5G in China: the enterprise story

More than another G of speed?

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GTI (Global TD-LTE Initiative), founded in 2011, has been dedicated to constructing a robust ecosystem of TD-LTE and promoting the convergence of LTE TDD and FDD. As 4G evolves to 5G, GTI 2.0 was officially launched at the GTI Summit 2016 Barcelona, aiming not only to further promote the evolution of TD-LTE and its global deployment, but also to foster a cross-industry innovative and synergistic 5G ecosystem. Today GTI has become one of the most influential international cooperation platforms with 132 operators and 167 vendors.

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Executive summary

5G has proceeded along a multi-year planning path, ahead of commercial launches in 2018, to allow for R&D, network deployment strategy, field trials and promulgation of harmonised standards. In 2017 GSMA Intelligence began a publication series on 5G at a regional level to shine a light on developments in these areas and complement higher-level research globally. Our focus is on early-adopter markets with large populations, economic power and high levels of technological advancement: first China, Japan and Korea, then the US. While these will not be the first countries to launch 5G, developments and performance will be closely watched by operators, vendors, internet companies and governments in other regions. Our regional series of reports will continue in 2018 with the Middle East and Europe.

The imminent arrival of commercial 5G mobile networks has shifted debate from the aspirational to the practical. What is actually unique in the eyes of consumers about 5G compared to 4G (LTE)? Is that worth paying for? For operators, how can 5G be monetised? How should network deployment proceed? And how should that be financed? Does 5G provide an impetus for a new enterprise and industrial story? If so, which vertical sectors of the economy have the highest potential?

Much of the hype has focussed on consumer applications. However, enterprise is the larger opportunity given the nascent but inexorable digital transformation of large swathes of advanced – and in some cases emerging – economies. This report addresses the potential of 5G in serving vertical use cases. The focus returns to China given that it is among the leading countries in product testing and has an economy capable of rapid structural change and a government intent on establishing global leadership in technological innovation. This report has been produced in partnership with GTI and is informed by survey responses and interviews with senior executives from each of the three Chinese mobile operators in April 2018 as well as observations from trials in partnership with companies from other industries.

To narrow the scope and allow for detailed analysis, our focus is on three verticals:

- automotive and autonomous driving
- drones (unmanned aerial vehicles or UAVs)
- manufacturing and the so-called Industry 4.0 transformation.

For each vertical, we profile the global context before analysing prospects in China for use-case deployments, 5G versus alternative technologies in serving the use case, and what the revenue model(s) could look like for telecoms operators. The final section provides implications and recommendations for public policy makers. Some of these recommendations are industry specific and some are general, such as spectrum policy and cross-sector regulation.

1 Market update

1.1 Telco performance and outlook

The mobile market operating environment in China has suffered a general deterioration into 2018, although overall performance remains above most other advanced markets. Service revenue growth slowed to 5.1% in Q1 compared to 12.5% in Q4 2017 and 7.3% for 2017, driven by a slowdown in 4G subscriber growth. LTE adoption is reaching an expected penetration plateau in the range of 70–80% (largely mirroring internet user penetration), which means that revenue growth will likely continue to slow over the coming quarters in the absence of meaningful contributions from new service lines. Free cash flow margins have come under pressure from rising capex. Capex intensity levels remain below the 25%+ of service revenues during the LTE network expansion of 2014/15, but the current 'in-between' phase of the investment cycle will soon run out, with an expected ramp-up for 5G and the planned launch of commercial networks in late 2019.

Figure 1

Service revenue growth trend

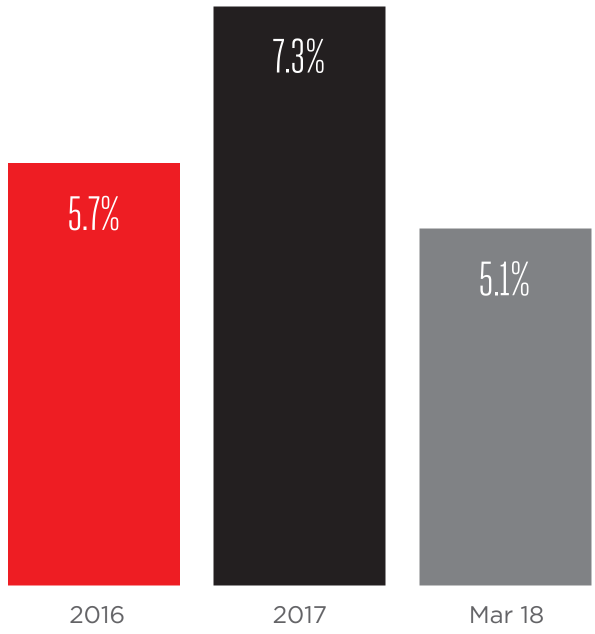
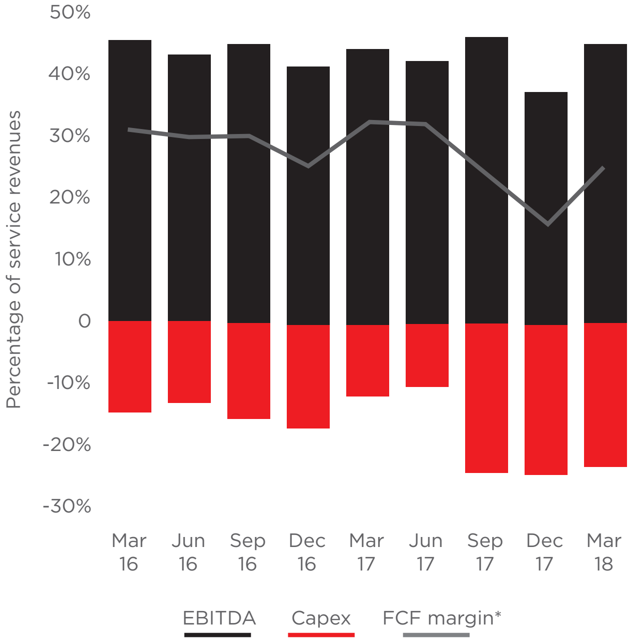


Figure 2

Margin pressure from rising capex



*Free cash flow (EBITDA minus capex, expressed as a percentage of service revenues)
Figures include China Mobile and China Unicom only
Source: GSMA Intelligence

1.2 5G trials and commercial launch timings

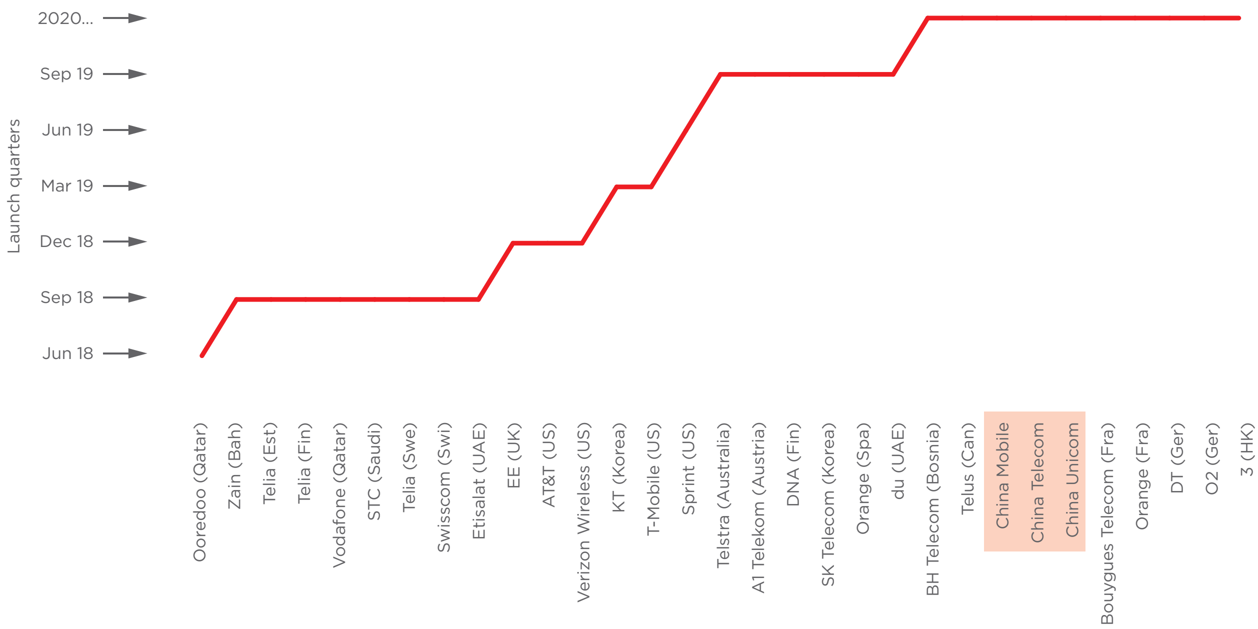
5G has proceeded along a multi-year planning path to allow for field trials, R&D, network deployment strategy and development of harmonised standards. All three operators continue to maintain live 5G trials:

- China Mobile will construct 500 5G base stations across five cities (Hangzhou, Suzhou, Guangzhou, Shanghai and Wuhan), with a further 12 smaller-scale city pilots planned for later in 2018 to test specific use-case applications.
- China Unicom will commence testing in 16 cities in 2018, including Beijing, Tianjin, Shanghai and Shenzhen. The company is also active in R&D, signing a joint innovation agreement with Huawei on 5G network slicing, which includes field testing in vertical markets including gaming (AR/VR focus), autonomous vehicles and manufacturing.
- China Telecom will start its 5G innovation pilots in 12 cities, including Lanzhou, Chengdu, Shenzhen, Xiongan, Suzhou and Shanghai, with six to eight base stations in each city. The main focus will be verification of mobile network deployment capability and solution performance.

Of mobile operators worldwide that have publicly stated 5G commercial network launch dates, 40% plan to launch in 2018 and 2019 (with the Middle East the earliest hive of activity), and the remaining 60% post-2020 once New Radio (NR) standards are completed. This is a relatively small sample size (55 of 800+ operating companies worldwide); for many regions, 5G is not a near-term priority. All three Chinese operators have commercial launches planned by the end of 2020. Initial 5G launch plans will focus on a limited footprint of dense urban centres to test network efficacy and consumer take-up levels before commitments are made to roll out into suburban and rural areas. In aggregate, China's pre-commercial and commercial launch footprints will be among the largest in the world in base station terms.

Figure 3

Planned 5G network commercial launch dates



Source: GSMA Intelligence

1.3 Network deployment and spectrum

Network deployment strategies have firmed up to involve the dual use of standalone and non-standalone architectures. Standalone builds are effectively a new network, including sites, RAN and core (contingent on NR standards). Non-standalone deployment would piggyback 5G RAN on existing LTE sites. A working model for how such a 'phantom cell' could work was developed by NTT DoCoMo, which we show in Figure 4.

The dual-use strategy reflects the trade-off between speed to market (non-standalone best and most cost effective in core network) and longer-term scale economics and quality (standalone best). Spectrum availability remains an important unresolved factor. If lower frequency spectrum is available for use, operator indications are that deployment would use a standalone model in urban centres, with site densification increasing compared to LTE (up to 2x) given the lower transmission rates. In this scenario, standalone 5G networks could even potentially expand into suburban and rural areas because the strong signal propagation characteristics would reduce the number of new sites needed in suburban and rural areas. If lower frequency spectrum is not available, a dual use strategy could be used where standalone networks are deployed in dense urban centres with non-standalone builds in suburban and rural areas. In either case, initial launches are going to be limited to cities. A second rollout phase into suburban and rural areas would not begin until 2021–22 to allow time to assess the results and commercial returns from initial deployments.

Higher frequency spectrum in the mmWave bands (24 GHz and above) was approved in July 2017 for testing. This spectrum is potentially ideal for high-density urban settings because it carries very high data capacity rates. It is not clear how mmWave spectrum will be used in commercial 5G networks in China, with operators tempted to take a wait and see approach based on results from trials and the maturity of the relevant component ecosystem.

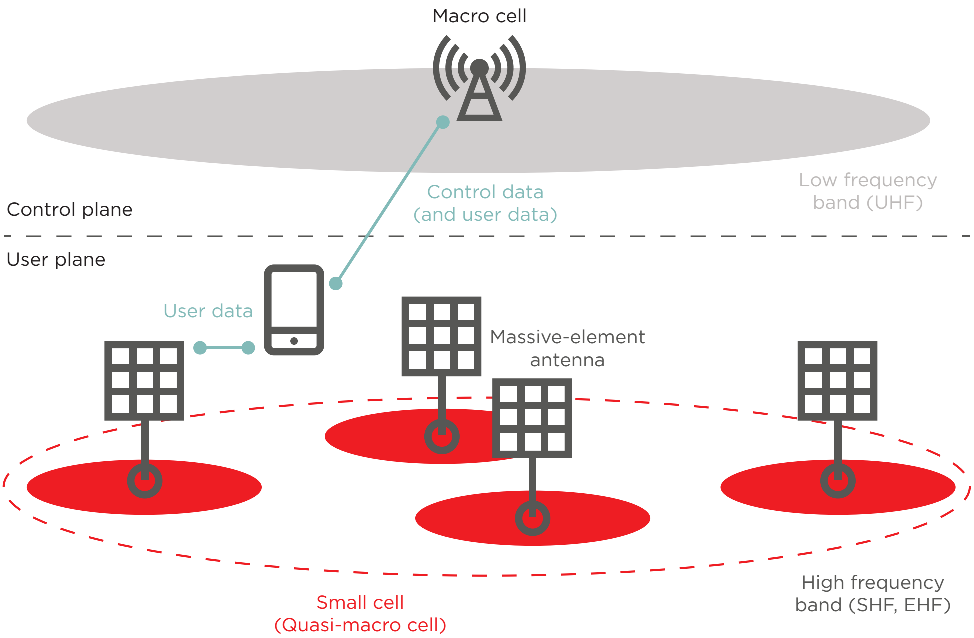
Also pertinent to a discussion of 5G vertical opportunities is the prospect of mobile edge computing (MEC) and network slicing.

MEC is an effective way to enable 5G services with built-in analytics. It provides an open platform and integrated IT environment based on the mobile edge network for internet application developers and cloud computing providers. Applications may include local content cache/M-CDN, local routing, service optimisation and data service based on network capability exposure. MEC also improves latency and relieves pressure on the core to help overall service quality.

Network slicing working in standalone mode provides a customised, isolated and guaranteed end-to-end dedicated connection. A network slice instance includes the network functions and resources of the access network, the transport network and the core network. This could work for manufacturing plants requiring low-latency connectivity with guaranteed uptime.

Figure 4

Non-standalone network through use of 'phantom cell' in dense urban centre



Source: Reproduced based on illustration by NTT DoCoMo, '5G multi antennae technology'

1.4 Forecast and outlook

China remains by far our largest projected market for 5G in absolute terms, with roughly 430 million connections by 2025. In penetration terms we expect it to be on a par with Europe at around 30% of subscribers, lower than the US, Korea and Japan. For most markets, our expectation is for 5G to proceed along a slower adoption curve than 4G, based on a number of assumptions:

Consumer appetite

- Early use cases have not moved beyond higher speeds (enhanced mobile broadband). Although this serves some unique use cases in 8K video and AR/VR, development is still nascent.
- LTE advanced speeds are high enough to blur the difference with 5G for all but the ultra-low latency services, which makes 5G less of a necessity.

Network coverage

- In Korea and Japan, most of the population live in cities and so will be potential 5G customers from an early point post launch. The US is also urban dominated, and will likely have fierce competition for early rollouts, with T-Mobile (pre Sprint announcement) laying down the gauntlet with a commitment to 'nationwide' 5G coverage by 2020 using its 600 MHz holding.
- Chinese operators also have nationwide coverage ambitions but this may take longer with the population dispersed.

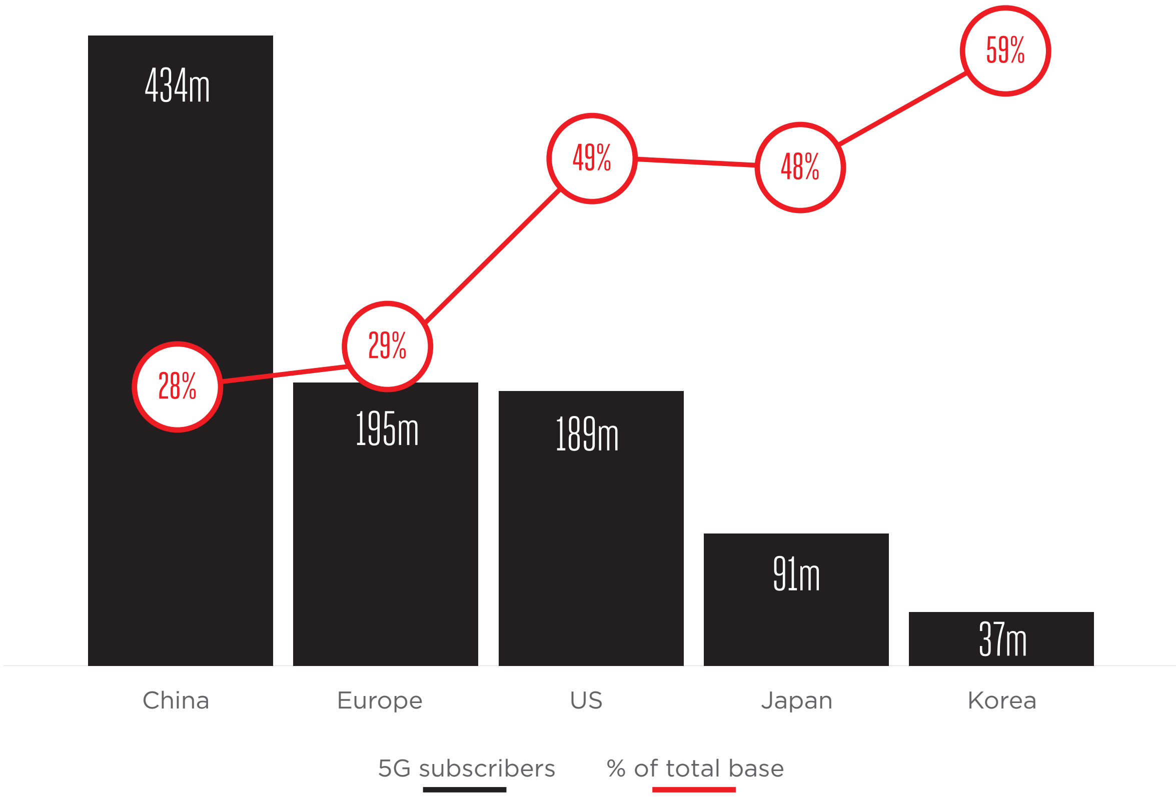
Handset availability ramp-up: 2021–2025

- The forecast is also conditioned on the assumption that there is a smaller portfolio of 5G handsets at launch than there was for 4G.
- While the portfolio will increase, the pace at which this happens depends on consumer demand for 5G, which is unclear.

It should be noted these forecasts are for consumer connections and do not include enterprise, which we expect to account for the majority of 5G revenues.

Figure 5

Projected 5G share of the total mobile subscriber base, 2025



Source: GSMA Intelligence

2 Automotive

2.1 Global context

The global automotive sector is undergoing significant transformation. Connected vehicles and electric cars are already mainstream, while consumers are increasingly embracing mobility-as-a-service (MaaS). The next frontier – autonomous driving – is set to dominate the scene over the next few decades.

From a technology perspective, future automotive developments are increasingly linked to advances in mobile technologies, with widespread recognition that 5G's superior capabilities will further enhance some of the existing connected vehicle services (UHD high-precision mapping, real-time traffic monitoring, advanced driver-assistance systems) and unlock new use cases, particularly in autonomous driving (remote driving and truly autonomous vehicles).

China is undoubtedly playing a key role in driving sector developments and bridging ICT and automotive industries. It is the largest market by number of automobiles sold[1] and is home to some of the largest car manufacturers in the world, including BYD, Changan, GAC Group and SAIC Motor. The government's ambition to make China a leading country in high-tech industries also plays a crucial role – automotive is one of the targeted key sectors in the 'Made in China 2025' strategic plan. Both Beijing and Shanghai have already issued regulations on road testing of self-driving cars.

[1]Nearly 30 million in 2017 according to the China Association of Automobile Manufacturers (CAAM)

All three Chinese mobile operators – China Mobile, China Telecom and China Unicom – are currently working on vehicle telematics, connected cars and the wider 'Internet of Vehicles'. As the mobile and automotive industries move towards 5G and autonomous vehicle technology respectively, Chinese operators are investing in R&D and conducting a number of LTE and 5G autonomous driving demonstrations through partnerships with vendors and automotive players. They are already working to establish new solutions – such as Cellular Vehicle-to-Everything (C-V2X) for remote driving, vehicle platooning and autonomous vehicles – that can be tested and implemented on the most advanced 4G networks with a view to exploiting enhanced 5G capabilities in the future.

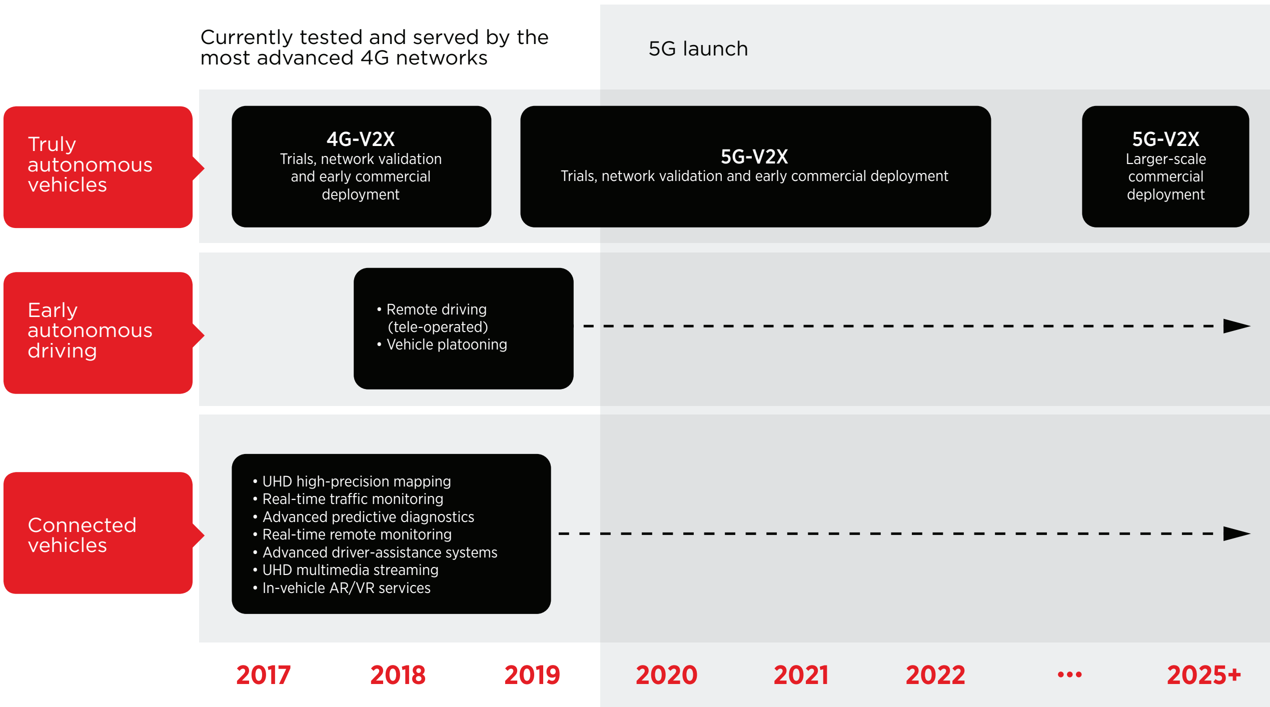
Finally, operators are supporting cooperation in the automotive ecosystem by launching or joining sector consortia. Notable examples include China Mobile's 5G Joint Innovation Centre and Baidu's Apollo open source software platform for autonomous driving, as well as China Unicom, Tsinghua ZTE, Datang, Ford and FAW on pre-crash warning for pedestrians. China Mobile and China Unicom 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.

2.2 Use cases

We have identified three 5G automotive use cases in China (and globally), as illustrated in Figure 6. Connected vehicles is an existing use case that will be further enhanced by 5G beyond 2020, while autonomous driving is a new use case that will massively benefit from 5G-based C-V2X. Network requirements change when moving from connected vehicles to remote driving, vehicle platooning and truly autonomous vehicles. These use cases require ultra-low latency, ultra-high bandwidth, high data transmission capacity and network reliability, which 5G networks are expected to provide.

Figure 6

5G automotive use cases



Source: GSMA Intelligence

Connected vehicles

Today's connected vehicles are largely served by 3G and 4G networks. With early 5G commercial launches expected in China in 2020, some of their functions and services (listed in Figure 6) will be increasingly served by 5G networks. Globally, the number of connected vehicles will grow three-fold between 2017 and 2025 to 1.2 billion connections, with China, the US and Europe leading the way. This market forecast includes built-in connectivity in cars, bikes (a large market in China), motorbikes and aftermarket telematics devices such as those for insurance and personal navigation.

Early autonomous driving

The ability to control fully technology-equipped vehicles by means of cellular networks allows remote driving. Potential applications of tele-operated driving include harsh environments such as mining or waste disposal sites, or extremely remote environments. Remote driving is also an option when remote work is more efficient or in emergency situations such as rescue missions in disaster zones. As we move into the autonomous vehicle and 5G eras, remote driving will increasingly be tested and used to complement driverless autonomous vehicles such as robotaxis (Waymo in California is a notable example).

Vehicle platooning is also a key 5G use case, currently tested for trucks. A platoon is a group of vehicles that travel very closely together; a lead vehicle controls the speed and direction while all following vehicles respond to the lead vehicle's movement. The linking and traveling together of several trucks – using cellular connectivity and autonomous driving systems – is expected to improve traffic safety, reduce fuel consumption and CO2 emissions, and allow better use of road space.

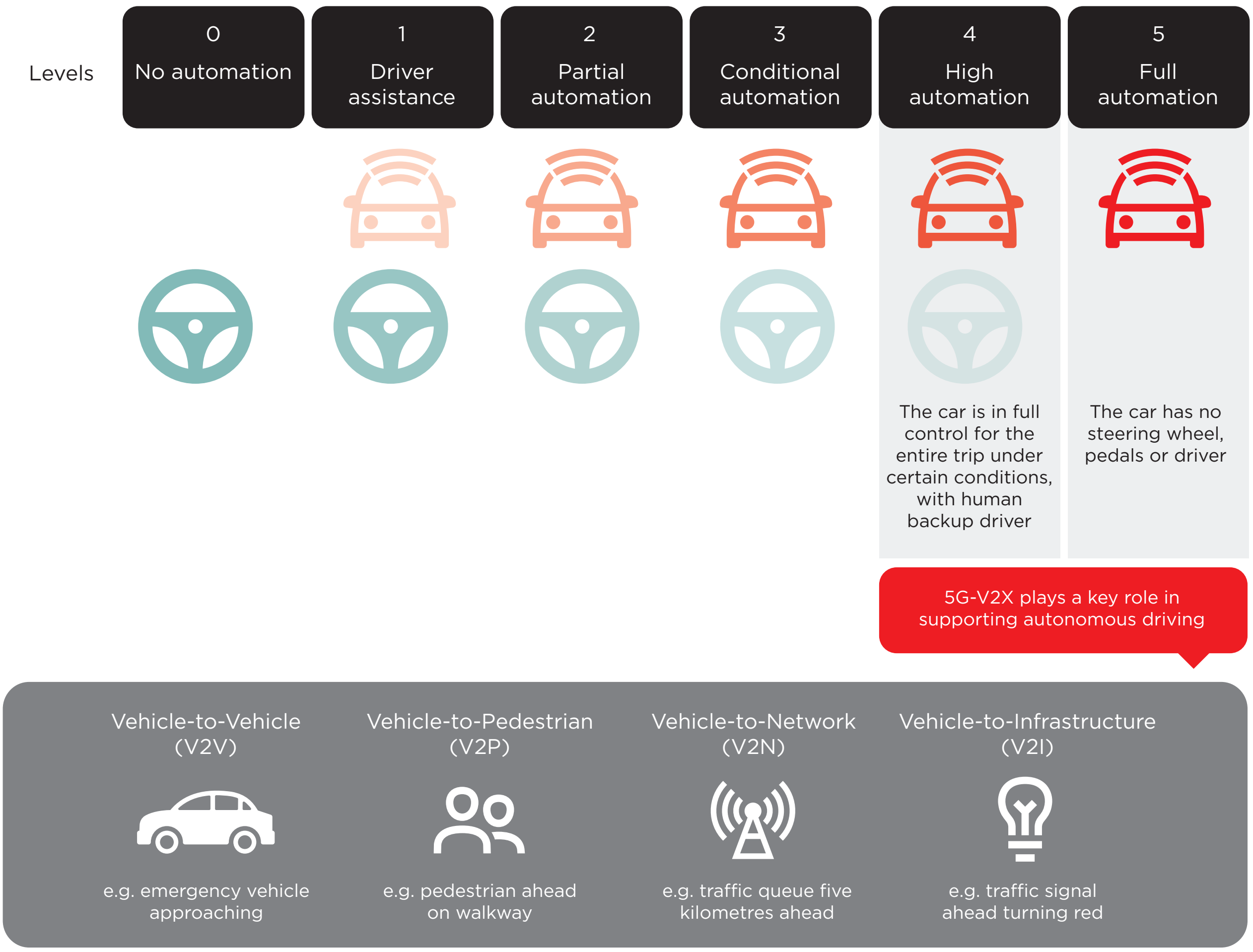
Demonstrations and trials in both fields are gaining momentum worldwide, with major vendors and operators increasingly involved. China Unicom and Chery demonstrated automated driving at the World Internet of Things Exposition (WIOT) in Wuxi, including typical business scenarios of automatic straight or bent road driving, automatic sensing of traffic lights and automatic follow-up/emergency braking. China Mobile, SAIC Motor and Huawei demonstrated 5G-based remote driving in C-band frequency with a passenger car. The driver was located more than 30 km away from the vehicle and was able to maintain full control over the vehicle at all times. More recently, a number of Chinese AI and autonomous driving companies unveiled the results of a remote-controlled car test in China's Xiong'an New Area. A human controlled a car remotely for 20 km using a 5G network; the response time was within 6 ms for the whole duration of the test, almost 10 times faster than 4G. This was, however, in a test environment and performance may be weaker in a live commercial deployment.

Truly autonomous vehicles

While 4G networks have been enabling early developments in the Internet of Vehicles and supporting the first C-V2X pilots, 5G will play a key role in future mobility by enhancing the C-V2X technologies needed to support larger-scale commercial deployments of truly autonomous vehicles for ride-hailing (level 4 and 5 of car autonomy, as illustrated in Figure 7).

Figure 7

Levels of vehicle autonomy



Source: GSMA Intelligence, SAE and NHTSA

From a technology perspective, two aspects need to be considered. A level 4 or 5 autonomous car will need to be self-sufficient, able to observe, analyse and travel in the selected environment. The car will rely on on-board computers to process and make all driving decisions as current cloud-based solutions are too slow for real-time processing in critical situations. The second aspect involves 5G networks. As well as gathering data to function as an independent entity, autonomous cars will increasingly interact with the wider ecosystem – including other vehicles (V2V), road infrastructure (V2I) and road users (V2P) – through V2X communications. This wide-area information is increasingly key and will be used to complement the data captured by car sensors, cameras, radar and LIDAR. This adds further complexity to on-board processing and can make on-board computers heavy and power hungry.

One promising paradigm is to augment on-board computers through edge computing solutions and C-V2X technology. C-V2X is designed to employ two complementary transmission modes. The first mode does not rely on a cellular network, covering direct communication between vehicles, between vehicles and infrastructure, and between vehicles and other road users. The second – network communication – will employ the conventional mobile network and is used to enable a vehicle to receive information about road conditions and traffic in the area.

2.3 5G versus alternative technologies

Today, there are two technologies and sets of specifications in play for V2X direct communications: Dedicated Short-Range Communications (DSRC) and Cellular Vehicle-to-Everything (C-V2X).

- DSRC is a two-way, short-to-medium-range wireless communication technology that utilises IEEE 802.11p, an approved amendment to the earlier Wi-Fi-based IEEE 802.11 standard. This extension adds wireless access in vehicular environments (WAVE) without the need for a Wi-Fi base station. IEEE 802.11p is not dependent on the presence of cellular network coverage, and operates in the unlicensed 5.9 GHz frequency band.
- C-V2X provides not only direct communications (which DSRC does too) but also network-based communications (V2N) which can be used to provide network assistance for safety-related features, as well as commercial services, requiring the involvement of a mobile operator, providing access to cloud-based data or information. Direct communications is supported via two modes: managed mode (PC5 Mode 3) which operates when the vehicle UE is scheduled by the network, and unmanaged mode (PC5 Mode 4), which operates when the vehicle UEs communicate independently from the network, operating on unlicensed 5.9 GHz and commercially licensed cellular spectrum. Network-based communications utilises cellular networks on commercially licensed cellular spectrum.

DSRC is the older and more established of the two direct communication technologies, especially in the US where the Federal Communications Commission (FCC) allocated 75 MHz of spectrum in the 5.9 GHz band for use by Intelligent Transportation Systems (ITS) vehicle safety and mobility applications. However, the more recent C-V2X is gaining momentum, supported by most mobile operators, major equipment makers and vehicle manufacturers including Audi, BMW, Daimler, Ford, PSA and SAIC. The 5GAA believes that 3GPP-based cellular technology offers superior performance and more futureproof radio access than IEEE 802.11p. There have been an increasing number of trials conducted across North America, Asia-Pacific and Europe, ahead of the first commercial deployments later in 2018. China is one of the first countries to deploy C-V2X.

Many car manufacturers are adding C-V2X connectivity to their vehicles because it has several key advantages over earlier technologies. C-V2X leverages the comprehensive coverage of secure and well-established cellular networks (LTE today, 5G in the future) and supports both short-range and long-range transmissions. With standards of C-V2X technology completed by 3GPP in June 2017 (Release 14) and further evolutions due later in 2018 (Release 15) and in 2020 (Release 16), C-V2X is set to continue to gain momentum.

2.4 Business model options

All three Chinese mobile operators are eyeing revenue opportunities in the automotive sector beyond the provision of traditional vehicle connectivity. Revenue opportunities include cloud and edge computing, storage, network slicing, real-time or near-real-time data analytics, and Internet of Vehicles platform-based services. Partnerships are key to drive business developments and faster time to market. Key partners include vehicle manufacturers, autonomous car technology providers (i.e. sensors, radars, LIDAR, cameras, software, maps and other navigation tools) and providers of in-vehicle services. Given autonomous driving is still pre-commercial, business models have not been laid out.

Revenue model

B2B for C-V2X communications: Operators provide the low latency, ultra-high bandwidth, high data transmission capacity connectivity required by V2X technologies to other companies such as a vehicle manufacturer, a fleet manager or a ride-hailing company, and charge them connectivity fees.

B2B2X for platform-based services: Operators work with a third party (i.e. an automaker or a vehicle information service provider) to jointly develop an Internet of Vehicles platform and take a share of some of the services delivered by the platform (i.e. data analytics, security, telematics), depending on B2B agreements. This could also open up opportunities for bundles of network communication and platform-based services. Given that autonomous vehicles are manufactured by a number of local and global companies, it will be difficult to aggregate all relevant data generated by those vehicles. Building 5G-based hierarchical platforms could allow faster data collection at a larger scale and create a better set of data for a range of data analytics, precision mapping and real-time software updates. Information and data related to traffic, roads and consumer mobility behaviours will increasingly become a new asset, particularly for governments and smart cities. Insurance companies could also be an important client for data analytics.

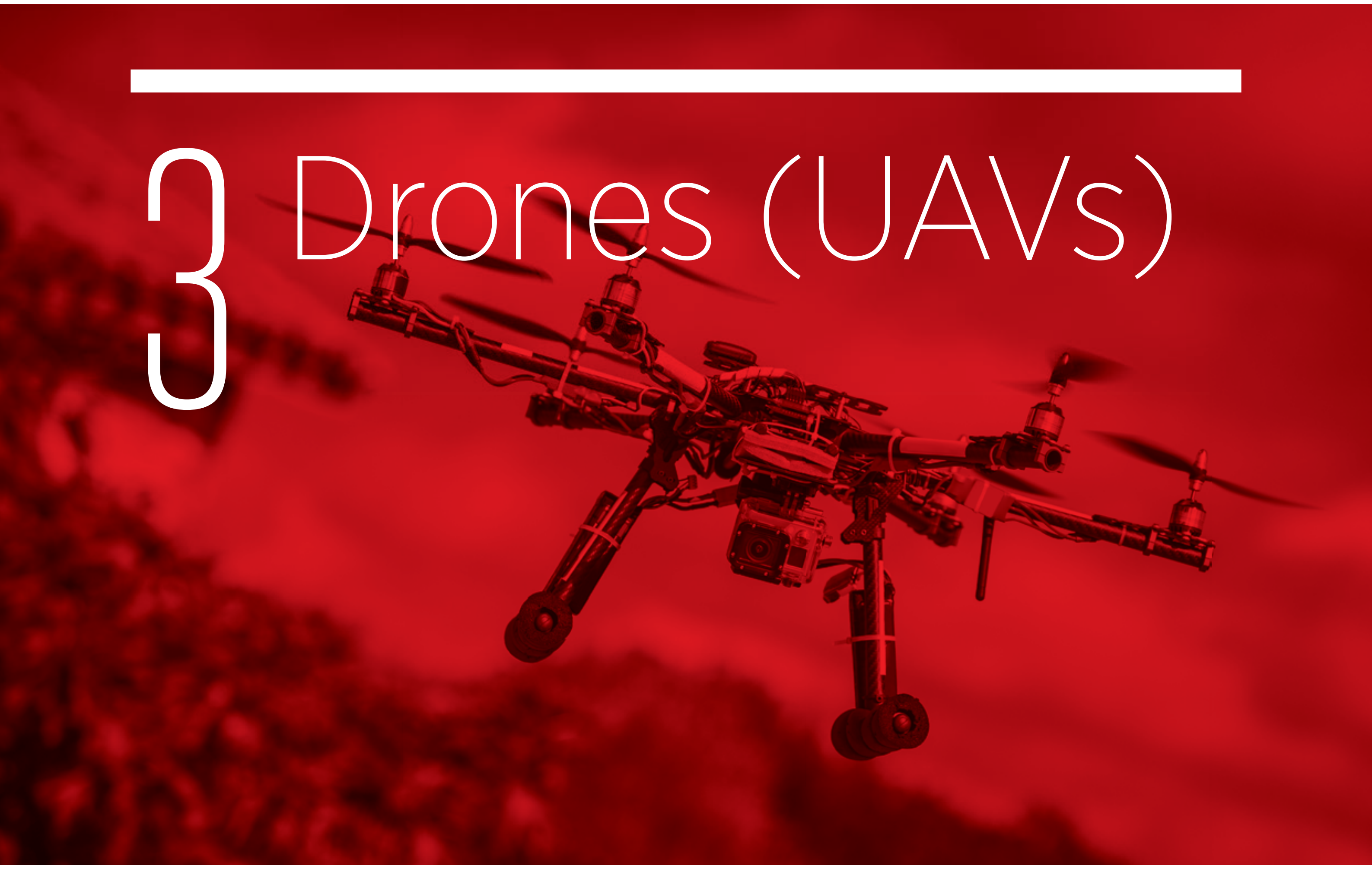
Infrastructure model

To fully exploit the 5G enterprise opportunity in the automotive sector, operators need to provide customised network functionality that suits the different automotive use cases described earlier. There is undoubtedly intense competition in this space as global cloud players – namely Amazon and Microsoft – are targeting the same opportunity.

A key aspect of 5G is the mobile edge computing architecture that distributes intelligence to multiple levels of the network, including to the extreme edge for very low-latency use cases. This localisation enables certain types of services and applications closer to the end user that would not otherwise be possible. Network slicing is a promising option. This would involve an operator reserving slices of network capacity for a particular automotive customer at a guaranteed quality of service on specific parameters such as latency, capacity and security.

Slicing is technologically attractive because it provides better use of network resources and greater operational flexibility compared to dedicated private networks (which require massive investment). With network-slicing technology, operators can customise their networks to meet business needs efficiently and in a cost-effective manner. Different network slices can be used to meet different speed requirements, different time delays and different service quality requirements for remote driving, autonomous vehicles and in-vehicle connected services.

3 Drones (UAVs)



3.1 Global context

The drone market continues to develop well outside of its military roots into civil applications. The technology is most developed in industrial verticals, driven by improvements in mapping, real-time video distribution and analytics platforms. Site surveying, damage assessments, mapping and remote security patrols have all come into play (see Table 1). Logistics use cases include internal warehouse inventory management (Walmart), parcel delivery and tracking (Amazon) and a host of NGO-funded efforts to ship essential supplies to areas stricken by disaster, often without road or central electricity grid access.

Facebook (via Ascenta) and Google (via Titan) have trialled drones at an altitude of 20–25 km above sea level as a means of providing internet connectivity to remote areas not covered by terrestrial networks. Both efforts attracted fanfare but have stalled or ended (in the case of Titan) without commercial deployments.

Major start-ups such as DJI (Shenzhen), 3DR, Airware and PrecisionHawk remain active, increasingly with corporate money and muscle behind them. In China, the civil UAV market – which includes consumer and industrial applications – is estimated at RMB80 billion ($13 billion) by 2025. These should, however, be taken as guides only. More important is the value chain structure, which is still fluid. Initial investment in hardware and components has given way to software and analytics platform development to enable precision flight and to pre-empt eventual regulations with strict safety thresholds.

Table 1

Greatest potential for drones in industrial applications

INDUSTRIAL	CONSUMER	LOGISTICS	INTERNET ACCESS
Remote site surveying (e.g. mining, oil rigs)	Photography	Goods delivery from warehouse to premises	Connectivity in rural and remote areas not served by terrestrial networks
Agricultural monitoring	Entertainment and leisure	Inventory management	Remote IoT
Security monitoring – private and border		Disaster response and monitoring	
Geological surveys (e.g. dams, waterways)			
Infrastructure inspection (e.g. base stations, power lines)			
Insurance (damage assessments)			
Entertainment (e.g. live sports broadcasting)			

Source: GSMA Intelligence

3.2 Use cases

Cellular service models being developed in China focus on industrial verticals in an altitude range of 500–3,000 metres. Specific applications sit in rural or remote locales out of range of terrestrial networks (see Figure 8). There are two levels of UAV flight operations that cellular connectivity could support. In each case, the SIM, or potentially eSIM, would sit on board the UAV.

Connectivity

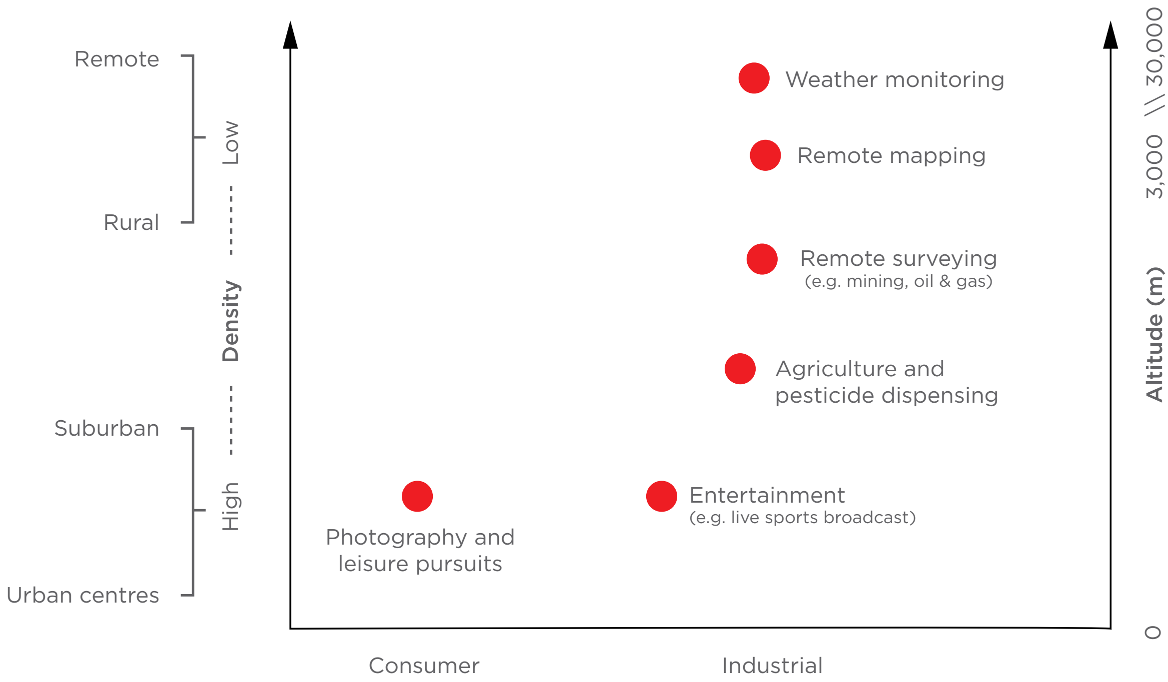
- Primarily serves the purpose of guiding and altering flight parameters such as altitude, direction, speed and tilt.
- Video transmission from drone to ground, particularly for high-altitude remote sorties (such as surveying damage after an earthquake).
- Coverage to remote areas out of range of terrestrial networks (China Unicom has promulgated an industry standard for emergency communications tied to UAVs, with pilots established in several provinces).
- Non-latency-sensitive applications can be met with LTE using low-frequency spectrum (higher signal propagation). Higher bandwidth above 1 Gbps (such as for super-high-definition video) would be serviced through 5G once available.

Control platform (cloud)

- Centralised platform to manage data flows, analytics and API access to third-party systems, either commercial or government.
- 5G is more of a requirement at the platform layer given latency demands required by aeronautical analytics. Edge computing infrastructure may also be required.
- China Unicom has developed an industrial UAV cloud platform at a test facility in Yunnan that is recognised by the Civil Aviation Administration. The central platform handles data flows and management from UAVs in all provinces.

Figure 8

Industrial drone flights are generally in remote areas out of terrestrial coverage



3.3 5G versus alternative technologies

Existing UAV connectivity is generally serviced through point-to-point or satellite-based control. Point to point involves constructing a large number of observation and control stations along the flight path using artificial or semi-automated measurement and control relaying. This works for short-range flights but is suboptimal for long range given difficulties in site selection in hard-to-reach areas. Point to point also involves high costs in site construction and equipment maintenance, and field results suggest inefficient use of spectrum. Satellite connectivity can play to longer-range flights but suffers from high costs of tracking equipment fitted to the drone and from signal delay, which increases exponentially with altitude and is subject to rain fade. IoT short-range protocols are unsuitable given the long distances required for transmission.

LTE and 5G provide better economics through network scale, allow non-line-of-sight signal transmission, and enable best-in-class security through the on-board SIM. The other important advantage is that connectivity can be linked with cloud-based platforms to run analytics that gives customers an end-to-end service model.

3.4 Business model options

Revenue models are conceptual at this point given that LTE and 5G connectivity for UAV has not reached commercial deployment. Options sit on two levels, as with use cases: connectivity and platform. Connectivity revenues are the baseline because most drone manufacturers and systems integrators do not have the capacity or desire to play in the connectivity level of the value chain. A higher-value approach may involve providing connectivity free and instead charging for access to the cloud platform for data management and analytics through a service wrap fee. The end-to-end model would involve operators handling all data transmission and analytics, with UAV companies left to fly the vehicle. This would require scale in the base network, a proven customer base and integration with the supply chain so would likely be a phase-two model as UAV applications mature over a three- to five-year period. API calls are a further option, although this becomes less attractive the higher volume of calls made, with bulk service packages more suitable.

4 Manufacturing and Industry 4.0

4.1 Global context

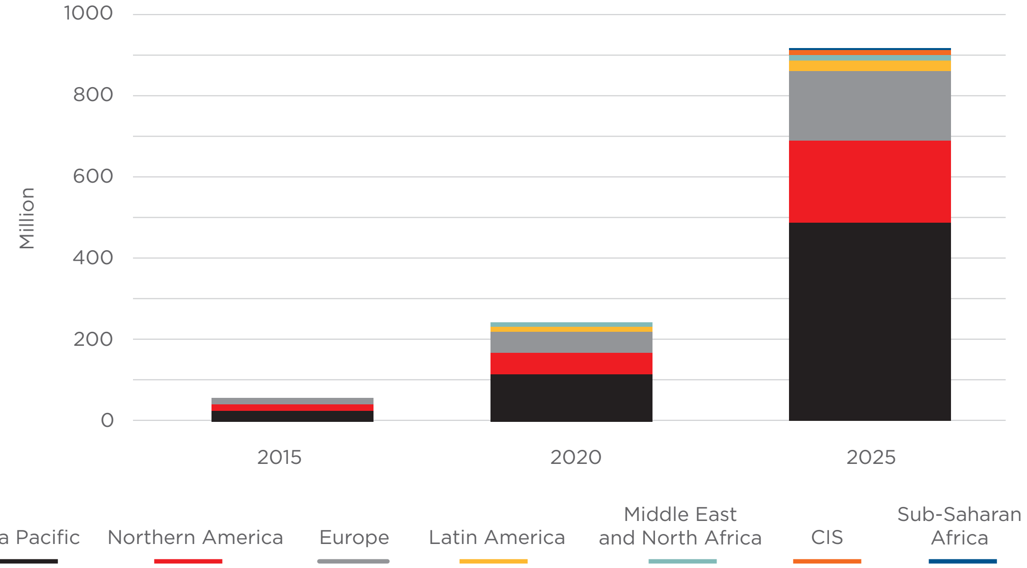
The fourth industrial revolution – also called Industry 4.0 – continues to gain momentum across Asia-Pacific, Europe and North America, with a number of manufacturing companies increasingly adopting robots, machine learning, sensors and a range of industrial IoT solutions. While the manufacturing sector digitises at different speeds across regions, the ultimate objective is consistent around the globe: digitisation and the use of automation, artificial intelligence and the Internet of Things are expected to optimise production processes, increase productivity and efficiency, and drive product innovation and new revenue opportunities in the manufacturing sector.

A number of countries have strategies and initiatives in place to drive adoption of IoT in manufacturing – notably Germany, the US, Japan, China, the Nordics and the UK. The Chinese government is intensifying national efforts to run pilots and implement projects in smart manufacturing across a number of key verticals including raw materials, equipment, consumer goods and electronics. This is part of the wider 'Made in China 2025' strategic plan that aims to transform the country into an advanced manufacturing economy. There are also consortia – for example, the Alliance of Industrial Internet (AII) – which aim to accelerate the development of industrial lower internet through industry cooperation in China.

Globally, the number of smart manufacturing IoT connections will grow nine-fold between 2017 and 2025 to almost 1 billion connections, with China, the US and Europe leading the way (Figure 9). This market forecast includes a range of IoT solutions including inventory tracking, monitoring and diagnostics, and warehouse management. Manufacturing will grow at the fastest rate in the wider industrial IoT as enterprises pursue the fourth industrial revolution.

Figure 9

Smart manufacturing IoT connections by region (cellular and non-cellular)



Source: GSMA Intelligence

4.2 Use cases

5G will play a key role in driving future developments in smart manufacturing as large-scale adoption of automation and AI adds new requirements in terms of latency and network reliability. 5G networks will also allow unprecedented levels of interaction and coordination between machines, devices and robots, making manufacturing more tech-based and data-driven. To stimulate developments and innovation, in December 2017, Huawei, together with several industry partners and research institutions, established a Wireless Connected Factory Special Interest Group (SIG) to explore manufacturing use cases that can be supported by 5G and promote 5G application in future smart manufacturing.

We have identified four categories of use cases for 5G in smart manufacturing, as illustrated in Figure 10. As well as connecting an increasing number of robots in factories, 5G can support remote manufacturing through monitoring and real-time remote decisions. An extreme case could be when factories operate autonomously and require no human presence. For example, the Changying Precision Technology Company has created an unmanned factory where all the equipment used for production and warehouse equipment, as well as unmanned transport trucks, is operated by computer-controlled robots. The technical staff monitor all activities through a central control system.

The combination of 5G with industrial AR and AI is expected to unlock other use cases such as high-precision simulations of human-machine interaction in various manufacturing situations – extremely useful for workforce training – and real-time data gathering to inform immediate manufacturing decisions.

Figure 10

5G uses cases in smart manufacturing

ROBOTS AND ROBOTICS

- 5G will increasingly replace Wi-Fi-based connectivity in factories
- Real-time robot collaboration and integration throughout the production line
- Cloud-based wireless robotics

REMOTE REAL-TIME OR NEAR-REAL-TIME MANUFACTURING

- Live remote monitoring and reconfiguration of robots and processes
- Remote quality inspection

LABOUR AUGMENTATION

- 5G coupled with industrial AR enables workforce training and augments human skills
- High precision simulations of human-machine interaction in various manufacturing situations

CONNECTED OPERATIONAL INTELLIGENCE AND ANALYTICS

5G coupled with AI enables real-time data gathering to inform immediate manufacturing decisions

5G based, large-scale data analytics in various areas (i.e. processes, inefficiencies, predictive maintenance for robots)

Source: GSMA Intelligence

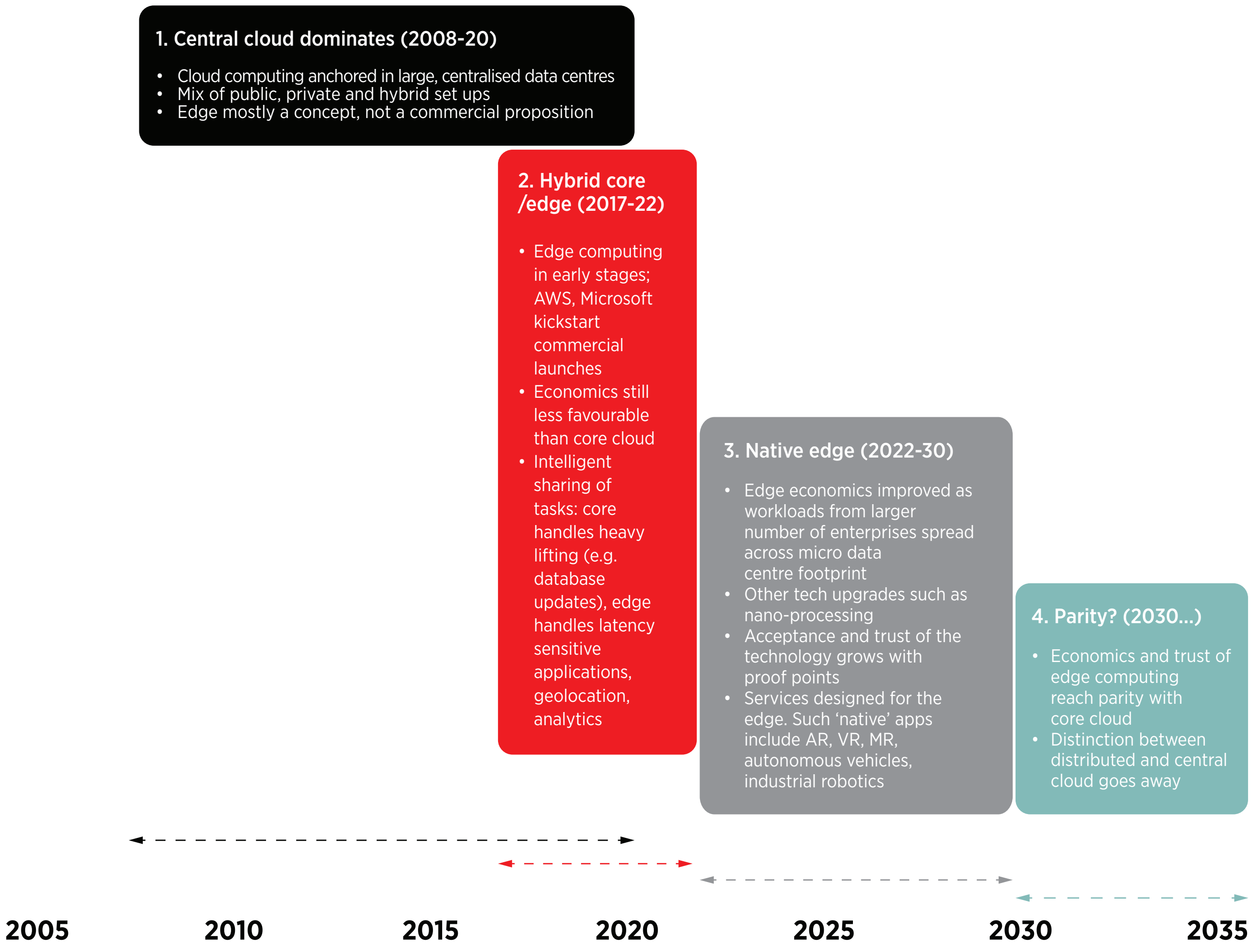
4.3 5G versus alternative technologies

The shift to automate processes in high-tech manufacturing (Industry 4.0) depends on low-latency connectivity to satisfy precision thresholds and real-time analytics. 5G theoretical standards are for sub-1 ms roundtrip, which is attractive when combined with the option of a network slice offering a guaranteed QoS to factory owners. However, achieving that kind of latency in practice will likely require edge computing infrastructure where cloud servers sit in close proximity to (or even inside) factories.

Amazon (AWS Greengrass), Microsoft (Azure Edge), Google and Alibaba are all heavily investing in edge products to serve industrial IoT applications. One level down sits a multitude of companies including GE, IBM, Bosch and Foxconn, which have proprietary control platforms linked to the cloud (either their own or through leased capacity agreements with, for example, AWS) and the ability to offer end-to-end service propositions. End-point connectivity is generally served by short-range sensors using unlicensed protocols. The value points from a customer perspective are in the control platform and analytics – not end-point connectivity. The share of smart manufacturing served by telcos versus cloud companies versus enterprise PaaS will be driven by the rate of improvement in edge computing economics over a 10–15-year period (see Figure 11).

Figure 11

Edge computing is a 10–15-year story…and it's still early days



Source: Macro Meta Consulting, GSMA Intelligence

4.4 Business model options

There are two broad revenue models for telcos selling into industrial clients. One is to supply connectivity alone, and possibly some of the terminal equipment and modules. This is potentially high margin with scale but is a relatively low share of overall value. The second is a full service proposition where connectivity is provisioned alongside supporting terminals and, importantly, the platform layer. Connectivity may be charged for or it could be provided as part of a larger service bundle where the telco becomes an integrated partner in overseeing the industrial operations of its clients. The full service model is where competition is highest, with a number of scaled cloud infrastructure companies (those mentioned above) and enterprise SaaS companies (SAP, Oracle) already in the market.

5 Policy implications

The use of 5G technology in vertical sectors carries a number of implications for a supportive public policy environment. Some of these are general and some are vertical specific. In each case, we have laid out comments in the spirit of a collaborative approach between industry and government to balance the potential benefits of 5G to the economy with investment capital required for scaled deployments.

5.1 General

In terms of national spectrum planning, requests for spectrum allocation from different verticals will cause spectrum fragmentation, resulting in inefficiency and a slowing of innovation. Regulations should avoid further spectrum fragmentation and, under a technology and service neutrality scheme, allow commercial IMT networks to provide 5G services to verticals. Assigning spectrum to mobile operators, which are most experienced in maximising spectral efficiency, will ensure best use of this scarce resource. Moreover, assigning internationally harmonised spectrum for 5G will help drive economies of scale, which manifest in the form of lower handset costs, other things being equal.

In terms of cross-sectoral regulation, the convergence of 5G in vertical sectors will challenge existing regulatory frameworks. The traditional telecoms ministry will soon need to regulate services in other sectors that may have their own regulation and regulators. There is a need to have a national coordination mechanism to manage cross-sectoral policy making and enforcement, especially for the three verticals studied in this report – automotive, drones and manufacturing.

5.2 Vertical specific

Automotive

Pro-innovation means pro-investment

- As we move into the autonomous vehicle and 5G eras, legislators and regulators need to create a policy framework that enables future developments and is pro-innovation and pro-investment.

Regulatory standards for level 4 and 5 autonomous driving

- Legislators across North America, Europe and Asia-Pacific have shown a willingness to create a supportive environment for the introduction of autonomous driving, for example issuing permits for companies to test autonomous vehicles on certain public roads.
- However, the bulk of this legislation refers to supervised trials where a driver is present and capable of assuming control of the vehicle when necessary. Developing suitable legislation for larger-scale level 4 and level 5 pilots presents a specific set of challenges regarding liability for accidents, car hacking and data privacy.

Technology agnostic

- We recognise there are a number of technology standards currently in deployment. From a telecoms perspective – given the key role that 5G-V2X will play in autonomous driving and future smart transport – policymakers need to ensure there are no regulatory barriers preventing 5G infrastructure developments, or spectrum availability or market rules that could slow down the deployment of 5G-V2X technologies.

Drones

Common standards

- UAV flights for industrial purposes do not have defined regulations in China. Common standards for connectivity management and flight parameters (e.g. allowable distance, altitude, line-of-sight path) would help accelerate investment and deployment of infrastructure and service models.
- For both retail and industrial purposes, a common standard and regulatory specification for built-in SIM cards will support interoperability between platforms and drive economies of scale.

Air traffic control agreements

- A collaborative approach is needed between industry and air traffic control authorities to agree airspace flight control regulations and cost-effective spectrum licensing for airspace use.

Technology agnostic

- Development of industrial UAV regulation that is technology agnostic would allow LTE connectivity for pilots and initial deployments before transitioning to 5G post-2020.

Manufacturing and Industry 4.0

Common standards

- The current value chain of IoT connectivity and systems integration in industrial verticals is highly fragmented. Development of common standards for interconnection between platforms and devices would help drive economies of scale and increase speed to market by reducing the need for stop-gap or custom-build solutions that bridge between two separate protocols.

Security

- Increases in the number of IP-enabled devices in factories and manufacturing facilities raise cyber-security threats proportionately. Regulators should consider introducing strict and common security thresholds for devices and connectivity protocols.

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