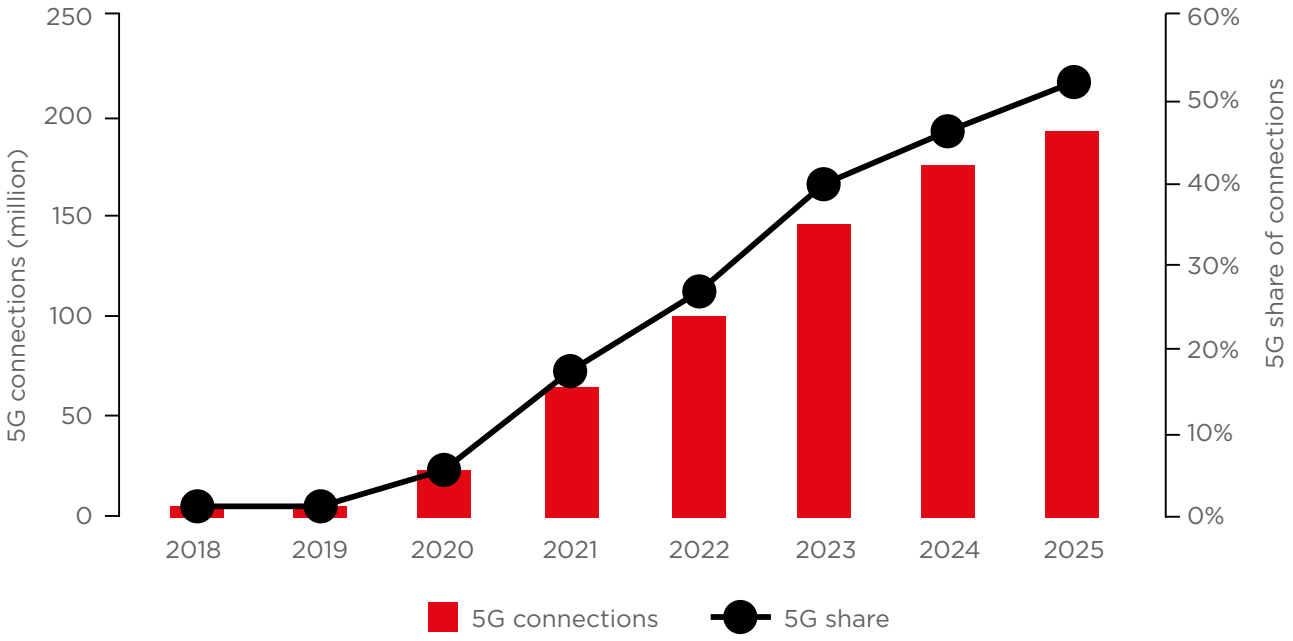
The early 5G adopters – about 50 million from launch to 2021 – will likely be attracted by enhanced or new use cases enabled by 5G technology. 4K and 8K ultra-HD video, 3D video, holograms, AR/VR devices and applications for gaming and immersive TV, as well as digital services and content for connected stadia and smart cities, will be key early drivers for 5G adoption. Sports coverage broadcasting offering a 360-degree view from the athlete's perspective could also be streamed via 5G. As new technologies mature (AI, autonomous vehicles, intelligent analytics, advanced AR/VR), new consumer use cases for 5G will likely emerge. In the longer term, 5G consumer adoption will likely decouple from underlying use cases and will be mostly driven by a larger scale connectivity upgrade.

[22]Source: GSMA Intelligence mobile forecasts. 82% smartphone share of mobile connections at the end of 2018
[23]Source: Global Mobile Engagement Index 2017 Survey, GSMA Intelligence

Figure 10

5G customer adoption in the US

5G mobile connections excluding cellular IoT



Source: GSMA Intelligence

Video

The US streaming video market continues to develop in terms of formats and features. In September 2017, Apple launched its TV 4K solution, supported by both 4K and High Dynamic Range (HDR). Meanwhile, hardware manufacturers are responding to anticipated growth in demand by increasing component production capabilities. Foxconn, for example, plans to produce '8K+5G' displays, which have the latest ultra-sharp 8K definition and can accommodate ultra-fast 5G wireless speeds, with production expected to begin in 2020. Operators are also working to meet this demand – for instance, in June 2017, AT&T launched 5G trials in which participants could stream premium live TV via DirecTV Now.

Although Netflix and Amazon Video are expanding their 4K and UHD content libraries, there is little official 8K content available currently. This is expected to change by the time 5G launches, with 8K recording taking place in Hollywood, and Japanese public TV company, NHK, expected to broadcast the 2020 Tokyo Olympics in 8K. Meanwhile, personal 8K video cameras are already available from manufacturers such as GoPro.

Augmented reality and virtual reality

AR and VR are expected to benefit from the introduction of 5G with its superior data streaming capabilities and lower latencies. The US is anticipated to be one of the first consumer markets to experience AR and VR applications, and one of the leading markets in terms of adoption over time. It is also home to many innovative companies in this space already releasing products into the market.

Since Facebook acquired Oculus in 2014, it has been at the forefront of VR development, shipping the Oculus Rift in late 2016. Meanwhile Google launched its Daydream headset and mobile content platform in early 2017. Microsoft has been developing the HoloLens headset and surrounding ecosystem for several years, with developer kits becoming available in late 2016.

Other major tech companies are also building AR capabilities into their platforms in anticipation of market development. Apple Launched the ARKit toolkit for developers in August 2017, and Amazon incorporated VR capability into its Lumberyard game-development platform in mid-2016.

AT&T, Sprint, T-Mobile and Verizon are also engaged in AR and VR through a number of trials and showcases. For example, in early February 2018, Verizon streamed live, 180-degree stereoscopic video from the Super Bowl field in Minneapolis directly to VR headsets in New York City, as well as offering a virtual in-stadium experience, including high-resolution replays on secondary screens, that demanded multiple 4K and HD video streams over 5G. In 2016, Verizon, through its subsidiary AOL, acquired RYOT, an independent media company and VR content studio. RYOT is now part of Huffington Post and produces films, linear video, 360-degree and VR content, as well as immersive branded advertising content. At the 2016 Copa América Centenario tournament in Santa Clara, California, Sprint demonstrated 5G capabilities for VR applications and advanced video; spectators were able to experience a live streaming VR system from VideoStitch and viewed 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.

Handsets

Although some new services and applications for AR and VR will require devices with new form factors, we expect the smartphone to be the principal 5G device in the US. The first 5G smartphone models are likely to cost more than the most advanced 4G devices currently available, as they will offer enhanced features (potentially including 4K and 8K displays) and additional cameras and sensors to support AR and VR applications. These handsets will also require an enhanced chipset and RF module supporting multiple spectrum bands and mmWave frequencies, as well as 4G and 5G in the same form factor. More advanced cloud functions may also be offered to relieve the burden on hardware.

A key challenge for mobile operators is how to monetise 5G commercially over time. The combination of handset and network upgrades – to smartphone and 4G, respectively – drove some ARPU uplift in the US market. As operators move in the 5G era, innovative and segmented customer propositions targeting an enhanced mobile/video customer experience could help drive 5G consumer adoption. As such, we expect US mobile operators to market 5G to early consumers by emphasising how faster speed and capacity compared to 4G can deliver a greater end-user experience across key use cases such as video, AR/VR gaming and immersive entertainment services.

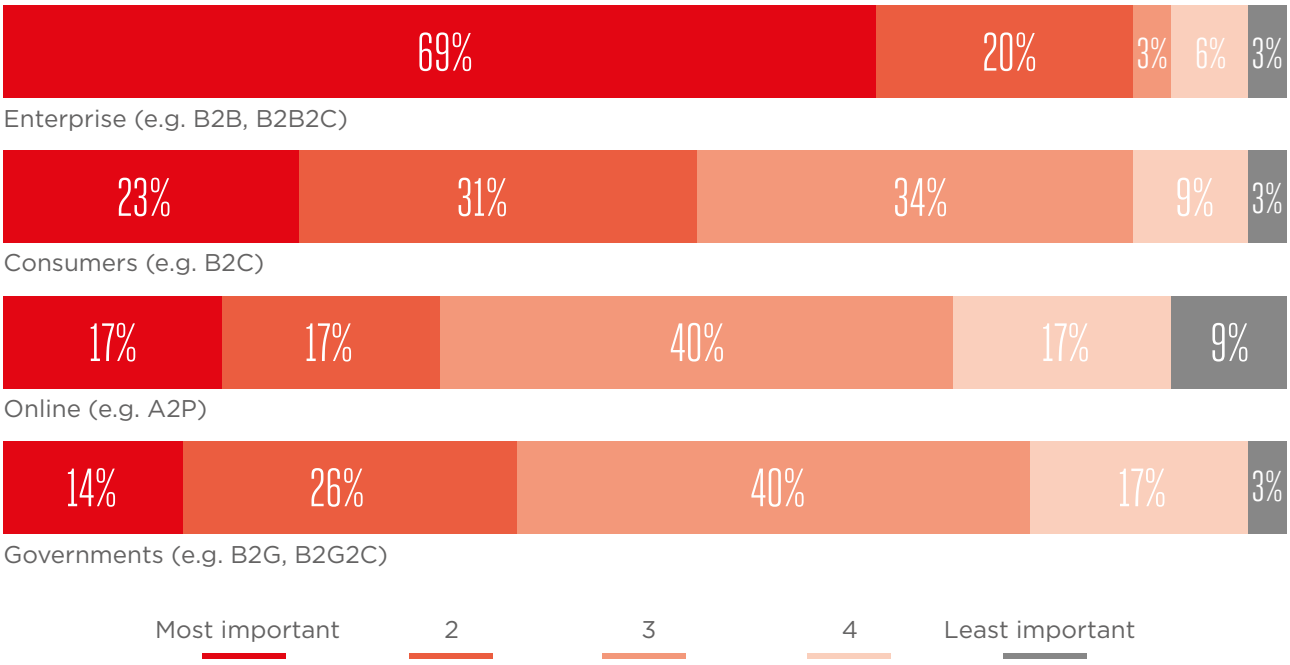
4.3 Enterprise market – the incremental mobile revenue opportunity

Most operator CEOs indicate that, globally, the main opportunity for incremental operator revenues in the 5G era will come from services targeted at the enterprise sector (see Figure 11). There is also broad agreement from operators across the US, China, Japan, South Korea and Europe on the key industry verticals where 5G can deliver greatest value. These include automotive, transportation, media, industrial manufacturing, logistics, energy, utilities, healthcare, agriculture and smart cities.

Figure 11

Sources of new operator revenues for 5G

Question: Where will new operator revenues in 5G come from?
Global results



Source: GSMA CEO 5G Survey (October 2016)

For some US operators, the enterprise market already generates a significant portion of their total revenue and EBITDA, which could be expanded on in the 5G era. For example, AT&T's business segment – which includes mobile and fixed connectivity services as well as business solutions[24] – accounts for more than 40% and nearly 60% of the company's total revenue and EBITDA respectively (2017).[25] Over the last few years, AT&T and Verizon have also established their presence in the industrial IoT market across several verticals, including those that have been attracting significant investor financing over the last few years – connected vehicles, telematics, unmanned aerial systems (drones), manufacturing, logistics, digital health, energy/utilities and smart cities. Following organic growth and acquisitions[26], IoT is a $1.5 billion business for Verizon (in annual revenue, 2017).[27]

US mobile operators largely concur that while LTE networks currently support early adoption of IoT solutions for enterprises, 5G capabilities will be key to drive future developments and larger scale adoption across vertical industries, providing lower latencies as well as higher speeds, capacity and reliability. From a technology point of view, the coexistence of both networks will enable a smooth transition between LTE and 5G IoT capabilities over time.

However, successful monetisation may require greater maturity of the 5G ecosystem, with new products and services available for enterprises. Industry-wide collaboration and innovation centres where companies from across different sectors can experiment with the 5G ecosystem to develop new products and services are key in the 5G era. Major US operators and other US companies from across the tech and industrial ecosystems are already working to bridge ICT and vertical industries, and establish new solutions that can be initially tested and implemented on 4G networks with a view to exploiting enhanced 5G capabilities in the future. Notable examples include automotive and public services (particularly smart cities and communities).

[24]AT&T's business solutions include VPNs, Ethernet, cloud, hosting, IP conferencing, VoIP, dedicated internet, IP broadband and security services
[25]Source: AT&T's earning releases
[26]Verizon acquired Fleetmatics and Telogis in 2016
[27]Source: Verizon's earning releases, and GSMA Intelligence analysis

Automotive

With a large presence in the connected car market and established telematics and vehicle connectivity solutions, AT&T and Verizon are looking to play a key role in the automated vehicle market and have pursued acquisitions and partnerships (see Figure 12). Both operators are also members of the 5G Automotive Association (5GAA), a global, cross-industry organisation that also includes vendors, automobile manufacturers and suppliers for cars and trucks. Cellular V2X (C-V2X) technology is an important area; the 3GPP finalised the specification work for supporting C-V2X communication in June 2017 (Release 14), while Release 15 and Release 16 for 5G will support further enhancements in safety as well as autonomous driving, through higher throughput, reliability and lower latency. 5G will also help progress developments in vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P) and vehicle-to-network (V2N). To demonstrate the potential of C-V2X technologies, including support for improved automotive safety, automated driving and traffic efficiency, the first 3GPP-based trials will be conducted at the San Diego Regional Proving Ground.

Figure 12

US operator initiatives in the automotive sector

Verizon has made a number of strategic moves in the automotive industry. After acquiring Fleetmatics and Telogis in 2016, and Movildata Internacional earlier in 2018, Verizon is the largest provider of built-in telematics and mobile applications for commercial vehicles in the world. Verizon has also invested in Renovo, an autonomous vehicle start-up, and Veniam, a worldwide provider of mobile Wi-Fi and data solutions for commercial fleets. In 2017, Verizon also acquired Skyward, a drone operations software company.

AT&T has established partnerships with 25 automative brands – including General Motors, Ford and Honda – and has 17.8 million vehicles connected to its network. It has also partnered with the American Centre for Mobility, a non-profit testing and product development facility in Michigan, allowing it to accelerate the development of its platform. AT&T is also part of the consortium for the C-V2X trials at the San Diego Regional Proving Ground.

Source: company announcements

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. This ranges from the provision of underlying hardware (e.g. Phillips and GE) to connectivity and software solutions (e.g. AT&T, Sprint, T-Mobile, Verizon, Intel, Microsoft and Cisco).

All four mobile operators in the US are engaged in smart city projects through partnerships with governments and city planners. The main areas include smart transport solutions to reduce congestion and optimise use of public transport, water management, remotely connected CCTV and automated incident detection, parking and smart street lighting. In addition to offering fully owned business solutions, mobile operators are also partnering with hardware and software companies to provide services while focusing on the connectivity element of the project.

AT&T has been involved in several smart lighting initiatives, including those in Atlanta and San Diego. Meanwhile, Verizon has helped deliver a broad range of projects, including a public safety solution in Charleston, South Carolina and a connected lighting scheme in Boston. Sprint has a partnership with Kansas City and Cisco for smart cities solutions including connectivity and smart streetlights with sensors to monitor both vehicle and foot traffic.

In July 2017, T-Mobile and the City of Las Vegas announced a new partnership to deploy IoT technology throughout the city, including Narrowband-Internet of Things (NB-IoT). T-Mobile is piloting several IoT projects in Las Vegas including flood abatement (flood and storm drainage sensors that will provide early warning and fault detection for Las Vegas residents); smart city lighting; and environmental monitoring (sensors placed on top of existing smart city light poles that will continuously monitor temperature, humidity and environmental gases).

5G networks combined with IoT solutions could generate significant cost savings while opening up opportunities for new, innovative services. Early examples of smart city initiatives that are generating savings can be found across the US. For instance, Los Angeles recently converted 215,000 street lights to LED smart lights, generating $9 million in savings annually.[28] In San Diego, IoT technology is now used to monitor energy usage at Petco Park (a baseball park); it is anticipated that operational costs will be reduced by 25% over the next five years through this technology.[29]

Cross-sector initiatives

Beyond vertical-focused associations, there are cross-sector initiatives that aim to spur developments ahead of and beyond 5G launches. For example, in early 2017, Ericsson and Intel launched the 5G Innovators Initiative (5GI^2), an open industry project that brings together equipment manufacturers, technology companies, industry leaders and top universities to explore, test and innovate with 5G network and distributed edge technologies. It will first focus on industrial IoT and AR/VR; as other participants join, the pilots are expected to expand to other industries such as autonomous driving, smart and connected cities, healthcare and media.

Enterprise business model – edge computing and network slicing

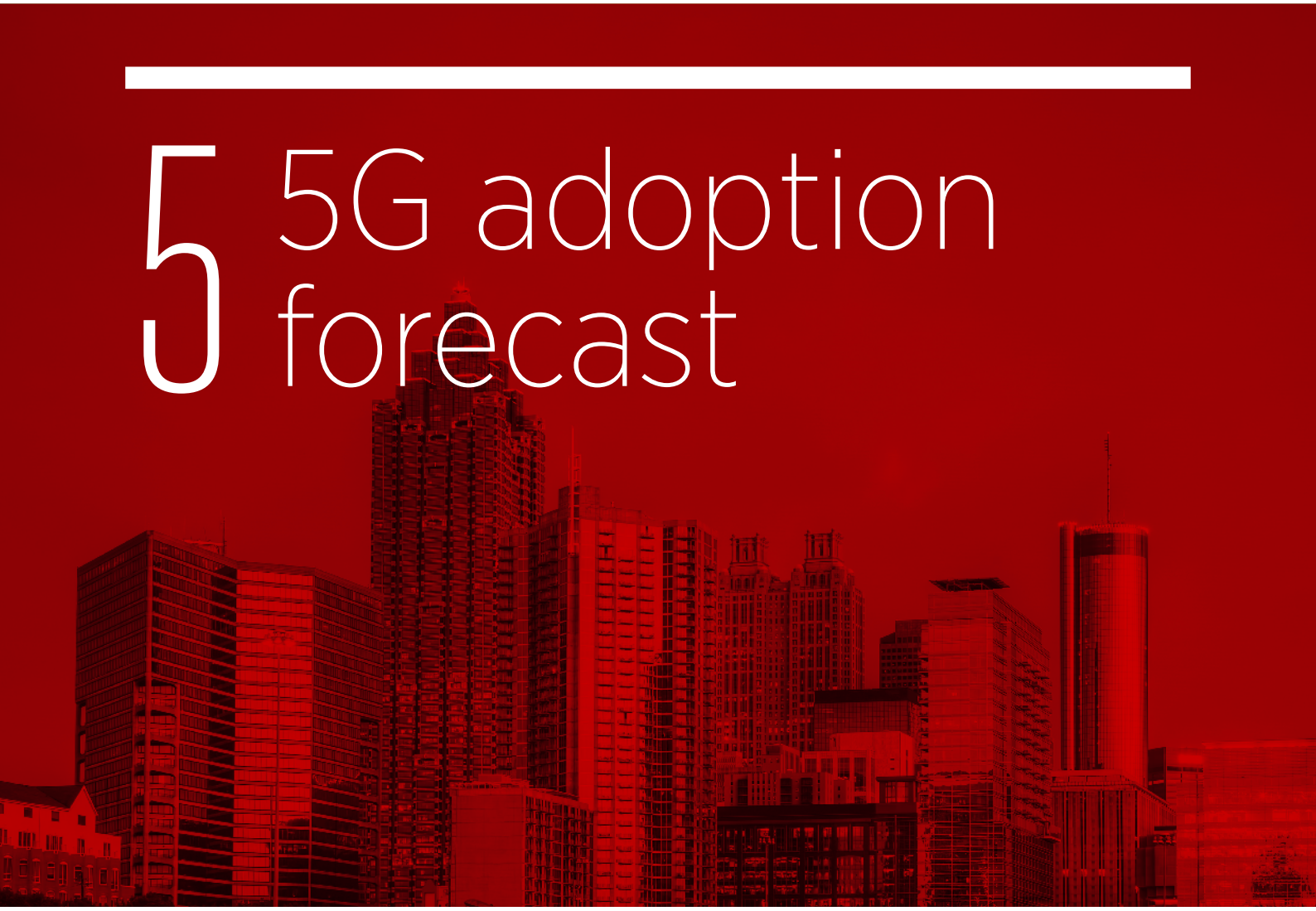
The open questions are less on technology and more on business model. Much of the 5G enterprise opportunity lies in providing customised network functionality to serve verticals such as automotive, energy, power generation, healthcare and advanced manufacturing. Incumbent cloud players – principally Amazon and Microsoft – are targeting the same opportunity, with several competitive advantages.[30] Each has high in-built scale from existing cloud footprints and balance sheet warchests to fund the rollout of edge computing infrastructure to complement existing data centres, commercial edge products already on the market (AWS GreenGrass and Microsoft Azure Edge were launched earlier in 2017) and existing large enterprise customer bases.

For operators without cloud infrastructure of this scale, extracting new use cases from integrated mobile and fibre networks offers more promise. One important aspect of 5G is mobile edge computing architecture that distributes intelligence to multiple levels of the network, including to the extreme edge for very low-latency use cases and thus delivers certain types of services and applications closer to the end user. Network slicing is one of the most promising options; this would involve an operator reserving defined segments, or slices, of network capacity for a particular customer (e.g. a factory using advanced robotics) at a guaranteed quality of service. For example, operators can separate one network slice to carry the connectivity for a corporate training programme with agreed data traffic capacity, and another slice for a connected car manufacturer with higher requirements in terms of latency and security.

While an elegant solution on paper, this is untested commercially. An additional option is opening up the network itself to third-party developers with the aim of catalysing an ecosystem of 5G service development, much in the way Apple and Google successfully did in the smartphone era. ETSI developed a standardised framework and released a set of common APIs in 2017, both positive developments. This approach is beginning to take root in Europe, with Deutsche Telekom and Vodafone launching network testbeds.

In the US, Verizon has already developed such a platform in the IoT space with ThingSpace, which we believe could be extended to further innovate for enterprise applications in the 5G era. The main considerations are openness and speed to market (applications need to be approved within hours or days as opposed to weeks), and thinking and acting with a start-up mentality.

[28]Source: article on TechRepublic (July 2016)
[29]Source: article on Inforce Computing (September 2016)
[30]Global Mobile Radar, GSMA, 2018



5 5G adoption forecast

5.1 5G will become the lead network technology in the US by 2025

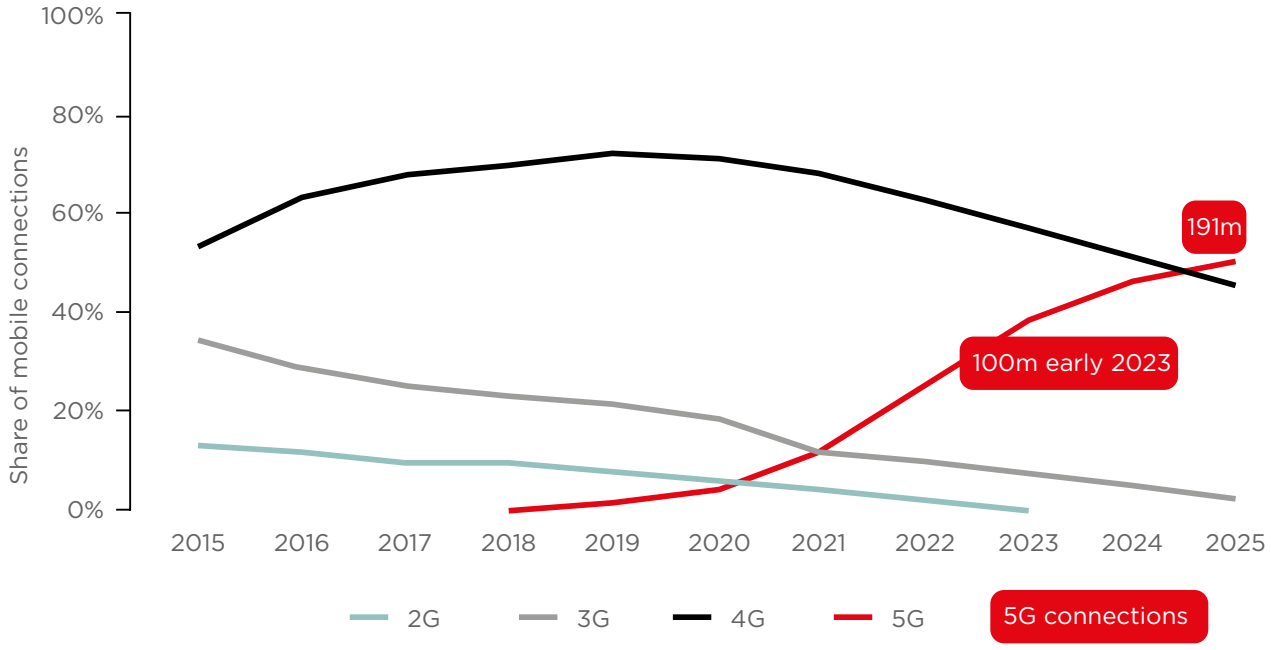
The US has always been the benchmark for fast migration to new mobile technologies. It was among the first few countries in the world to reach 50% smartphone adoption in 2012, and 50% 4G adoption three years later. Nearly 70% of mobile connections in the US currently operate on LTE networks. Only a few countries worldwide have reached a similar level of uptake – namely, South Korea, Japan, Australia and China.[31]

We forecast 5G adoption in the US to grow as fast as 4G adoption did. The country will reach 100 million 5G connections in early 2023, about four years after launch. By 2025, 5G will become the lead mobile network technology in the US with more than 190 million mobile connections, accounting for around half of total mobile connections. This forecast does not include 5G-based fixed wireless connections.

[31]Source: GSMA Intelligence mobile forecasts

Figure 13

US mobile connections by technology, excluding cellular IoT



Source: GSMA Intelligence

Our 5G adoption forecasts are informed by a number of operator announcements as well as key assumptions across several areas:

1) Spectrum and coverage – we expect that different spectrum bands (low, mid and high frequencies) will be available for the provision of 5G services, as was the case for 4G. As discussed in section 3.2, T-Mobile plans to use its 600 MHz spectrum to reach 5G nationwide coverage by 2020. Sprint also plans to use its 2.5 GHz spectrum for a nationwide 5G mobile network slated to begin launching in the first half of 2019.

2) Devices and pricing – while innovation has plateaued in smartphone design and features over the last few years, the frequency of new smartphone releases has remained high. At the current rate of releases and factoring in a 12–18-month handset development cycle since the release of 5G specification, we expect that an increasing number and variety of 5G smartphones will be available during early 5G commercial launches across different vendors. 5G also presents an opportunity for vendors to resume handset innovation, particularly if successfully coupled with new technologies such as AR, VR and enhanced video. We expect the average price of a 5G smartphone in the US to fall over time as more affordable handsets become available for the mass market.

3) Consumer behaviour and competition – historically, US consumers have shown a higher propensity to switch to the newest technologies compared to some of the other large developed markets across Asia-Pacific and Europe. As discussed earlier, the addressable market for 5G services is also larger than in any other country, with 58% of US smartphone users in the Aficionados category. 5G will also launch in a competitive mobile market; intense competition could stimulate market dynamism and help drive 5G adoption.

5.2. 5G adoption worldwide – the US will lead the way

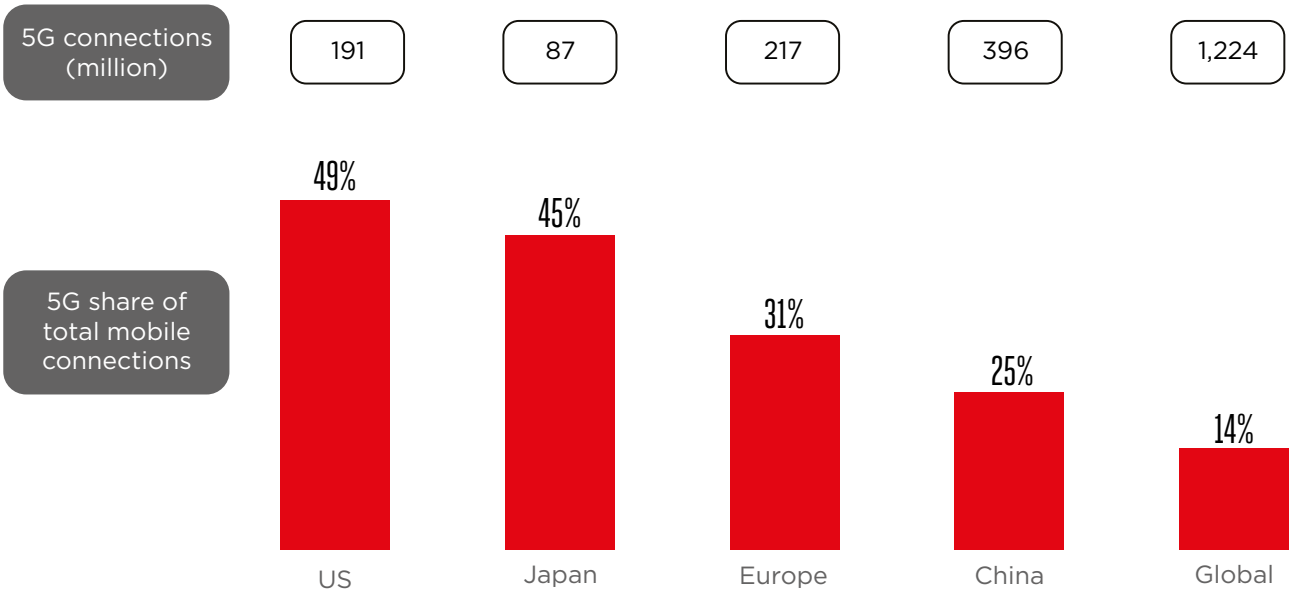
Compared to 4G, more markets are set to be involved in early 5G deployments around the world. At the time of this publication, more than 40 operators had already announced plans to launch 5G commercial services across over 30 markets, including the US, China, Japan, South Korea and across Europe.[32]

China, the US and Japan will be the leading countries by connections in 2025[33], while Europe as a whole will continue to make progress with 5G deployment (see Figure 14). In total, these four economies will account for more than 70% of the 1.2 billion 5G mobile connections expected globally by 2025. From launch through to 2025, the US will also experience the fastest customer migration to 5G among the major countries/regions (measured as "5G as a percentage of total mobile connections").

Figure 14

5G adoption in 2025, major countries/regions

Mobile connections excluding cellular IoT



Source: GSMA Intelligence

[32]Source: GSMA Intelligence, based on operator announcements. These markets include Australia, Canada, China, Finland, France, Germany, Hong Kong, Italy, Japan, Qatar, Norway, Singapore, South Korea, Sweden, Switzerland, Taiwan, Turkey, UAE, UK and US
[33]Source: GSMA Intelligence mobile forecasts

6 Policy and regulatory outlook

For nearly three decades, policy and regulatory developments have supported growth in the global mobile industry. As the industry moves into the 5G era, appropriate regulatory conditions, transparent spectrum rules and a clear and predictable policy framework will continue to be key to drive further mobile developments.

This section focuses on the US, while an earlier GSMA report *The 5G era: Age of boundless connectivity and intelligent automation* provides an overview of the key policy and regulatory challenges at a global level. Streamlining regulation as well as further developments in three main areas could influence the development of 5G in the US and the evolution of the country's mobile ecosystem over the next decade.

6.1 Spectrum

5G requires a mix of frequencies at sub 1-GHz, 1–6 GHz and above 6 GHz, to deliver widespread coverage of the population and support a multitude of consumer and enterprise use cases. Therefore, the availability of spectrum, at what frequency, rules for its use, timelines, and cost will have a major impact on the development of 5G. As discussed in section 3.2, the US government has been supportive over recent years through a number of initiatives that have made – or are opening up – a variety of spectrum bands available for commercial 5G use. Making further spectrum available this year is seen by operators as a government priority and would enable further progress with 5G rollouts.

Timely availability of spectrum applies to all frequency ranges, including the mmWave frequencies, as well as licensed and unlicensed bands. Licensed bands will be crucial to 5G development as they allow quality control and the maximum potential to be realised, and also drive the equipment market. Additional unlicensed spectrum may also be required to ease capacity constraints by helping operators deliver exceptionally high data throughput in hotspot areas. In the US, the FCC has proposed unlicensed frequencies in 57–71 GHz for 5G use, and has authorised LTE-U and LTE-LAA devices in the 5 GHz band.

5G will also require predictability in long-term spectrum availability across all bands. US mobile operators generally agree that expectations for long-term mobile data traffic outweigh the capacity that can be provided with existing spectrum holdings.

As far as spectrum re-farming is concerned, unlike some other countries in the world, the US does not designate certain bands exclusively for specific mobile network technologies. Some operators have already begun the process of re-farming – for 4G – spectrum bands initially deployed for 2G technology. Although there are no operator announcements at this stage, some 4G spectrum may be reallocated to 5G in certain locations and markets; the coexistence in the same spectrum band of 4G and 5G may also provide other options beyond the traditional re-farming approach.

Finally, while the CBRS initiative discussed earlier is a notable novel and experimental approach in the 3.5 GHz band, exclusively licensed spectrum will still be essential as a spectrum management model to guarantee the vital long-term heavy network investment required for 5G. The risks surrounding network investment are significantly increased without the assurance of long-term, reliable spectrum access. US operators believe the mobile industry needs to assess how this model works for the 3.5 GHz band before considering application of similar rules to other spectrum bands.

6.2 Infrastructure

US mobile operators see (the time and cost associated with) site access for broadband facilities as one of the foremost challenges to the rollout of 5G services, especially for small cells to be deployed in urban and suburban areas. US operators believe federal, state and local officials need to continue to work towards modernising and harmonising regulation, and removing obstacles to fibre and small cell deployments. This will provide the support operators need to effect planned rollouts.

From an operator perspective, this regulatory support should include reforming and streamlining local permitting processes, obtaining favourable municipal ordinances and state legislation that allow for timely and cost-effective infrastructure deployments, and removing practices such as small cell moratoria and undergrounding requirements. Regulatory developments should also grant non-discriminatory access to poles (with reasonable, cost-based fees for such access) and rights of way to install new 5G equipment, as well as FCC-imposed “shot clocks” for review of siting applications. “Deemed granted” remedies should also be in place in the event that there are barriers to approving an application.

Operators express different views on the degree to which backhaul may be a potential hurdle to deployment. There is, however, extensive fibre deployment in the US and a robustly competitive fibre market, ensuring in most cases that operators will have adequate access to the necessary infrastructure whether through a build, buy or lease model. In addition, certain spectrum bands (e.g. mmWave) may offer the potential for in-band backhaul solutions, thereby reducing the need to have fibre deployed to every mobile site.

Network sharing is also an important topic. Operators in other geographies have previously expanded their network sharing agreements to reduce the cost of 4G network deployment – and some have not ruled out joint deployments for 5G. Views from some US operators suggest that commercially based infrastructure sharing may reduce operating costs and provide additional capacity in congested areas where space for sites and towers is limited. However, arrangements for infrastructure sharing should be considered by looking at the business case and should take the form of negotiated contracts between operators – e.g. entered into voluntarily and involving commercially agreed terms. While government should allow appropriate network sharing arrangements, US operators believe these agreements should develop commercially and organically over time, if they are viable, rather than policymakers introducing rules that could slow the pace of deployment.

6.3 Economics

The long-term economics of 5G for the mobile industry are still uncertain in the US (and around the world). While US operators anticipate that a number of factors and network features will help reduce deployment and operational costs, there is little guidance currently on the wider economics of 5G.[34] Ultimately, operators' ability to profitably build and operate 5G networks will largely depend on finding models to roll out 5G cost-effectively and cultivating incremental revenue opportunities that can be served with 5G network capabilities.

Pro-innovation and pro-investment reforms can play a key role. For example, following the US tax reform signed into law in late 2017, AT&T committed to step up its 2018 capital investment through an additional $1 billion, and expects increased investment and business activity in other industries that could create additional demand for services provided by telecoms operators. In December 2017, the FCC decided to restore the bipartisan light-touch regulatory framework that was in place for nearly 20 years until 2015, which returns broadband internet access service to its prior classification as an information service.

Finally, there is an outstanding question as to the extent to which 5G network deployment will be driven by actual demand (consumer and enterprise) and how much will be determined by the supply side of the market (e.g. operators build widespread 5G networks as B2C, B2B and B2B2C use cases emerge over time). US operators largely agree that 5G network deployment will be driven by both supply- and demand-side factors – a situation similar to the ongoing development of the IoT ecosystem. Operators are also keen that the FCC makes progress with allocating monies from the Connect America Fund (CAF) and Mobility Fund Phase II (MF-II) to spur investment in areas where it would otherwise be uneconomical to do so and thus where broadband services may not currently be provided.

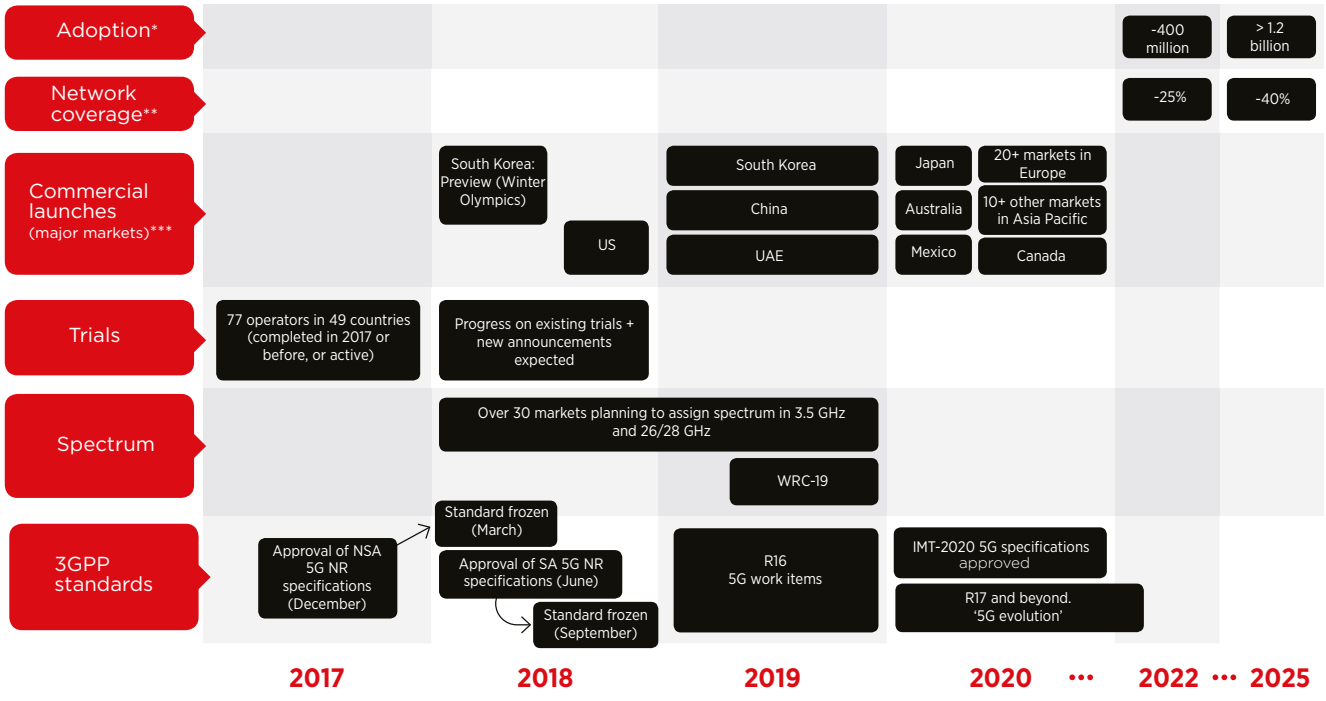
[34]These factors include a phased approach to network deployment, the coexistence feature of 5G, as well as the ongoing move to software-defined networking (SDN), network function virtualisation (NFV) and open network automation platform (ONAP)

Mobile industry journey to 5G – what next?

Around the world, 2018 will be another important year for 5G. Significant progress is expected across key areas, including the approval of the standalone 5G new radio specifications by June, work to assign additional spectrum as well as new operator trials (see Figure 15). It will also be the year of early 5G commercial launches, with a 5G preview during the Winter Olympics in South Korea and the launch of both 5G-based fixed wireless and 5G mobile services in the US. Looking ahead, 5G momentum will intensify in 2019 and 2020 with further commercial launches around the world and continuous work across the industry on spectrum, specifications, network deployments and devices.

Figure 15

5G timelines across key areas



* Number of mobile connections excluding cellular IoT, worldwide. Source: GSMA Intelligence 5G forecast.
** Percentage of global population. Source: GSMA Intelligence 5G forecast.
*** Not exhaustive.
Source: industry announcements and GSMA Intelligence

In 2018 and beyond, the GSMA will continue to bring together all stakeholders in the mobile industry to support further progress with 5G. By working closely with its members and other players in the ecosystem, the GSMA will focus on how to help define the technologies, identify the spectrum bands and develop the business models and policy initiatives that will bring 5G to life. The GSMA will also continue to monitor and report on 5G developments across all key areas, including spectrum, trials, commercial launches, network coverage and customer adoption.

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