GSMA Intelligence

CAICT 中国信通院

5G in China:
Outlook and regional comparisons

The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with almost 300 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai, Mobile World Congress Americas and the Mobile 360 Series of conferences.

For more information, please visit the GSMA corporate website at www.gsma.com

Follow the GSMA on Twitter: @GSMA

GSMA Intelligence

GSMA Intelligence is the definitive source of global mobile operator data, analysis and forecasts, and publisher of authoritative industry reports and research.

Our data covers every operator group, network and MVNO in every country worldwide – from Afghanistan to Zimbabwe. It is the most accurate and complete set of industry metrics available, comprising tens of millions of individual data points, updated daily. GSMA Intelligence is relied on by leading operators, vendors, regulators, financial institutions and third-party industry players, to support strategic decision-making and long-term investment planning. The data is used as an industry reference point and is frequently cited by the media and by the industry itself.

Our team of analysts and experts produce regular thought-leading research reports across a range of industry topics.

www.gsmaintelligence.com

info@gsmaintelligence.com

GSMA Intelligence
David George, Research Director
Tim Hatt, Research Director
Calum Dewar, Director of Forecasting
Mark Giles, Lead Analyst

China Academy of Information and Communications Technology (CAICT) is a scientific research institute directly under the Ministry of Industry and Information Technology.

CAICT is a specialised think-tank for the government and an innovation and development platform for the industry. Its service portfolio covers telecommunications, the Internet, informatisation and the integration of industrialisation and informatisation. It contributes to the development and innovation of the country and the ICT industry by providing support and services in terms of strategies, plans, policies, regulations, technologies, standards, testing and certification.

www.caict.ac.cn

CAICT
YU Xiaohui, Chief Engineer
WANG Zhiqin, Vice President

Industry and Planning Research Institute:
YANG Zizhen, Deputy Director
PAN Feng, Vice Chief Engineer
LI Shan, Senior Engineer
CAO Lei, Senior Engineer
SHI Lifeng, Senior Engineer
ZHANG Chunming, Senior Engineer
LUO Zhendong, Senior Engineer
WANG Qiushi, Senior Engineer
HE Yang, Senior Engineer

Contents

Executive summary

This report focuses on the outlook for 5G in China, as well as making comparisons with the outlook in other leading markets in the region, including Japan and South Korea. It explores the near-term outlook for testing and commercial launches, and potential use cases in the consumer and enterprise segments, as well as presenting forecasts for the number of 5G connections and the key future challenges. The report follows earlier analysis published by the GSMA (*The 5G Era: Age of boundless connectivity and intelligent automation*), which set out the five high-level goals for the 5G era, based on feedback from an extensive survey of 750 operator CEOs and other industry stakeholders.

This report has been produced through collaboration between GSMA Intelligence and the China Academy of Information and Communications Technology (CAICT). It combines market research and survey feedback from a number of operators and other ecosystem players in China, South Korea and Japan.

Consumer use cases: early deployments target an enhanced mobile broadband experience

Enhanced mobile broadband (eMBB) will be the core consumer provision for early 5G networks, and the headline 5G services at launch are likely to be based around 4K/8K Ultra-HD video and augmented reality (AR) and virtual reality (VR) applications. China is likely to be a key market for VR, as many businesses have been early adopters, giving consumers direct experience of the technology. However, a lack of consumer content and device availability could limit the adoption of VR services. As such, the core application of 5G in its early phase will be to supplement the capacity of 4G networks as cellular data traffic continues to rise.

Although some services will require devices with new form factors, we expect the smartphone to be the principal 5G device at the launch of 5G networks. The first 5G smartphones are likely to be priced at a premium to 4G models, as they will require an enhanced chipset and RF module supporting multiple sub-6 GHz – and possibly mmWave – frequencies, as well as, potentially, a 4K (or 8K) screen. We expect prices to fall with large-scale adoption, as with earlier technology generations.

Given that early 5G deployments will be mainly aimed at upgrading capacity for high-speed MBB, we expect the majority of operators to initially market 5G to consumers by emphasising its improved speed compared to 4G, which should allow some scope for ARPU uplift through larger data bundles. There may be scope for operators to price 5G at a premium to users of applications such as VR gaming and immersive entertainment services, who could conceivably be offered a guaranteed quality of service (QoS) level for an additional fee. Outside of this, it is difficult to see other opportunities for generating increased return on investment (RoI) from 5G in the consumer segment at present.

Enterprise use cases: the largest incremental opportunity

While operators will continue to explore opportunities in the consumer space with the advent of 5G, and compete strongly to retain existing customers, it is the enterprise segment that presents the largest incremental revenue opportunity. Chinese, Korean and Japanese operators are broadly aligned on the key verticals in which 5G can deliver value. These include automotive and wider transport, logistics, energy/ utilities monitoring, security, finance, healthcare, industrial and agriculture. They are collaborating with the broader mobile ecosystem and vertical industry players to develop new services and business models that will utilise 5G networks.

5G will deliver a number of enhanced capabilities over and above 4G, including increased data rates, reduced latency and enhanced reliability, which operators can attune to enterprise needs. Over time, as operators roll out 5G networks more widely, and as they implement virtualised core networks, edge computing and new back-office IT orchestration systems, we will begin to see them offer differentiated networks as a service to enterprises, based on the concept of network slices. Such a step would be a departure from the traditional enterprise connectivity business model. The positive is that, in theory, better network quality offered through slicing provides pricing leverage. On the other hand, the burden of maintaining a guaranteed QoS means operators will require rigorous monitoring software and redundancy measures to mitigate the risk of penalties if SLAs are not met.

Deployment approaches: merits of standalone vs non-standalone

There are two broad deployment scenarios for 5G networks: standalone and non-standalone. Standalone would be a new-build network, including new base stations, backhaul links and core network. A non-standalone network would piggy-back on existing infrastructure, supplemented by targeted small cell deployment in areas of high density. This is unlikely to be a one-size-fits-all story, with different approaches adopted by different operators at different points in the 5G rollout timeline, reflecting the trade-offs associated with either option.

Standalone offers larger scale economies and high performance as well as less complexity from legacy LTE integration, but it is more expensive in the early commercial stage. By contrast non-standalone offers a quicker route to market, but its suitability is arguably greater for hyper-localised deployments than national rollouts, and additional complexity needs to be introduced to realise the interoperability with existing LTE networks.

In China, operators are more inclined to adopt the standalone route from the beginning. Our expectation is that at least some operators in other countries, such as Japan, will opt for a non-standalone approach in the early stage, which, if not a permanent configuration, could serve as a bridge to eventual standalone 5G networks.

Existing IoT use cases can largely be handled through LPWA protocols, which include 2G, 3G, 4G, NB-IoT and a range of unlicensed cellular options, such as Sigfox and LoRa. The parts of IoT that fall within the exclusive purview of 5G are those that are either much larger in scale or that are mission-critical and therefore demand low latency. In China, we expect the former to include logistics tracking, energy and grid management. Mission-critical applications could include connectivity for robotics in industrial settings and traffic management in cities. This is as much about the broader 'softwarisation' of network architecture and the pushing out of computing power to the edge through the cloud (i.e. building more data centres), as it is the new 5G standard.

On capex, indications from the Chinese mobile operators are that 5G investment will follow a more gradual path and over a longer timeframe than 4G, roughly seven years, from 2018 to 2025. Japanese operators claim that the deployment of 5G will not lead to any significant spike in capex. Early commercial rollouts are likely to require investment in small cells and transmission upgrades, with fibre backhaul (up to 10 Gbps) to support sub-10 ms latency. Subsequent expansion of 5G to a larger footprint in rural areas could require new site build and further incremental capex, but such a scenario is dependent on business case viability and the presence of international standards and so is unlikely before 2020. We would not expect capex as a share of revenue to reach the 25%+ levels, as with 4G, before 2020 at the earliest – if at all.

5G connections in China to exceed 400 million by 2025

From launch in 2020, we forecast that Chinese 5G connections will scale rapidly over time, to reach 428 million by 2025. This represents a slower rate of adoption compared to 4G, with the key reasons for this difference including the following:

- The rollout of 4G networks within China was very aggressive, serving a latent demand for high-speed mobile data services. By contrast, early 5G networks will be deployed principally as a hot-spot technology to supplement the capacity of current networks, with operators in the region indicating that they will roll out as demand dictates.

- The price point at which 5G devices are available will fall over time, as economies of scale kick in. However, given the hardware requirements to support 5G speeds, it is likely to take some significant time for the price point for 5G devices to decline to the same degree as has been witnessed for 4G.

- The transfer of subsidies from 3G to 4G, and wide availability of 4G devices helped to spur rapid 4G adoption in China. China Telecom and China Unicom will be aggressive in trying to capture share from the market leader, and are therefore likely to transfer subsidies to target 5G adoption. However, as China is an early launch market, it will initially face a less mature device ecosystem, which will limit the scope for subsidies to drive 5G adoption to the same degree.

Regional comparisons

The recent agreement by the 3rd Generation Partnership Project (3GPP) wireless standards body to accelerate some elements in the 5G new radio (NR) timeline has seen some operators around the globe bring forward their commercial launch plans. This includes Korea Telecom and SK Telecom, although operators in China and Japan appear to be still focused on the original 2020 date for commercial launches.

KT plans to launch field trials of its 5G service at the PyeongChang Winter Olympics in 2018 and has brought forward plans for a commercial launch to

2019. SK Telecom plans to launch field trials before the end of this year, and will work with end-users to understand the most appealing use cases, which will help shape its commercial 5G deployment in the second half of 2019.

Operators in Japan on the other hand continue to target a 2020 commercial launch date, but are focussing their efforts on moving well beyond the network provider model with 5G to explore potential use cases and to further develop their existing areas of expertise or commercial strength.

New business models and near-term revenue outlook the key challenges ahead

The last 5G report from the GSMA highlighted five key risks and challenges that need to be addressed or managed in order to realise the full potential of 5G. These included: the need for new business cases both to roll out 5G cost effectively and to identify incremental revenue opportunities; the need for sufficient amounts of spectrum in harmonised bands; technological progress in the ongoing evolution of 4G emerging technologies; avoiding standards fragmentation; and the need for a pro-investment regulatory regime.

This report examines these challenges from the perspective of the Chinese market. As highlighted above, new business models and the near-term revenue outlook remain a challenge, given in part the lack of available content and applications in areas such as AR and VR, as well as questions around the cost and availability of devices. Clarity on business models and revenue opportunities in the enterprise space may rely on more widespread network deployments and greater maturity of the 5G ecosystem, particularly for the more innovative and mission-critical services based on ultra-reliable low latency capabilities of 5G.

Based on operator discussions across the region, C-band (3–5 GHz) spectrum will form the principal bands in early deployments. 5G is a heterogeneous technology and, as such, will require a range of spectrum bands over the long term. In addition to C-band, and drawing on deployments in other regions, this is likely to require sub-1 GHz and mmW spectrum. While China's spectrum requirements are similar to those in other regions, there has been concern expressed at the availability of spectrum in the sub-6 GHz band.

There is a clear desire to see harmonisation of spectrum bands for 5G across regions in order to both facilitate roaming and reduce the cost of new devices and handsets. Similarly, in terms of the more general risk of standards fragmentation, there is strong support from across the ecosystem in China on the need for a global unified 5G standard that allows both a faster and more cost-effective deployment and helps achieve the potential benefits of 5G networks.

1

Use cases

Consumer market opportunity

Enhanced mobile broadband (eMBB), offering higher speed and lower latency than existing technologies, will be the core consumer provision for early 5G networks, with real-world performance of up to 1 Gbps with less than 10 ms round-trip latency. However, few if any mobile applications currently exist that require this level of network performance, and the LTE Advanced networks now in operation or deployment across China should provide sufficient speed for most services that will come to market between now and the launch of 5G networks. The headline 5G consumer services at launch that are true mobile 5G applications (i.e. they cannot be supported by 4G networks) are likely to be based around two key areas:

- **Video:** i.e. live streaming video content to mobile devices at increasingly high resolutions (i.e. 4K or 8K HD video), or other formats that require a high data transfer rate (e.g. 360-degree video). While there is very little official 8K content around currently, this is expected to change by the time of 5G launches, with 8K recording now taking place in Hollywood, and Japanese public TV company, NHK, expected to broadcast the 2020 Tokyo Olympics in 8K. Also, personal 8K video cameras are already available from manufacturers such as GoPro; these, combined with the popularity in China of live-streaming apps – which helped drive revenue from the live-streaming industry in the country to $3 billion in 2016, according to estimates by Credit Suisse – could stimulate demand for video-based social media in ultra-HD. Meanwhile, sports coverage broadcasting offering a 360-degree view from the athlete's perspective could also be streamed via 5G; this is one of the applications that KT will be trialling at the 2018 Winter Olympics in South Korea.

- **AR and VR applications:** these could take advantage of the low latency offered by 5G, as well as the high speed. The potential for superimposing virtual imagery and text onto a real-world view could give rise to a number of applications, in areas such as translation, gaming and mapping/schematics (e.g. a virtual instruction manual with diagrams that are overlaid when a car engine is viewed through the device) and combine with cloud services and AI to instantly provide increasingly personalised information. Meanwhile, the cellular VR experience will improve immeasurably for gaming, with the potential for a fully immersive experience using 8K panoramic video. Again, a considerable increase in available content will be required to stimulate demand for VR services, and device availability and pricing could also be a bottleneck. A further question is whether cellular VR gaming could provide the consistency and quality of service of a tethered connection.

Despite these challenges, China is likely to be a key market for VR, as many businesses have been early adopters, giving consumers direct experience of the technology in use cases ranging from sales (e.g. a real estate agent giving a client the opportunity to "view" a property thousands of miles away) to entertainment; terminals are being installed in internet cafes, theme parks, shopping centres and "experience museums" across the country, allowing people to use VR for free or for a small fee. These experiences have, in turn, driven consumers to purchase VR adaptors for their own smartphones, which are made by local manufacturers and sell at a much lower price than overseas equivalents, such as the Oculus Rift.

While there remains considerable uncertainty around the content and 5G device availability that will define the level of demand for the above types of services, one clear application of 5G will be to supplement the capacity of 4G networks as cellular data traffic continues to rise. Average monthly data consumption per handset on China Mobile's 4G network increased from 0.75 GB in 2015 to 1.03 GB in 2016 which, while still lower than many developed markets, is compounded by the operator's 4G connections increasing from 312 million to 535 million over the same period. Despite continuing 4G deployments and upgrades across the country, 4G networks are likely to become increasingly stretched in the run-up to 5G launches in 2020. With initial 5G deployments set to use small cell technology in densely populated traffic hotspots, the principal use case of 5G at launch is likely to be upgraded capacity for the continued provision of high-speed mobile broadband services and an acceptable (and marketable) level of speed and latency.

A further application of eMBB is in the form of fixed-wireless, which is a key element of the 5G strategy for US operators such as AT&T and Verizon. Both of these operators have investments in video content producers and will use fixed-wireless 5G to supplement their existing fibre-to-the-home (FTTH) networks. However, this is not the main focus for Chinese operators, as FTTH has already been rolled out extensively. There is still potential to use fixed 5G to connect homes in rural areas where the FTTH availability is lower than in cities.

Devices

Although some new services will require devices with new form factors, we expect the smartphone to be the principal 5G device at the launch of 5G networks. By 2020, GSMA Intelligence forecasts that two thirds of all mobile connections globally, and almost three quarters of mobile connections in China, will be smartphones, up from 53% and 71% respectively today. We expect the smartphone to continue to evolve to support 5G networks in the same way that it has developed alongside the schedule of LTE releases, and for smartphone adoption to further increase out to 2025.

The first 5G smartphone models are likely to be priced at a premium to 4G models, as 4G models were to 3G. So as to derive a competitive advantage from the increased network performance of 5G, manufacturers will look to include 4K (or even 8K) displays – even though the increased resolution may be almost imperceptible to the human eye due to the small screen size. Other hardware features required to support AR could include additional cameras and sensors to generate 3D maps of rooms and spaces. Pricing is more likely to provide an initial barrier to adoption in price-sensitive markets such as China, and adoption will depend heavily on the amount of subsidies that operators target 5G devices with. We expect prices to decrease with large-scale adoption, as has been seen with earlier technology generations.

The range and pricing of 5G devices at launch will also be determined to a great extent by the availability of supporting chipsets and RF modules. Development of 5G chipsets is well underway; for example, Qualcomm expects that commercial devices using its 3GPP-compliant Snapdragon X50 5G modem will be available by 2019. However, the number of spectrum bands that will need to be supported by 5G RF modules is unclear, and a lack of global harmonisation in terms of spectrum bands will make integration of RF modules in devices more challenging – particularly when mmWave bands are present – and have a knock-on effect on 5G device availability.

Initially, 5G VR services are likely to be consumed through separate attachments to the smartphone, similar to those currently available: e.g. Samsung Galaxy Gear, Google Daydream View and Google Cardboard. As the 5G ecosystem develops, standalone VR and AR devices could appear on the market.

Tariffing

The opportunity for mobile operators to separately market and bill for 5G services, such as 8K video, cellular VR or cloud-based AI, depends greatly on demand and the structure of the market for content, and will probably require them to move beyond the traditional network provider model. While some operators may have adopted the role of content or cloud computing provider by the beginning of the 5G lifecycle, given that early 5G deployments will be mainly aimed at upgrading capacity and providing reliable high-speed MBB – particularly in key business areas – we expect the majority will initially market 5G mainly by emphasising its improved speed and capacity compared to 4G – as was the case when operators upgraded their networks from 3G to 4G.
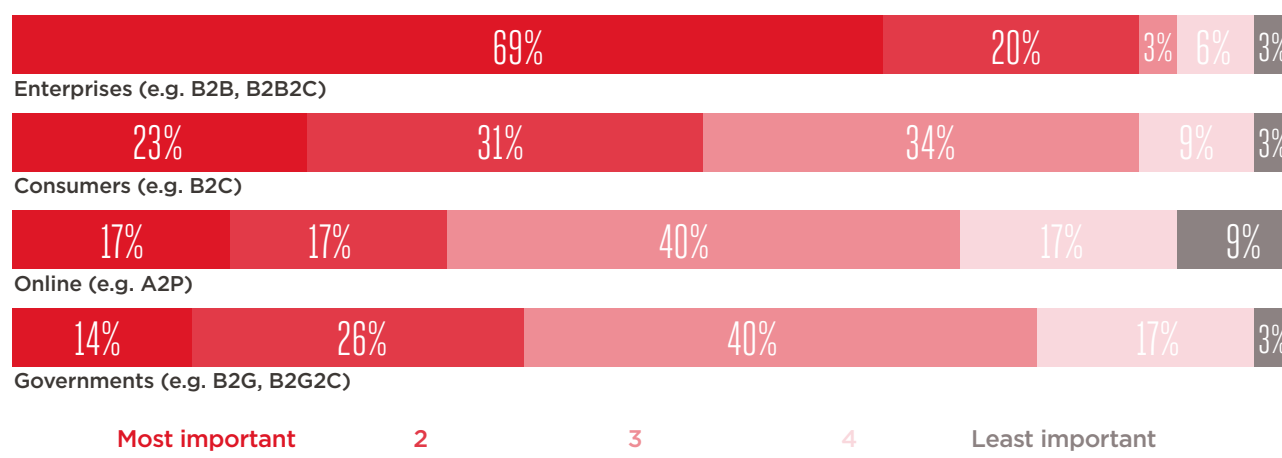
This approach will limit the scope for specifically pricing 5G at a premium to 4G in the B2C segment, although there will be scope for ARPU uplift through larger data bundles. One possibility is that operators will look to market their networks based on agreed QoS levels, using network slicing to offer guaranteed performance levels in terms of downlink/uplink speed and latency, and pricing accordingly. Such guarantees may appeal to users of VR gaming and immersive entertainment services, where a consistent, low-latency connection is imperative, and may form the basis of specialist tariffs for these types of services. However, outside of this, it is difficult to see other opportunities for generating increased ROI from 5G in the consumer segment, particularly if the move back towards unlimited data – which has been witnessed recently in the US – continues.

Enterprise market opportunity

The story of mobile telecoms has, to date, been largely consumer-centric. While operators will continue to explore opportunities in the consumer space with the advent of 5G, and compete strongly to retain existing customers, it is the enterprise segment where most operators see incremental opportunity.

Source: GSMA Intelligence – The 5G era: Age of boundless connectivity and intelligent automation

1 Sources of new operator revenues for 5G

Category	Most important	2	3	4	Least important
Enterprises (e.g. B2B, B2B2C)	69%	20%	3%	6%	3%
Consumers (e.g. B2C)	23%	31%	34%	9%	3%
Online (e.g. A2P)	17%	17%	40%	17%	9%
Governments (e.g. B2G, B2G2C)	14%	26%	40%	17%	3%

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

Chinese, Korean and Japanese operators are broadly aligned on the key verticals in which 5G can deliver value. These include automotive and wider transport, logistics, energy/utilities monitoring, security, finance, healthcare, industrial and agriculture.

Operators across the region are actively engaging with ecosystem players and directly with industry verticals to help identify technical solutions and business models. For example, in February 2016, China Mobile launched a 5G joint Innovation Centre. Working with internet players and vertical industries, the Centre will focus on developing opportunities within communication services, IoT, the Internet of Vehicles, industrial internet, cloud robotics and VR/AR, among others. In addition, all three Chinese operators have planned to help develop the Xiongan New Area, turning it into "a green smart city and innovation development pilot region". As part of this effort, they plan to launch 5G trials in the area, with China Telecom calling for resource sharing among rivals to help build the network.

The automotive sector, with the march towards driverless cars, is a widely talked about example of an industry that could benefit from 5G's superior capabilities, with operators across China, Japan and Korea targeting it as an early vertical opportunity. The Chinese Ministry of Industry and Information Technology and the Ministry of Transport have sought to promote technology research and the development of standards for connected cars through a pilot, based on a 5G car network demonstration. The trio known as BAT (Baidu, Alibaba and Tencent) and other internet and content companies have contributed to areas such as autonomous driving, social entertainment, cloud services and automotive systems, and some companies have launched a clear timetable for when these services will be available.

Developing the 5G enterprise business model

5G NR will deliver a number of enhanced capabilities over and above 4G, including increased data rates and mobility, and reduced latency, which operators can attune to enterprise needs. The early signs are that initial 5G deployments will target increased network capacity in dense urban areas, supporting enhanced mobile broadband services. Over time, as operators roll out 5G networks more widely, and as they implement new virtualised 5G core networks, edge computing and new back-office IT orchestration systems, we will begin to see them offer differentiated networks as a service to enterprises, based on the concept of network slices.

With these capabilities, operators will be able to replicate the business model found within the fixed-line enterprise space, where they sell network services to enterprises based on myriad service-level agreements (SLAs). Operators will need to give attention to business-to-business (B2B), business-to-government (B2G) and business-to-business-to-consumer (B2B2C) business models. While operators will be able to differentiate by building SLAs around factors such as network speed, reliability and coverage, they will be held to account contractually should performance targets not be met. Incumbent operators who are already set up to deliver detailed SLAs (in terms of tools, monitoring and sales) to

enterprises on the fixed side have a clear advantage in transitioning to such a model, but it will still require significant network investment to support it.

This is also not purely a 5G debate – low power wide area (LPWA) networks such as NB-IoT, which support some of the key use cases for 5G networks, have been developed within the 4G standard, and operators are already in the process of rolling them out. These networks utilise existing licensed operator spectral resources, and allow operators to roll out dedicated networks to support IoT devices requiring low data rates, longer battery life and wide area coverage.

A number of challenges exist that will serve to limit early demand for enterprise 5G services. Some verticals, from regulatory and security perspectives, as well as their position in their investment cycles, will not be ripe as short- to mid-term opportunities, while relative business maturity will vary between sectors and countries. Furthermore, vertical industry market demand is fragmented, technical solutions and business models are still to be defined, and operators have still to establish themselves as technological partners for vertical industries where, in many cases, they are limited to a traditional communications supplier role.

2
Deployment

Merits of standalone vs non-standalone deployment scenarios

There are two broad deployment scenarios for 5G networks: standalone and non-standalone. Standalone would be a new-build network, including the construction of new base stations to site 5G equipment, backhaul links and a core network. A non-standalone network would operate as a hybrid model, piggy-backing on existing infrastructure supplemented by targeted small cell deployment in areas of high density, allowing 4G and 5G services to run in parallel. Operators have not yet disclosed detail on deployment plans, in large part because the technical feasibility of hybrid configurations is still being assessed; 3GPP is expected to release updated 5G NR and core specifications in December 2017 and June 2018 respectively.
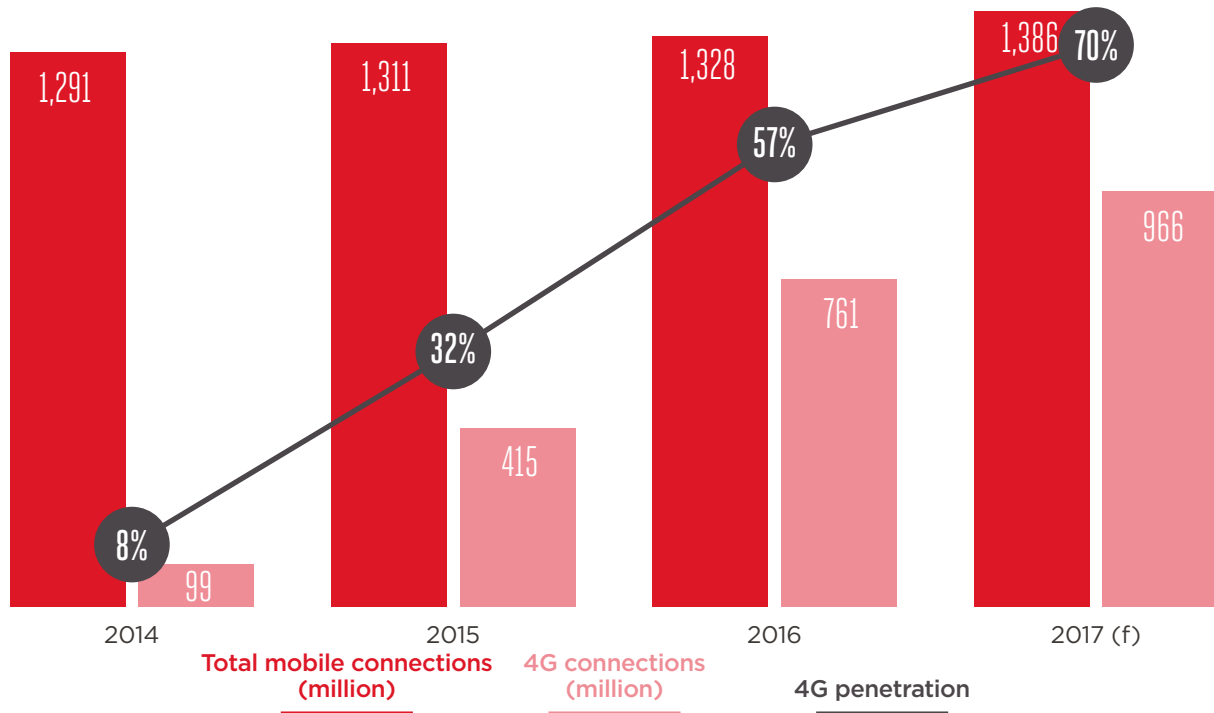
We expect different approaches to be adopted by different operators, reflecting the trade-offs associated with either option. Standalone 5G networks allow 4G and 5G services to run in parallel and remove the complexity of LTE integration. Scale economies on a national level would be significant but this option is likely to prove more expensive at least in the early stages.

The rationale for non-standalone centres on multiple factors. Firstly LTE has a lot of headroom for growth, with significant infrastructure investment still to be recouped. In China, 4G penetration has increased fivefold to 61% over the two-year period to March 2017, driven by the withdrawal of 3G handset subsidies and rise of cheap smartphones (see Figure 2). In penetration terms, China is now on a par with the US and above many European countries, but its large population provides it with an outsized opportunity to generate positive operating leverage from incremental increases in 4G users – that is, more people generating revenue across an LTE network that has for the most part been laid. Secondly, integrating a 5G network on existing LTE infrastructure allows for faster rollout with a lower capex burden. Thirdly, it allows operators the flexibility to build out in selected areas (mostly cities) to support early commercial 5G services without committing to national scale coverage, which is unlikely to happen before international standards and spectrum bands are agreed in 2020. Its suitability is arguably greater for hyper-localised deployments rather than national rollouts, with additional complexity needed to realise the interoperability with existing LTE networks.

2 4G evolution in China

	2014	2015	2016	2017 (f)
Total mobile connections (million)	1,291	1,311	1,328	1,386
4G connections (million)	99	415	761	966
4G penetration	8%	32%	57%	70%

Total mobile connections (million)   **4G connections (million)**   **4G penetration**

Operators in China are more inclined to adopt the standalone route from the beginning, with 5G and LTE co-existing for a considerable period of time.

Mobile operators in China plan to run a phased testing period for 5G networks from 2017–19 before commercial launch in 2020. China Mobile has testing plans for 2017 which will include four or five cities each with roughly seven sites. The company will expand to 20 sites per city in 2018 and further again in 2019 before a planned commercial launch in 2020. China Unicom plans to test capacity and performance across six cities over 2017–19 before a commercial launch with 1,000 sites in 2020.

There is general consensus that initial 5G rollouts will target increased speeds to consumers in dense urban areas – so-called enhanced mobile broadband. This is a logical extension of current efforts to augment LTE speeds through carrier aggregation (increases bandwidth capacity) and network optimisation techniques, such as massive MIMO and 256 QAM. But what does 5G provide that 4G cannot? By 2020, LTE speeds of over 200 Mbps could well be commercially available in China, which satisfies most of the things we can envisage today, except super high-definition TV (8K) and applications demanding ultra-low latency (for consumers, AR and VR). In short, for personal use cases that only require faster bit rates such as video and even high-definition 4K TV, there is currently no need for a 5G network per se operating in excess of 1 Gbps, because the user would not be able to distinguish a material difference with enhanced 4G. It is more likely that initial 5G networks will serve low latency use cases on a limited basis but would mostly be used as a capacity offload mechanism as data traffic rises from increased use of high bandwidth services and as 4G capacity approaches saturation.

How a non-standalone 5G network could work

Japan's DoCoMo has proposed a dual connectivity network layout for 5G, following a so-called phantom cell approach (see Figure 3A). The idea here is that 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, which provides 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 the 1 Gbps+ speeds. It is not yet clear exactly which bands would be used in the small cell configuration; in China, indications from the operators are that C-band spectrum (3.4–3.6 and 4.8–5.0 GHz) is most likely.
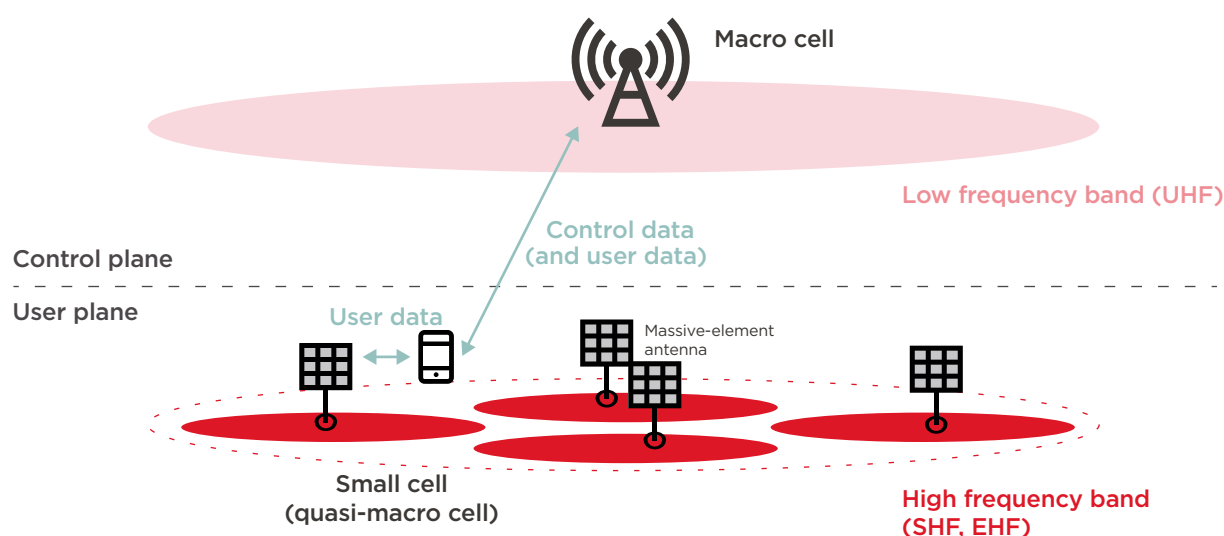
The other option is millimetre wave spectrum (roughly 24 GHz and above). This has the advantage of providing ultra-fast speeds because it offers wide spectrum channels (e.g. 200 MHz). It is for this reason that AT&T and Verizon are both experimenting in the band to deploy 5G as a last-mile connectivity solution for fixed-wireless broadband in the home (as opposed to laying fibre). However, there are a number of challenges in using mmW for other types of 5G deployments. It would require careful urban planning, given that the larger antenna size needed to compensate for weaker signal propagation in the mmW makes deployment on city infrastructure sites, such as lamp posts or billboards, cumbersome. Another challenge is maintaining line of sight communication. One potential solution to this is the use of beamforming. We show an illustration of the concept – again modelled on DoCoMo research – in Figure 3B. It is possible to increase coverage radius by 3–4× by using a large antenna, and through modulation the signal can be 'beamed' in a straight line direction. In theory, beams can be redirected through a network of small cells until the signal reaches its intended target (outside or in-building).

Rural 5G deployment presents a further challenge of needing long-range coverage, something the millimetre wave spectrum is ill-suited for, even with signal amplification. However, it is possible that 4G sites could also be reused in rural settings. The downlink connection could use low-frequency spectrum – such as 3.5 GHz – and travel further as a result of beamforming, while the uplink signal could use existing LTE spectrum.
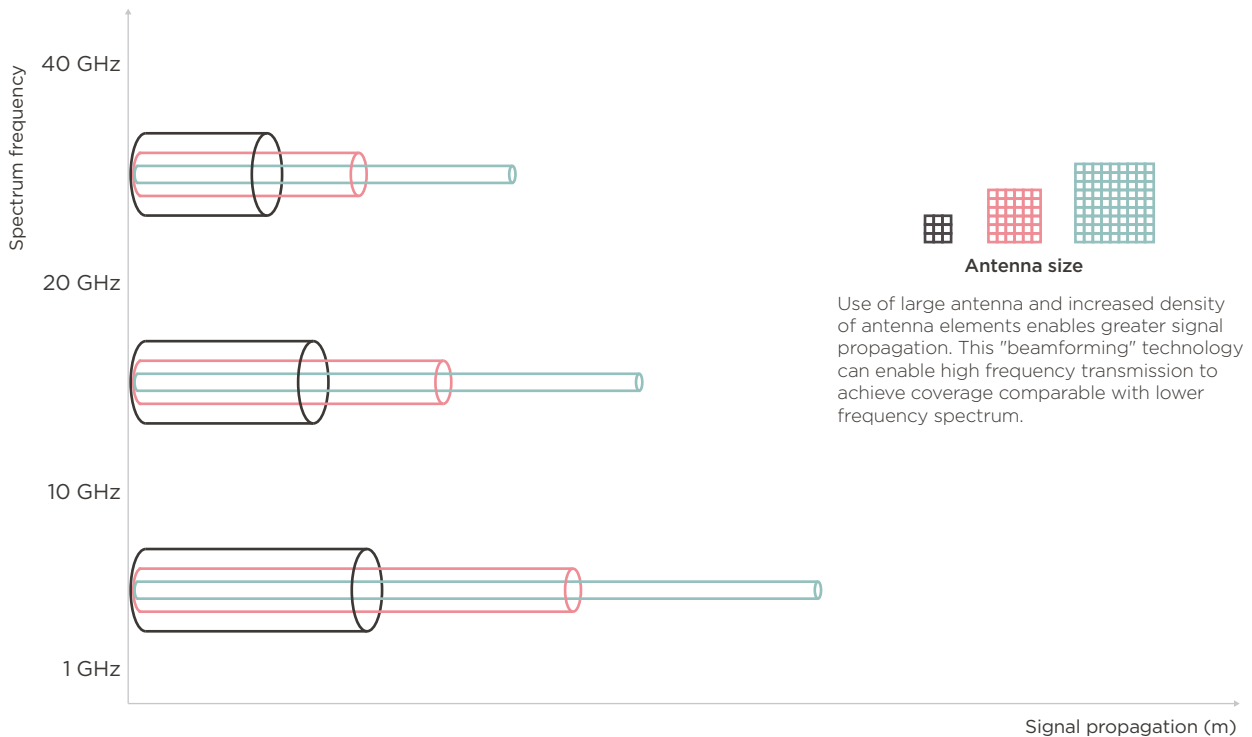
Source: Reproduced based on illustration by NTT DoCoMo, '5G Multi-antenna Technology'

3A Phantom cell configuration – 5G coexisting

3B Extending signal propagation through massive MIMO and beamforming

Antenna size

Use of large antenna and increased density of antenna elements enables greater signal propagation. This "beamforming" technology can enable high frequency transmission to achieve coverage comparable with lower frequency spectrum.

Spectrum frequency

40 GHz

20 GHz

10 GHz

1 GHz

Signal propagation (m)

Enterprise – IoT, edge and slicing

Operators are taking an evolutionary as opposed to revolutionary approach. As with the discussion on 5G versus LTE advanced in servicing high-bandwidth applications such as video, IoT has several sub-segments that can be addressed through a mixed deployment strategy. Devices or things that have longer battery lives and low power consumption – such as utility monitoring, street signage, traffic monitoring and parking meters – are already being serviced through a range of LPWA technologies. NB-IoT only recently achieved standardisation, in June 2016, with multiple operators signalling ambitious deployment plans starting in 2017. Legacy 2G remains in use for some IoT, while there are also unlicensed LPWA options in Sigfox and LoRa.

The parts of IoT that fall within the exclusive purview of 5G are those that are either much larger in scale or that are mission critical and therefore demand low latency (sub-1 ms). In China, we expect the former to include

logistics tracking, energy and grid management. Mission-critical applications could include connectivity for robotics in industrial settings, vehicle-to-roadside communication and traffic management in cities. Remote surgery and autonomous driving are also touted, although 5G's use as a connectivity medium would demand a very high QoS and uptime burden when the stakes are life and death, rather than just a "great service".

The key network requirements for massive IoT and critical communication services are the ability to support greater connection density (supplemented by wide coverage from low frequency spectrum) and low latency respectively – as opposed to speed for enhanced mobile broadband. However, this is as much about the broader 'softwarisation' of network architecture and pushing out of computing power to the edge through the cloud (i.e. building more data centres) as it is the new 5G standard. Investment in

network function virtualisation (NFV) in the core is a prerequisite for much of the enterprise connectivity that 5G can reliably target through new techniques like network slicing (guaranteeing capacity and QoS for enterprise customers). Most investment before 5G commercial launches in 2019–20 is therefore likely to be focused on upgrading existing networks in preparation for 5G, rather than buying new 5G RAN equipment.

Capex implications

The 4G capex cycle in China appears to have run for roughly four years, with a peak in 2015 at 31% of revenue before sharply declining 50% in 2016 (see Figure 4). The investment cycle followed a classic lead-lag profile of a national network rollout. Indications from the Chinese mobile operators are that 5G will follow a more gradual path and over a longer timeframe, roughly seven years from 2018–25. Early commercial rollouts are likely to be targeted in cities and require investment in small cells, new antennas and signalling equipment, and transmission upgrades with fibre backhaul (up to 10 Gbps) to support sub-1 ms latency. Subsequent expansion of 5G to a larger footprint in rural areas could require new site build and further incremental capex but such a scenario is dependent on business case viability and the presence of international standards, so is unlikely before 2020. In any respect, we would not expect capex as a share of revenue to reach the 25%+ levels, as with 4G, before 2020 at the earliest – if at all.

Source: GSMA Intelligence

4 **4G capex cycle in China has peaked**
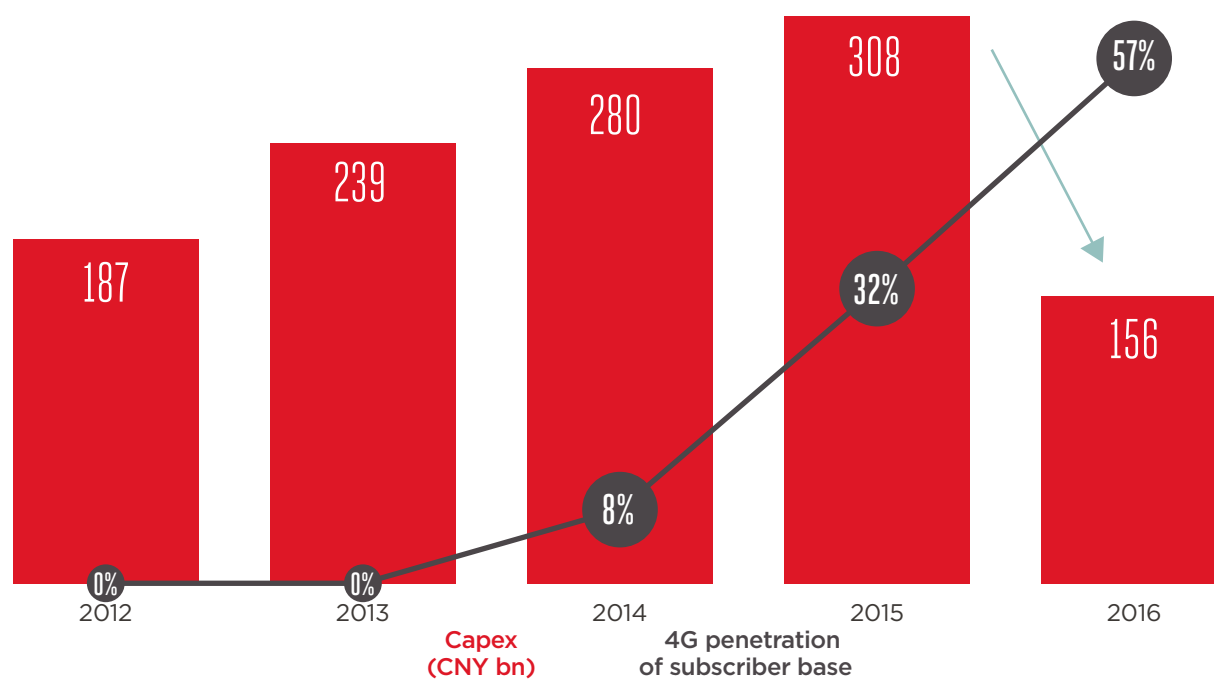
Note: figures include all Chinese mobile operators. Includes fixed line contribution in some cases

3

Forecasts

From launch in 2020, we forecast that Chinese 5G connections will scale rapidly over time, to reach 428 million by 2025. Beyond this date, further growth will be determined by incremental network rollout (and the ability of operators to earn ROI), and the price point at which 5G devices are available.

5 China – forecast for 5G connections

5G connections (million)

2020	2021	2022	2023	2024	2025
4	44	117	227	354	428
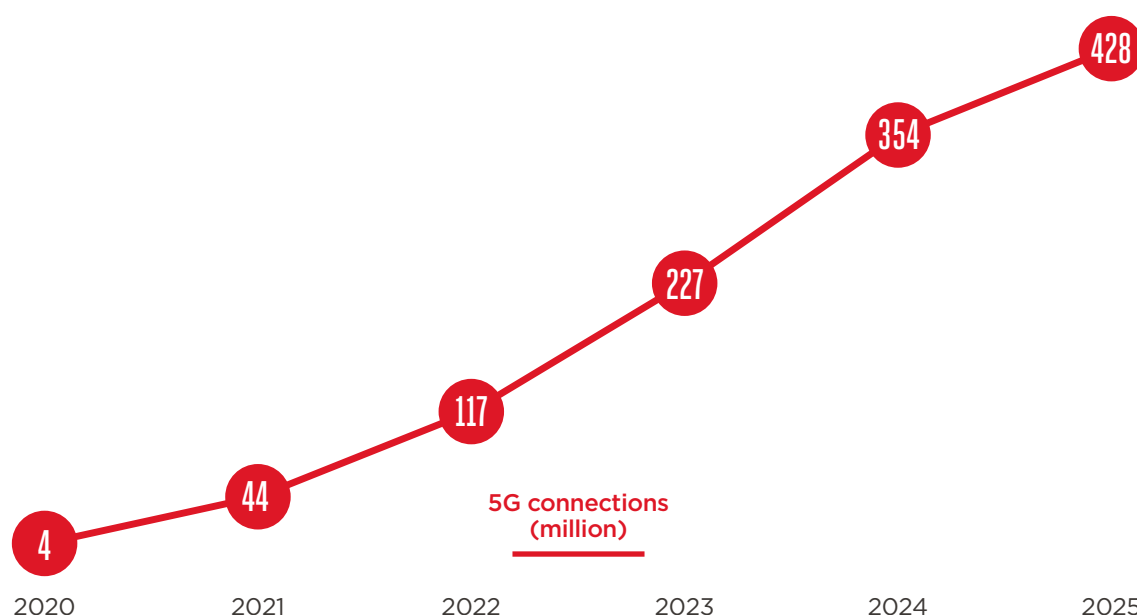
Our 5G forecasts are informed by the following assumptions:

- Rollout will be slower for 5G than for 4G.

  – The rollout of 4G networks within China was incredibly aggressive, serving a latent demand for high-speed mobile data services.

  – Early 5G networks will be deployed principally as a hot-spot technology to supplement the capacity of current networks, with operators in the region indicating that they will roll out as demand dictates.

- 5G adoption to proceed at a slower rate than 4G.

  – Taking account of the reduced speed of rollout, coverage constraints will act as a limiting factor on adoption.

  – In a similar manner to previous generations, a variety of 5G devices are likely to be available at launch, with OEMs keen to bring devices to market in support of the first 5G networks. However, the range of devices will initially be limited when compared to the more mature market for 4G devices.

  – The price point at which 5G devices are available will fall over time, as economies of scale kick in, and Chinese OEMs, in particular, will play a key role in driving this. However, in the short- to mid-term, given the hardware requirements to support 5G speeds, it is unlikely we will see the price point for 5G devices decline to the same degree as has been witnessed for 4G.

  – The transfer of subsidies from 3G to 4G, and wide availability of 4G devices helped to spur rapid 4G adoption in China. China Telecom and China Unicom will be aggressive in trying to capture share from the market leader, and are therefore likely to transfer subsidies to target 5G adoption. However, as China is an early launch market, it will initially face a less mature device ecosystem, which will limit the scope for subsidies to drive 5G adoption to the same degree.

4

5G: regional comparisons

The recent agreement by the 3GPP wireless standards body to accelerate some elements in the 5G new radio (NR) timeline has seen some operators around the globe bring forward their commercial launch plans. The accelerated schedule includes a plan to complete key components of the 5G standards by December 2017 (stage three specifications with detailed protocols and parameters), specifically those needed to start chipset development.

This standard is important, because it will set the terms for the air interface by which base stations communicate with mobile devices, and its agreement should allow increased performance, as well as ensuring consistency across carriers and manufacturers. However, as was the case with 4G, there is a risk that a rush to agree standards can lead to sub-optimal standards and fragmentation, as vendors rush products to market.

The remainder of the new timeline is then for the completion of Stage 3 for standalone in June 2018, and the setting of specifications for standalone 5G in September 2018 (standalone 5G means that the control signals, coverage and data transmission are entirely on 5G NR, not relying on 4G). These specifications will become part of Release 15.

Source: 3GPP, Credit Suisse

6 3GPP: new schedule

December 2017	March 2018	June 2018	September 2018
Stage 3: Non-standalone 5G NR	Non-standalone 5G NR	**Stage 3:** Standalone 5G NR	Standalone 5G NR

The different timelines for operators around the world are shown in Figure 7, with several operators bringing forward their own commercialisation plans in response to the accelerated standardisation plan.

7 Current 5G timelines across the world

Country/ region	Focus
China	China Mobile plans widespread trials by 2018 and commercial launches by 2020, with China Unicom also targeting 2020 for commercial services.
	China Telecom has started trials in Guangdong province and also targets 2020 for commercial launch.
US	AT&T is awaiting finalisation of standards to launch standards-based 5G and has suggested a commercial launch by the end of 2018.
	Verizon has released its own 5G technical specification and will launch fixed wireless trials this year.
	T-Mobile has plans to start deployments in 2019, and a 'nationwide' plan by 2020, with Sprint suggesting a commercial launch in 'late 2019'.
Japan	Both SoftBank and NTT DoCoMo are targetting commercial launch by 2020.
South Korea	KT plans to field test 5G at the PyeongChang Winter Olympics in 2018 and has brought forward plans for a commercial launch to 2019.
	SK Telecom is undertaking field trials this year and commercial launch is planned for the second half of 2019.
EU	Commercial large-scale introduction is targetted for 2020.
	5G coverage in main urban areas and transport routes by 2025.

China

Chinese government policy is to support both the development of 5G standards and the commercial deployment of 5G networks through a range of policies and initiatives, including government support for research and development. These include the 'Made in China 2025' plan and the 13th Five Year Plan, which aims for a commercial launch of 5G services by 2020.

The National Information Development Strategy sets out the blueprint for the country's IT strategy. As well as looking to further broaden internet access, the plan calls for 'breakthroughs' in 5G through expanded research and development efforts by 2020. The

longer-term goal by 2025 is to build a leading mobile communications network.

China has established agreements to collaborate on 5G with both governments and industry associations in a number of countries and regions, including the EU, the US, Japan and Korea. The goal is to further enhance international cooperation in order to build a globally unified 5G standard and industry ecosystem.

The Chinese operators are currently focused on limited trials, which will be expanded further over the course of 2018 and 2019 into larger-scale field trials, with the common objective of commercial launches in 2020.

South Korea

The South Korean government is actively involved in the development of 5G and is in the process of developing its own 5G standard, in collaboration with local operators, which will be delivered to the ITU in early 2018. Korea aims to be one of the first countries to commercialise 5G and believes that playing a leading role in the 5G standardisation process will help achieve this goal. The Ministry of Science, ICT and Future Planning (MSIP) will hold regular forums to seek ways to establish 5G converged test beds and improve regulations, as well as studying potential use cases.

KT plans to launch field trials of its 5G service at the PyeongChang Winter Olympics in 2018 and has brought forward plans for a commercial launch to 2019. However, the company has provided limited details of the services to be offered to date. SK Telecom plans to launch field trials before the end of this year, and will work with end-users to understand the most appealing use cases, which will help shape its commercial 5G deployment in the second half of 2019.

Japan

Operators in Japan are looking to move well beyond the network provider model and focus on potential use cases and to further develop their existing areas of expertise or commercial strength. For example, NTT has a strong presence in data centres and cloud services, and has recently announced a partnership with Toyota around autonomous cars and a focus on next-generation data centres that are capable of processing the large amounts of data these vehicles will produce. SoftBank has been following a broad strategy around IoT and has acquired key strategic assets, such as ARM, whilst KDDI has a partnership

with Toyota focused on developing a global platform for autonomous cars.

NTT DoCoMo launched a number of trial sites in May 2017, and has announced a range of partnerships as it looks to identify the most prominent use cases and target industry verticals for 5G. This is in line with comments from DoCoMo management at Mobile World Congress that it would not necessarily look to be the first operator to launch services, with no plans to change its target of a commercial launch by 2020.

US

In the US, the two largest operators are taking differing approaches to 5G deployments. Verizon is focusing on a fixed broadband strategy, with trials launched in around a dozen markets. The company has previously established its own 5G technical forum with a number of equipment vendors, subsequently releasing its own 5G technical specifications. Based on comments from the company and its FCC filings, it appears that Verizon will use fixed base stations and mobile terminals that use beamforming antennas in the 28 GHz band. The most likely use case would then be to use 5G in the first instance as a fibre replacement to deliver video and broadband services to consumers.

AT&T has said that its 'evolution networks' will "lay the foundation" for 5G, although these networks represent the deployment of LTE-Advanced. The company has supported moves to accelerate the 3GPP standardisation process, suggesting it will look to launch commercial services once standards are agreed and as an evolution from its existing network deployments. AT&T has started deploying small cells using Centralised RAN (C-RAN) architecture in San Francisco and will adopt a similar model in other cities, with this approach to network densification a key step in the move to 5G.

T-Mobile recently announced plans to begin rolling out a 5G network in 2019, with the goal of achieving 'nationwide' coverage by 2020. The company indicated that once standards are agreed and equipment begins to come to market, then it will 'quickly deploy 5G nationwide in a large swath of unused spectrum'. T-Mobile has highlighted its low band 600 MHz spectrum as key to the nationwide rollout, allowing rapid deployment compared to some of the higher frequency 5G bands, which will require considerable network densification.

5

The outlook and key challenges

The recent report by the GSMA (*The 5G Era: Age of boundless connectivity and intelligent automation*) highlighted five key risks and challenges that need to be addressed or managed in order to realise the full potential of 5G:

- **Business case:** the 5G business case is based on finding new models to roll out 5G cost-effectively and identifying incremental revenue opportunities that can be served with 5G's superior capabilities. The challenge for the industry is to identify new services, new market segments (especially enterprise) and the right business models to unlock the incremental 5G opportunity while optimising the cost of 5G network investment.

- **Spectrum availability:** spectrum will remain a critical but scarce resource in the 5G era. This applies to both the licensed and unlicensed bands that will play a key role in delivering the 5G era vision. 5G needs spectrum within three key frequency ranges to deliver widespread coverage and support all use cases: sub-1 GHz, 1–6 GHz and above 6 GHz. The availability of spectrum, at what frequency bands, and at what cost, will have a major impact on the business case for 5G.

- **Technological improvements:** many of 5G's technological improvements will build on the ongoing evolution of 4G with technologies such as NFV/SDN, massive MIMO and carrier aggregation. However, the new 5G radio will be challenged to deliver a much-improved spectral efficiency compared to 4G, and the push for less than 10 ms latency will challenge the laws of physics and the topology of network layouts. Likewise, the use of millimetre wave frequencies will require significant technological breakthroughs in device and network designs.

- **Fragmentation:** an important lesson from earlier technology cycles is that the mobile industry is more successful when it avoids fragmentation in spectrum, technology and operator services. For 5G, it is vital to ensure that fragmentation is minimised and that operator services are included in the standards from the onset to achieve maximum scale benefits.

- **Regulation:** given the heavy investment required to deliver 5G and provide reliable connectivity for all, it is important for policymakers to provide a transparent and predictable pro-investment and pro-innovation policy framework. The GSMA supports regulatory modernisation as a key precursor to the 5G era. Ultimately, the way 5G is developed, regulated, funded and commercialised will determine the future of the mobile industry.

From discussions with operators and other ecosystem players in China, Japan and Korea in preparation for this report, the perspective from these markets is as follows:

- **Business case:** As in other regions, the initial focus from operators and other ecosystem players is on enhanced mobile broadband services, with specific use cases such as higher resolution video and the potential for AR/ VR video. There was some uncertainty over the potential revenue impact in the near to medium term, especially given the lack of available content and applications in areas such as AR and VR, as well as questions around the cost and availability of terminal equipment. Clarity on business models and revenue opportunities in the enterprise space may rely on more widespread network deployments and greater maturity of the 5G ecosystem, particularly for the more innovative and mission-critical services based on ultra-reliable low latency capabilities of 5G.

- **Spectrum:** While China's spectrum requirements are similar to those in other regions, there was concern expressed at the availability of spectrum in the sub-6 GHz band, which will be vital for ensuring coverage and fast initial deployment of 5G. The Chinese government is consulting on 5G's use of spectrum at 3.3–3.6 GHz and 4.8–5 GHz. China is also assessing spectrum needs in the millimetre wave band for extremely high data rate requirements in hotspot areas, and has consulted on frequency planning in the 24.75–27.5 GHz, 37–42.5 GHz and other millimetre wave bands for 5G.. So far, the EU, the FCC and the Korean MCIP have identified 'pioneer' bands for 5G in the 600 MHz, 700 MHz, 24.25–29.5 GHz or 37–43.5 GHz ranges.

In China, there is an initial focus on the 3.4–3.6 GHz frequency for trial deployments and for use as a coverage band, although different trial bands have been selected in other regions. There was a general desire to see harmonisation of spectrum bands for 5G across regions in order to facilitate roaming and reduce costs of new devices and handsets.

- **Technological improvements:** Technical innovation, including flexible system design, advanced coding and novel multiple access schemes, will be required if 5G is to fulfill long-term diverse service requirements. Also, the evolution of 4G technologies will play an important role during the transition from 4G to 5G. In the long run, 4G evolution will be challenged to deliver a much-improved spectral efficiency and system capacity as well as less than 10 ms latency. Likewise, the use of millimetre wave frequencies will require significant technological breakthroughs in device and network designs.

Several respondents noted that 4G and 5G networks are likely to co-exist for a considerable period of time. Widespread 5G adoption will require a degree of maturity across the value chain, from devices to the access network to content providers and industry verticals.

- **Fragmentation:** There was strong support from across the ecosystem in China on the need for a global unified 5G standard that allows both a faster and more cost effective pace of standardisation and to help achieve the potential benefits of 5G networks.

- **Regulation:** Beyond spectrum, network sharing was another topic that was mentioned in the feedback from players in the Chinese ecosystem. China Telecom and China Unicom have previously expanded their network-sharing agreement to reduce the costs of 4G network deployment. China Telecom recently commented that it did not rule out joint network deployments for 5G.

The development of 5G is accelerating worldwide. New technologies such as massive MIMO and network slicing are changing network architectures and expanding the line-up of potential services. But a lack of significant new harmonised spectrum can hamper these advancements. WRC-19 will be vital to realising this vision. That is especially true for the work done on Agenda Item 1.13. It is looking at spectrum for mobile broadband in the frequency range between 24.25 and 86 GHz. The sooner all involved can gain clarity on what bands will be available, the better.

gsma.com