The 5G era:
Age of boundless connectivity and intelligent automation

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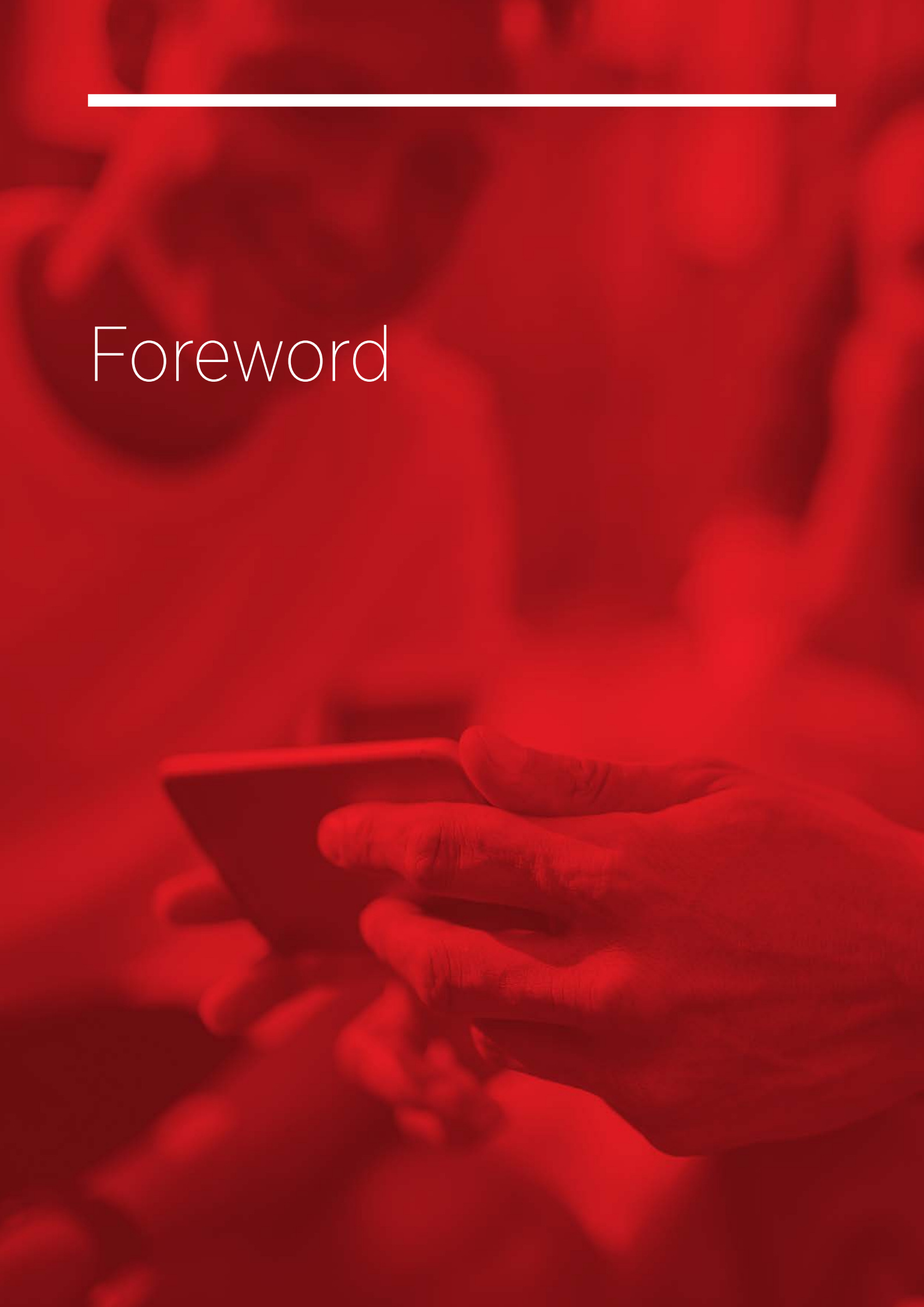
Contents

Foreword



5G: a network of opportunity

5G is more than just a generational step; it represents a fundamental transformation of the role that mobile technology plays in society. As demand for continuous connectivity grows, 5G is an opportunity to create an agile, purpose-built network tailored to the different needs of citizens and the economy.

It is an opportunity for operators to move beyond connectivity and collaborate across sectors such as finance, transport, retail and health to deliver new, rich services. It is an opportunity for industry, society and individuals to advance their digital ambitions, with 5G a catalyst for innovation.

5G will naturally evolve from existing 4G networks, but will mark an inflection point in the future of communications, bringing instantaneous high-powered connectivity to billions of devices. It will be designed specifically for the way we want to live and provide a platform on which new digital services and business models can thrive. It will enable machines to communicate without human intervention in an Internet of Things capable of driving a near-endless array of services. It will facilitate safer, more efficient and cost-effective transport networks. It will offer improved access to medical treatment, reliably connecting patients and doctors all over the globe. From low-power, sensor-driven smart parking to holographic conference calls, 5G will enable richer, smarter and more convenient living and working. It is a giant step forward in the global race to digitise economies and societies.

Although 5G will engage a new generation of consumers attracted by innovative services and seamless connectivity, new demands will be placed on finite spectrum resources. We will need greater bandwidth to meet the speed and capacity requirements of an increasingly connected society. Operators must be prepared to meet the challenges of a network designed for people and machines, and governments and service providers must also be ready to meet the demands that lie ahead. The success of 5G depends on the adoption of common global standards to ensure that all parties can begin using 5G as a platform for innovation as quickly as possible and at the lowest possible cost.

The GSMA is working closely with its members and players across the ecosystem to help define the technologies, identify the spectrum bands and develop the business models and policy initiatives that will bring 5G to life. Through industry collaboration, we can ensure that 5G is an evolutionary change with a revolutionary impact.

Mats Granryd
Director General, GSMA

1 Executive summary

The mobile industry is developing and preparing to deploy 5G. Thanks to technology advances in many different fields, 5G networks will be at the centre of an ecosystem that powers society's continued digital transformation.

Over the past 30 years, the mobile industry has demonstrated its ability to transform society through 2G, 3G and 4G. 5G will build on these successes to deliver the networks and platforms to support existing and new services, with new business models and use cases that are unknown today. The GSMA expects commercial 5G networks to be widely deployed in the post-2020 period: the 5G era.

All stakeholders are working to define what 5G should be. Technically, the aspiration for 5G is to deliver 1 Gbps speeds and <10 ms latency. However, more fundamentally, the 5G era will be characterised as the age of boundless connectivity for all and intelligent automation, enriching people's lives and transforming industrial processes. 5G networks will integrate with 4G and alternative network technologies to provide pervasive connectivity in the 5G era. This will happen as advances in computation, artificial intelligence and device capabilities come to maturity.

The 5G era will be characterised as the age of boundless connectivity and intelligent automation.

The GSMA has five mobile industry goals for the 5G era:

- Provide boundless connectivity for all
- Deliver future networks innovatively and with optimal economics
- Accelerate the digital transformation of industry verticals
- Transform the mobile broadband experience
- Drive growth in new use cases for massive IoT and critical communications services

To achieve these goals, the mobile industry needs to unify around a common technology standard and seek to deploy 5G networks on a set of harmonised spectrum bands. The 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.

5G networks will primarily support an enhanced mobile broadband experience in early deployments. Other use cases linked to massive IoT and critical communications will follow, as operators seek to unlock the incremental opportunity, particularly in key enterprise verticals. The GSMA expects 5G connections to reach 1.1 billion, some 12% of total mobile connections, by 2025. We forecast overall operator revenues to grow at a CAGR of 2.5% to reach $1.3 trillion in 2025. The GSMA's aspiration is for 5G to drive annual growth to 5%.

Society expects 5G to deliver innovation and ultimately economic growth. The expectation is that the benefits of 5G should be realised across society, within the constraints of network economics and with appropriate reward for investment and risk. All stakeholders need to recognise this, and work together to ensure their visions of the 5G era are aligned, and that the right foundations are in place to deliver them. Ultimately, the way 5G is developed, regulated, funded and commercialised will determine the future of the industry.

Headlines from the future

Industrial digitisation and automation drive GDP growth to 5%

Final figures for 2026 show that GDP grew by 5% and unemployment hit a 10-year low thanks to continued growth in industrial productivity. The economy is benefiting from digitisation and automation across almost all sectors as businesses embrace new technology to drive productivity growth. Economists predict that the trend will continue as the full scale of the 5G Internet of Things device explosion is only just beginning to become clear.

Mobile World Times (01/03/2027)

Scientists announce breakthrough in human-to-machine communication

Scientists at the National Laboratory for Science Research have announced a miniaturised computer for eye glasses that can interpret non-verbal facial communication from humans. “This is a significant advance that paves the way for super-intelligent eye glasses that bring powerful capabilities for users in their daily lives”, the lead researcher said. The technology relies on advances in machine learning, plus biological and quantum computing. As with other wearables, experts expect the computers to be linked to users’ personal cloud storage via 5G networks, enabling each user to capture, process, upload and store their daily emotions. Human-to-machine communication is already widely used for ads that react to human emotions.

Mobile World Times (01/03/2027)

Hackers go on shopping spree with 10 million hacked avatar assistants

The scale of the hacking of personal avatar assistants is becoming clearer. A report from security experts AvatarSecure warns that up to 10 million avatars may have been hacked, and the volume of illegal transactions could reach $10 billion. The hackers targeted people whose avatars regularly and automatically made orders for them, and were careful to keep within the typical spending limits to avoid detection. "As people increasingly rely on their avatar assistants to manage their lives, it is important that avatars are registered with the home 5G small cell gateway to ensure that avatars are protected by the robust security features of 5G", the report advised.

Mobile World Times (01/03/2027)

A billion postal deliveries signed for via augmented reality

Post Delivery Inc's Away from Home service has hit the 1 billion landmark four years since launch. The popular service, which is available to customers with a 5G device, enables customers to confirm and remotely sign for their parcel using augmented reality. "We are delighted to reach the 1 billion landmark a year ahead of target, demonstrating the appetite of our customers for the innovative services we offer them", a company spokeswoman said. Customers who have signed up to the service receive a video call and are able to sign for their parcel on their device's augmented reality interface to acknowledge delivery. Away from Home is available for deliveries by postal delivery staff or post drones.

Mobile World Times (01/03/2027)

2

Visions and goals for the 5G era

Technology is changing the world around us. The future will be defined by advances in artificial intelligence, autonomous IoT, big data analytics, machine learning and augmented/virtual reality, supported by high-speed, low-latency, secure connectivity that is ubiquitous and reliable. Many of these technological developments will come to maturity in the 5G era – the period from 2020 when commercial 5G networks are widely deployed.

The 5G era will usher in an age of boundless connectivity and intelligent automation. As society comes to rely more and more on mobile connectivity, 5G will turbo-charge connectivity to deliver mobile data services that are always available to customers when they need them. This pervasive connectivity will unleash the age of intelligent automation. The growing sophistication of artificial intelligence and the availability of cheap computing power will drive the widespread adoption of digital assistants, intelligent IoT nodes and automated industrial processes.

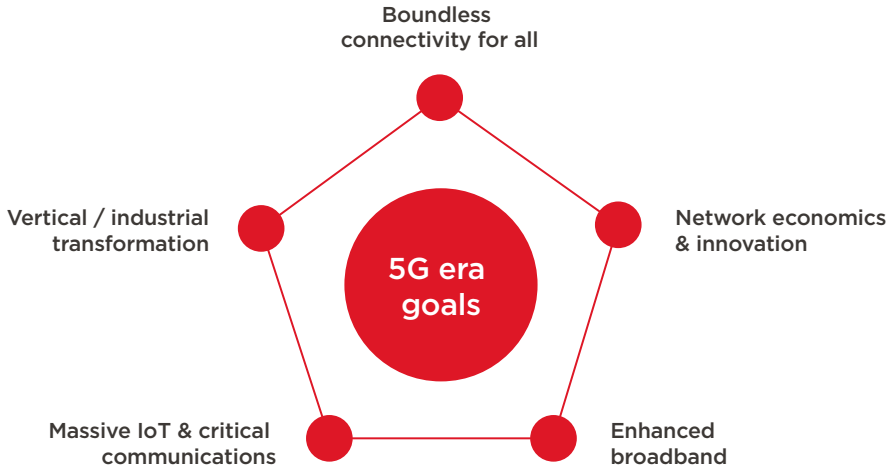
5G will provide the underlying infrastructure to realise this vision. It will be the first mobile technology to be developed in an era when the vision of ubiquitous internet access is close to reality. Already 60% of the world's population is covered by 4G networks. And more than 2.5 billion individuals are connected to, and benefiting from, 3G or 4G networks and services. 5G will build on this legacy, providing the networks and platforms in the global race to digitise economies and societies.

Various industry stakeholders have identified several potential use cases for 5G. Most of these can be grouped under three main categories: enhanced mobile broadband (eMBB), massive IoT and critical communications. The GSMA expects 5G to deliver high-speed, low-latency, reliable and secure enhanced mobile broadband in its early deployments. This is the primary use case that will justify the investment in 5G and drive development and deployment of 5G networks.

Based on the vision of the 5G era, the GSMA has five mobile industry goals:

Source: GSMA

1 Five mobile industry goals



1 **Provide boundless connectivity for all:** 5G networks will co-exist with 4G networks and alternative network technologies to deliver a boundless, high-speed, reliable and secure broadband experience, and support a plethora of use cases for society.

2 **Deliver future networks innovatively and with optimal economics:** All stakeholders will strive to cost-effectively deliver better quality networks either independently or through sharing and partnerships. Future networks will rely on a combination of mainstream and alternative technologies, and use both licensed and unlicensed spectrum, across different spectrum bands.

3 **Accelerate the digital transformation of industry verticals:** The mobile industry will provide the networks and platforms to drive the digitisation and automation of industrial practices and processes (including the fourth industrial revolution).

4 **Transform the mobile broadband experience:** 5G networks will provide an enhanced broadband experience of up to 1 Gbps and <10 ms, and provide the platform for cloud- and artificial intelligence-based services.

5 **Drive growth in new use cases for massive IoT and critical communications services:** 5G networks will support the massive rollout of intelligent IoT nodes for a multitude of scenarios, and provide a competent platform to support the widespread adoption of critical communications services.

5G will continue the success story of the mobile industry

The mobile industry has transformed society since its early days. We saw this in the 2G (1990s), 3G (2000s) and 4G (2010s) eras. In each of these, technological advancement – and the commitment of all stakeholders in the mobile industry to roll out networks and platforms – transformed society. Technology and social innovation have continually evolved to take advantage of new networks, helping the mobile industry to continue to drive investment in networks and platforms. The 5G era will be the same, and will deliver significant societal benefits – both direct and indirect.

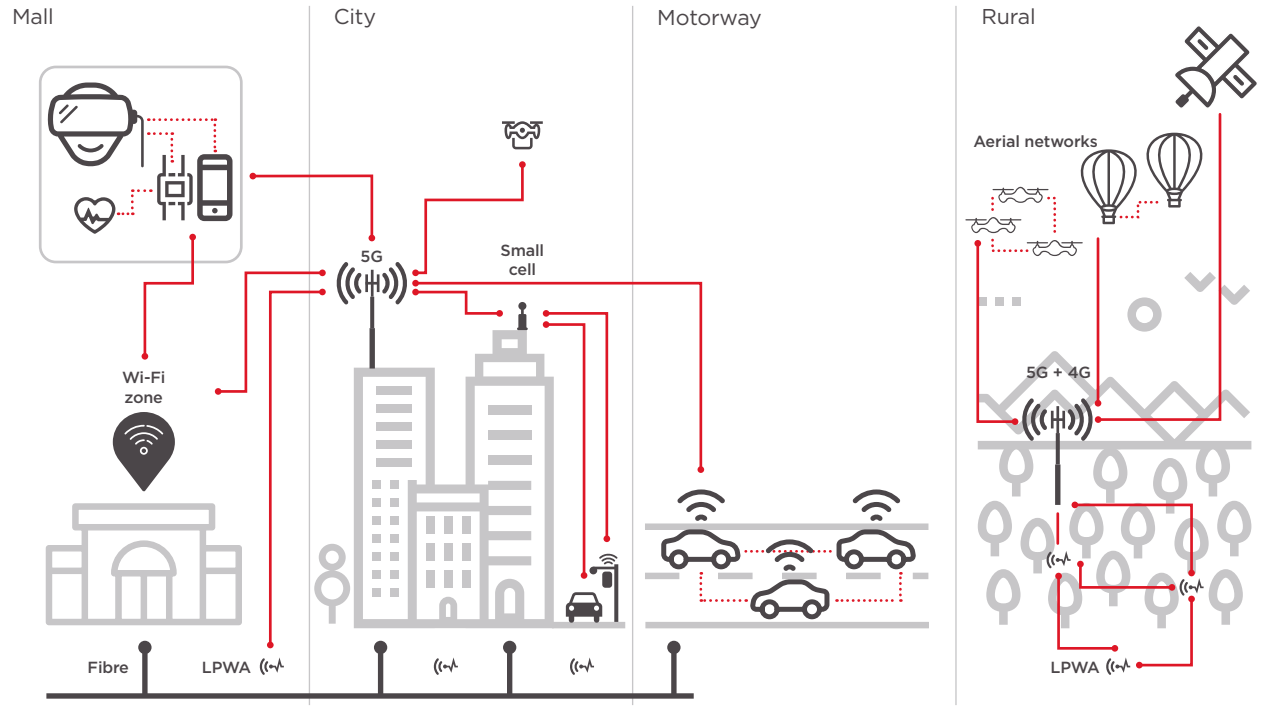
There are several critical drivers needed to realise the vision of the 5G era. Connectivity is the most important one. Within the constraints of physics and economics, the mobile industry will drive for data speeds of up to 1 Gbps and latencies of <10 ms for 5G networks. This superior technical performance, combined with the continued evolution and availability of 4G networks plus relevant alternative network technologies, will provide the underlying broadband capabilities of the 5G era. While 5G should help to drive down the cost per MB, the industry will be keen for it to drive top-line growth for operators who can capture a slice of the new value created.

Operators will continue to play a central role in providing connectivity in the 5G era. To realise the vision of boundless connectivity, operators will deploy an agile, on-demand 5G core network to coordinate an ecosystem of heterogeneous, multi-access network infrastructure to provide connectivity in three usage scenarios:

- **Indoors:** relying on 5G macro cells (if on low-frequency bands), 5G small cells (for capacity or if on high-frequency bands or as a fixed wireless access unit) and integrating other heterogeneous networks, including Wi-Fi, fibre and device-to-device communication
- **Outdoors in dense urban areas:** relying on the new 5G RAN, including 5G small cells in high-footfall areas (e.g. train stations, stadia, shopping malls)
- **Outdoors in economically challenging areas:** relying on a mix of 5G RAN (if available on low-frequency bands), 4G RAN, low earth orbit (LEO) satellites and other alternative network technologies.

Source: GSMA

2 5G as the centre of a heterogeneous network environment



Other use cases, both existing and new ones, will build on the broadband use case to enrich the 5G proposition. In particular, operators will rely on 5G to provide the required platform for enhanced enterprise services which will be crucial in unlocking the incremental 5G opportunity.

But the 5G vision will not become reality without a clear framework on how to use – and the ethics and privacy of using – artificial intelligence and customer data. 5G networks must cope with the privacy and cybersecurity risks that are increasingly concerning users, organisations and governments. Operators will need to drive the conversation on privacy and create an industry consensus on what customer data can be stored, how it can be used and with who it can be shared. For the development of the 5G security requirements, the level of risk and vulnerabilities dictate a more comprehensive review of security than has occurred for previous generations of mobile networks.

This means the road to 5G will be different from the traditional generational step forward of the mobile industry. It will be a story of cooperation and competition, in a heterogeneous network environment, to deliver a boundless, high-speed, reliable, consistent and secure broadband experience that can support critical services and unleash innovative solutions for society.

The scale of the success of 5G will be determined by its impact on society

5G will build on the success of previous mobile network technologies that have enabled the mobile industry to deliver huge benefits to society. The GSMA's Mobile Economy 2017 report highlights that in the period to 2020, the global economic footprint of the mobile sector in value-added terms will continue to grow, expanding from $3.3 trillion in 2016 to reach $4.2 trillion by 2020.

From its early days, the mobile industry has transformed society and will continue to have significant societal benefits – both direct and indirect. 1G (analogue) proved that mass-market mobile telephony was technically feasible. 2G brought global interoperability and proved that reliable mobile telephony can be commercially deployed to be affordable for all. It also brought SMS, a message service that transformed the way society communicated. 3G gave us the mobile internet and incubated the rise of online platforms and services that benefited from the switch to packet data networks. In 4G, the first truly IP network, online platforms and services came of age, benefiting from the availability of high-speed mobile internet services for the masses. 5G will build on these.

In the 5G era, the broadband infrastructure will be treated as critical national infrastructure for delivering digital services. So when citizens require such services, they are assured that it will work on their devices, in the same way they expect the lights to come on whenever they flick the switch.

For operators, 5G in its initial phase will be, first and foremost, an opportunity to deliver a transformed mobile broadband experience to customers. This will be targeted predominantly at consumers, but operators will be looking to the enterprise segment to unlock the incremental opportunity of the 5G era. As the focus shifts to the next phase with massive IoT and critical communications services, 5G will provide an opportunity for operators to go beyond connectivity and partner with other service providers across finance, transport, retail, health and other industry segments to deliver new services.

While 5G will provide faster and better connectivity, it is important for the industry to recognise its commitment to global digital inclusion. At the start of 2017, after eight years of rollout, only 60% of the global population have access to 4G-grade internet services. Accordingly, new 5G networks should combine with 4G and other innovative network technologies to deliver boundless and ubiquitous connectivity for all. This is in line with the GSMA's Industry Purpose to "connect everyone and everything to a better future" and its commitment to support the UN's Sustainable Development Goals.

The GSMA expects 5G to scale rapidly after launch in 2020, with coverage reaching just over a third of the global population in five years, and 5G mobile broadband connections exceeding 1 billion, some 12% of total mobile connections, over the same timeframe. If operators pursue new business models to improve data monetisation and unlock the enterprise opportunity then we anticipate that they will be able to grow revenues globally at a CAGR of 2.5% during the 5G era, to $1.3 trillion in 2025. The GSMA's aspiration is for 5G to drive annual revenue growth to 5%.

All stakeholders should collaborate to realise the vision of the 5G era

All stakeholders in the industry are keen to define, develop and deploy a 5G system to drive the next wave of growth in the industry. But there are risks and challenges that must be managed and minimised to realise the 5G vision:

1 **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. Early commercialisation of 5G will rely on the business case for mobile broadband. This is the lesson of 4G, proving that providing good quality mobile broadband with the right business model is profitable. The investment required for 5G networks, particularly in terms of dense small cell deployments and the requisite backhaul, plus the provision of reliable connectivity globally, is huge. The challenge for the industry is to identify new services, new market segments (especially enterprise) and the right business models (including a new IP interconnect model) to unlock the incremental 5G opportunity while optimising the cost of 5G network investment.

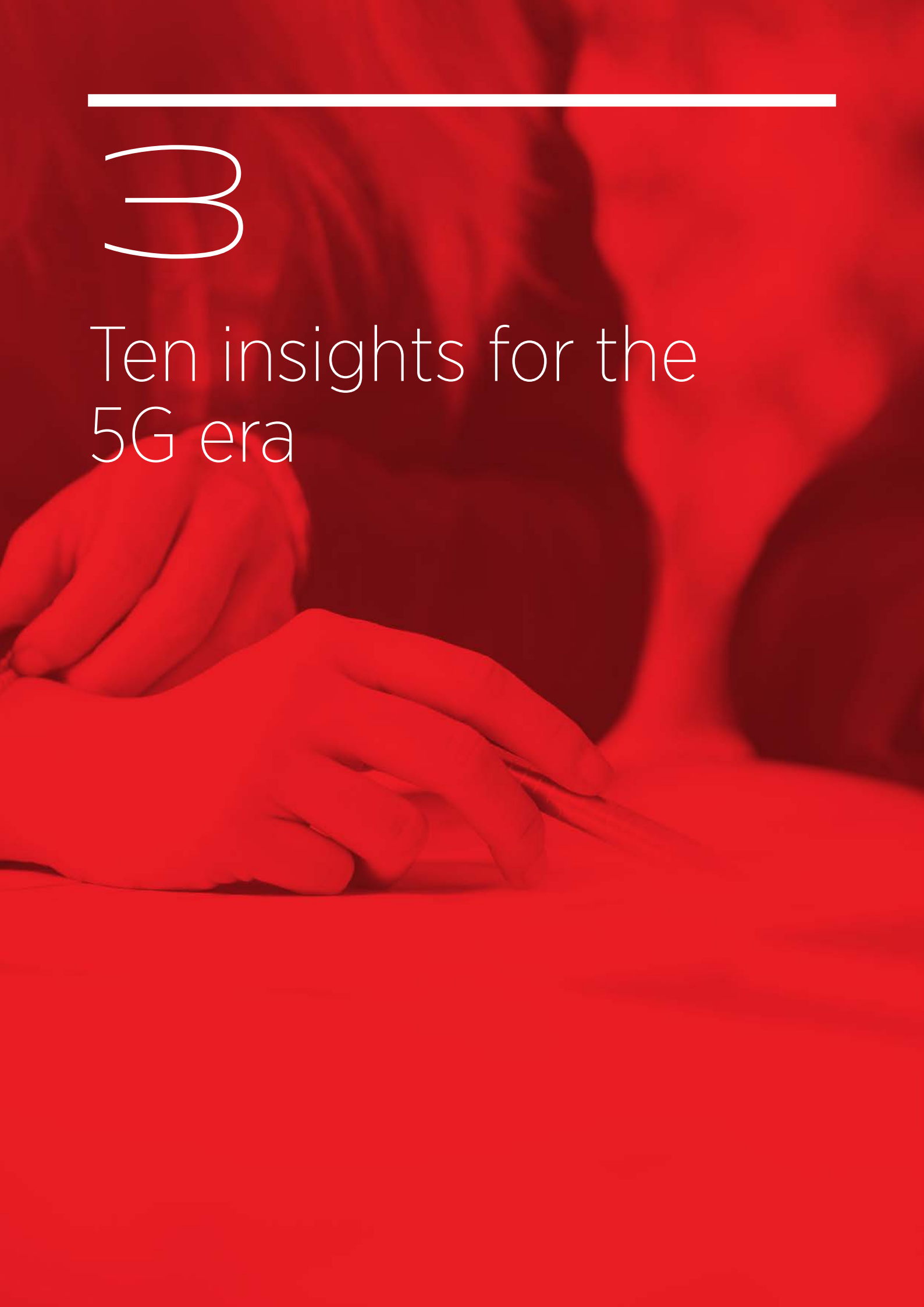
2 **Spectrum availability:** Spectrum will remain a critical but scarce resource in the 5G era. This applies to both the licensed and unlicensed bands that will play a key role in delivering the 5G era vision. 5G needs spectrum within three key frequency ranges to deliver widespread coverage and support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

3 **Technological improvements and breakthroughs:** Many of 5G's technological improvements and breakthroughs will build on 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 <10 ms latency will challenge the laws of physics and topology of network layouts. Likewise, the use of millimeter wave (mmW) frequencies will require significant technological breakthroughs in device and network designs.[2,3]

4 **Fragmentation:** An important lesson from 2G, 3G and 4G technologies is that the mobile industry is more successful when it avoids fragmentation in spectrum, technology and operator services. For 5G, the GSMA is supporting the industry to ensure that fragmentation is minimised and that operator services are included in the standards from the onset to achieve maximum scale benefits.

5 **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.

1 5G Spectrum Policy Position, GSMA, February 2017
2 Understanding 5G: Perspectives on future technological advancements in mobile, GSMA Intelligence, December 2014
3 Unlocking Commercial Opportunities From 4G Evolution to 5G, GSMA, February 2016



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Ten insights for the 5G era

The GSMA seeks to focus the wider debate on 5G and align its members around a core set of expectations for the 5G era. We surveyed 750 operator CEOs on their expectations and plans for the 5G era. We also interviewed 50 senior managers in the industry, discussed 5G with selected financial analysts tracking the telecoms sector, and engaged with university research teams. We have distilled the findings from this extensive engagement into 10 key insights for the 5G era

Source: GSMA

3 The 10 insights that will shape the 5G era

Basics	Opportunity	Market structure	Sustainability
• Transform the broadband experience • Deliver new technological capabilities	• Unlock incremental enterprise opportunity • Provide boundless connectivity economically • Grow revenues by 2.5% CAGR	• Balance competition & collaboration for services • Embrace new models for infrastructure	• Advocate for supportive regulation • Avoid technology & spectrum fragmentation • Support required services as default

These 10 insights illustrate both the concerns that mobile operators share in terms of putting in place the foundations to support sustainable investment and innovation during the 5G era, and the potential opportunity that 5G presents to the industry and society. Together they form a holistic view of the key factors that will shape the debate on 5G over the coming years and beyond.

The 10 insights

1. 5G will transform the mobile broadband experience in early deployments and drive new intelligent automation use cases in later phases.

2. 5G as a technology will evolve over time and leverage a variety of spectrum ranges, plus robust security, to support new use cases.

3. Enterprise services and solutions will drive 5G's incremental potential.

4. 5G will start as an urban-focused technology and integrate with 4G to provide boundless connectivity for all.

5. 5G will deliver revenue growth to mobile operators, with a 2.5% CAGR in the early 5G era.

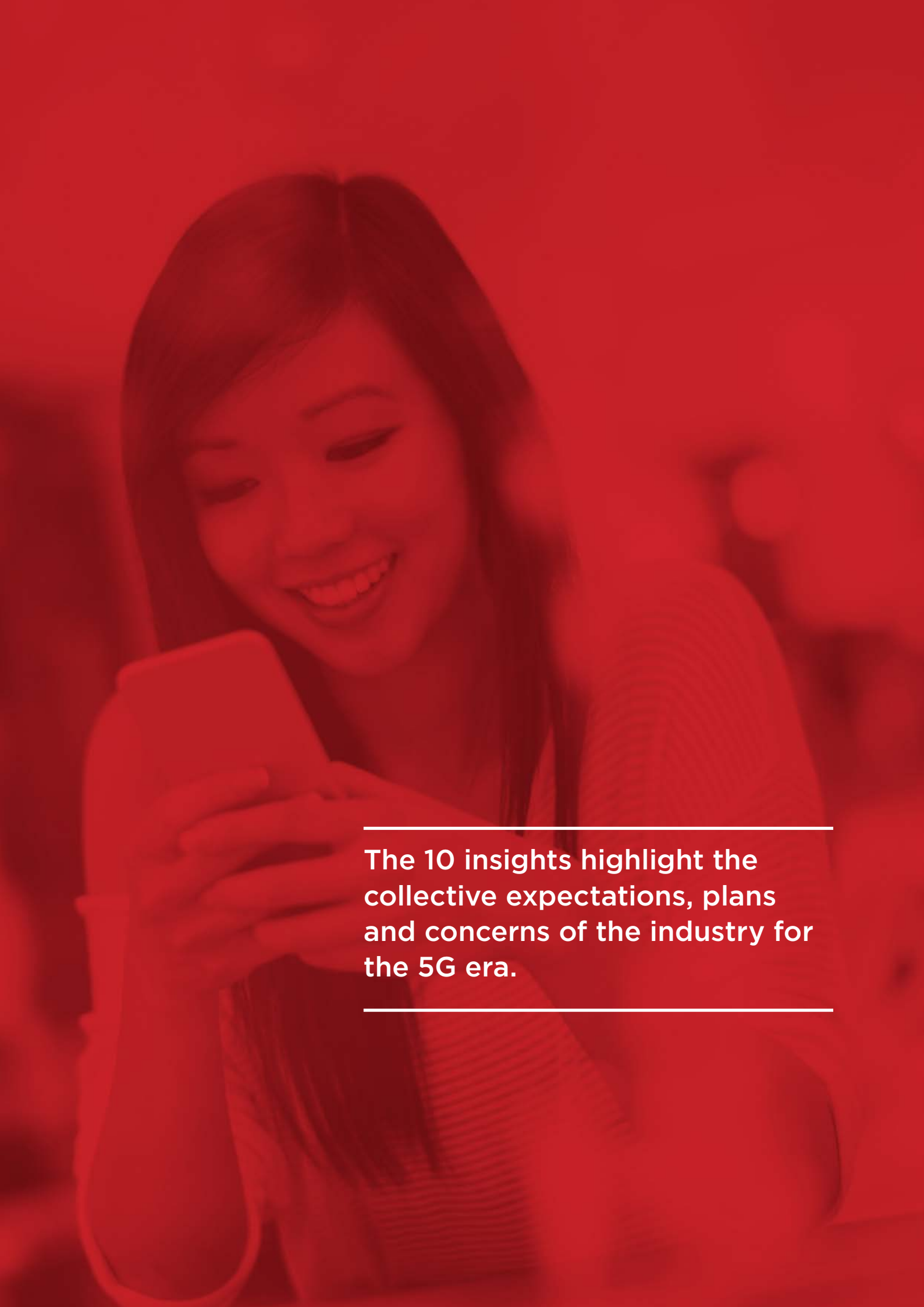
6 Competition and collaboration between operators and other ecosystem players to provide services will intensify in the 5G era.

7 New models for infrastructure ownership, competition and partnerships will be required for the 5G era.

8 Regulation, licensing and spectrum policy will make or break the 5G opportunity.

9 The industry should strive to avoid spectrum and technology fragmentation for 5G.

10 Interoperable and interconnected IP communication services, including device-to-device, should be supported as default in the 5G era.



The 10 insights highlight the collective expectations, plans and concerns of the industry for the 5G era.

Insight

1

5G will transform the mobile broadband experience in early deployments and drive new, intelligent automation use cases in later phases

Enhanced mobile broadband (eMBB) will be the key proposition in early 5G deployments and will drive increased performance, functionality and efficiency across society. This is the clearest potential 5G use case and will support the delivery of high-definition video (e.g. TV and gaming), immersive communication (e.g. video calling and augmented & virtual reality) and smart city services (e.g. video cameras for surveillance).

As the technology matures, 5G will enable new usage scenarios such as massive and critical Internet of Things (IoT) communications, and will drive the proliferation of artificial intelligence-based services for personal devices, IoT nodes and industrial processes.

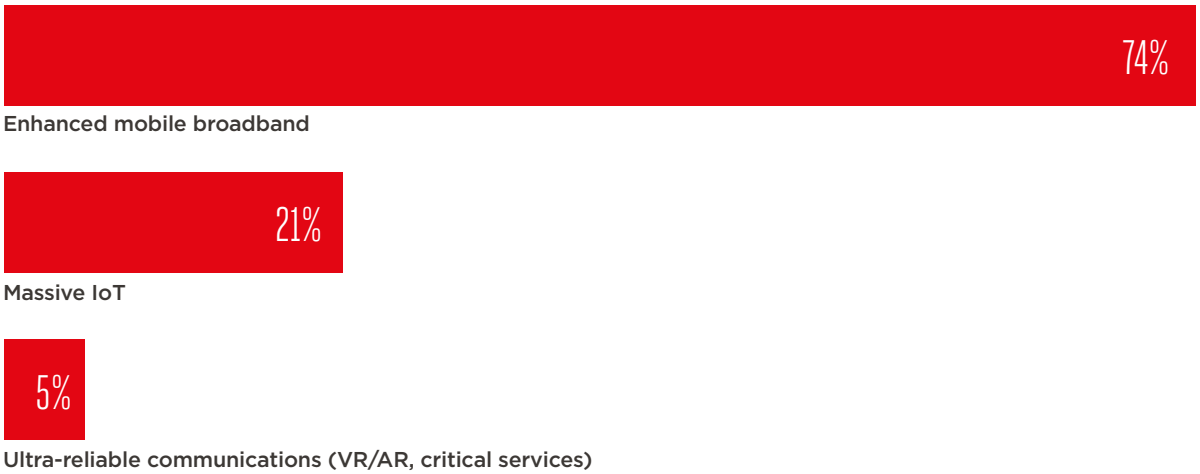
The phased nature of 5G rollout, coupled with concerns around the 5G business case, will impact development. Mobile operators are pragmatic in their approach to 5G use cases, with a clear majority indicating that eMBB will form the key customer proposition in early 5G deployments.

The push for eMBB in 5G is a continuation of the 4G mobile broadband transformation. The emphasis on eMBB will sustain the 5G business case, and drive 5G network investment, in the absence of any new mobile use cases. However, under current operator business models, building a ubiquitous 5G network to support the latency that autonomous vehicles require remains as unrealistic as funding the level of small cell deployment needed to support a seamless augmented reality experience.

While massive IoT remains an attractive opportunity for 5G, operators will rely on current cellular IoT standards such as NB-IoT in the early 5G era. A substantive IoT business case for 5G will become clearer later in the 5G lifecycle.

Source: CEO 5G survey, October 2016

4 Priority use cases in early 5G deployments



Question: What will be your highest priority use case in early 5G deployment?

Insight

2

5G as a technology will evolve over time and leverage a variety of spectrum ranges, plus robust security, to support new use cases

From a technology perspective, 5G is beginning to crystalise. It is clear that early deployments will be largely evolutionary to LTE, supporting the ever-growing demand for high-bandwidth mobile data in dense urban and suburban areas, or used for specific use cases such as fixed wireless access (FWA) to extend the reach of fixed networks (e.g. Verizon's proposals in the US). All of this points to the need for new business models to make the economics of 5G work.

Over time 5G will see a major shift in how cellular networks are designed. Existing services will evolve and new services will emerge that can be served by a 5G system. Mobile operators will use new network architectures, as well as new radio technologies, to achieve the flexibility required to serve a diverse set of applications. The security of networks and services will also be critical given the cybersecurity threat and changing security landscape.

The evolution to 5G, both in terms of technology and network launches, will occur via the following use cases:

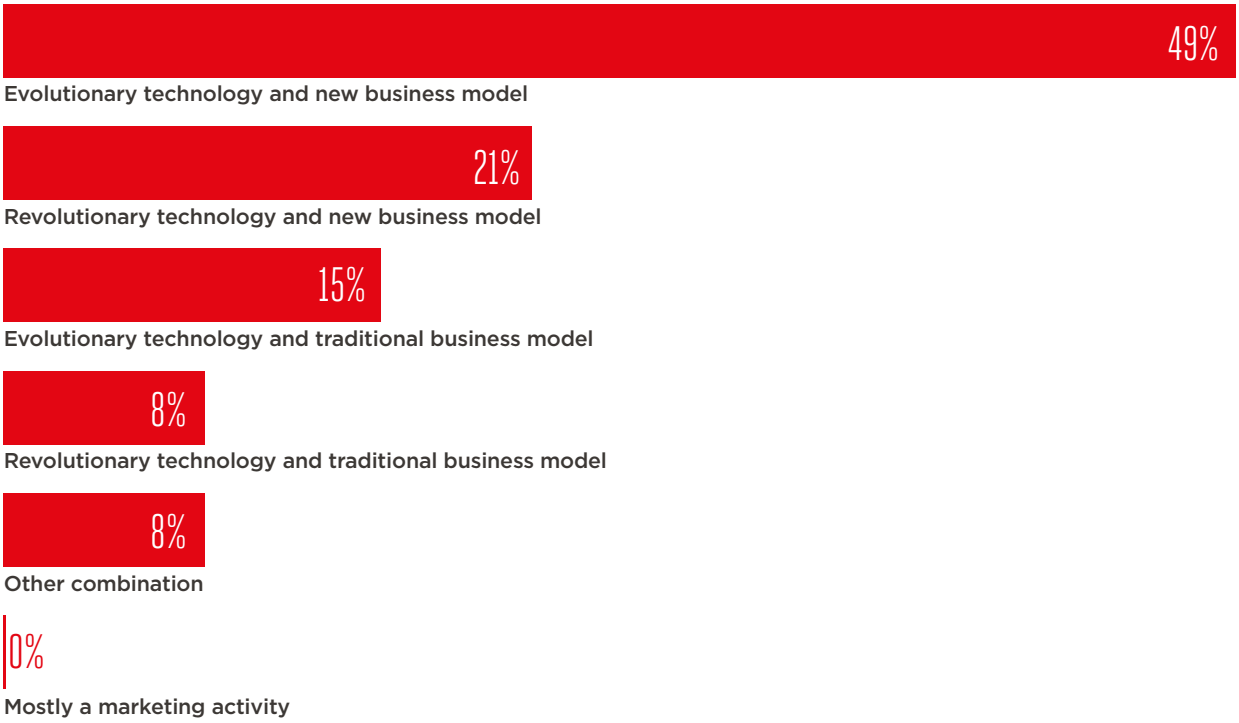
- **Stage 1:** FWA networks
- **Stage 2:** extensive trials at sporting events pre-2020
- **Stage 3:** wide commercial network rollout from around 2020.

The early version of 5G standards (based on 3GPP Release 15) will offer increased performance for enhanced mobile broadband and some low latency applications. The next stage, based on 3GPP Release 16, will bring further enhancements to mobile data, and the rest of the commercial requirements including massive IoT and critical communication services. This is likely to incorporate mmW bands, especially following WRC-19, as well as lower frequency bands including sub-1 GHz. The operator community recognises the reality of this phased approach and that, as a result, early 5G networks will represent an evolutionary technology to LTE.

Mobile operators maintain that 5G requires a new business model in order to drive the level of investment required to deliver some of the early identified use cases. A concerted effort is required to frame that agenda and identify the sustainable network operator business model(s) of the future. Otherwise, given 5G's evolutionary nature, the industry risks ingraining current business models across the 5G era. This in turn is likely to constrain network investment, particularly when it comes to the deployment of small cells to support mmW 5G services.

Source: CEO 5G survey, October 2016

5 Perceptions of 5G



Question: What do you see 5G as?

Insight

3

Enterprise services will drive 5G's incremental potential

The story of mobile telecoms is the story of how consumers in all countries, across all social classes, have been empowered to communicate and access the internet from a personal mobile device. While opportunities will always remain to provide more mobile services directly to consumers, the incremental 5G opportunity will come from services targeted at the enterprise sector.

Providing services to enterprises uses the same underlying platform as providing services to consumers. In the 5G era, operator platforms will support massive IoT, network slices using virtualised network functions, and common enablers and APIs. To fully address these opportunities, operators will need to focus on business-to-business (B2B) and business-to-business-to-consumer (B2B2C) business models.

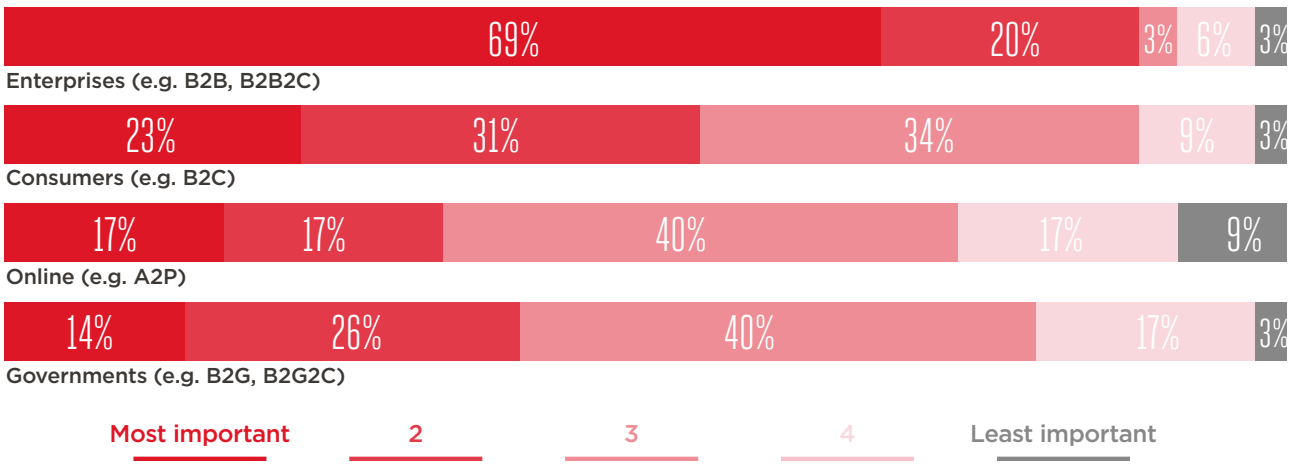
Operators see opportunity in many industry verticals. The automotive sector, and the progress towards driverless cars, is a much discussed example of an industry that could benefit from 5G's superior capabilities. Manufacturing, healthcare, entertainment, financial services, utilities and other segments of the transport sector could all be targeted for growth opportunities in the 5G era.

To tap into these opportunities, operators will need to address the following three critical factors:

- Without interconnection of IP services, most of the services that operators seek to sell to the enterprise market will be subscale and unable to achieve global reach, roaming and universal continuity.
- To adequately address the enterprise opportunity, 5G networks will need to be packaged as an open platform that can be used by enterprises – via APIs – to deliver services to their customers.
- Unlike the consumer market (where operators have relied on a direct, transactional business model for consumer services), the enterprise opportunity in 5G will require an indirect, occasionally asymmetric, business model.

Source: CEO 5G survey, October 2016

6 Sources of new operator revenues for 5G



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

Insight

4

5G will start as an urban-based technology and integrate 4G to provide boundless connectivity for all

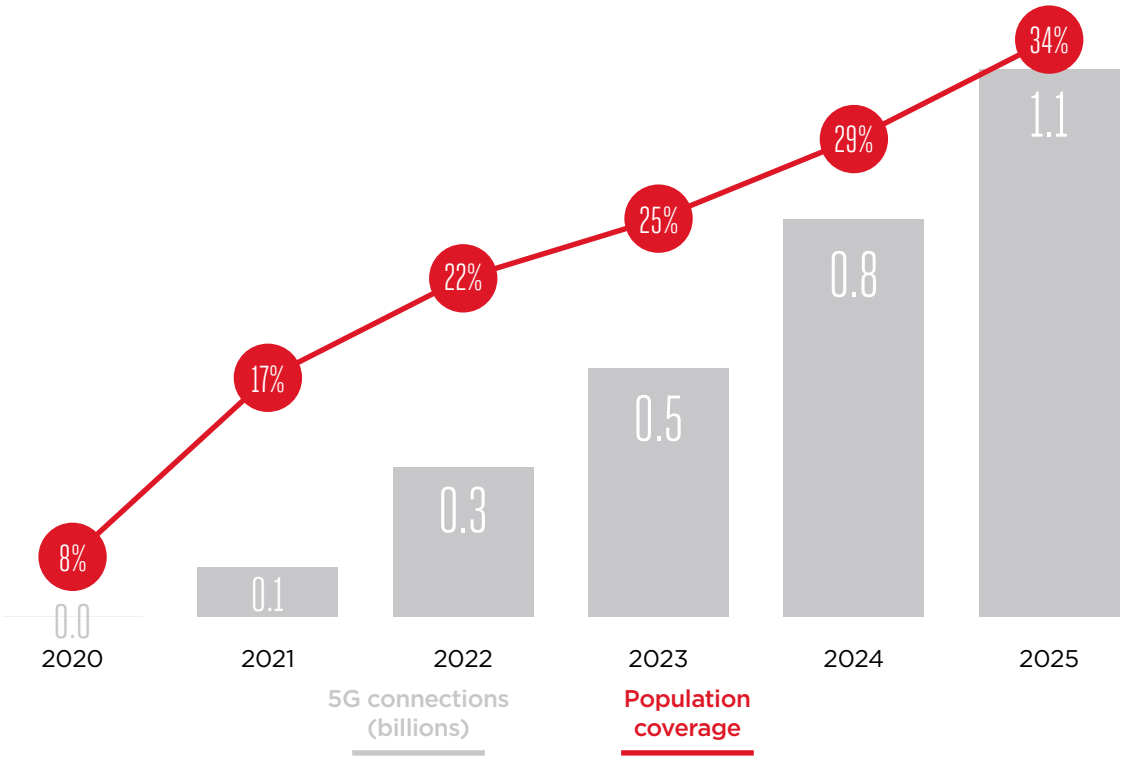
Early 5G networks based on 3GPP Release 15 will be deployed in dense urban areas, as operators look to supplement existing mobile broadband capacity, while also providing a test-bed for 5G use cases to emerge. This approach ensures that 5G will provide additional capacity for specific use cases such as in city centres and other locations with high footfall (e.g. stadia, shopping malls and transport hubs).

We expect operators initially to selectively upgrade macro cell sites to 5G in key locations and where network capacity is under pressure. This will utilise the existing 4G infrastructure as a fall-back option.

As a result, capex will remain relatively flat over this period, as operators seek to maximise cash flow. We expect operators to roll out 5G at a similar rate to the deployment of 4G, attaining coverage of 34% of the global population – 2.6 billion people – by 2025. As an early-adopter market, China will add its scale to help drive 5G adoption at a rate broadly in line with that of 4G. Harmonised and early access to spectrum will help to drive the development and adoption of 5G across other big markets. By 2025 GSMA Intelligence forecasts that 5G mobile broadband connections will reach 1.1 billion globally.

Source: GSMA Intelligence

7 Global 5G coverage and adoption

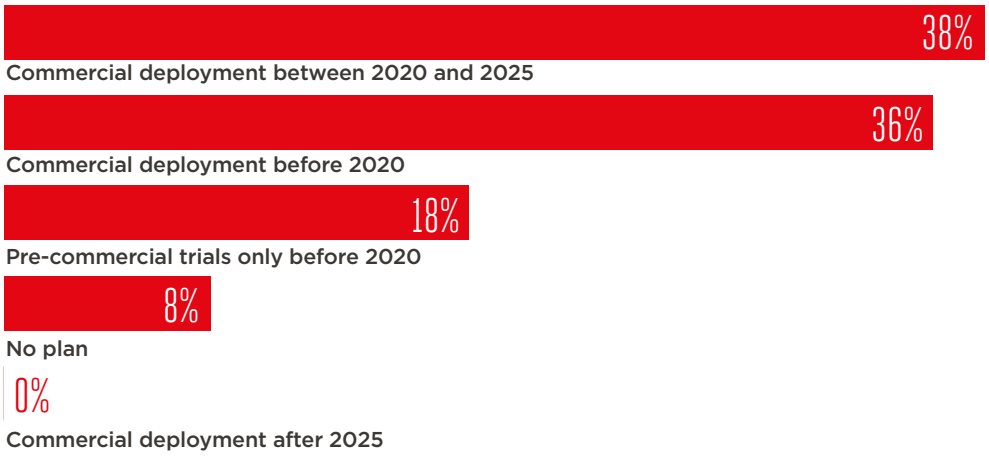


The rollout profile for 5G Phase 2 (3GPP Release 16, based on small cell deployments) will be much more varied among operators and countries. Cost is the principal concern; rolling out a dense small cell network in urban areas will require considerable amounts of capex, while also adding to current network opex burdens. This will increase the importance of access to – or ownership of – dense urban fibre networks.

This all points to the importance of network economics and innovation to fully realise the potential of 5G. In the 5G era, the industry will need to address the underlying economic assumptions for cellular networks and embrace new business models that can achieve a healthy balance between network competition and sustainable investment in infrastructure. This also means that 5G networks will complement 4G and other alternative networks to provide connectivity for all, including people and things. Regulators and public bodies will need to promote a supportive and transparent climate that incentivises investment, and removes bottlenecks to network rollout and partnerships, particularly those linked to planning regulations.

Source: CEO 5G survey, October 2016

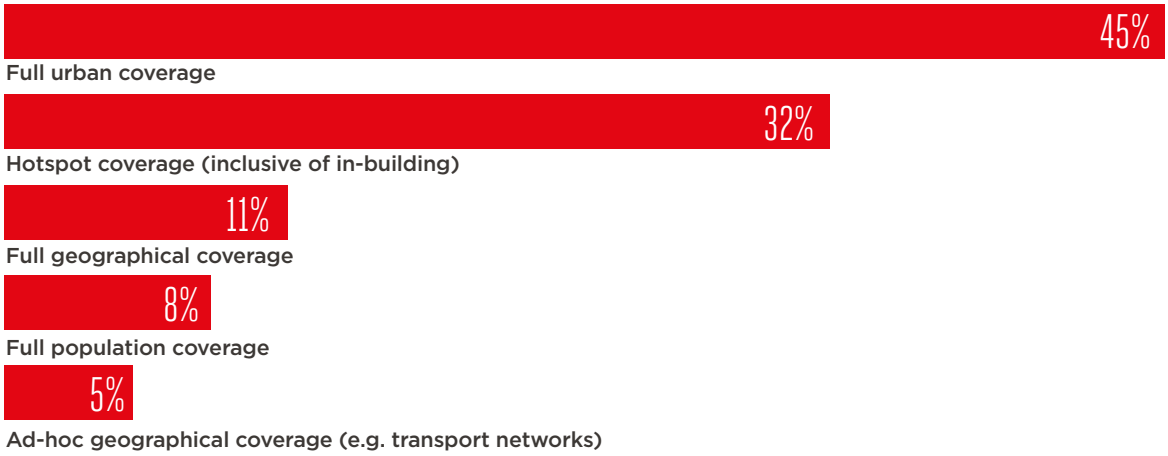
8 5G rollout plans



Question: What is your current plan for 5G rollout?

Source: CEO 5G survey, October 2016

9 5G coverage in early deployments



Question: What level of coverage should a new 5G network aim to provide in its early deployment?

Insight

5

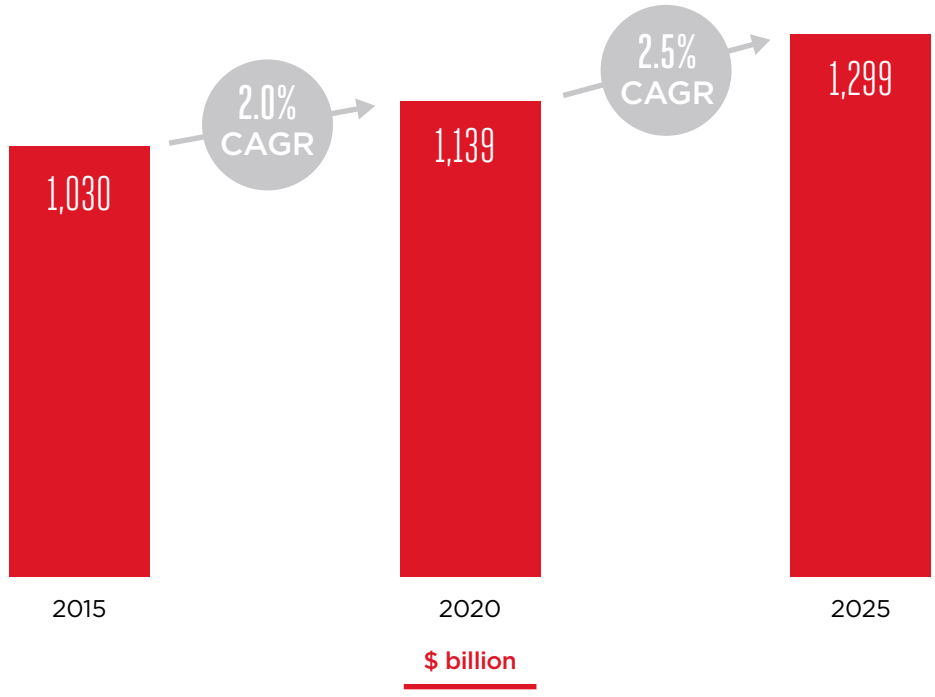
5G will deliver revenue growth to mobile operators, with 2.5% CAGR in the early 5G era

With 5G rollout expected to cover 34% of the world's population by 2025, following the launch of 5G cellular networks in late 2019, we expect 5G adoption to scale rapidly. Connections (excluding cellular IoT) will reach 1.1 billion, or approximately 12% of global connections, by 2025.

While revenue growth has slowed over the past five years, we forecast continued single-digit growth to 2025, at a CAGR of 2.5%. Growth will be sustained through connecting more unique subscribers as populations grow and more unconnected demographics subscribe to mobile services. Furthermore, operators will actively pursue new business models to improve data monetisation and begin to unlock the enterprise opportunity. There is potential upside to these forecasts if operators are able to capture growth opportunities in areas such as digital identity and IoT. If realised, we believe mobile operators could increase annual revenue growth to 5% during the 5G era.

Source: GSMA Intelligence

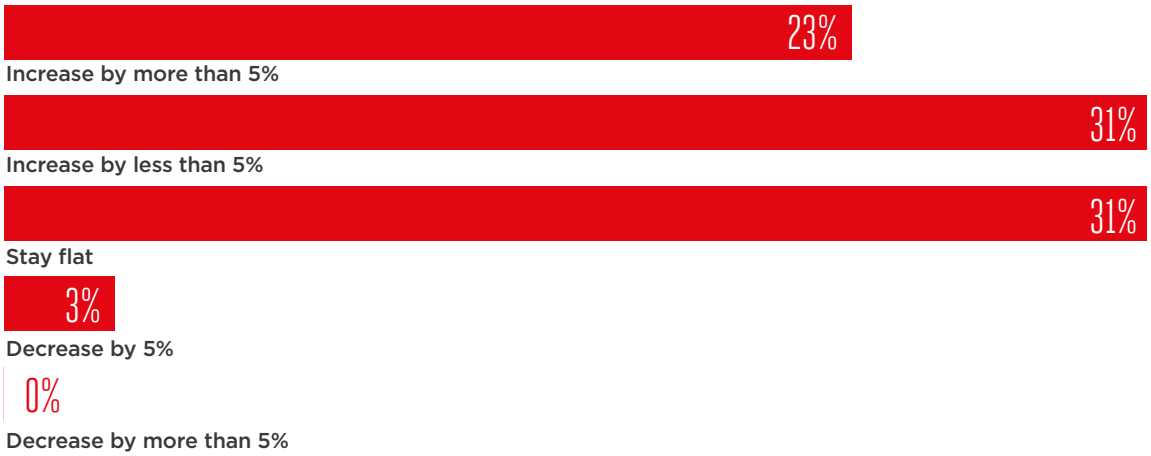
10 Mobile operator revenues, 2015–2025



By the time mobile operators launch 5G networks, they will have operated in a low-growth environment for almost a decade. We are already witnessing the impact of consolidation and cost-reduction initiatives in developed markets, delivering more stable and improving EBITDA margins. However, it is not yet clear how 5G will alter this dynamic, particularly given the uncertainty over deployment models for the dense small cell infrastructure required to support mmW services.

Source: CEO 5G survey, October 2016

11 Expectations for industry revenues



Question: How do you expect industry revenues to change in the early 5G era?

Insight

6

Competition and collaboration between operators and other ecosystem players to provide services will intensify in the 5G era

The 5G era will witness further disruption in the telecoms market, with competition intensifying at the service layer. Traditional operator services, particularly communications and identity, will continue to migrate to IP, and new services will be created natively in IP. For example, the industry is gradually rolling out the suite of operator IP communications services (VoLTE, ViLTE, RCS and VoWiFi); these should replace current operator communications services during the 5G era.

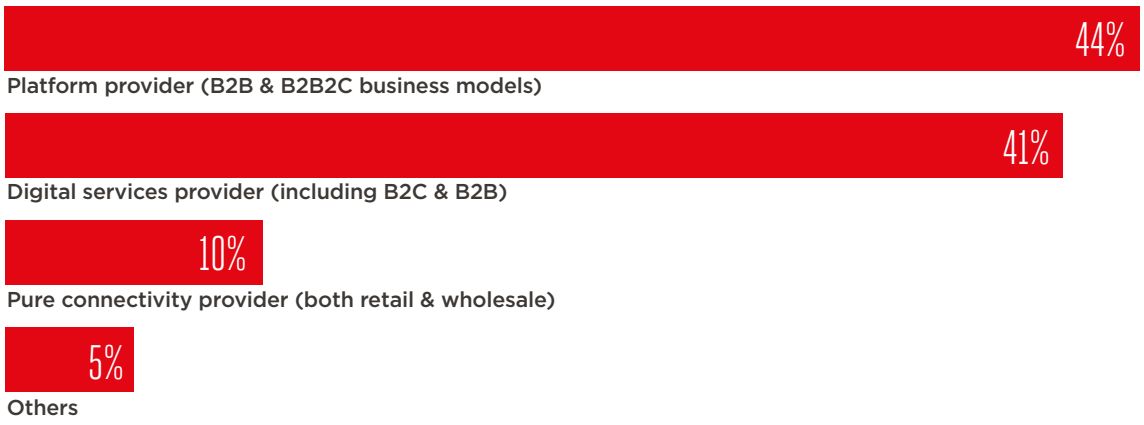
Many communication services are now provided as over-the-top solutions, with operators now competing with non-operator providers. This trend will accelerate as network coverage continues to increase and becomes more consistent, and if data-only smartphone packages become more common.

Mobile operators see their role in the industry as extending beyond that of connectivity provider to encompass the provision of digital services directly to consumers and enterprises, and as an enabling platform that provides B2B and B2B2C services. In the lead up to (and during) the 5G era, operators will seek to compete strongly with internet companies and other ecosystem players, to provide the services that customers want. This competition will be most intense for services that require global scale such as communications. In addition, operators will be well positioned to leverage local assets and knowledge to deliver services that require a more localised approach. These will mostly be services targeted at enterprise customers, services for IoT, or those that require big data and artificial intelligence.

To unlock these opportunities, operators will need to collaborate with the ecosystem to develop new technical solutions and commercial models. This will include the standardisation of network interfaces and APIs, the adoption of new universal service continuity models, and the development of appropriate partnership models with the ecosystem.

Source: CEO 5G survey, October 2016

12 Operator role in the 5G era



Question: What is the primary role of operators in the 5G era?

Insight

7

New models for infrastructure ownership, competition and partnerships will be required for the 5G era

The mobile industry remains a capital-intensive infrastructure business. Accordingly, strategies regarding where and how to roll out networks are fundamentally investment decisions. Mobile infrastructure relies on the right mix of appropriate technological solutions, attractive economic incentives and a conducive policy framework to ensure that billions of devices and things can be connected to the internet.

In the 5G era, operators will remain the primary owners and managers of telecoms infrastructure and will continue to compete aggressively among themselves to deploy the best quality network. Operators believe that other mobile network operators will continue to be their chief competitors for telecoms infrastructure and delivering connectivity.

The challenge for all stakeholders in the industry is to balance the merits of infrastructure competition with the necessity for economies of scale for infrastructure. While operators want to own and build their own 5G networks, key components of the 5G system such as small cells and heterogeneous and alternative networks will require new deployment and commercial approaches.

A key change to the structure of the industry will come from network sharing. Many operators have already embraced the model on a commercial basis, and policymakers should do too to achieve positive outcomes based on competition. Network sharing will intensify in the 5G era, particularly given the level of investment required for network densification. Indeed, the mobile industry is beginning to realise that the model will be required for many operators.

Alternative network providers will play an important role in expanding network coverage and capacity across society. Wi-Fi is already pervasive in many societies and its role and that of other alternative networks will continue to grow. Similarly, the industry needs to engage with third-party connectivity providers on how to integrate alternative networks (e.g. drones, balloons, satellites) to provide ubiquitous and consistently high-quality connectivity.

Operators will use connectivity solutions provided by other players or by customers to provide services. In some cases, operators might form direct partnerships, but in other cases the end user could have a relationship with a third party and reach the mobile services from there (as with Wi-Fi calling, for example).

These infrastructure realities have implications for collaborative industry activity and policymaking for 5G. For 5G to be a success, policies and regulations that strengthen the investment case are essential. This may involve supporting innovative spectrum and infrastructure sharing models (subject to commercial agreements), dynamic renting of infrastructure and backhaul, or enabling capacity sharing marketplaces. A neutral host approach could be required for small cells, learning the lessons from femtocells. Alternatively, the industry could embrace a bring-your-own small cell model to lower the cost of network densification.

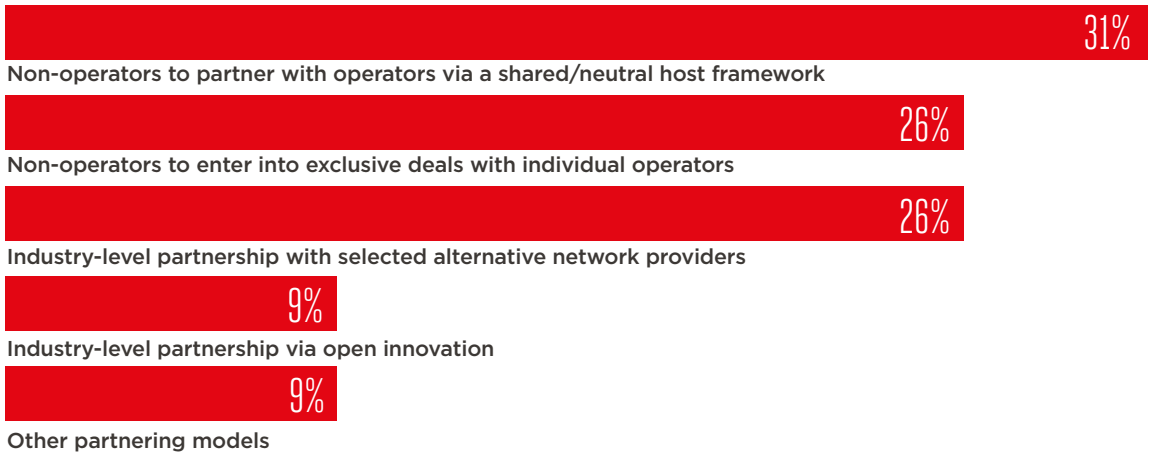
Source: CEO 5G survey, October 2016

13 Industry structure for infrastructure ownership

Question: What will be the most common industry structure for infrastructure ownership in the 5G era?

Source: CEO 5G survey, October 2016

14 Partnership models



Question: How could operators partner with non-operator-owned connectivity solution providers (e.g. small cells, Wi-Fi or drones) for coverage or for backhaul?

Insight

8

Regulation, licensing and spectrum policy will make or break the 5G opportunity

The success of the global mobile industry can be linked to a clear policy framework, predictable rules on licensing, and transparent spectrum policies. These will continue to be relevant in the 5G era. Both operators and policymakers will need to strike a balance between global harmonisation (to prevent fragmentation) and regionalised plans (to cater for localised priorities).

Appropriate regulatory conditions, including timely and cost-effective access to spectrum for testing and commercial use, plus satisfactory arrangements for small-cell deployment and compliance, will be crucial to meeting 5G deployment timelines.

Spectrum is a critical resource for the mobile industry. Its availability, and at what frequency bands, will help determine the business case for 5G. Significant new, widely harmonised mobile spectrum is needed (in both low- and high-frequency bands) to ensure timely rollout of 5G networks, maximise network investment and deliver the full range of 5G's potential capabilities. Operators need clear technical and policy rules on the use of unlicensed spectrum, other forms of spectrum sharing, and support for long-term technology-neutral spectrum licences to enable refarming. A spectrum roadmap is vital, and policy measures should be adopted to avoid artificially high spectrum prices. The GSMA will continue to focus its advocacy efforts on spectrum harmonisation and regulatory activities for the 5G era.

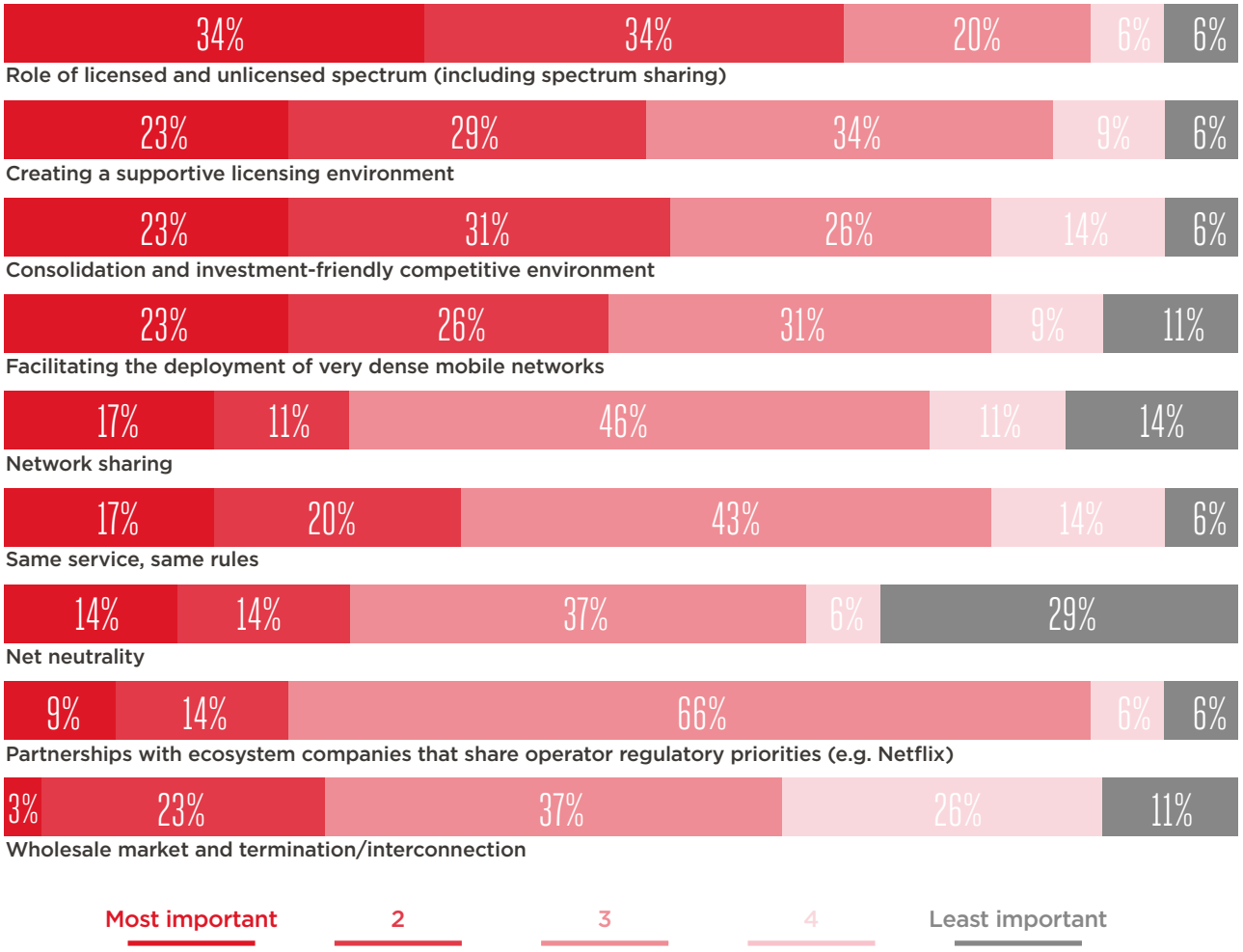
For 5G to be a success, policymakers need to embrace a future-oriented, pro-innovation and investment-friendly policy framework so that all players in the digital value chain are empowered and have the flexibility to develop and grow.

Failure to adapt regulation to this dynamic new environment can distort competition, stifle innovation and negatively impact consumer welfare. Policymakers should seize the opportunity provided by 5G and the digital revolution to reset policy and regulatory frameworks – to make investment in connectivity a priority and build an innovative digital economy.[4]

4 Resetting competition policy frameworks for the digital ecosystem, GSMA, 2016

Source: CEO 5G survey, October 2016

15 Advocacy priorities



Question: What do you expect to be the top advocacy priorities for your business in 5G?

Insight

9

The industry should strive to avoid spectrum and technology fragmentation for 5G

The desire for first-mover advantage, or to play a leading role in the development of the 5G standard, is seeing operators set ambitious targets for 5G commercial launches. 5G is the first technology cycle that the mobile industry is approaching in a state of maturity, with subscriber penetration close to demographic ceilings in most developed markets, and revenue growth averaging low, single digits globally. As a result, the imperative to deliver a new network technology with optimal network economics is stronger than ever.

Operators of scale, particularly in the US and China, are creating and driving the mobile ecosystem in a direction that suits their development path; they are currently among the most vocal proponents driving the 5G standard. Numerous standardisation bodies are expected to be involved in the 5G standardisation work. There is a risk of technology fragmentation due to the diverse interests of the involved parties.

Meanwhile, network equipment vendors see 5G as a means to drive sales, which have slowed in line with the speed of 4G deployment, while governments and other public bodies see early 5G deployment as a means to foster the development of national or regional digital industries and thereby drive economic growth.

With an ambitious launch timeframe of close to 2020, the desire of the industry and public bodies to realise the 5G vision early is accelerating the technology roadmap compared to previous generations.

This pressure is set to build as 2020 approaches. Many of the operator CEOs we surveyed indicated that they are planning trials or launches of 5G services before 2020. The following countries look set to host the first commercial 5G network deployments:

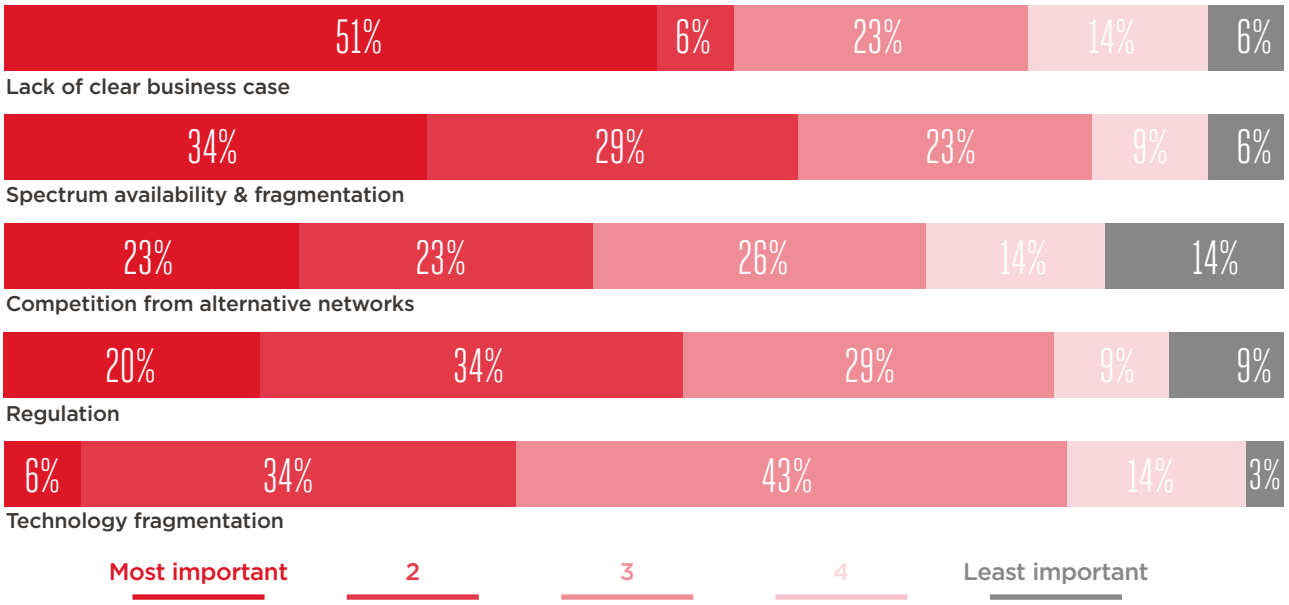
- **South Korea:** KT has announced that it will launch commercial 5G services in 2019
- **Japan:** NTT DoCoMo has announced that it will launch commercial 5G services in 2020
- **China:** China Mobile has announced plans to deploy 10,000 5G base stations by 2020
- **US:** operators have been active in testing and developing fixed-wireless access solutions using mmW technologies, and are expected to be among the first to launch commercial 5G wireless networks
- **Europe:** In July 2016, the major European operators published a 5G manifesto, which indicated a target of launching 5G in at least one city in each of the EU Member States by 2020
- **Middle East:** Etisalat has indicated that it will launch a nationwide 5G network in time for Expo 2020 in the UAE.

By seeking to bring launch dates forward, operators run the risk of 5G fragmentation both in terms of spectrum and technology. To avoid this the industry needs to adopt a similar approach to the development of NB-IoT, which provides a common infrastructural base for IoT to overcome fragmentation due to proprietary IoT networks.

All stakeholders should be vigilant that fragmentation would create interoperability issues and undermine efforts to scale 5G, and should therefore look wherever possible to create consensus. The GSMA also has a role to play in socialising the lessons learned in 5G trials and early deployments to avoid fragmentation.

Source: CEO 5G survey, October 2016

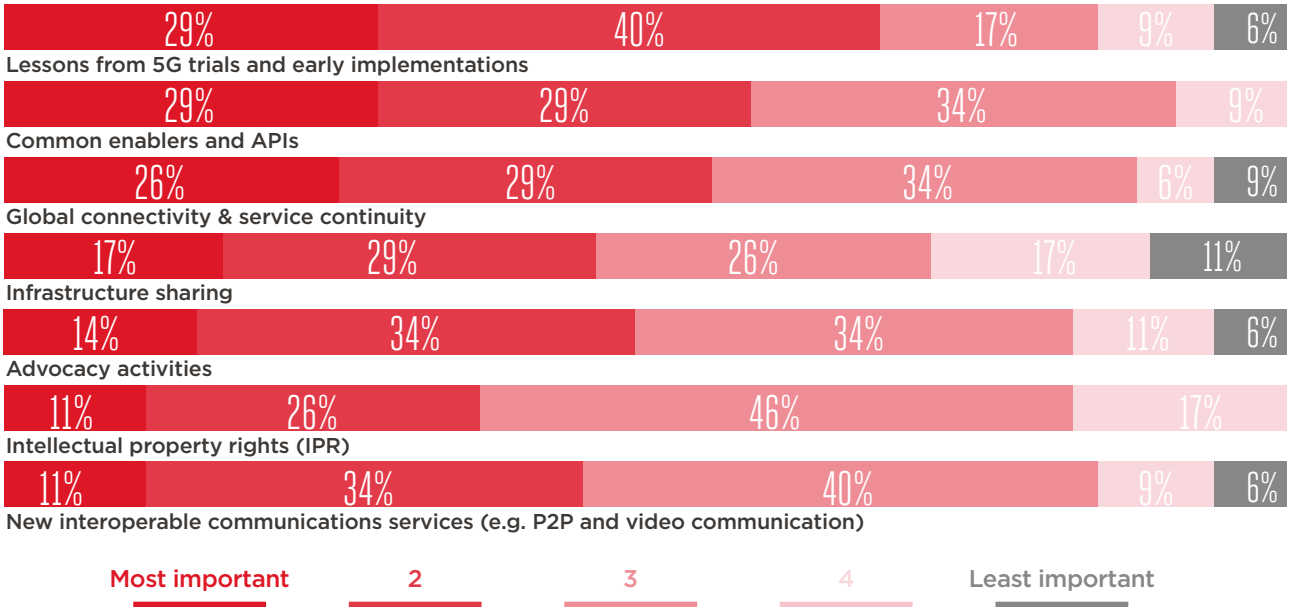
16 Operator risks in delivering 5G



Question: What are the risks facing operators in delivering 5G successfully?

Source: CEO 5G survey, October 2016

17 Importance of collaboration



Question: How important is collaboration in each of the following areas for the success of 5G?

Insight

10

Interoperable and interconnected IP communication services, including device-to-device, should be supported as default in 5G

The mobile phone remains the single most pervasive communications tool in history. Thanks to interoperability, interconnection and roaming, it allows anyone anywhere to directly contact someone else in the world. Operators want to continue to support this universal reach for communication services in the 5G era.

Mobile phones achieved universal reach because of the traditional voice and messaging services that were integrated by default in 2G and 3G. Users did not have to worry about whether the other party had mobile voice and SMS enabled or had the correct version of an app before attempting to contact them.

In 4G, this native capability for communications services was originally missing. The industry is working hard to resolve this; many operators are now launching VoLTE, ViLTE, VoWiFi and RCS services. These IP communications services will come to maturity and global reach in the next five years. 5G systems should be designed to support them by default from day one. It is important that legacy services should be included in the standard from the beginning to avoid interoperability issues in later stages.

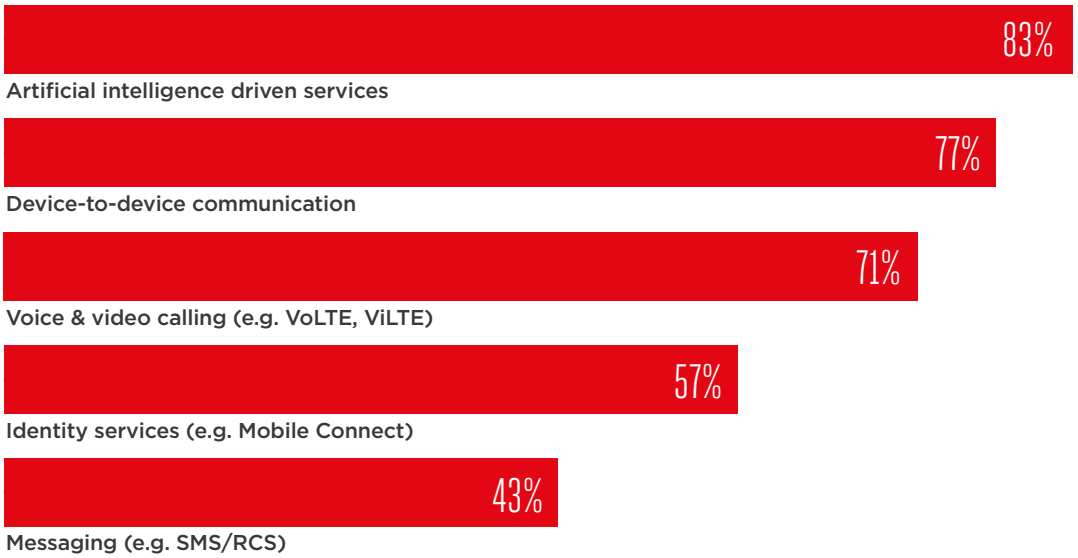
Operator communications services will compete with other OTT communications apps. While some of these apps have reached global scale, they are mostly non-interoperable and lack universal reach. Accordingly, enriched/advanced communications services from operators will remain the default, back-up communications option for customers in all countries. This will be especially key for governments and businesses seeking a fail-safe way to communicate with their citizens/customers.

Device-to-device (D2D) communications services hold similar promise to revolutionise society by making it possible for people and things to talk to each other when they are close together. D2D has already been packaged as 'LTE proximity services' to enable emergency services personnel to communicate with each other in the absence of a coordinating cellular network. Other potential use cases will be in the healthcare and automotive sectors, where D2D could have a profound impact.

It is important for 5G systems to support D2D communications services natively and by default in the same way 2G and 3G systems supported voice and SMS. This is the right lesson to draw from the slow take-off of VoLTE and RCS, the non-interoperability of OTT communications apps, and the fragmentation in the short-range communications markets (Bluetooth, ZigBee and so on).

Source: CEO 5G survey, October 2016

18 5G service support



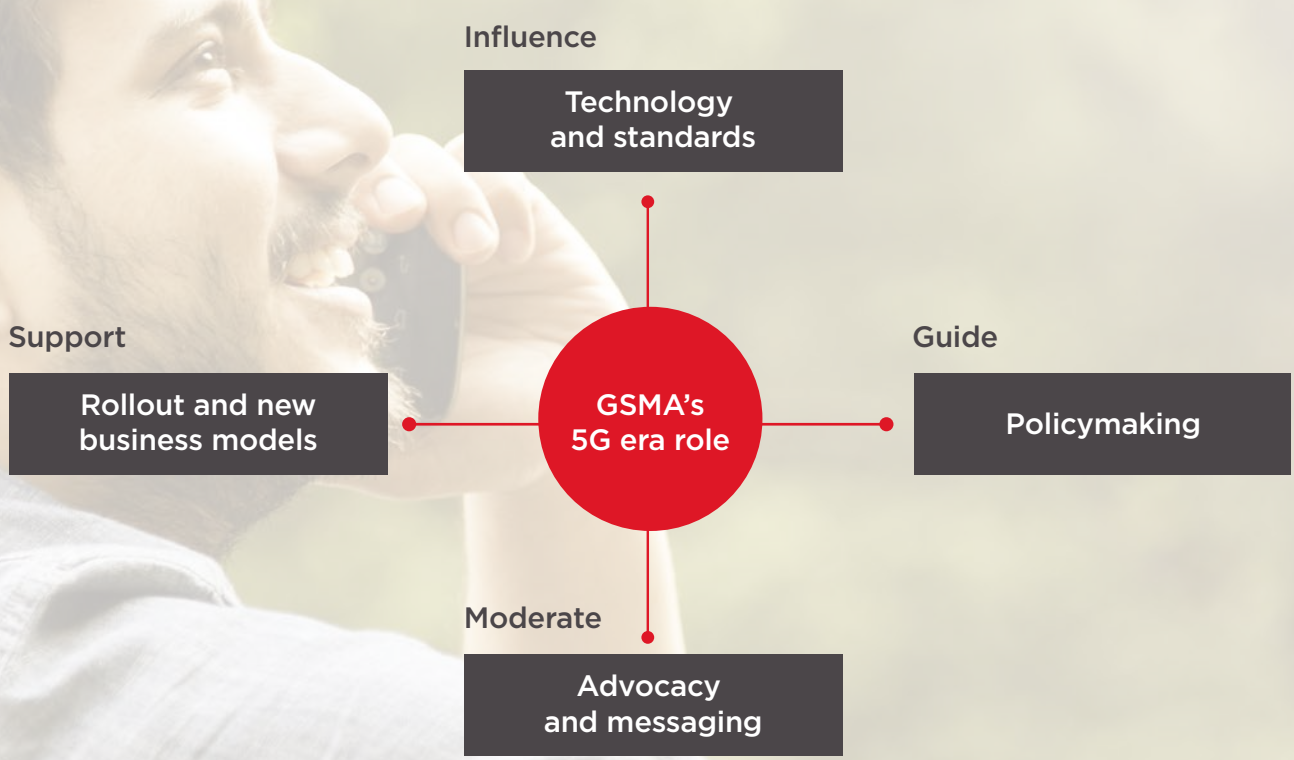
Question: Which of these services should be supported in 5G?

The GSMA's role in helping shape the 5G era

The role of the GSMA is to bring together all stakeholders in the mobile industry to ensure that the visions of the 5G era are well defined, understood and delivered. On behalf of its members, the GSMA will focus on how to influence the development of 5G technologies and standards, support the rollout of 5G networks and development of new business models for the 5G era, guide the development of government agenda and policies, and moderate the messaging around 5G.

Source: GSMA

19 5G era – the GSMA's role



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