THE 5G GUIDE

A REFERENCE FOR OPERATORS

APRIL 2019

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators with over 350 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

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5G rollout remains a critical competitive differentiator between operators which must be decided at an individual level, based on prevalent market conditions in the relevant country and operators' individual business decisions. Only the continuation of inter-operator competition can ensure the degree and pace of innovation, value and quality of service customers rightly expect.

Please note that it is not the role of the GSMA to recommend any particular commercial model nor to give any instruction on the timing, intensity or structure of operators' investments in new technologies and networks. Rather, the purpose of this report and models is to describe common factors all operators will probably need to consider in elaborating their individual strategies to ensure efficiency of their investment in 5G, and which will help to accelerate innovation in the best interest of customers.

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Additional legal disclaimer applies to, and is included at the start of, Chapter 5.

Acknowledgements

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KT	LG U+
Megafon	MTN
MTS	NTT DOCOMO
Orange	SK Telecom
Softbank	STC
Telecom Italia	Telefónica
Telenor	Telia Company
Telstra	Turkcell
Verizon	Vodafone

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Members of the GSMA 5G Task Force were drawn from Strategy, Technology, Policy, Mobile for Development, Legal, Marketing and GSMA Intelligence.

Emeka Obiodu
Editor and Project Lead
GSMA 5G Task Force

April 2019

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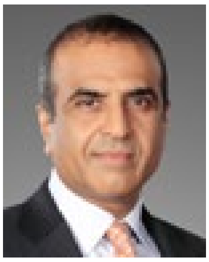
Glossary

AI	Artificial Intelligence
API	Application Programmable Interfaces
AR/VR	Augumented Reality / Virtual Reality
ARPU	Average Revenue Per User
B2B	Business-2-Business
B2C	Business-to-Consumer
BBF	Broadband Forum
BBU	Baseband Unit
BEMECS	Basic, Economic, Market, Enterprise, Consumer, Spectrum indicators
BYO (X)	Bring-Your-Own-X
CBRS	Citizens Broadband Radio Service
CDN	Content Delivery Network
Cloud RAN	Cloud Radio Access Network
COTS	Commercial Off-The-Shelf
CPE	Customer premises equipment
CSFB	Circuit Switched Fallback
CVC	Corporate Venture Capital
DAS	Distributed Antenna Systems
DL	Deep Learning
eMBB	Enhanced mobile broadband
EMF	Electromagnetic field
EPC	Evolved Packet Core
ETSI	European Telecommunication Standards Institute
FTTH/P	Fibre-To-The-Home/Premises
FWA	Fixed Wireless Access
Gbps	Gigabits per second
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GEO	Geosynchronous
GHz	Gigahertz
GST	Generic Slice Templates
HTTP/2	Hyper Text Transfer Protocol 2
IAB	Integrated Access Backhaul
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
IMT	International Mobile Telecommuincations
IoT	Internet of Things
IT	Information Technology
ITU-R	International Telecommunications Union Radiocommunications Sector
JSON	JavaScript Object Notation
KT	Korea Telecom
LEO	Low Earth Orbit
LPWA	Low Power wide Area
LTE	Long Term Evolution
LTE – M	LTE –for Machines
MEC	Multi-access Edge Computing
MENA	Middle East and North Africa
MHz	Megahertz
MIMO	Multiple input Multiple output
MW	Megawatts
NB - IoT	Narrowband – Internet of Things
NDAF	Network Data Analytics Function
NEF	Network Exposure Functions
NFV	Network Function Virtualization
NFV/SDN	NFV/software defined network
NPV	Net Present Value
NR	New Radio
NSA	Non- standalone
OEM	Original Equipment Manufacturer
OFCF	Operational Free Cash Flow
OFDMA	Orthogonal Frequency Division Mulitple Access
OPEX	Operating Expenditure
OTT	Over The Top
PC	Personal Computer
PMP	Point –to –Multipoint

PPP	Public Private Partnership
QoS	Quality of Service
RAN	Radio Access Network
REST	Representational State Transfer
ROI	Return on Investment
SA3	Service and System Aspects
SCEF	Service Capability Exposure Function
SDO	Standard Defining Organisations
SD-WAN	Software Defined-Wide Area Network
SMS	Short Message Service
SON	Self-organising Networks
SRVCC	Single Radio Voice Call Continuity
SWN	Single Wholesale Network
TCP	Transmission Control Protocol
TLS	Transport Layer Security)
TQM	Total Quality Management
URLLC	Ultra-reliable and Low-latency Communications
VNF	Virtual Network Functions
VoLTE	Voice Over LTE
VoNR	Voice Over New Radio
WAC	Wholesale Application Community
WiMAX	Worldwide Interoperability for Microwave Access
WOAN	Wholesale Open Access Networks
WRC	World Radio Conference

Foreword

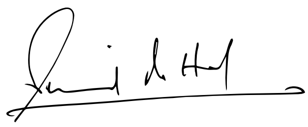


Our purpose as the mobile industry is to *Intelligently Connect everyone and everything to a better future* and 5G is the next major step in delivering on this goal. 5G, building upon and working together with 4G, provides the ability to connect people and things faster and more efficiently as part of a *5G Era.* 5G will drive new innovation and growth – it will be an evolutionary step with a revolutionary impact, delivering greater societal benefit than any previous mobile generation. This technology will fundamentally improve the way we live and work, enabling new digital services and business models to thrive.

The 5G journey is a hugely exciting one for the mobile industry to embark upon, to the benefit of all in society. At the same time, it presents a complex landscape for operators who will need to make careful judgements about investments and timing. As such, and at the request of the GSMA board, this unique 5G Guide has been produced by the GSMA to assist operators with their journeys; we think of this resource as being like a compass to help assist operators in navigating the 5G Era landscape.

We would like to thank the GSMA board steering group, including Juan Carlos Archila from América Móvil, Hatem Dowidar from Etisalat and Serpil Timuray from Vodafone, for the helpful guidance, counsel and support that they provided to the GSMA team in relation to the creation of this guide.

With 4G networks already covering 81% of the global population across 208 countries, and 5G networks set to cover nearly 40% of the global population by 2025 (GSMA Intelligence), the 5G Era is truly upon us. The GSMA looks forward to continuing to support its members in realising the benefits of the 5G Era and Intelligent Connectivity to the benefit of society as a whole.



Sunil Mittal
Chairman, GSMA
2017/2018

Mats Granryd
Director General, GSMA

Executive Summary

The 5G era is upon us!

The mobile industry has begun the periodic journey to upgrade its infrastructure and services to the next-generation of technologies. This is the story of 5G – an inevitable, next generation technology upgrade that all operators will eventually adopt. It is, thus, a question of 'when' rather than 'if' 5G will become mainstream around the world.

5G is usually discussed from five perspectives:

- First, the technology-focused narrative seeks to showcase the superiority of 5G technology compared to previous generations;
- Second, the focus to pinpoint definitive, yet somewhat elusive, new 5G use cases has almost become a *cause célèbre*;
- Third, the debate on spectrum availability, how it is allocated, to whom, and at what cost is particularly topical in the run up to WRC-19;
- Fourth, there is the political nexus, with talk of '5G races', and simmering debates over patents, security loopholes, trade wars, urban versus rural coverage dichotomy and the competitive advantage of nations;
- Fifth, there is the less headline-grabbing, yet practical task of upgrading the mobile infrastructure with the latest technology (i.e. 5G) based on a sustainable business case. This perspective is often missing from the news and commentary about 5G. But it is the key driver for The 5G Guide – an in-depth reference resource to support operators as they evaluate their plans and timings to sustainably evolve their business to 5G.

The GSMA has developed The 5G Guide, the accompanying Business Case Considerations Model and the Readiness Database for 160 countries, to provide a summary of the economic case for 5G, and to provide support to operators and the industry as they decide how to deliver 5G sustainably.

The guide builds on GSMA's extensive body of knowledge in supporting operators. In that sense, it builds upon every 5G-related paper/report written or commissioned by the GSMA since 2016. This also includes insights from the future megatrends and scenario planning work of the GSMA Strategy Group, the policy positions developed and adopted by the GSMA Policy Group, and the technology strategy frameworks developed by the GSMA Technology Group.

In addition, the guide includes insights from recent interviews with 25 operators, 8 leading telecoms equipment vendors, 30 enterprise companies and a consumer survey of 36,000 respondents in 34 markets. It also integrates the insights from the GSMA global survey of 750 operator CEOs in Q4 2016 which led to the development of the mobile industry's 5G era vision in the 2017 report *"The 5G era: age of boundless connectivity and intelligent automation"*.

The 5G Guide is primarily for operators, especially C-level executives in operators who will take the critical 'when' and 'how' decisions on 5G. It is designed to be used by operators regardless of where they are on their 5G journey – whether they are planning to launch 5G in 2019 or those who need to lay the foundation to launch after 2025. In the guide, operators will also find support for their discussions with policymakers, vendors, customers, industry analysts/consultants and other stakeholders.

The core thrust of the 5G Guide is different to many other 5G reports. Instead of a technology-led narrative that focuses on the constituent 5G technological features and how these may be implemented, the GSMA has used a typical business-focused framework to structure the guide. Hence the book focuses on the timing (readiness) for 5G launch, how 5G will create value for the benefit of all, and how to optimise deployment and operational costs.

There are six chapters (comprising of 41 sections) in the book, and each of these can be read as a standalone guide. Each of the sections also has a 'Key Takeaways' summary at the start. The details of the 6 chapters are as follows:

1. **Introducing the 5G era - five key questions:** The answers to the five questions provides a quick roundup of the most important issues on 5G.
2. **5G Readiness:** As 5G is a question of 'when' and not 'if', this chapter provides clear guidance on what factors influence readiness from a technological, policy and market perspective. The GSMA has developed the accompanying 'BEMECS' 5G Readiness tool which provides 40 Readiness indicators for 160 countries.
3. **5G Value Creation and Capture:** This is the heart and soul of the 5G Guide. It explores the different value segments and opportunities in the 5G era (from the evolutionary to the revolutionary), identifies the value enablers, and highlights six potential business models for operators in the 5G era.
4. **5G Cost Considerations:** Explores how innovations in 5G architecture, capability and ownership will impact the operator business case. The impact of some of these factors (e.g. network coverage) can be clearly assessed. There also will be factors of less clear impact in the 5G era – from the prospect of private networks to AI-based automation that are also assessed.
5. **Business Case Considerations Model:** A hypothetical model that explores the costs and revenue potentials for 8 operator archetypes based on 3 deployment scenarios. The model suggests a capacity-optimisation, evolutionary rollout plan as the optimal option.
6. **Key Messages and Positions:** As a member organisation, the GSMA seeks to highlight the key messages and positions for the industry. Operators can rely on this resource to develop and complement their own perspectives and positions on 5G.

Imagine the future

Headlines from the future

Industrial digitisation and automation drive GDP growth to 5%

Final figures for 2029 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 (01/03/2030)

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 (01/03/2030)

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 after 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 (01/03/2030)

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 (01/03/2030)

A typical day for Mr G in the 5G era

11.46 PM 80%

Mr G wakes up to natural light and the sound of a piano concert playing softly. His automated home has raised his bedroom blinds early to let in the sun as recommended by his doctor. His holographic display projects his calendar for the day on the wall next to his breakfast table for him to see as he eats. It highlights important meetings and adds work items for him to do on his commute. His avatar assistant follows him around as he gets ready for work, telling him the latest news, traffic updates and warning him not to wear that red tie because it wouldn't be appropriate for his dinner date.

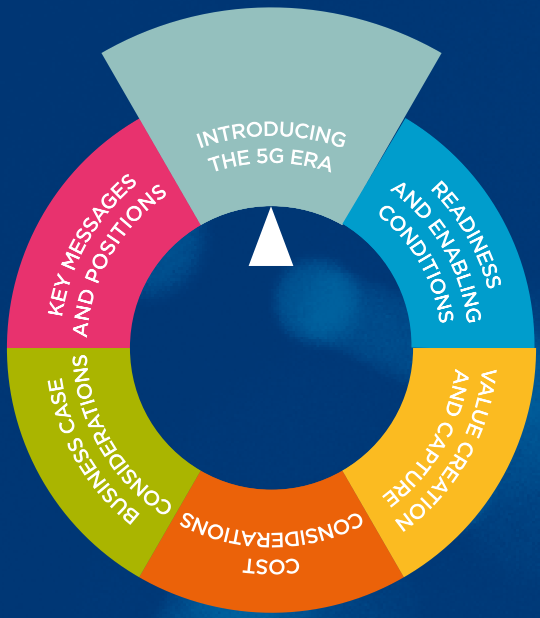
Before he leaves home, his Z-Phone syncs with the cloud to save a local copy of his current working files. It does this over his combined Wi-Fi and 5G Small Cell home gateway. His driverless car notes when he is about to finish his breakfast, and starts warming up in the cold winter morning.

As the car drives off, his avatar provides companionship while he works on his latest presentation. When he needs a new video file, his Z-tablet pulls the 2GB video via 5G in less than 20 seconds and allows him to edit and embed it in his presentation on the fly. As he drives through remote areas, the 5G core network integrates with a satellite backhauled 4G cell to provide a heterogeneous, boundless connectivity experience. His avatar recommends and books a training session at the gym near his office for before lunch.

His day in the office is normal. He is connected to the Bring-Your-Own 5G Small Cell in the office which his Z-Phone prefers over the office Wi-Fi. The hot-desk space recognises him and configures the seat and desk to his own personalised ergonomic settings. The coffee maker 'sees' him as he comes over and says: "Hey, Mr G, same as usual?". As he chats with his colleague over coffee, he projects the presentation he is working on onto the table. His avatar transforms the table into a touch screen.

As evening draws near, Mr G's avatar orders flowers for his date, books the table and checks with the avatar of his date that she would enjoy vegetarian cuisine. His connected fridge had originally scheduled a delivery of groceries for 7pm in the evening, but his avatar rescheduled it for 10pm once his date had confirmed – it will continue to monitor his location and amend the delivery further if necessary. He has a wonderful evening, returns home happy and wonders what life must have been before the 5G era!

His avatar ends the day by sending a message to his doctor detailing his medical signs, showing her that he was very happy and positive today, and that his blood pressure was on average down 5%. His avatar then sends a message to the government's "Office for the Promotion of National Happiness" telling them that Citizen G had a happiness index of 9.5 today.



1 Introducing the 5G Era

Chapter 1 of the 5G Guide addresses five key questions about the introduction of 5G:

- **What is the expectation for the 5G era?**
- **How is 5G different?**
- **Why does 5G matter?**
- **When is 5G coming?**
- **Where is 5G happening?**

Readers will get an insight into the capabilities of 5G and why 5G will fundamentally transform the role of mobile across industry and society.

1.1 What is the expectation for the 5G era?

KEY TAKEAWAYS

- **5G is the next generation mobile technology and will transform the role of mobile in society.**
- **The 5G era will commence in full from 2020, creating huge opportunities for consumers, enterprises, operators, vendors and all stakeholders.**
- **To deliver on its promise, the mobile industry has five clear goals for the 5G era:**
  - **Provide boundless connectivity for all**
  - **Deliver sustainable network economics & innovation**
  - **Transform the mobile broadband experience**
  - **Drive growth in new use cases for massive and critical IoT**
  - **Accelerate the digital transformation of industry verticals**
- **Based on the insights from a survey of 750 CEOs of mobile operators, the GSMA has distilled the top ten industry expectations for the 5G era.**

1.1.1 5G: a network of opportunity

5G represents a fundamental transformation of the role that mobile technology plays in society

5G is more than just an evolutionary step to a new generation of technology; 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.

Deploying 5G 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 to consumers and businesses. 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 users want to live and will 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 (IoT) 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.

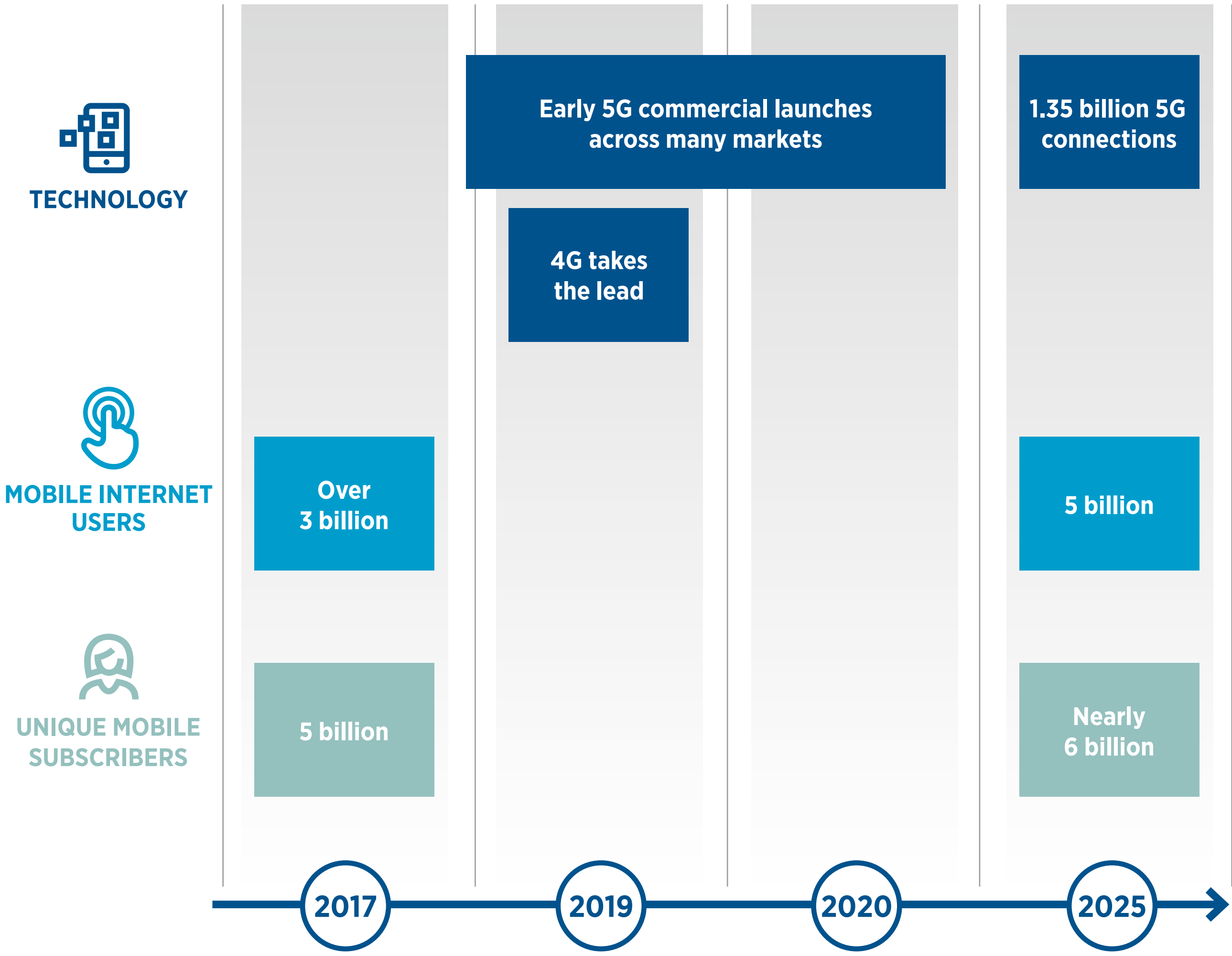
1.1.2 The post-2020 5G era

Commercial 5G networks will be widely deployed in the post-2020 period: the 5G era

Thanks to technology advances in many different fields, 5G networks will be at the centre of an ecosystem that pushes society's continued digital transformation. The mobile industry has demonstrated its ability to connect and transform society through its 2G, 3G and 4G networks over the last 30 years. 5G will build on these successes by delivering a platform that enhances existing services, and enables new business models and use cases. The GSMA expects commercial 5G networks to be widely deployed in the post-2020 period, the 5G era, as outlined in Figure 1.1.1 below.

FIGURE 1.1.1

THE 5G ERA WILL BEGIN FULLY FROM 2020



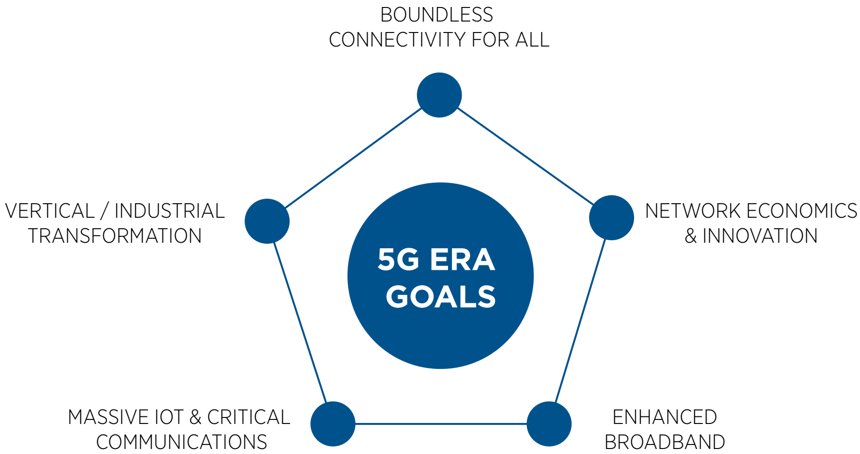
1.1.3 Goals of the 5G era

The mobile industry's five goals for the 5G era align with the industry's purpose for society

Following consultation with 750 operator CEOs in 2016/17[1], and in line with the Mobile Industry's Purpose to "Intelligently Connect Everyone and Everything to a Better Future", the GSMA has identified five mobile industry goals for the 5G era:

FIGURE 1.1.2

MOBILE INDUSTRY GOALS FOR THE 5G ERA



1.1.3.1 Provide boundless connectivity for all

5G networks will coexist 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.

1.1.3.2 Deliver sustainable network economics & innovation

The mobile industry will strive to cost-effectively deliver better quality networks either independently or through sharing and partnerships. 5G era networks will rely on a combination of established and innovative technologies, and use both licensed and unlicensed spectrum, across different spectrum bands.

1.1.3.3 Transform the mobile broadband experience

5G networks will provide an enhanced broadband experience with speeds of up to 1 Gigabit per second and latency of <4 milliseconds, and provide the platform for cloud and artificial intelligence (AI) -based services.

1.1.3.4 Drive growth in new use cases for massive and critical IoT

5G era networks will support the massive rollout of intelligent IoT connections for a multitude of scenarios and provide an enhanced platform to support the widespread adoption of critical communications services.

1.1.3.5 Accelerate the digital transformation of industry verticals

The mobile industry will provide the networks and platforms to accelerate the digitisation and automation of industrial practices and processes (incl. supporting the Industry 4.0 goals).

1. "The 5G era: Age of boundless connectivity and intelligent automation", GSMA, February 2017

1.1.4 Industry expectations for the 5G era

The operator community is clear on its expectations for the 5G era

The GSMA has been engaging with its members since 2016 to help focus the wider debate on 5G and align its members around a core set of expectations for the 5G era. The expectations, outlined after the engagement with operator CEOs, and other senior managers, in 2016/17 is distilled into key insights for the 5G era as shown in Table 1.1.1

These ten insights illustrate both the concerns that 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.

TABLE 1.1.1

TOP 10 EXPECTATIONS FOR THE 5G ERA

Basics	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.
Opportunity	3	Enterprise services and solutions will drive 5G's incremental revenue 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 at least a 2.5% CAGR in the early period of the 5G era.
Market Structure	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.
Sustainability	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 should be supported as default in the 5G era.

1.2 How is 5G different?

KEY TAKEAWAYS

- **As an evolutionary technology, 5G will do all the things that 4G can do; and it will do it even better.**
- **But 4G is not going away just yet. It will coexist with 5G well into the 2030s and together they will be the bedrock of next generation mobile networks.**
- **The definitive 5G design goals (IMT-2020) defines a set of specifications that will deliver new capabilities and possibilities beyond what 4G can deliver.**
- **5G's superior throughput (speed), latency, device density, flexibility, heterogeneity and energy efficiency will support a plethora of existing and new use cases.**
- **These new or improved capabilities will provide additional opportunities for operators to develop new use cases for niche segments within industry verticals.**

1.2.1 5G design specifications

The IMT-2020 goals steer 5G design

5G is a global and multi-stakeholder technology development with a range of design goals. Diverse stakeholders within and across different countries and regions have been working hard since 2012 to define and shape what 5G should become. However, the IMT-2020 requirements in Table 1.2.1, proposed by the International Telecommunications Union Radiocommunications Sector (ITU-R), are the definitive 5G design goals[2].

TABLE 1.2.1

IMT-2020 5G REQUIREMENTS (SOURCE: ITU-R)

Requirement		Value
Data rate	Peak	Downlink: 20Gb/s Uplink: 10Gb/s
	User experience	Downlink: 100Mb/s Uplink: 50Mb/s
Spectral efficiency	Peak	Downlink: 30 bit/s/Hz Uplink: 15 bit/s/Hz
	5th percentile user	Downlink: 0.12-0.3 bit/s/Hz Uplink: 0.045-0.21 bit/s/Hz
	Average	Downlink: 3.3-9 bit/s/Hz Uplink: 1.6-6.75 bit/s/Hz
Area traffic capacity		10 Mbit/s/m2
Latency	User plane	1ms-4ms
	Control plane	20ms
Connection density		1,000,000 devices per km2
Energy efficiency		Loaded: see average spectral efficiency No data: Sleep ratio
Reliability		This is 1-10^(-5) success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1ms
Mobility		0km/hr-500km/hr
Mobility interruption time		0ms
Bandwidth		100MHz

2. https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx

1.2.2 Comparison with 4G

5G will provide a superior experience to end users

5G networks will provide between 10-times and 100-times faster data rates, at latencies of up to 10 times smaller when compared to current 4G networks. This improved performance will come from a more advanced core network and by using more efficient radio technologies (i.e. spectral efficiency), using more spectrum bandwidth (i.e. spectral capacity) and more network densification (i.e. spectral reuse).

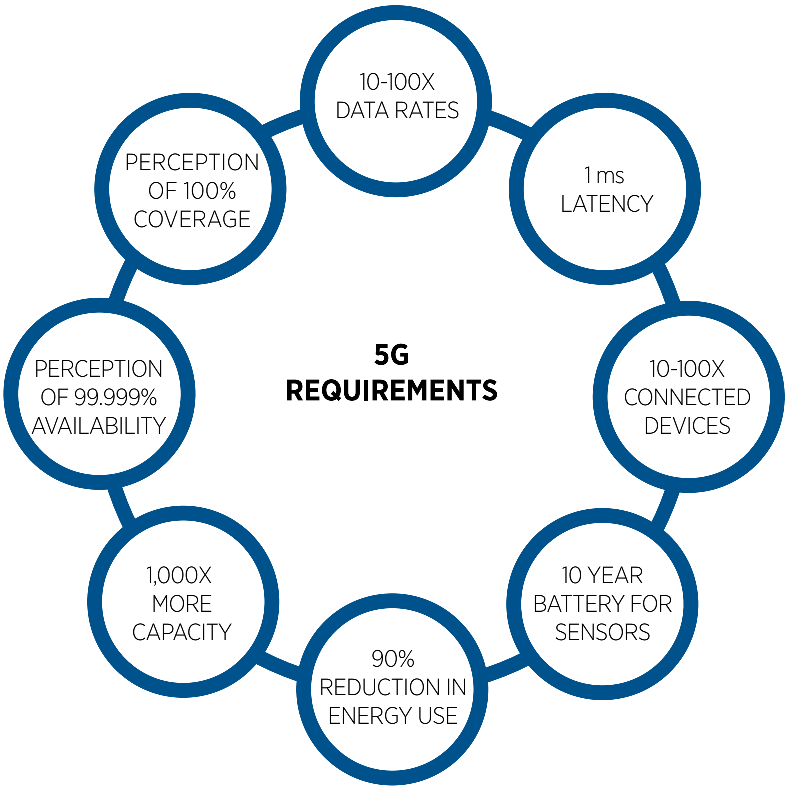
A superior experience from 5G will not only enhance the experience for existing users and use cases: it looks set to unlock new, currently unimaginable, possibilities.

As a comparison, consider the step-change in performance as 4G replaced 3G networks. This unleashed a wave of innovation across society, bringing to life real-time messaging (e.g. Line, WeChat, WhatsApp), the sharing economy (e.g. Airbnb, Didi, Uber), streaming services (e.g. Deezer, Netflix, Spotify) and a raft of services that make use of the enhanced 4G capabilities (e.g. always on, IP centric design, location).

Figure 1.2.1 summarises the comparison of 5G with 4G.

FIGURE 1.2.1

THE 5G ADVANTAGE AND COMPARISONS WITH 4G



1.2.3 Coexistence with 4G

5G and 4G networks will coexist well into the 2030s

While 5G offers superior performance over 4G, both will coexist comfortably into the 2030s as the bedrock of next generation mobile networks. There are three perspectives that help to underline this point.

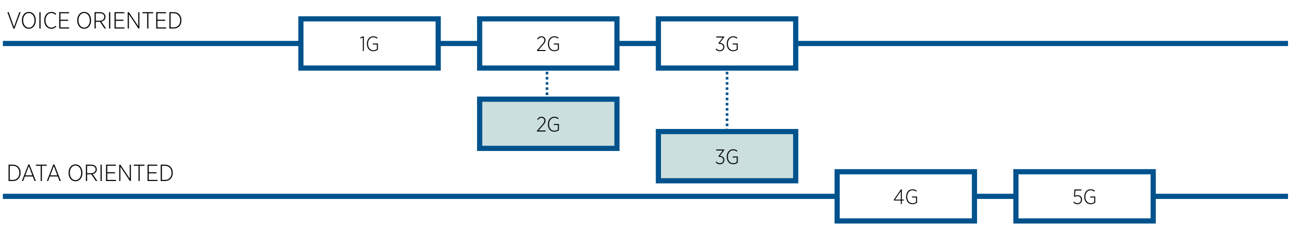
Firstly, unlike voice-oriented 2G and 3G (which were primarily circuit-switched networks with varying attempts to accommodate packet-switching principles), 4G is a fully packet-switched network optimised for data services. 5G builds on this packet-switching capability as is shown in Figure 1.2.3. Therefore, 4G and 5G networks can coexist for a long while because the transition from 4G to 5G does not imply or require a paradigm shift in the philosophy of the underlying technology.

Secondly, as the parallels with fibre rollout for fixed broadband show, Fibre-To-The-Home/Premises (FTTH/P) coexists with variations of copper-based Digital Subscriber Lines (DSL) and customer migration to the superior FTTH system is a long term, multi-decade project. In many markets, 5G coverage will be less than complete for at least a decade until the late 2020s and users will continue to rely on the 4G network for 5G non-spots (see Section 1.4.5 for forecasts).

Thirdly, given the absence of a philosophical paradigm shift, it was always envisioned that 4G is a futuristic project; hence the acronym LTE (Long Term Evolution), a registered trademark of the European Telecommunications Standards Institute (ETSI). As the first fully packet-based mobile network technology, LTE laid the foundation for future iterations of packet-based mobile networks.

FIGURE 1.2.3

4G AND 5G ARE BASED ON THE SAME TECHNOLOGY PHILOSOPHY



1.2.4 5G latency & speed

Faster speed and lower latency will define the 5G era customer experience

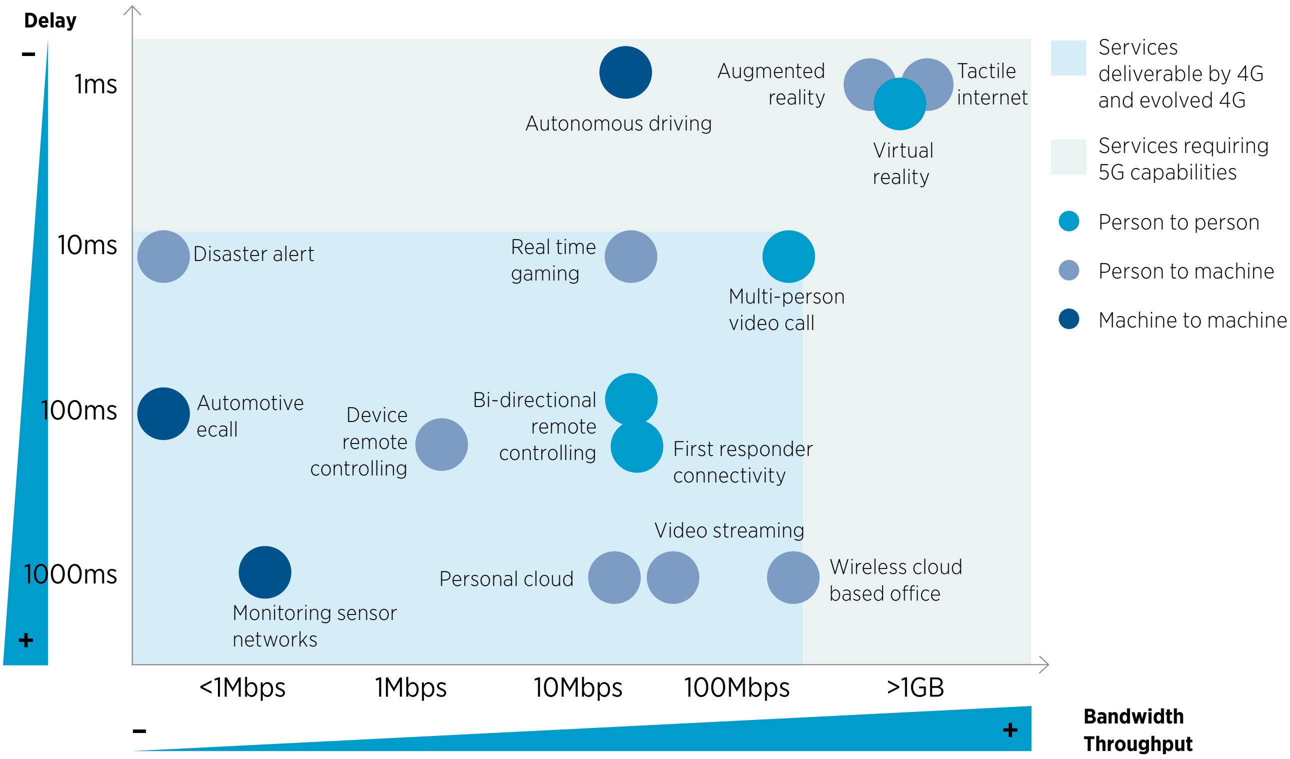
5G will provide much higher data throughput, enabling a significantly better customer experience. Most of the headlines, marketing pitches and even official targets, will be based on the faster speeds delivered by 5G networks.

Faster speeds, however, are not the only determinant of overall customer experience[3]. In particular, the reduction in latency (delay) for data's transit across the 5G networks and to end users will play a major role in unlocking new use cases in the 5G era. The Tactile Internet and Immersive Communications services are examples of use cases that will benefit from 5G's lower latency capabilities, as outlined in Figure 1.2.4.

While the headline speed and latency will be regularly promoted, what will matter most for 5G era services is the consistency in achieving the claimed service performance. For example, suppose tactile internet can work with 10ms latency, this can be achieved in modern 4G networks, however only on a few occasions and in ideal scenarios. In contrast, 5G networks should be able to meet the same performance levels most of the times.

FIGURE 1.2.4

5G WILL SUPPORT LOW LATENCY AND HIGH THROUGHPUT SERVICES



3. https://www.econstor.eu/bitstream/10419/148707/1/Stocker-Whalley.pdf

1.2.5 5G and heterogeneous networks

A flexible framework, and modularised design puts 5G at the centre of the heterogeneous network

5G networks will utilise and integrate a mixture of spectrum and access networks to meet customers' capacity and coverage needs. This possibility puts 5G at the centre of the heterogeneous network (HetNet) in a way that has not been feasible with previous generations.

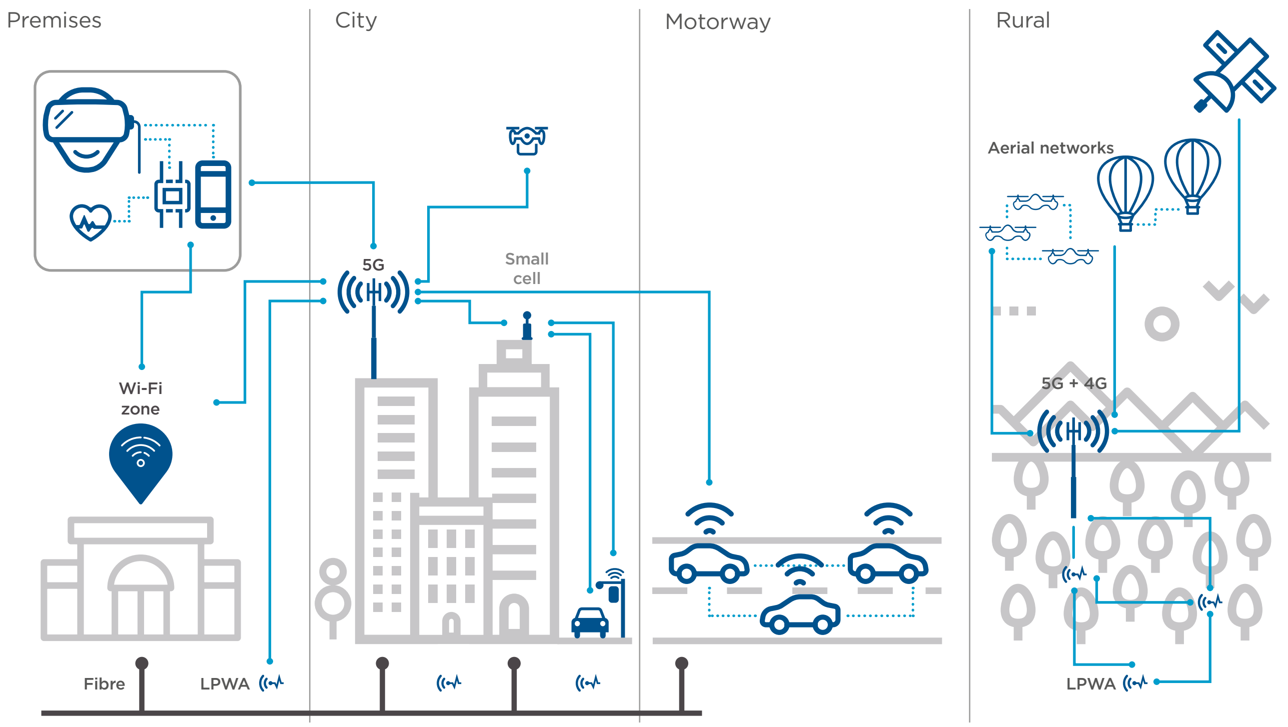
This new role at the centre of the HetNet is because, unlike previous generations, 5G networks have been designed from inception to be multi-access. For example, the 5G core network can be accessed by the 5G New Radio, 4G, Wi-Fi or the fixed broadband network. At the radio level, several 5G deployment options envisage that 5G will work with 4G.

It also follows that, by design, 5G networks will be flexible and modular, with technologies such as Network Slicing; Software Defined Networks (SDN); Network Function Virtualisation (NFV); and Cloud Radio Access Network (Cloud RAN). A flexible architecture makes it feasible to increase overall network capacity by adding small cells to complement macro networks. In addition, completing the standardisation of APIs towards underlying infrastructure will be key for automated connectivity to hetnets. These are discussed in detail in Section 4.4 on Network Flexibility.

A 5G HetNet provides several benefits. First, it makes it possible to add 5G hotspots or small cells to an existing 4G network to increase capacity. This is likely to be the early deployment scenario for 5G and is explored in detail in Chapter 5. Second, a 5G HetNet can synergistically incorporate Wi-Fi offload and Fixed Mobile Convergence, bringing these into play as network operations and management options.

FIGURE 1.2.5

5G IS AT THE CENTRE OF THE HETEROGENEOUS NETWORK OF THE FUTURE



1.2.6 5G and Intelligent Connectivity

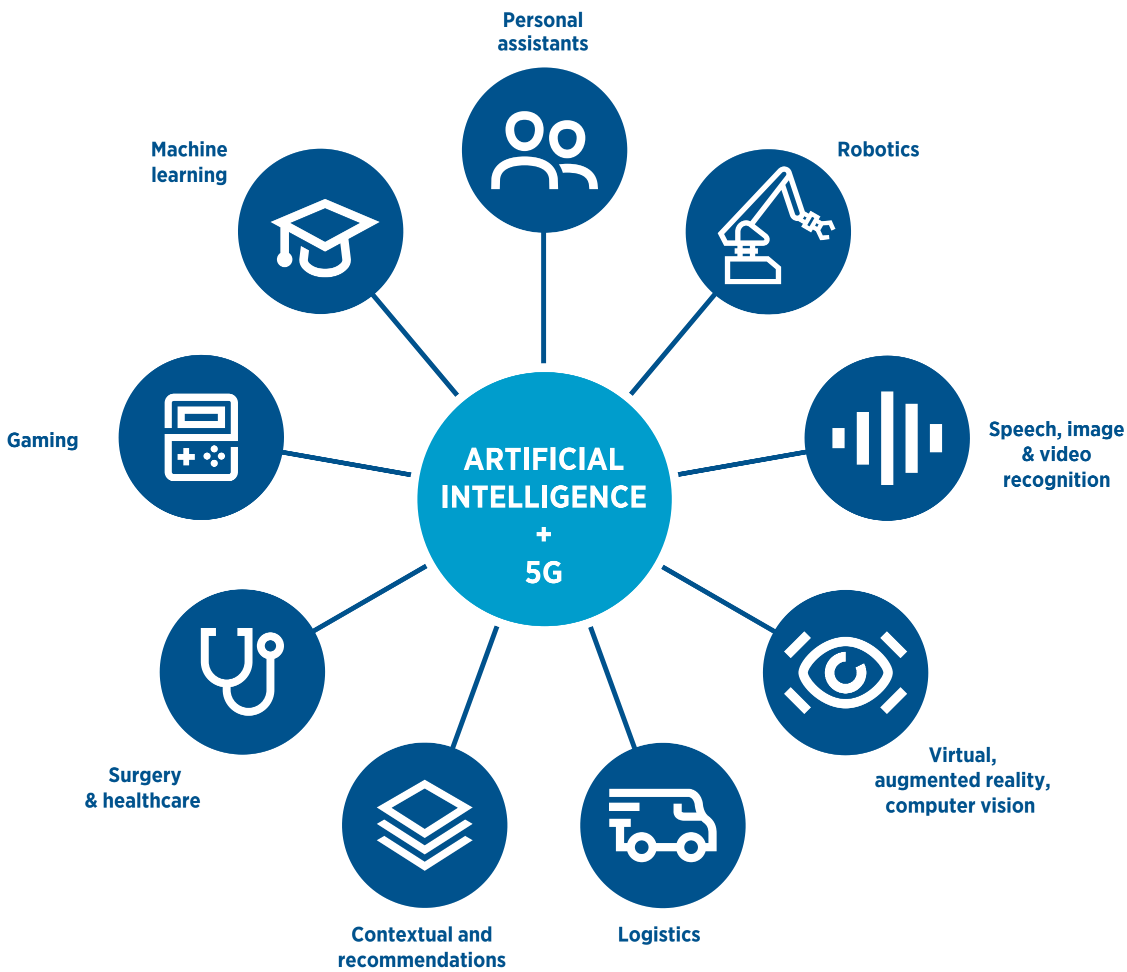
The combination of 5G, AI and IoT will usher in a new age of Intelligent Connectivity

5G is developing in parallel with rapid advancements in AI and IoT. The combination of flexible, high-speed 5G networks with AI and IoT will underpin the new age of Intelligent Connectivity.[4]

Figure 1.2.6 illustrates the central role that 5G and AI will play in powering the intelligent connectivity era. This era will be defined by highly contextualised and personalised experiences, delivered on demand. It will have a significant and positive impact on individuals, industries, society and the economy, transforming the way people live and work.

FIGURE 1.2.6

5G AND INTELLIGENT CONNECTIVITY



4. https://www.gsma.com/IC/wp-content/uploads/2018/09/21494-MWC-Americas-report.pdf

1.2.7 5G use cases

5G will empower operators to target niche opportunities without undermining the mass market proposition

5G will support a plethora of new use cases, in addition to evolving the current use cases supported by previous mobile generations. The business opportunities for operators that will be supported in the 5G era are enhanced along both product and customer dimensions, as illustrated in Figure 1.2.7.

Firstly, operators will evolve their current business while tapping into new opportunities that have been enabled by a more efficient technological framework. The evolutionary consideration is crucial to ensure that customers continue to enjoy the services that they do today. The lesson from the 4G era is that the delay in standardising and rolling out voice over LTE (VoLTE) undermined operators' voice market share. For 5G, the final version of the user-network-interface (UNI) profile for voice over 5G is being finalised.

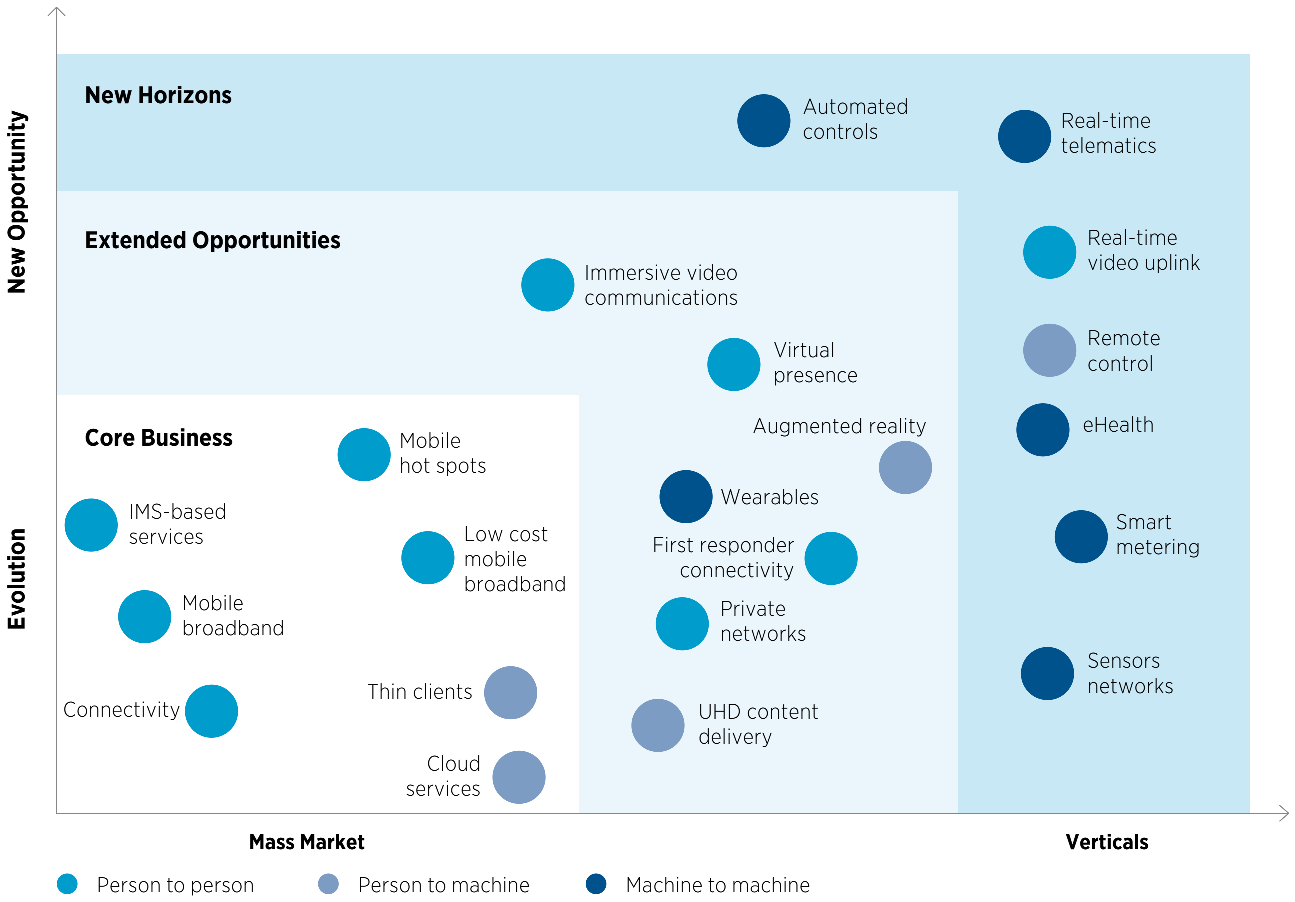
Secondly, while operators have historically focused on use cases that appeal to the mass market, new capabilities will provide additional opportunities for operators to develop new use cases for specific segments within industry verticals.

Some of these opportunities can be addressed by evolving the 4G network. However, as explored in the *Unlocking Commercial Opportunities from 4G Evolution to 5G* paper[5], these opportunities will come to full fruition in a mature 5G system.

The GSMA is creating a *"5G Resolution Centre"*, to provide an online repository of issues that GSMA members have come across while testing and launching 5G Era networks and services, and the solutions to the issues raised.

FIGURE 1.2.7

5G WILL SUPPORT EXISTING AND NEW PRODUCTS AND MARKETS (NOT EXHAUSTIVE)



5. https://www.gsma.com/futurenetworks/4g-evolution/gsma-unlocking-commercial-opportunities-4g-evolution-5g/

1.3 Why does 5G matter?

KEY TAKEAWAYS

- **5G matters because it is a necessary upgrade of the biggest consumer technology that is used by over 5 billion users globally.**
- **The mobile industry contributes immensely to society. GSMA estimates that this was worth $3.9 trillion to the global economy in 2018 alone.**
- **As the latest and most capable mobile network, 5G will underpin the growth of the digital economy in many countries.**
- **In particular, 5G alone is forecast to create $2.2 trillion of economic value by 2034.**

1.3.1 The importance of mobile

5G is a necessary upgrade of the biggest consumer technology

With more than 5 billion unique mobile users at the end of 2018, mobile has a greater reach than any other technology, and is thus the most important consumer technology product today. In that sense, 5G is a necessary upgrade to the mobile product, ensuring that it continues to remain relevant to consumers, enterprises, governments and society in general.

The importance of mobile, and its centrality to daily life, will become even more profound in the 5G era as more and more of society's services are digitised and accessible via the mobile platform.

1.3.2 Economic value created by 5G

5G will create $2.2 trillion of economic value by 2034

The mobile ecosystem created $1.1 trillion in economic value in 2018, while additional indirect and productivity benefits brought the total contribution of the mobile industry to $3.9 trillion (4.6% of total global GDP).

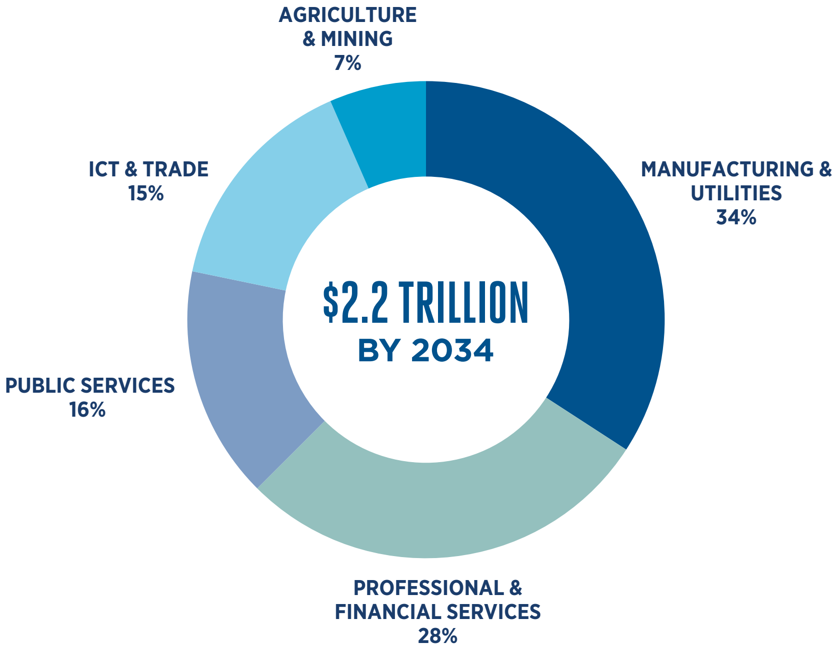
Mobile operators account for more than 60% of the economic value created by the mobile ecosystem. The rest, including infrastructure providers; retailers and distributors of mobile products and services; mobile device manufacturers; and mobile content, application and service providers, contribute the remaining 40%.

The direct economic contribution to GDP of the mobile ecosystem is estimated by measuring their value added to the economy, including employee compensation, business operating surplus and taxes. Most of the value-added increase will be due to productivity gains. In the developed world, the adoption of IoT solutions will drive increased productivity. In developing countries, productivity growth will be mostly driven by the adoption of mobile internet services.

Looking further ahead, 5G alone is forecast to contribute $2.2 trillion to the global economy over the next 15 years[6].

FIGURE 1.3.1

CONTRIBUTION OF 5G TO THE GLOBAL ECONOMY (SOURCE: GSMA INTELLIGENCE)



6. For more information, see the GSMA report 'Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands'

1.3.3 5G as a Digital Economy enabler

5G is the next-generation enabler of the Digital Economy

It is universally accepted that a high-speed, reliable and robust network infrastructure is a critical requirement for the growth of the digital economy.[7] From shopping to entertainment, socialising to managing the household (and household finances) the digital economy has fundamentally altered human behaviour. Users have been, and remain, ever ready to embrace and integrate new digital tools in their daily lives.

As the latest and most capable mobile network, 5G will underpin the growth of the digital economy in many countries. This explains a lot of the government-backed activities around the world that seek to influence or accelerate the pace of 5G deployment and commercialisation.

Figure 1.3.2 identifies the key enablers of the digital economy in the 5G era.

FIGURE 1.3.2

KEY ENABLERS OF THE DIGITAL ECONOMY IN THE 5G ERA (SOURCE: BCG, GSMA)

7. https://www.gsma.com/publicpolicy/embracing-the-digital-revolution-policies-for-building-the-digital-economy

1.4 When is 5G coming?

KEY TAKEAWAYS

- **The first 5G networks were rolled out in 2018, kicking off the 5G era globally.**
- **However, the standardisation roadmap from 3GPP sets the schedule on when different parts of the technology will be ready for deployment.**
- **Thanks to earlier adoption in China, adoption of 5G will be faster than 4G. GSMA Intelligence forecasts that there will be a total of 1.35 billion 5G connections by 2025.**
- **But the 5G journey is a marathon and not a sprint. It will take at least 7 years and 5 3GPP releases to reach 10% of total global connections by 2024.**
- **As adoption grows, 5G revenues will grow, reaching $1.15 trillion by 2025.**

1.4.1 Standardisation roadmap

Accelerated agreement of 3GPP specifications

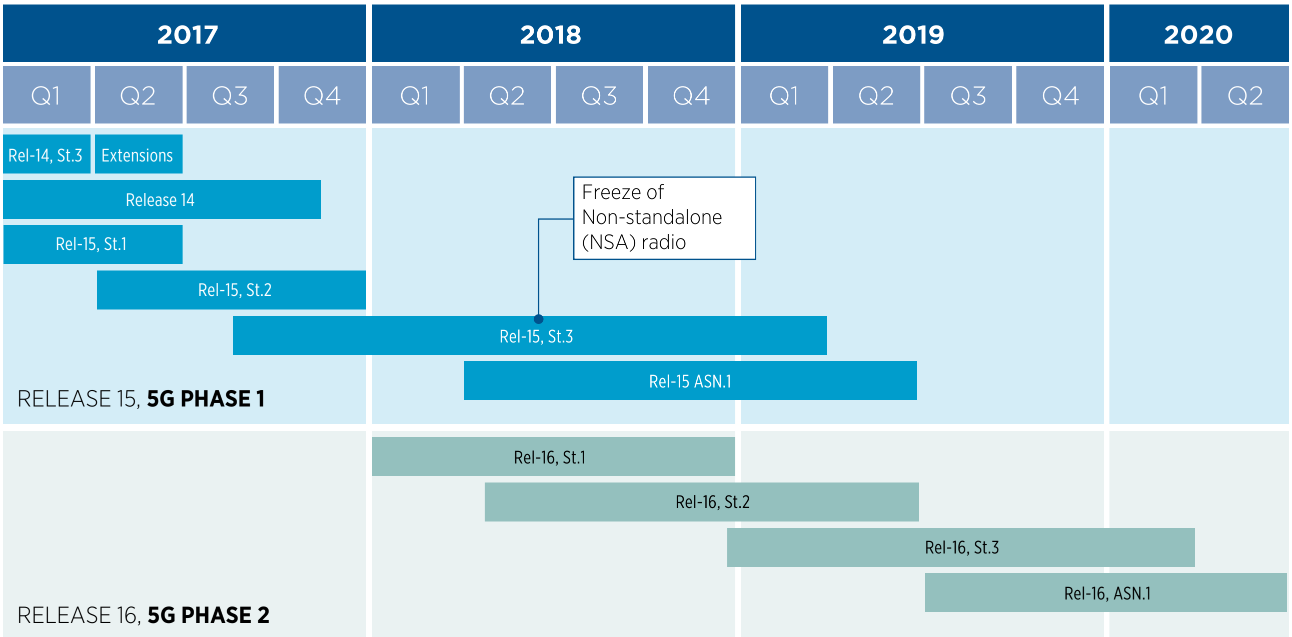
The accelerated schedule agreed to by the 3rd Generation Partnership Project (3GPP) in 2017 allowed many operators around the globe to bring forward their 5G commercial launch plans. Non-standalone 5G new radio (NSA 5G NR) specifications were officially approved in December 2017, while the standalone (SA) version was approved in June 2018, which represented the full 3GPP Release 15.

The relatively rapid agreement of 5G specifications has allowed hardware manufacturers, chip makers and other suppliers to progress their tests further, and to build and design components that implement the 5G NR specifications, while awaiting final standardisation across all NSA and SA models.

The focus of future 5G specifications will be for other use cases including, for example, industrial IoT use cases such as robotics and telepresence systems. This covers 3GPP Release 16 for ultra-reliable and low-latency communications (URLLC), with the goal that this should be completed by December 2019. Figure 1.4.1 shows the 3GPP 5G roadmap for Release 15 and 16.

FIGURE 1.4.1

THE 3GPP ROADMAP FOR RELEASE 15 AND 16



5G Phase 1
- New Radio access
- New core network (Service based Architecture for CP)
- SA scenario 2, NSA scenario 3
- Cloud native RAN
- Scenarios 4 and 7

5G Phase 2
- Radio enhancements
- Service based Architecture enhancements
- Trusted non-3GPP access
- Better network slicing
- Ultra Reliable Low Latency services

1.4.2 5G connections forecast

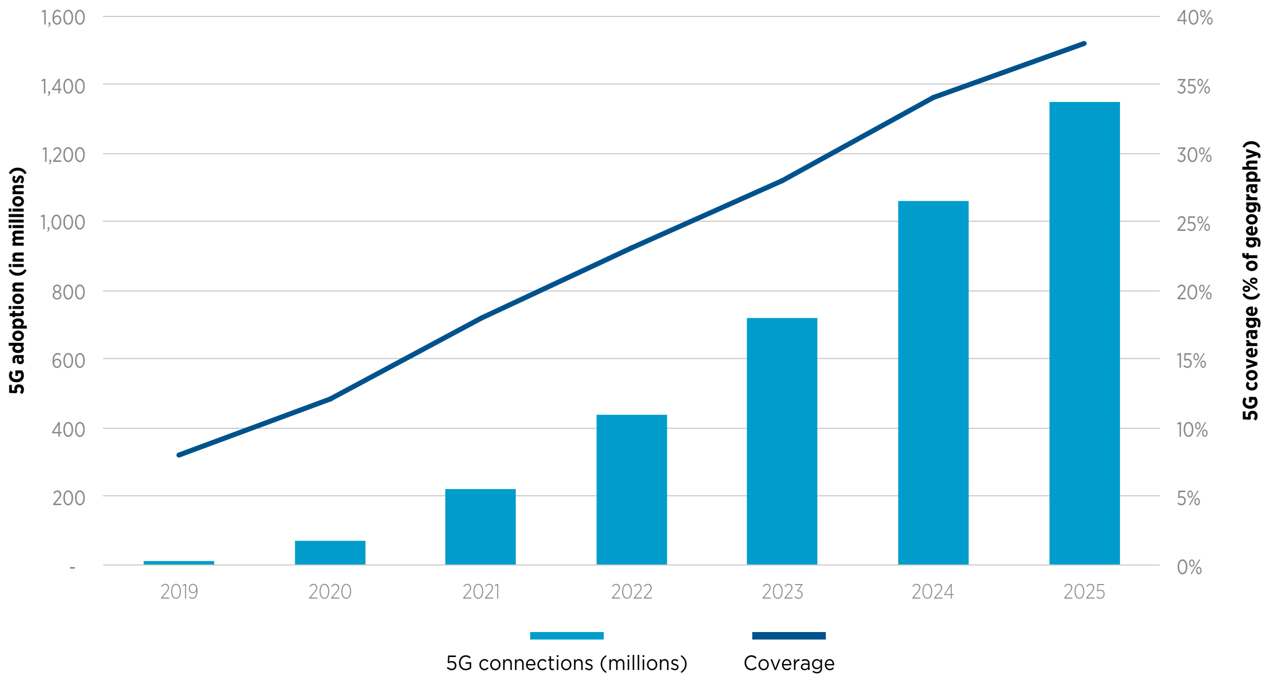
There will be 1.35 billion 5G connections by 2025

GSMA Intelligence (GSMAi) forecasts rapid 5G adoption rates after the initial launches in 2019. Total 5G connections will pass the 1 billion mark by the end of 2024 and reach around 1.35 billion by the end of the forecast period in 2025. At this point, 5G connections will account for close to 15% of the total mobile connections.

This does not include Internet of Things (IoT) connections. Separately, GSMAi forecasts 1.9 billion licensed cellular low power wide area connections by 2025, setting the base for Massive IoT, as both Long Term Evolution for Machines (LTE-M) and Narrow Band IoT (NB-IoT) have a long-term status of 5G standards.

FIGURE 1.4.2

COVERAGE AND ADOPTION FOR 5G (SOURCE: GSMA INTELLIGENCE)



1.4.3 5G vs 4G connections growth

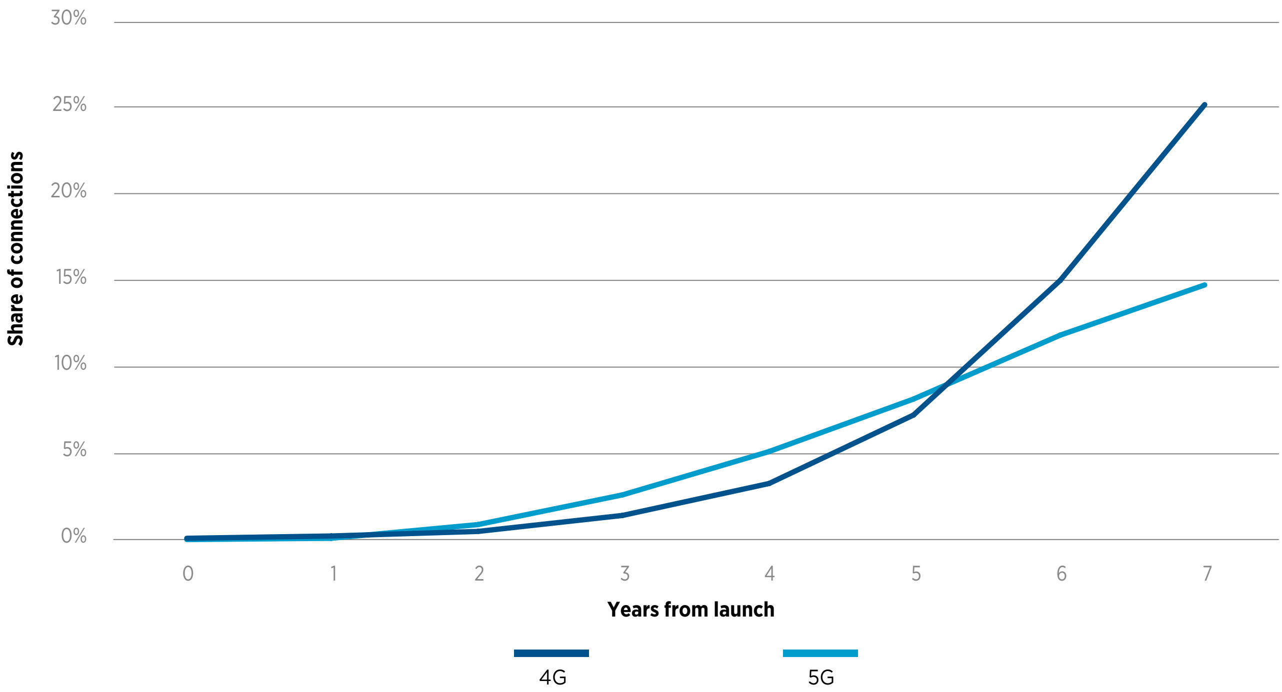
5G connections will grow faster than 4G because of earlier adoption in China

GSMAi forecasts a faster rate of 5G adoption compared to 4G in the first five years post launch. This is primarily due to China's earlier launch and adoption of 5G compared to 4G. Also factors such as lower-cost devices and a rise in non-smartphone connections will boost growth.

However, as coverage begins to reach the limits of major urban areas, GSMAi forecasts a slight slowdown in the rate of adoption compared to 4G, as shown in years six and seven of Figure 1.4.3 below. This reflects the challenges to 5G network densification needed for rural (assuming 5G is deployed on the high frequency bands - 3.5GHz and mmWave).

FIGURE 1.4.3

ADOPTION OF 5G VS 4G (SOURCE: GSMA INTELLIGENCE)



1.4.4 5G Journey as a marathon

The 5G race is a marathon whose full impact will be felt by 2024

Market commentary suggests that there is a race to 5G and announcements about being 'first' abound. However, history suggests the 5G race will be a marathon, not a sprint. Figure 1.4.4 shows that 3G and 4G both took a minimum of seven years and five 3GPP releases to reach 10% global market share, and 5G will only exceed the globally significant 10% mark by 2024.

In this context, announcements and plans within the industry need a level of realism and maturity to ensure that in the race to be first to 5G, due consideration is given to the business case and the sustainability of 5G era systems.

FIGURE 1.4.4

REACHING THE 10% MARKET SHARE MILESTONE – 3G, 4G AND 5G

8 YEARS

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
% total connections	0%	0%	0%	1%	2%	3%	5%	8%	10%	13%
3GPP Release	99	4	5		6			7	8	9
Main development	UMTS	All-IPcore	HSDPA		HSUPA			HSPA +	LTE	LTE Small Cell

7 YEARS

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
% total connections	0%	0%	0%	0%	1%	3%	7%	15%	25%	31%
3GPP Release	8	9		10	11			12	13	14
Main development	LTE	LTE Small Cell		LTE Advanced	CoMP			Carrier Aggregation	LTE Advanced Pro	Mission Critical Services

7 YEARS

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
% total connections	0%	0%	0%	1%	3%	5%	8%	12%	15%	20%
3GPP Release	15									
Main development	5G									

1.4.5 Replacement of legacy networks

It is a matter of when, not if, for 5G to replace legacy 2G/3G/4G networks

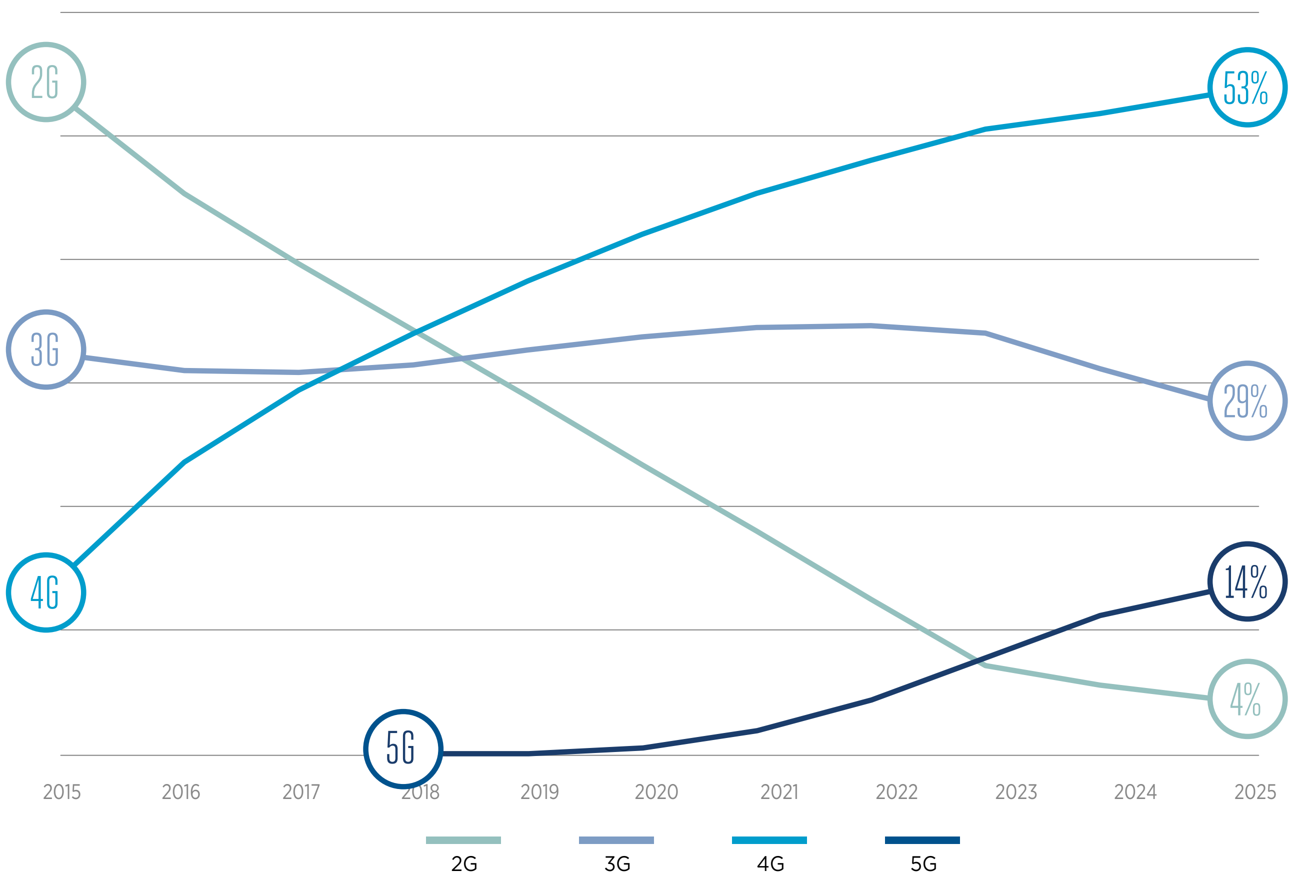
The mobile industry is committed to 5G and, eventually, legacy 2G/3G/4G networks will be replaced by 5G era networks. This is applicable to players in mature 4G markets that launch 5G in 2019, and also players in markets where 2G/3G are the majority of their connections.

5G connections will grow from the initial launches in early 2019 to reach around 15% of the global connection base by 2025. However, this headline figure masks significant variations at the country level: some of the early adopters will see adoption rates close to 50% by this date. These higher levels of adoption (and implicitly higher levels of 5G coverage) will give operators in these leading markets greater flexibility to consider turning off legacy networks on a more accelerated timeline when the commercial case allows.

Technology neutrality has been used to enable operators to refarm their existing spectrum assignments for use with newer technologies. Expectedly 2G and/or 3G networks will be the first to be replaced by 4G depending on the legacy network usage, and this has already happened in several markets. By 2025, GSMAi forecasts that only 4% of connections will still be on 2G, with 3G also tending towards extinction. 4G networks will exist well into the 2030s before they will ultimately be replaced.

FIGURE 1.4.5

MARKET SHARES BY 2025 – 2G, 3G, 4G AND 5G (SOURCE: GSMA INTELLIGENCE)



1.4.6 5G era revenues forecast

5G revenues will reach $1.15 trillion by 2025

While mobile revenue growth has slowed over the past five years, GSMAi forecast continued single-digit growth to 2025, at a global CAGR of 1.5%. Growth will be sustained through connecting more unique subscribers as additional unconnected people adopt to mobile services and populations grow.

Furthermore, operators will actively pursue new business models to improve data monetisation and seek to unlock the enterprise opportunity. There is a potential upside to these forecasts if operators capture more of the growth opportunities in areas such as IoT and digital identity, which could increase annual revenue growth to 5% during the 5G era.

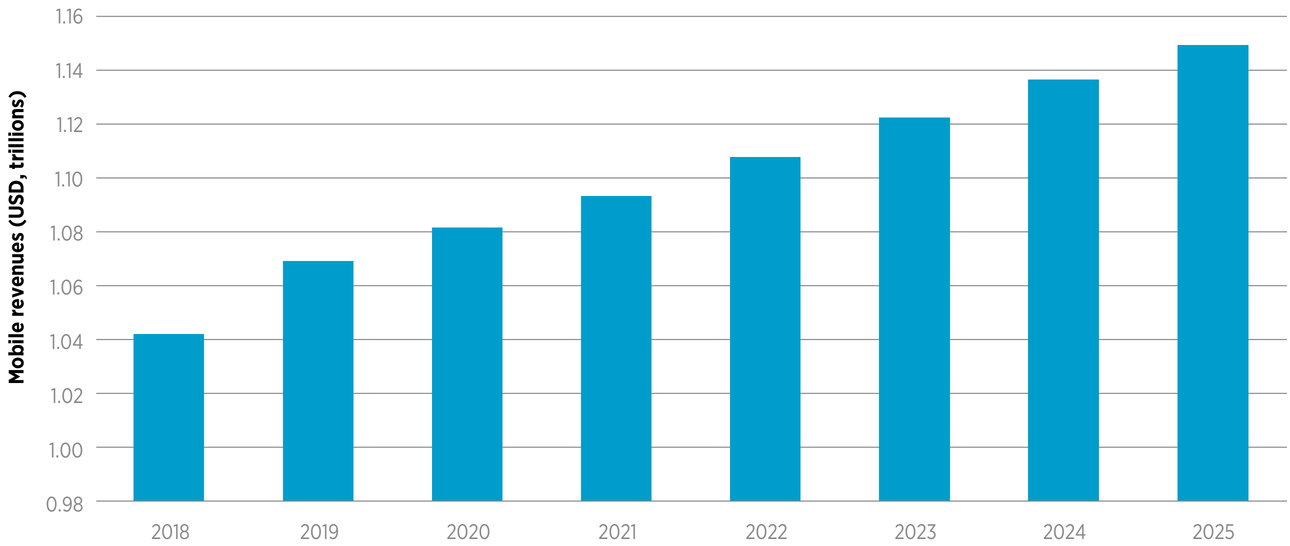
A number of operators in the most developed markets are upgrading their 4G networks to faster speeds and lower latencies, while 5G investments are still in their infancy and focused on trial deployments. In developing countries, many operators are still investing in increasing the coverage and capacity of existing 3G and 4G networks.

The level of 5G investment required will depend on a number of factors, including the model (SA, NSA or phased approach) selected for 5G network deployments; the targeted network coverage; the range of spectrum bands in use; and the availability of fibre infrastructure and nationwide LTE networks.

The Cost Considerations chapter of this book goes into more detail, exploring the different cost drivers that will shape 5G rollout and analysing their potential known and unknown impacts on operators.

FIGURE 1.4.6

MOBILE REVENUE FORECAST (SOURCE: GSMA INTELLIGENCE)



1.5 Where is 5G happening?

KEY TAKEAWAYS

- **There is growing momentum around 5G, with over 120 operators globally undertaking 5G trials, and over 70 announced plans for commercial launches.**
- **The US and South Korea kicked off the 5G era with 5G service launches in the fourth quarter of 2018.**
- **By 2025, GSMA Intelligence forecasts that 5G will account for 50% of connections in the US while China will have the highest absolute number of 5G connections (450m).**
- **The launch of commercial Mobile IoT (NB-IoT and LTE-M) networks has established the foundation for 5G Massive IoT.**
- **Commercial licensed LPWA networks were available in 40 markets as of the end of November 2018.**

1.5.1 5G trials and commercial launches

Accelerating 5G momentum in developed markets

There is growing momentum around 5G, with over 120 operators globally undertaking 5G trials, and over 70 announced plans for commercial launches. Device and network infrastructure vendors have also been active in announcements to highlight their 5G readiness, supporting operators in their trials and with the first 5G handsets already now slated for launch in 2019.

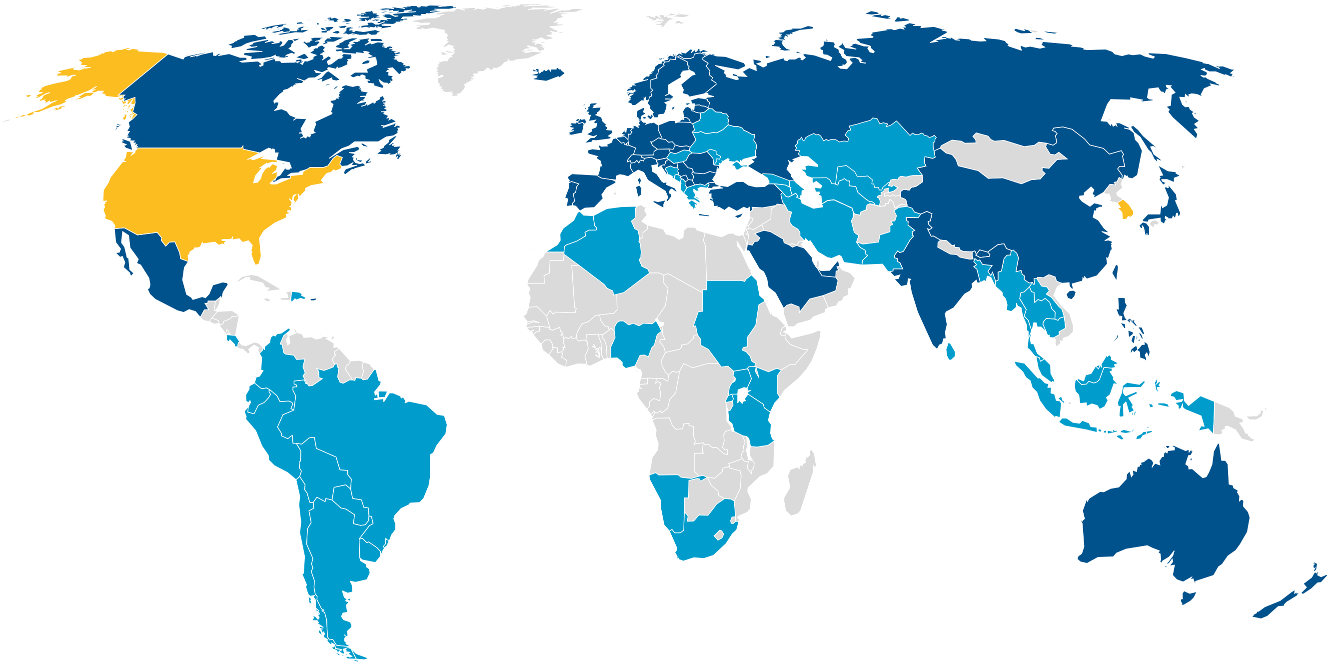
Approximately 40% of the mobile operators worldwide that have announced 5G commercial network plans will launch in 2019 (with the Middle East the earliest hive of activity), and the remaining 60% plan to launch in 2020 or later, once NR standards are commercially available.

Meanwhile, launch of commercial Mobile IoT (NB-IoT and LTE-M) networks has established the foundation for Massive IoT. Commercial licensed LPWA networks were available in 40 markets as of the end of November 2018, and their global availability will increase further and be supported via global roaming agreements during 2019.

Figure 1.5.1 shows GSMAi's projected number of countries that will launch 5G by 2020 and 2025.

FIGURE 1.5.1

PROJECTED PLANS FOR 5G LAUNCHES PER COUNTRY (SOURCE: GSMA INTELLIGENCE)



BY 2018 BY 2020 BY 2025

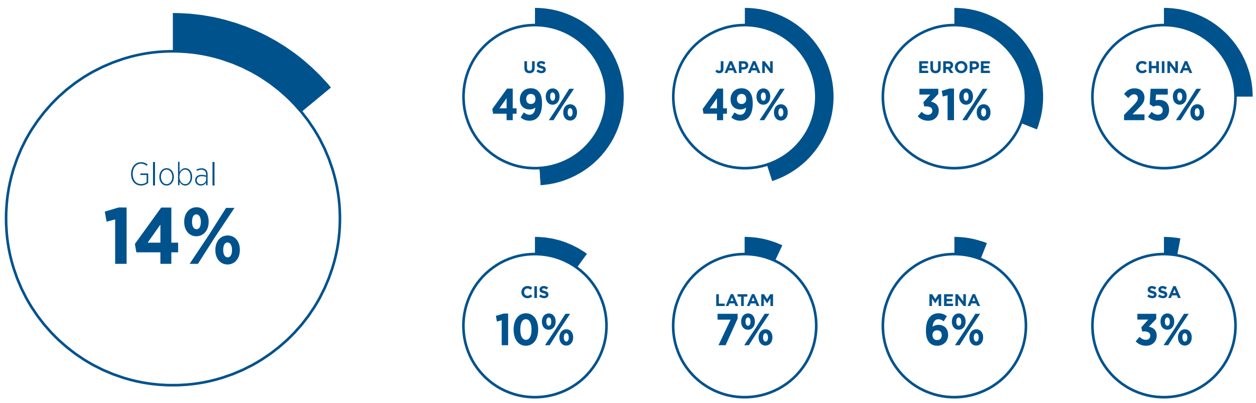
1.5.2 Regional/Country 5G forecasts

Wide variations in 5G adoption

GSMAi forecasts significant regional variances in 5G adoption. This is driven primarily by the readiness of local markets for 5G, as well as the desire of both operators and governments in each region to be seen as leaders in the 5G era. The GSMA provides deeper coverage of 5G developments in the regional 5G reports and the Mobile Economy reports.

FIGURE 1.5.2

REGIONAL 5G ADOPTIONS BY 2025, EXCLUDING IOT AND FWA CONNECTIONS (SOURCE: GSMA INTELLIGENCE)



(2025, percentage of connections excluding cellular IoT)

1.5.2.1 US: leading in 5G adoption

North America, and specifically the US, will have the highest rate of 5G adoption, driven by early launches and the propensity of domestic consumers to rapidly adopt new technologies. By 2025, GSMAi forecasts 202 million 5G connections (predominantly smartphones) in North America, amounting to almost half of the mobile connections.

US mobile operators are targeting a phased approach to 5G network deployments, beginning with an NSA architecture, where 4G and 5G radio access technologies will be used in tandem. The provision of enhanced mobile broadband to the consumer market will be the core proposition in early 5G deployments in the US, with massive IoT and ultra-reliable, low-latency communications gaining scale at a later stage.

5G-based fixed wireless, as well as 5G-based services targeted at the enterprise sector, represent major opportunities for incremental operator revenue in the US. 5G offers a potentially lower cost and faster means – compared to FTTH – of expanding high-speed offerings to households and businesses in some areas. US operators are already working with other tech players and industrial companies to bridge ICT and vertical industries, and establish new solutions that can be initially tested and implemented on 4G networks with a view to exploiting enhanced 5G capabilities in the future.

1.5.2.2 Japan: accelerating 5G deployment

Japan will closely follow the US on adoption, with forecasts of around 49% of connections being 5G by 2025, for a total of 95 million connections. Operators in the country have accelerated their deployment plans in recent months, with indications of limited commercial service in 2019 including a range of services during the Rugby World Cup running from September to November. This would represent an acceleration of previously communicated plans to showcase services during the summer Olympics of 2020.

1.5.2.3 South Korea: aggressive and concerted 5G launch

South Korean operators (SK Telecom, Korea Telecom and LG U+) launched the world's first commercial 5G services on smartphones in April 2019. They had earlier set a March 2019 date for commercial launch but surprised many with the announcement that their 5G services went live, although with limited coverage and focused on enterprise solutions, in December 2018. The accelerated deployment is a testament to Korea's reaction to the intensifying global race to usher in the 5G era and its push for global leadership. In September 2017, SK Telecom showcased 360 degree video over pre-commercial 5G network in Seoul near Myoung-Dong, one of the densest urban areas in Korea. Likewise, KT offered a glimpse of 5G at the 2018 Winter Olympics in Pyeongchang, when it provided immersive services and 360-degree video over a pre-commercial 5G network.

The 5G services launched in December 2018 are available only in the form of mobile routers providing connectivity, while operators plan to make nationwide coverage and services available to the consumer market as handsets become available in 2019. For example, auto-parts manufacturer Myunghwa Industry is now able to remotely perform real-time quality control analytics on its production line, by connecting super-high-resolution cameras to cloud-based AI over 5G connectivity.

1.5.2.4 China: will be the largest 5G market

China will play a key role in driving global 5G adoption rates, given the size of its market and the impressive rate at which it adopted 4G. 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 terms of coverage and number of base stations.

China will be the largest projected market for 5G by some distance, with 450 million connections by 2025. This will put it on a par with Europe in terms of 5G penetration at just under 30% of the total connections, and a little lower than the leading markets such as US, Korea and Japan. China sees 5G leadership as a key element in the country's 'Made in China 2025' roadmap, which envisages 5G as helping to play a transformative role in China's ambition to gain worldwide lead in a range of new technologies such as industrial IoT, cloud computing and AI. Chinese operators already account for two thirds of the overall IoT connections and also lead the adoption of low power wide area NB-IoT technologies that will become the base of Massive IoT. As a result, there is potential upside to existing forecasts if Chinese operators accelerate deployment plans beyond the main urban areas.

Chinese operators look set to adopt the SA deployment route for 5G networks from the beginning. This is in contrast to other regions of the world where most operators have indicated a preference for a NSA deployment. Standalone offers larger-scale economies and high performance as well as less complexity from legacy LTE integration, but it is more expensive in the early commercial stage.

1.5.2.5 Europe: efforts to accelerate 5G

Europe is keen to play a leading role in 5G, having trailed other developed regions in 4G adoption. Reflecting these ambitions, the European Commission launched the 5G for Europe Action Plan in 2016 and established the 5G Infrastructure Public Private Partnership (5G PPP) in conjunction with the region's wider ICT industry. National level initiatives are also underway supported by operators and governments.

5G coverage will reach three-quarters of the population in Europe by 2025. By this date there will be 203 million 5G connections, accounting for 29% of total connections. From a regional perspective, Europe will account for the third largest share of 5G connections by 2025, behind Asia Pacific and North America.

1.5.2.6 Middle East: host to some of the earliest 5G rollouts

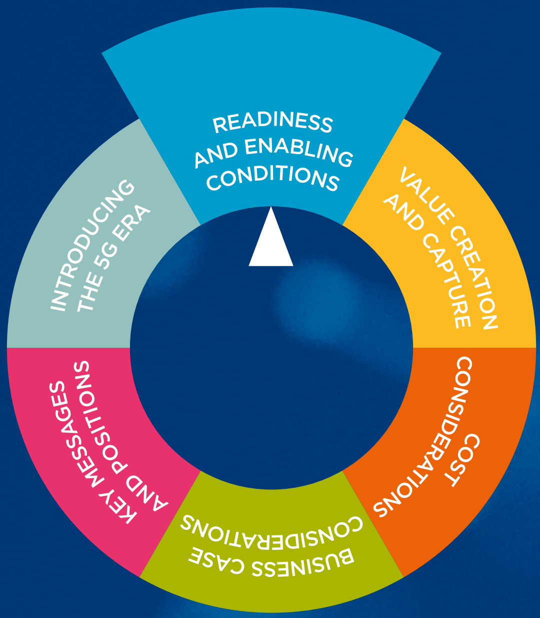
Middle East is a diverse region in terms of mobile market maturity, mobile internet adoption and 5G timelines. The major operators in the oil-exporting Gulf Cooperation Council (GCC) states are looking to be global leaders in 5G deployments and are rapidly moving from trials to early commercialisation. Launch of 5G mobile services in the GCC region will begin in 2019, when the first 5G smartphones will be commercially available. Further ahead, 15 MENA countries have announced plans to launch 5G mobile services by 2025, which together account for more than half of the markets in the region. For example, UAE successfully trialled FWA in 2018 and is ready for 5G mobile commercial launch as soon as 5G devices are available.

Enhanced mobile broadband will be the key use case in early 5G deployments in the MENA region, while applications and services for enterprises are tested. The opportunity for MENA operators to enhance the consumer experience through 5G networks, and hence drive incremental revenue, rests on linking 5G commercial propositions to developments in applications and content for immersive reality, eSports and enhanced in-venue digital entertainment (stadia, music venues). Some Middle East operators are already showcasing potential applications of immersive reality.

1.5.2.7 India: getting ready for 5G while deepening 4G

The Indian market is currently seeing a rapid migration to 4G, with over half the connection base set to be running over 4G networks by 2020 and operators investing heavily in LTE networks. Whilst India is unlikely to be a first mover in terms of 5G launches, there is growing discussion amongst operators and other industry stakeholders around the potential benefits of 5G. The government has created a high level forum that has made recommendation around spectrum, as well as other initiatives to support 5G including the development of India-specific 5G applications. Spectrum auctions are currently planned for the second half of 2019 that would potentially cover a number of bands relevant to 5G, including the 700MHz, 3.5GHz, 24GHz and 28GHz.

Initial commercial 5G launches are currently expected by 2020, in line with the government's own targets. Bharti Airtel has suggested that initial use cases could include FWA, whilst Reliance Jio has suggested an early launch of 5G with a focus on enhanced mobile broadband. Both operators and regulators are focused on the need to increase fibre deployments across the country to provide backhaul and enhanced backbone connectivity for future 5G deployments.



2 5G Readiness and Enabling Conditions

Chapter 2 focuses on the enabling conditions for 5G rollouts and provides guidance to operators on the key considerations ahead of 5G deployments. While these vary across markets, there are common prerequisites, enabling conditions and initial considerations. The Chapter is structured around three key readiness questions: technology readiness; policy readiness; and market/operator readiness, which in combination are the critical pillars that underpin the overall viability of the 5G business case.

In order to support the assessment of viability, the GSMA has developed a framework tool that examines many different indicators of readiness.

2.1 Technology Readiness

KEY TAKEAWAYS

- Technology readiness is the most pivotal factor for 5G. 3GPP delivered the first phase of 5G standards in June 2018; commercial handsets will follow from April 2019.
- There are two 5G deployment models that have been standardised to meet initial market requirements: Non-Standalone Access (NSA) and Standalone Access (SA).
- 5G NSA will be available for deployment from 2019, with full standalone 5G ready from 2020.
- NSA and SA 5G deployments are optimised for different needs:
  - NSA configuration is suitable for providing more broadband capacity since 5G NR can act as a supplementary capacity overlay to the 4G network.
  - SA configuration allows operators to fully exploit the features of NR as well as the capabilities of the new core network architecture.
- Based on the time lag between standardisation and device availability, NSA equipment was ready from late 2018 and SA equipment will be ready from 2020.
- The different spectrum bands to be used for 5G create interesting perspectives:
  - 5G deployment at 3.5GHz can reuse the existing infrastructure for 4G at 1800MHz
  - mmWave frequencies can support high bandwidth services. However, due to cost, they will initially be restricted to localised and specialised deployments.
- Given its high capacity, 5G sites will need fibre or high capacity microwave backhaul
- 5G will inherit services from 4G. For communication, the industry is working to support IMS-based services from Day 1. For IoT, NB-IoT and LTE-M are already part of 5G.
- Identity and access management (incl. e-SIM) are key requirements for 5G success, especially given the significantly more complex devices and services 5G landscape.
- 5G is an opportunity for the mobile industry to enhance network and service security levels to better address the threat landscape resulting from the move to all-IP.

2.1.1 Standards completion schedule

First phase of 5G standards ready in 2018, commercial devices expected from April 2019

The Technology Readiness for 5G is predicated on its standardisation process led by the 3GPP, the body that designs the technical specifications of the radio access network and core network. 3GPP released a subset of the specifications sufficient to deploy the NR access network in NSA mode in December 2017, before completing the first phase of the 5G specifications with Release 15 in June 2018.

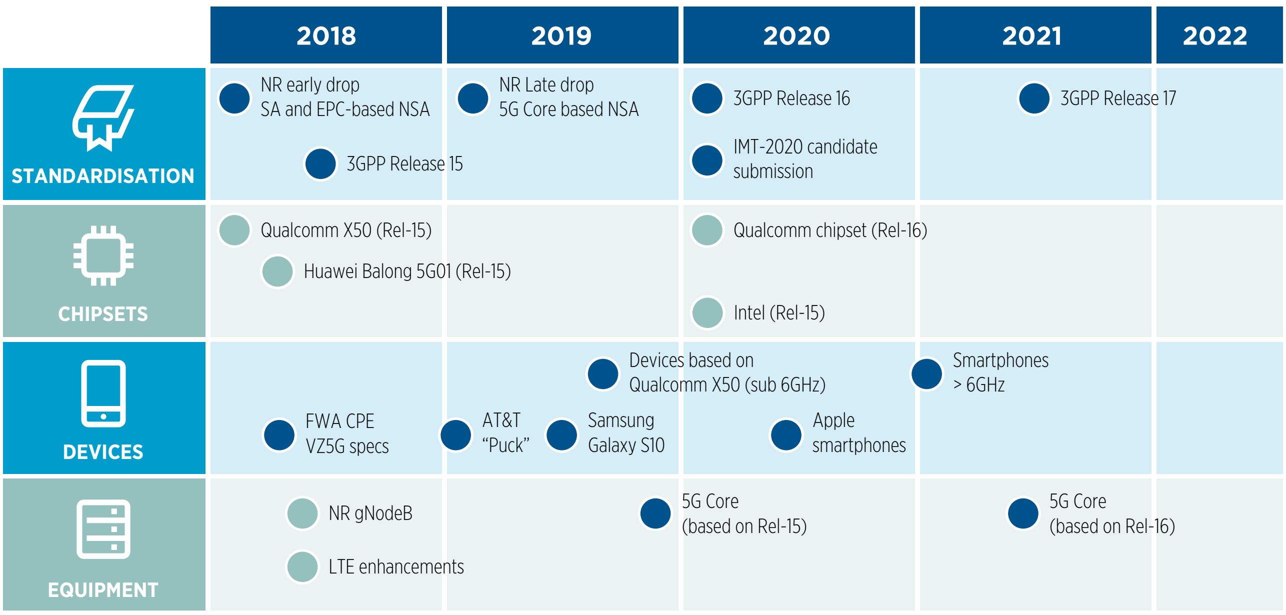
5G phase 2 (Release 16) is set to be completed by December 2019. Release 16 will enhance the capabilities of the NR and introduce additional features such as enhancements to ultra-reliable low-latency communications for industrial IoT; integrated access and wireless backhaul; and more sophisticated network slicing.

As Figure 2.1.1 highlights, the 3GPP releases kick-start the roadmap for commercialisation of chipsets, equipment and devices. Commercial volumes typically lag standardisation by 12-18 months, whilst development, testing, trials and pre-commercial activities take place.

Low power wide area IoT technologies are part of the 5G Roadmap, as NB-IoT and LTE-M already meet 5G requirements.

FIGURE 2.1.1

5G NR TECHNOLOGY ROADMAP



2.1.2 5G deployment models

Two 5G deployment models standardised to meet initial market requirements

Although several possible 5G configurations have been proposed, two deployment models (or options) have been standardised to meet initial market requirements. These are the Non-standalone (NSA) and Standalone (SA) 5G deployment models. With these, different operators will have different approaches on when and how to deploy 5G.

Unlike earlier generations, 5G NR is designed to tightly interwork with the existing 4G system at both radio and core network levels. The deployment method where the device is able to connect simultaneously to the 4G radio network and the NR (a technique known as dual connectivity) is referred to as NSA.

Conversely, the scenario where the NR capable device connects to one radio access technology at any given time, is known as SA deployment. Both are illustrated in Figure 2.1.2 and 2.1.3.

FIGURE 2.1.2

NSA CONFIGURATION (OPTION 3). NR CONNECTED TO, AND CONTROLLED BY EXISTING 4G CORE NETWORK

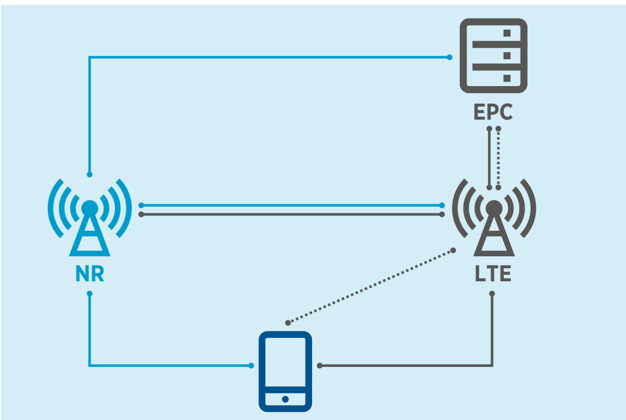
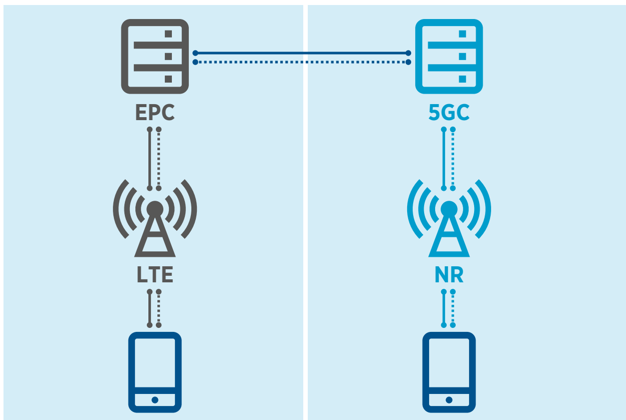


FIGURE 2.1.3

SA CONFIGURATION (OPTION 2). NR CONNECTS TO THE 5G CORE ONLY. THE STANDALONE 5G SYSTEM INTERWORKS AT CORE NETWORK LEVEL WITH LEGACY 4G SYSTEM



User Plane   Control Plane

2.1.3 SA vs NSA 5G

Non-standalone and Standalone 5G deployments are optimised for different needs

The NSA configuration is most suitable for providing enhanced mobile broadband services since NR can act as a capacity overlay to the 4G network, supplementing existing network investments. Where an operator aims to focus on eMBB alone (at least initially), then NSA is suitable.

The 4G Radio and access networks will need upgrades to support 5G NSA. These will include software; new hardware to support new 5G frequency bands and to aggregate the processing capacity in baseband that 5G needs; and antenna systems for MIMO. NSA devices only need to support the new radio access technology: the control protocols are the same as those used by LTE devices.

SA 5G configuration allows operators to fully exploit the features of NR as well as the capabilities of the new core network architecture. This will include network slicing (multiple logical networks on a single physical network), as well as ultra-reliable and low-latency transmission. This set of features makes an SA deployment more suitable to address the enterprise market.

A full 5G system deployment, comprising the new radio access technology and new core network architecture, will require new investment cases and market readiness is critical to these decisions.

It should be observed that while NSA 5G was originally intended as an intermediate step for operators ahead of the full rollout of Standalone 5G, market realities will ultimately shape if, and when, the migration to SA 5G happens. Both NSA and SA deployments are likely to coexist over the long term and some kind of upgrading would be required for a full-fledged 5G (SA) network (software versions, configuration, transport…).

2.1.4 Equipment readiness: 5G NSA

Equipment for 5G NSA became available in late 2018

Timely availability of network equipment is essential, not only for testing but also to plan the integration with existing sites. With the technical specifications for NSA NR completed in December 2017, many vendors have already started testing standards-compliant equipment. Interoperability testing between major vendors has also started.

The release of the Snapdragon X50 5G modem[8] by Qualcomm and of the Balong 5G01[9] by Huawei led to the expectation that 5G-ready smartphones, from several vendors, may become commercially available as early as 2019[10]. Customer Premises Equipment (CPE) for Fixed Wireless Access became available by the end of 2018.

2.1.5 Equipment readiness: 5G SA

Equipment for 5G SA will be ready from 2020

SA requires operators to deploy a completely new core network that was only defined in the first 5G standards finalised in June 2018. Given a typical lag of 18 months from standard completion to commercial introduction of a new technology, 5G Core will likely be used in commercial deployments after 2020. All operators should pay attention to device compatibility with NSA and SA architectures, as some chipsets will not be dual mode NSA and SA compatible.

8. http://www.trustedreviews.com/news/qualcomm-unveils-snapdragon-x50-world-first-5g-modem-2935894
9. https://www.totaltele.com/499418/MWC-2018-Huawei-launches-worlds-first-commercialised-5G-chip-set
10. https://www.digit.in/mobile-phones/5g-phones-heres-a-list-of-all-5g-ready-smartphones-expected-to-launch-in-2019-44894.html

2.1.6 5G technical features

5G technical features will spur new services

There are a number of 5G Radio layer features that improve the coverage, performance, and time to deploy 5G NR on a 4G cellular site portfolio in the short term, especially at 3.5GHz (see Figure 2.1.4). Further development will look to increase the spectrum and cost efficiency of NR. This subsection introduces Network slicing, Edge computing and virtualisation: please refer to Chapter 3 (value creation) and Chapter 4 (cost considerations) for a fuller analysis.

Network slicing, a mechanism that allows operators to create virtual networks dedicated to a specific service, use case or customer over a common physical network infrastructure, is a potentially key 5G capability. Network slicing is a very attractive tool in operators' quest to address the different needs of enterprise customers. For example, the quality of service requirements of connected car use cases will be vastly different from the needs of agriculture customers.

Multi-access Edge Computing (MEC), an approach that deploys computation and storage resources closer to the edge of the network, will provide lower latency capabilities to enable real-time control and automation in various fields (e.g. remote control and real-time monitoring of heavy machinery, remote surgery in healthcare).

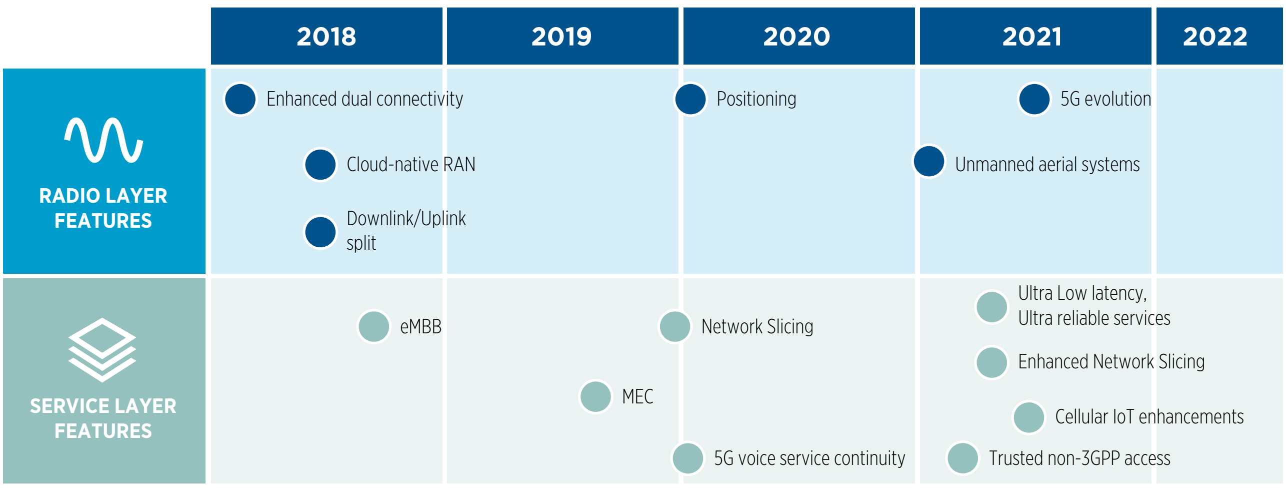
Virtualisation, which was already in progress, will accelerate with 5G. The 5G Core Network will be fully virtualised to support faster service provisioning and enhanced network maintenance.

Service continuity will need to be considered collaboratively by operators for network configuration including communication services on 5G and 5G roaming.

5G will further evolve Mission Critical Services (defined in LTE Release 13) to support the next generation of public safety networks. Such networks will utilise 5G NR, network slicing, the improved positioning, proximity communication and most importantly the ability to prioritise communication.

FIGURE 2.1.4

TIMELINE OF 5G FEATURES



2.1.7 5G coverage using 4G Infrastructure

5G deployments at 3.5GHz can reuse the existing infrastructure for 4G at 1800MHz

Operators will need to densify their networks for 5G, especially by deploying many more small cells to boost capacity. However, the scale of the densification may not be as big as it has been occasionally suggested. By utilising advanced antenna techniques such as massive MIMO and beamforming, simulations (e.g. by Qualcomm[11]) have shown the feasibility of matching the downlink coverage provided by LTE 1800MHz with 5G radio base stations operating at 3.5GHz: this implies a potential for the same cell grid to be reused for the initial rollout, albeit with challenges on managing the power output for urban massive MIMO deployments as well as the feasibility of installing complex antenna systems required for MIMO in micro base stations.

In the uplink direction massive MIMO and beamforming are impractical due to the limited power and real estate in the device, therefore the cell coverage at 3.5GHz becomes uplink limited and smaller than a cell operating LTE in the 1800MHz band. To overcome this limitation two strategies have been proposed: utilise lower band spectrum for the uplink, such as the 1800MHz spectrum (downlink/uplink decoupling); or aggregate carriers at 3.5GHz with carriers at lower frequencies.

It should be noted that the limited availability of spectrum in lower bands would result in a limitation of the uplink throughput. Therefore, although the strategies discussed in this section address the potential coverage impairment resulting from reusing the LTE grid for NR, it is unlikely to address the capacity demand of symmetric or uplink skewed services (such as many wideband IoT services).

2.1.8 Millimetre wave deployments

Millimetre wave technologies will be used for localised and specialised deployments

The large amount of spectrum available in the millimetre wave range combined with the opportunity for creating extremely dense networks will enable operators to launch ultra-high throughput services such as 8K video or high definition AR. Commercial applications of 5G in millimetre wave spectrum will initially appear in the form of fixed wireless access for both consumers and enterprises. The use of millimetre wave technologies for self-backhauling of cell sites is being studied by the 3GPP as a candidate feature of Release 16.

However, the deployment of a large-scale millimetre wave network is not without challenges. As the size of a millimetre wave cell, depending on propagation characteristics, is expected to be in order of 200metres to 1000metres outdoors and few tens of metres indoors, the cost to achieve nationwide coverage will be prohibitively expensive. Accordingly, use of millimetre wave technologies will initially be restricted to localised and specialised deployments. Operators may also want to consider models of infrastructure sharing including with each other, through public-private partnerships and neutral hosting for millimetre wave deployments.

10. https://www.qualcomm.com/news/releases/2018/02/25/qualcomm-network-simulation-shows-significant-5g-user-experience-gains

2.1.9 Backhaul upgrade for 5G

Non-fibre 5G sites need upgrade to provide up to 10Gbps backhaul

5G sites will rely on a combination of fibre and microwave backhaul solutions. This mix of backhaul options will persist deep into the 5G era: by 2025, the proportion of base stations connected via fibre backhaul will grow from 30% in 2017 to just over 40%.[12]

Fibre is the ideal option for 5G, as capacity demands are significantly higher compared to current typical microwave installations. A site hosting a 5G radio base station operating on 100MHz of spectrum using beamforming and MIMO is expected to require up to 10Gbps (depending on site size and access spectrum) for backhauling. For comparison, LTE backhaul demand is in the region of 1Gbps to 2 Gbps per site. In addition, latency and availability need to be also considered in backhaul technology selection and design processes.

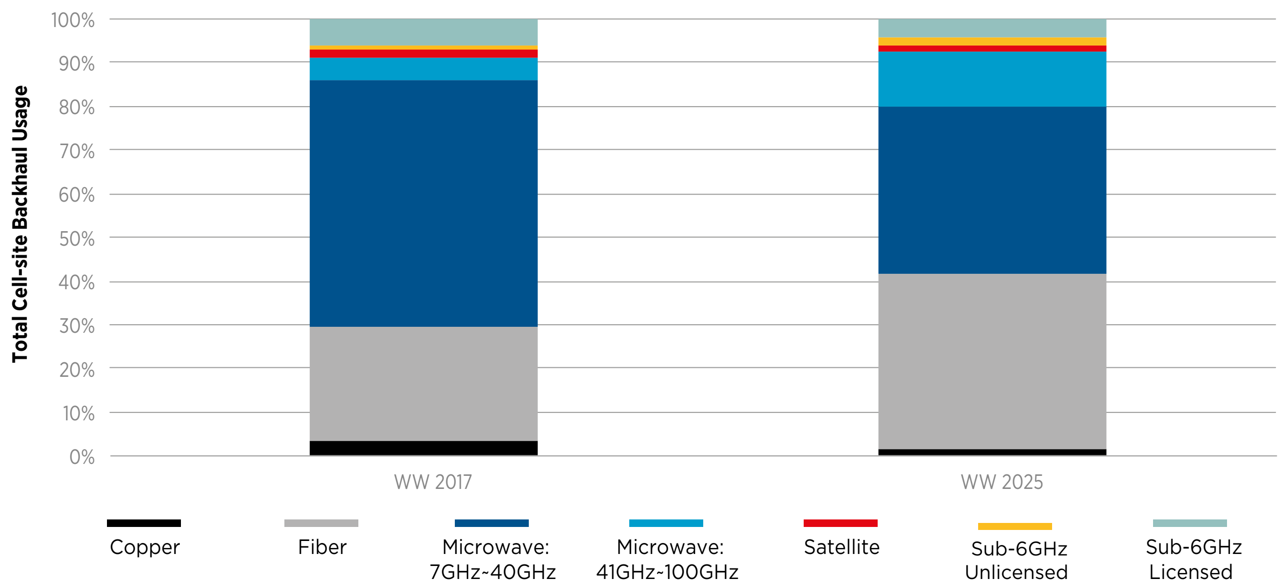
Existing microwave links will likely need to be upgraded in order to provide the up to 10Gbps throughput that 5G will require because currently, a typical microwave link can carry 1Gbps. This type of upgrade is possible by adopting new technical solutions that operate in the E band and that can achieve speeds of up to 10Gbps. NTT has also demonstrated a 100Gbps link using Orbital Angular Momentum.[13]

Readers should also be mindful of the fact that network deployment does not only take into account the peak traffic, but also average traffic rate within a certain percentile to meet economic feasibility.

Ericsson Microwave Outlook 2017[14] forecasts that for some operators in Western Europe, backhaul for 80% of 5G sites will be provided by microwave links with the remaining 20% of the sites connected by fibre.

FIGURE 2.1.5

TOTAL MOBILE BACKHAUL BY METHOD (SOURCE: ABI RESEARCH)



12. https://www.gsma.com/spectrum/wp-content/uploads/2018/11/Mobile-backhaul-options.pdf
13. https://www.thestar.com.my/tech/tech-news/2018/05/23/record-breaking-100gbps-wireless-transmission-is-a-world-first/
14. https://www.ericsson.com/assets/local/microwave-outlook/documents/ericsson-microwave-outlook-report-2017.pdfd

2.1.10 5G voice & messaging

IMS-based IP Communications should be supported in 5G from Day 1

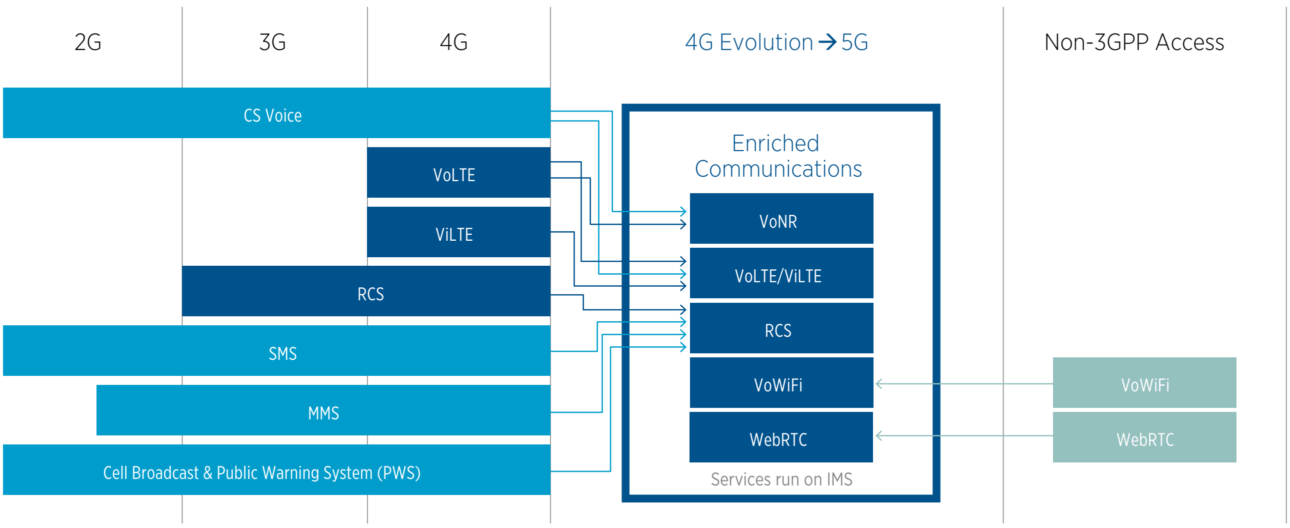
The 'regulated' nature of voice services in most markets means that operators would be expected to support voice services in the 5G era. For example, operators may be mandated, as part of the licence condition, to provide voice services, especially emergency voice services, to their subscribers at substantial coverage. IMS-based communications services are the future of operator communications and VoNR (IMS voice service over 5G New Radio) will become the standard operator voice service for the 5G era (as shown in Figure 2.1.6).

The GSMA recommends that VoNR is planned to be deployed as soon as possible to avoid a repeat of the challenges with the retrospective introduction of VoLTE on 4G networks; provide guidance to operators on rationalising their legacy 2G/3G networks; and provide enhanced communications functionality for users. As IP communications services are set to replace their legacy counterparts (e.g. RCS will replace SMS) in the 5G era, operators should begin to leverage their 4G investments to provide full IP communications services.

Profiling of VoNR based on 3GPP specifications is ongoing in GSMA Networks Group and operators are encouraged to contribute in order to provide clarity to device manufacturers and infrastructure vendors as to what the minimum set of functionality to be supported are. Strict adherence to the profile will accelerate the introduction of the service, and unlock economies of scale and interoperability around the globe.

FIGURE 2.1.6

EVOLUTION OF IMS-BASED IP COMMUNICATIONS SERVICES



2.1.11 Voice service continuity

Operators need to take special consideration in adopting IP Communications for 5G

5G coverage will likely be limited initially, so operators should have mechanisms in place to secure the continuity of communication services when the device roams across different access technologies. Unlike 4G, there will be no provision in the standards to force the device to select a legacy circuit switched (CS) network (2G or 3G) to make or receive a call in the case where voice service over IMS is not supported (CS Fallback).

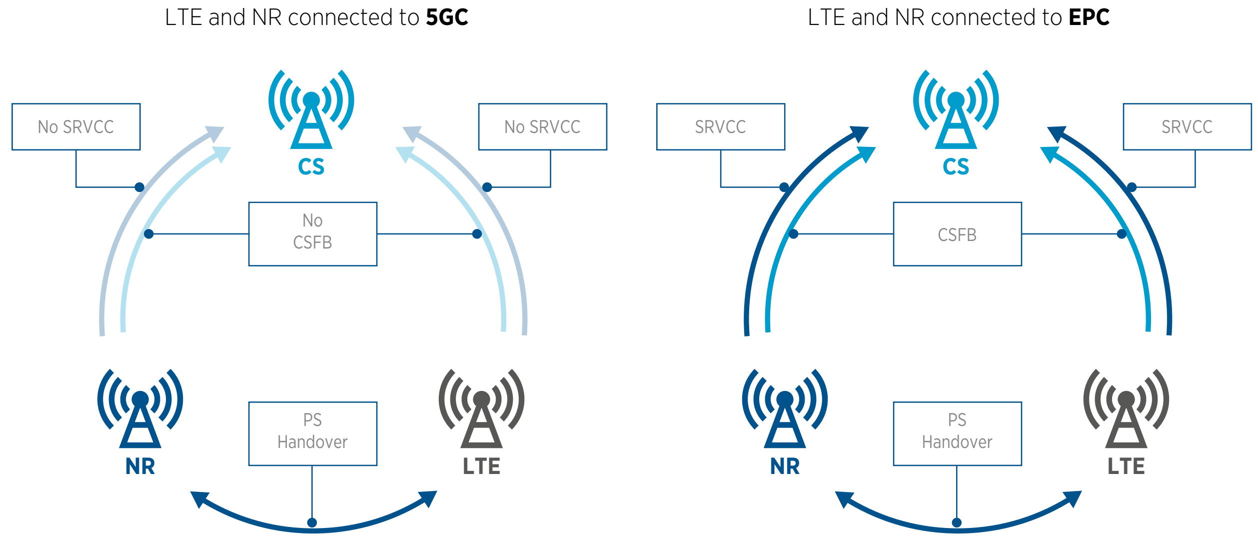
When the operator supports voice over IMS (that is VoLTE and VoNR) voice continuity can be attained when the device moves between these two radio access technologies by means of regular handover. The capability of transferring a voice call to a legacy CS access (Single Radio Voice Call Continuity – SRVCC) that was standardised for 4G, is currently not specified in the first release of the 3GPP specifications for 5G (Release 15). It is a Study Item for Release 16 and will be standardized by earliest in 2021.

Figure 2.1.7 illustrates the various voice continuity scenarios.

The recommendation is, therefore, to deploy nationwide IMS-based IP communications services as soon as possible. This would eliminate the need for having to resort to SRVCC or CSFB and enhance the user experience by providing consistent HD voice quality within the network. If the operator does not have VoLTE, deploying nationwide VoLTE would be the first step to achieving future-proof voice service continuity in the 5G era. Furthermore, operators should take into consideration that interconnection and roaming of IMS networks will allow higher quality services to be provided to its subscribers with expanded user base that enjoys the quality service. Operators are therefore recommended to interconnect and adopt roaming of IMS networks to leverage full network effect of global communications service.

FIGURE 2.1.7

INTERWORKING AMONG RADIO ACCESSES



2.1.12 NB-IoT and LTE-M as part of 5G

NB-IoT and LTE-M as deployed today are already part of 5G[15]

3GPP has indicated that both NB-IoT and LTE-M will be proposed to ITU-R as meeting the 5G Massive IoT requirements for IMT-2020. The results from initial studies are available in the *Evaluation of LTE-M towards 5G IoT requirements*[16]; *3GPP Tdoc R1-1802529*[17]; and *3GPP Tdoc R1-1801796*[18], and a number of other studies are currently being conducted as part of the 3GPP assessment of the IMT-2020 requirements.

To further support the view that NB-IoT and LTE-M support the 5G LPWA requirements, 3GPP has agreed that the LPWA use cases will continue to be addressed by evolving LTE-M and NB-IoT as part of the 5G specifications[19].

3GPP Release 13 provided the initial set of capabilities for both LTE-M and NB-IoT. Both technologies have been designed to be power efficient and to achieve better coverage and penetration. In addition, each technology offers a variety of capabilities that allow mobile operators to address a wider range of IoT use cases. Please refer to Appendix 7.2 for further descriptions of the NB-IoT and LTE-M requirements.

2.1.13 Cellular Vehicle-to-Everything (C-V2X) in 5G

5G will enable new capabilities for vehicular communications

With the advancements of technologies, vehicular communications are set to greatly evolve and 3GPP has already defined a wide variety of features in LTE with further enhancements slated for 5G to address this sector. 3GPP refers to features that are fulfilling vehicle use cases as C-V2X (Cellular Vehicle to Everything), encompassing all cellular based communications between a vehicle and other entities such as other vehicle (V2V), road side units' infrastructure (V2I), pedestrians (V2P). Some of these communications can take place in "direct mode" without the intermediation of a network infrastructure.

It is noteworthy that 3GPP scope is wider than just cars and covers instead a wide variety of vehicles classified in three main categories: terrestrial, aerial and submarine. Most of the specifications are aimed at cars and trains belonging to the terrestrial category, however a lot of work is already ongoing to address unmanned aircrafts. Unmanned aircrafts are evolving rapidly and they are more often employed in critical situations for disaster response and they are becoming part of public safety use cases.

15. https://www.gsma.com/iot/mobile-iot-5g-future/
16. "Evaluation of LTE-M towards 5G IoT requirements", Sierra Wireless, Ericsson, Altair, Sony, Virtuosys, AT&T, Verizon, Orange, Nokia, China Unicom, NTT DOCOMO, KDDI, KPN, KT, Sequans, SK Telecom, SingTel, Softbank, Sprint, Telenor https://www.sierrawireless.com/-/media/iot/pdf/LTE-M_White_Paper_171114B
17. "IMT-2020 self-evaluation: mMTC connection density for LTE-MTC and NB-IoT", Ericsson http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_92/Docs/R1-1802529.zip
18. "Consideration on self-evaluation of IMT-2020 for mMTC connection density", Huawei, HiSilicon http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_92/Docs/R1-1801796.zip
19. "Interim conclusions for IoT in REL-16", 3GPP http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_79/Docs/RP-180581.zip

2.1.14 Identity & Access Management in 5G

Identity and access management will be more important and complex in 5G

The 5G era will experience a number of challenges around identifying users, devices and the various associations formed between the two. For example, a device may need to be associated with a manufacturer (for lifetime maintenance), an owner (who may be paying for the core 5G services consumed by the device) and a user (who consumes third-party services via the device).

These challenges already exist to some extent in previous generation systems and were solved in a proprietary manner by third-party service providers, resulting in closed environments and a lack of interoperability. A standard identity and access management framework (and management of privileges) will therefore become increasingly important in order to simplify interworking between different solutions.

5G will herald a move from legacy subscriber-centric services, where operators have focused on providing voice and data services to the subscriber, towards the need to support personalised user-centric services where the focus shifts to the user. In this model, users will take their services with them, regardless of the subscription and the access network used.

For this, operators can step-up as trusted Identity Providers and, in doing so, will be able to better understand and serve their customers, while also unlocking new revenue opportunities by offering such capabilities to third parties delivering services over 5G networks. For example, operators could play a key role in enabling a "car as a service" solution by providing the capability to identify and authenticate users to the car sharing service provider.

2.1.15 eSIM in the 5G era

eSIM take up will continue to be measured, although ultimately the benefits to OEMs will cause mass-market adoption

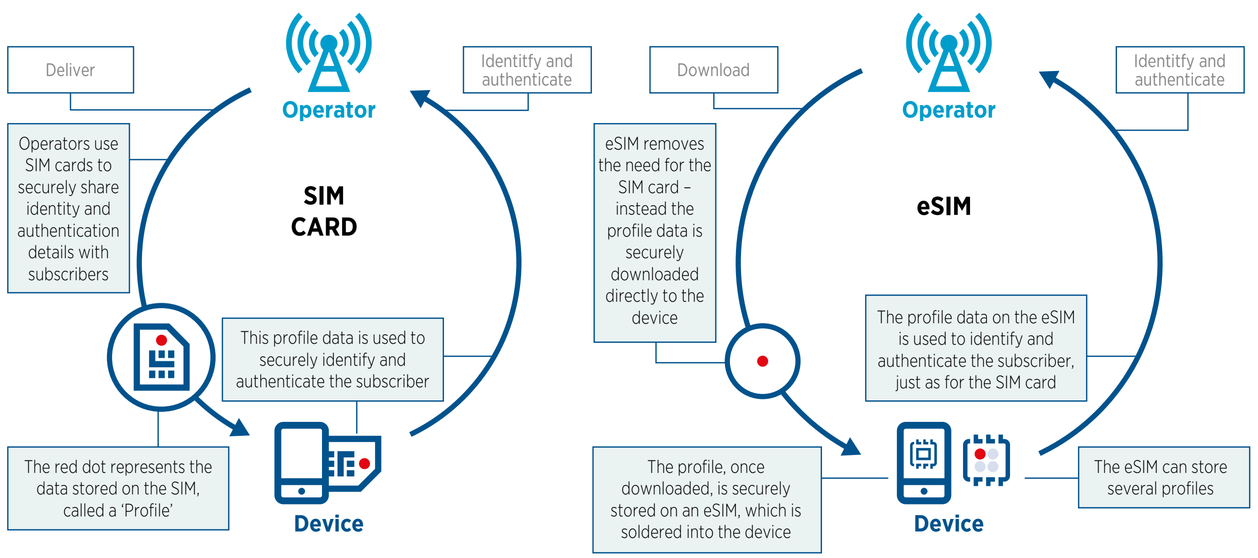
In recent years, developments in embedded SIM (eSIM) technologies that permit remote management of the SIM on mobile devices have matured to the point that major manufacturers have started to deploy eSIM technology on an increasing range of connected devices, including smartwatches and smartphones.

The traditional removable SIM card will continue to be the most used form factor in the early 5G era for mass-market devices such as smartphones. However, eSIM does provide benefits that may be very valuable for OEMs for 5G devices, two significant benefits being a 98% reduction in space over the removable SIM (allowing more room for batteries and modems in 5G devices) and the ability to provision devices post-sale to the consumer allowing much more freedom in device distribution models. This will lead to an increase in eSIM deployment as OEMs launch new devices with eSIM capability and operators increasingly support eSIM functionality (currently 100 operators worldwide support eSIM). Furthermore, the diversity of IoT applications for which 5G will be used will undoubtedly further increase the range of connected devices available to consumers and enterprises, requiring smaller form factors and remote provisioning. Secure, scalable and minimal friction processes that enable operators to securely authenticate devices on 5G networks will become increasingly important.

Achieving these secure, scalable and minimal friction eSIM processes is likely to see further evolution in the way eSIMs are manufactured. One possible evolution is an emphasis on enabling manufacturers to incorporate eSIM capability in their devices that bring with them pre-certified compliance to personalisation and certification schemes. Such techniques are being developed by manufacturers supporting so-called integrated or 'system-on-chip' eSIM solutions and can enable manufacturers to support eSIM without actually having the skills and capabilities in their own companies to manage eSIM production and personalisation and at reduced overall cost to the mobile industry. Ultimately, this would see eSIM as an enabler to connecting many more devices and device types to many different types of networks, potentially to even non-cellular networks.

FIGURE 2.1.8

TRADITIONAL SIM CARDS VS. REMOTE SIM PROVISIONING OF ESIM



2.1.16 Delivering on virtualisation

Common infrastructure abstraction is needed to realise the full benefits of virtualisation and Open Networks

With the introduction of NFV, telecommunication networks are preparing to undergo the same transformation that took place in the Information Technology sector (IT) from where the virtualisation software paradigm originates. Network Virtualisation promises an acceleration in time-to-market for existing and new services, as well as more flexible networks that can scale and evolve as needed. Many of the solutions for virtualisation are devised in groups adopting Open Source, thus operators will work in the future with new suppliers and a new layer of configurability.

While the goal is to be able to use common hardware and standardised platforms to run Virtual Network Functions (VNFs), the reality is that virtualised services (whether it's VoLTE, 4G Enhanced Packet Core [EPC] or enterprise services like Software Defined-Wide Area Network [SD-WAN]) come with their own set of infrastructure requirements and custom design parameters. This results in the creation of various vendor/function based silos which are incompatible with each other and have different operating models, and crucially drives up cost beyond what is anticipated.

This topic is covered in more detail in Section 4.4: Network Flexibility and in Section 4.9: Network Equipment Sourcing

2.1.17 Vendor ecosystem for 5G

Operators should expect equipment from many more vendors in the 5G era

The cloud native design of the 5G core and adoption of a service-based architecture has the potential for disrupting the equipment vendor landscape, with suppliers that are currently associated with the IT sector being in a position to provide their products to telecommunication companies. In the 4G era, operators already started to introduce virtualised network elements and functions (e.g. virtual IMS) and horizontal IT/technology vendors specialised in cloud, virtualisation, SDN and so on are starting to make inroads in mobile operator networks.

5G operators will, therefore, need to forge new business relationships with these new partners and possibly adapt to a business model that could be very different from that of traditional vendors. This will be of particular relevance when working with vendors who sell products based on open source.

System integrators are also likely to play a much bigger role as the decomposition of the network will result in a multitude of suppliers of components that need to work harmoniously.

This topic is covered in more detail in Section 4.9: Network Equipment Sourcing.

2.1.18 Security considerations for 5G

Security is a critical enabler for 5G

5G allows operators to leverage the latest technologies and as such benefit from a more secure network. This is due to the fact that 5G has been designed with security at each level of the network. It offers the mobile industry an unprecedented opportunity to uplift network and service security levels.

5G services scale up and offer flexibility to the operator, with this comes the additional opportunity to remove costly unilateral security controls. 5G security controls should be appropriate to the specific service needs. For example, a content delivery service may not warrant the same security investment as an autonomous vehicle. This flexibility allows the operator to invest in the most appropriate security controls for the service.

2.1.18.1 5G era threat landscape

Introducing a new technology to any network alters the threat landscape. Vulnerabilities and threats against technology are likely to be unknown at the time of launch. New threats will be developed as attackers are provided live service environment to develop their techniques.

5G is the first generation that recognises this threat and has security at its foundation. The threat landscape will diversify due to the unprecedented combination of new technology and differing service models being introduced. For example, new players to the market may not have the same maturity to personal data management as an operator, therefore increasing the chances of poor security practices impacting the end to end service.

2.1.18.2 Operational security in the 5G era

5G has designed in new authentication capabilities, enhanced subscriber identity protection and additional security mechanisms. Preventative controls are outlined within the standards but applications to protect and monitor the ecosystem as a whole will need to be implemented. The ability to identify and respond to these threats will require data analysis.

Traditional security operations will struggle to contend with the volumes of data a 5G network will produce; it is not envisaged that collecting all network and user data will be effective or even feasible. Threat modelling of the 5G services offered by an operator should be part of the service design phase and the purpose of this process is to identify key threats the service is likely to be impacted by.

Operators should leverage technologies such as Machine Learning (ML) and Deep Learning (DL) to automate the identification of the threats within the data, given the rapid increase in data volumes (see Section 4.7: Network Automation, for more details). If processed in near real time, potentially at the edge, this automated detection could be paired with real time blocking capabilities to mitigate the effects of an attack. 5G's Network Data Analytics Function (NDAF) could support real-time threat detection.

2.1.18.3 3GPP security standards

5G standards enable security. SA3, the security subgroup of 3GPP, has outlined a standard security architecture in Release 15. This architecture introduces controls to prevent several known threats, including numerous fraud types. The standards outline the use of more industry defined and supported, IP-based protocols. Enabling the move away from historical insecure protocols, such as SS7, is the right strategic evolution for operators.

The correct implementation of these standards should fulfil an operator's security requirements when deploying 5G. Failure to deploy standard architectural controls may result in a less secure network and necessitate additional security requirements being added post launch. Experience has shown this costs operators more in the long term, in capex and impact on service.

FIGURE 2.1.9

SECURITY CONTROLS OUTLINED IN 3GPP RELEASE 15

SUBSCRIBER PROTECTION	RADIO PROTECTION	CORE PROTECTION
• Subscriber Permanent Identifier (SUPI); a unique identifier for the subscriber • Dual authentication and key agreement (AKA) • Anchor key is used to identify and authenticate UE. This key is used to create a secured access throughout the 5G infrastructure. • X509 certificates and PKI are used to protect various non UE devices	• Encryption keys are used to demonstrate the integrity of signalling data • Authentication when moving from 3GPP network to non 3GPP network • Security Anchor Function (SEAF) allows re-authentication of the UE when it moves between different access or serving networks	• The home network carries out the original authentication based on the home profile (home control) • Encryption keys will be based on IP network protocols and IPSec • Security Edge Protection Proxy (SEPP) protects the home network edge • 5G separates control and data plane traffic

2.1.19 Energy efficiency in the 5G era

Energy efficiency is a major consideration for 5G era networks

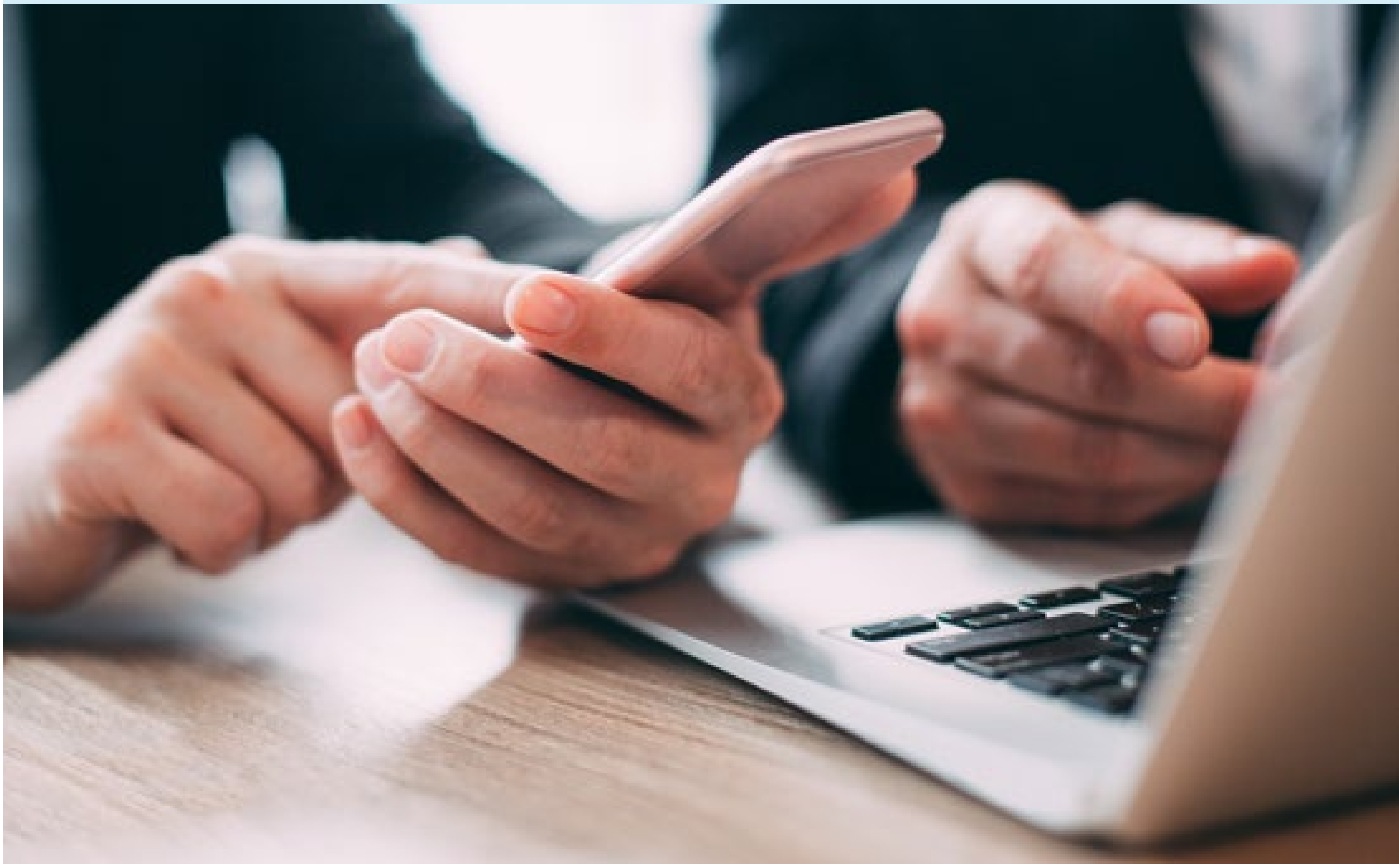
3GPP specifications point to an aspirational goal for 5G networks to be much more efficient than 4G. This will be driven by more efficient constituent components. Yet, in several ways, the overall 5G era networks will be challenged to deliver a greener operational outcome. Network densification will add more sites and 'softwarisation' of the core will add more control points. This disaggregation of the network will likely result in multiple sites consuming relatively small amounts of energy, and imposing a complex challenge to optimise overall energy consumption.

While the debate and discussions continue, in the short-term, operators are likely to see an energy increase in maintaining legacy networks in 2G, 3G and 4G networks in addition to new requirements in deploying 5G, at least until legacy networks are decommissioned.

2.2 Policy Readiness (including Spectrum)

KEY TAKEAWAYS

- **An enabling policy environment is a prerequisite for 5G success. Accordingly, policymakers need to foster a pro-investment and pro-innovation environment for the mobile ecosystem.**
- **To accelerate 5G into commercial use, policymakers should focus on network deployment, network flexibility, spectrum access and regulatory costs, including reducing sector specific taxes on customers and operators.**
- **Specifically, regulators need to promote streamlined network deployment regulations to address the emerging challenges of network densification.**
- **Likewise, regulators should promote flexibility to support emerging 5G services (e.g. through a pragmatic interpretation of the Open Internet principle) and modernising regulatory frameworks.**
- **Sufficient, affordable, exclusively licensed, contiguous spectrum should be made available in harmonised 5G bands. Set-asides in these bands jeopardize the success of public 5G services and could waste spectrum.**
- **Spectrum policy measures should be adopted which support long-term 5G investment. These should include long-term technology neutral licences, clear renewal processes, a spectrum roadmap and due care taken to avoid artificially inflated spectrum prices.**



2.2.1 5G era policy framework

Supportive policy framework is a key enabler for 5G readiness

To accelerate 5G into commercial use, governments and regulators need to consider market structures that will foster a pro-investment and pro-innovation environment for the mobile ecosystem. Many mobile operators face significant headwinds from the prevailing policy and regulatory environment, in terms of investment; spectrum access; network management flexibility; and infrastructure deployment.

It is important to note that across a broad range of policy and regulatory issues, the industry position is no different in a 5G world to earlier generations of mobile network technology. Positions published in the *GSMA Mobile Policy Handbook*[20], spanning infrastructure sharing, taxation and spectrum, to name but a few, are as relevant and applicable as ever.

Policymakers, as vocal proponents of mobile network evolution and technology-led economic growth, should play a driving role in the realisation of 5G, creating the conditions for efficient and timely mobile network deployment while bringing down the regulatory costs for operators. Their attention should focus on the following key areas to bring 5G to fruition: network deployment; network flexibility; spectrum access; and regulatory costs.

Figure 2.2.1 is a summary of the four key policy considerations for the 5G era.

FIGURE 2.2.1

KEY POLICY CONSIDERATIONS FOR THE 5G ERA

STREAMLINE REGULATORY CONDITIONS
TO FACILITATE 5G DEPLOYMENT

PROVIDE REGULATORY FLEXIBILITY
FOR INNOVATIVE 5G PROPOSITIONS

RELEASE SUFFICIENT SPECTRUM FOR 5G
THAT IS HARMONISED AND AFFORDABLE

EASE FINANCIAL DEMANDS OF 5G
BY BRINGING DOWN COSTS

25. https://www.gsma.com/publicpolicy/handbook

2.2.2 Network deployment regulations

Streamlined network deployment regulations are a necessity

Operators are still rolling out 4G infrastructure in most markets, with 5G as the evolutionary step with newer equipment added to earlier-generation sites. Operators will rely, in some geographical areas, on the deployment of small cells, including more densely distributed antennas and the provision of backhaul, to connect a far greater number of mobile base stations. As a frame of reference, in a hypothetical scenario where 5G small cells are installed on all street lamp posts, the GSMA calculates that London in the UK could see up to 500,000 small cells installed across the city.

The densification of networks to cope with urban capacity demands requires significant new investments in additional sites and supporting infrastructure, potentially four- to six-times higher than for 4G based on some market estimates. Furthermore, complex planning procedures involving multiple layers of approval in some countries create additional burden, significantly delaying 5G deployment. Policymakers must strive to ensure that the deployment regulations at the local level are aligned with the national digital ambitions and market realities. For example, governments should adopt a national code for new mobile sites and modification of existing sites, implemented by local authorities (e.g. FCC orders).

Policymakers are urged to:

- Simplify planning procedures and regulations for site acquisition, colocation and upgrades of base stations;
- Provide operators access and right-of-ways to public/government facilities for antenna siting on reasonable terms and conditions;
- Establish uniform electromagnetic field (EMF) rules that are no more restrictive than internationally agreed levels.
- Encourage and incentivize fibre investments, and enact appropriate policies to ease and expedite fibre rollouts.
- Strive to ensure that the deployment regulations at the local level are aligned with the national digital ambitions and market realities. This includes setting reasonable fees and other conditions for network deployment at local level.
- Offer a reasonable expectation of approval for voluntary network sharing deals while avoiding mandated sharing agreements that may amount to an access obligation.

2.2.3 Regulatory flexibility

Regulators should enable operators to leverage 5G network features for innovative propositions

To realise the full economic potential of 5G, regulators should protect operators' flexibility to meet the connectivity requirements of emerging services made possible with 5G. With 5G operators can use network virtualisation techniques to dynamically configure network resources to deliver bespoke, managed connectivity services. Network slicing is a core capability that enables operators to create such service offerings and it is also critical to support public-safety services as they migrate to 5G infrastructure.

While the GSMA and its members are committed to the open internet principle and advocate for technical and commercial flexibility, some operators have raised concerns that potential regulation related to the open internet and net neutrality could prevent them from fully utilising capabilities such as network slicing to offer tailored services to vertical sectors (e.g. urgent software updates for driverless cars vs. streaming a cat video on a smartphone).

Regulators should interpret the open internet principle in a manner that encourages flexible and efficient networks instead of taking an overly-restrictive view of the logical architecture of the network. Where rules on open internet conduct are in place, services other than mass-market consumer internet access services should remain outside of those rules. Additionally, regulators should review old-fashioned regimes and update regulatory frameworks to adapt them to the new industry reality.

2.2.4 Spectrum in the 5G era

2.2.4.1 5G spectrum bands

Approved 5G bands pave the way for refarming 2G/3G/4G spectrum for 5G

3GPP has approved 36 spectrum bands for 5G in the sub-1GHz; 1GHz to 6GHz; and above 24GHz bands. The approval creates a group of spectrum bands that are globally and colloquially recognised as 5G spectrum (e.g. 3500MHz). Crucially, it also paves the way for operators to refarm their existing 2G/3G/4G spectrum, where permitted, for 5G services. Some of these bands are applicable globally while many are only applicable on a regional basis. Please refer to Appendix 7.1 for a table of all the 3GPP approved 5G NR spectrum.

2.2.4.2 Spectrum Access

Availability of the identified 5G spectrum bands in each market is crucial

5G will be best delivered using dedicated, licensed spectrum and the industry has identified the need for spectrum in three frequency ranges to deliver widespread coverage and support all use cases. These are: sub-1GHz; 1GHz to 6GHz (e.g. 3.5GHz); and above 6GHz (e.g. 26GHz, 28GHz and 40GHz). Governments should strive to make sufficient spectrum in these bands available for 5G to drive global interoperability and achieve economies of scale for both the industry and customers.

Sub-1GHz bands provide good 5G coverage and support specific use cases such as wide-area IoT. Spectrum in this range will include both refarmed bands (800/850/900MHz) and new bands (600/700MHz).

The 1GHz to 6GHz mid-range spectrum bands provide a good mixture of coverage and capacity. It is expected that most of the operators will deploy in the wider 3.5GHz range (3.3GHz to 4.2GHz). This spectrum shows great promise for international harmonisation and initial deployments of 5G are likely to be in this range. In areas intended for 5G, it is recommended that administrations consider clearing the band, e.g. relocating incumbent users, with the goal of making large contiguous blocks available for 5G in the most appropriate portion of the wider 3.5GHz range.

With regard to spectrum above 6GHz, spectrum in the mmWave range, 26/28/40GHz, is emerging as key for realising the ultra-high speed 5G vision. This spectrum is especially useful for short range, high capacity communication. Identifying harmonised international mobile spectrum allocations in the mmWave bands is on the agenda at WRC-19, where the 26GHz and 40GHz bands are currently the focus of the mobile industry. Outside of WRC-19, 28GHz will also be a vital band for 5G.

In practice, while mmWave spectrum will eventually play a key role for 5G, many initial deployments are likely to be in the 3.5GHz band, which would be the primary 5G band globally for a number of years. Hence, it is important to clarify that in the short-term, 5G deployments in spectrum above 6GHz are unlikely to be as widespread due to the need for significant densification and small cell deployments.

2.2.4.3 Spectrum Allocations

5G will reach its full potential if sufficient harmonised spectrum is made available

Governments should make available sufficient amounts of spectrum for 5G in the, sub-1 GHz, 1 - 6GHz, and the above 6GHz ranges. In the sub-1 GHz range, a portion of UHF television spectrum should be made available for this purpose through the second digital dividend.[21] The European Commission supports the use of the 700 MHz band for 5G services[22] and in the United States the 600 MHz band has been assigned and T-Mobile has announced plans to use it for 5G.[23]

In the 1GHz to 6GHz range, 5G services will benefit significantly from assignments of at least 80MHz to 100MHz of contiguous spectrum blocks per operator in the 3.5GHz range[24] in order to deliver better experience than 4G and address all 5G use cases.

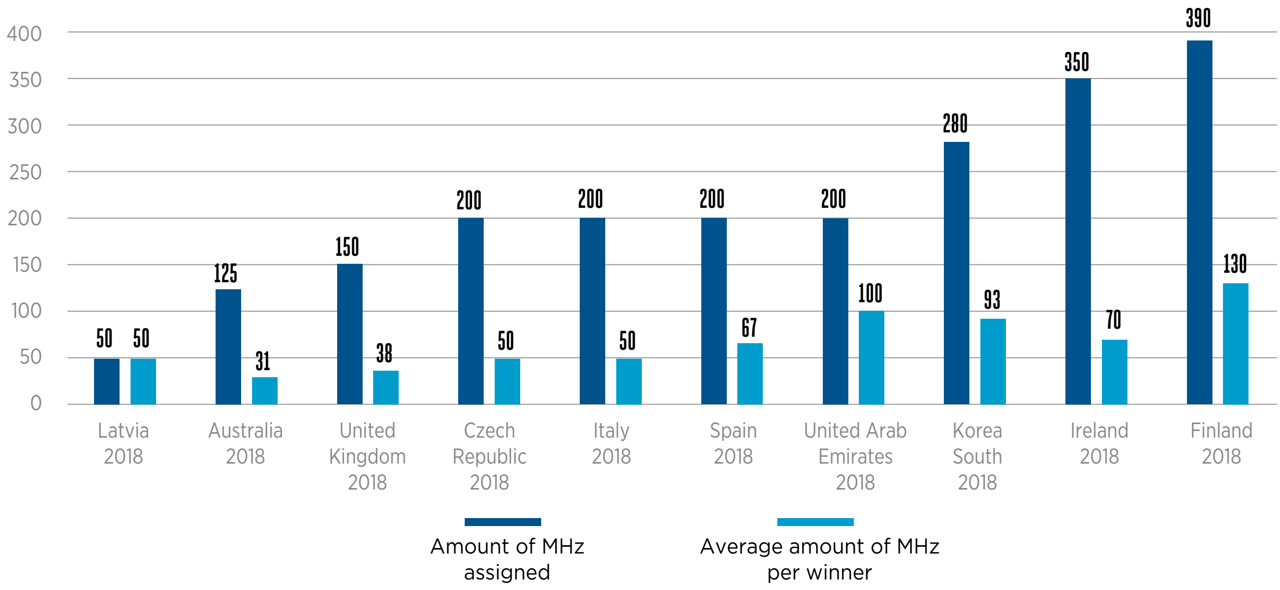
There is a growing risk that, in practice, governments assign an insufficient amount of spectrum to mobile operators due to legacy users in the band, spectrum being set aside from MNO access, or fragmented assignments. Requisite network synchronization with legacy users and spectrum assigned to small players can be challenging and result in an inefficient usage of spectrum and may rule out some 5G use cases. Recent auctions in this band (see Figure 2.2.2) show that the goal of 100MHz of contiguous blocks per operator in this band is at risk.

In the above 6GHz range, the goal is for contiguous spectrum of 1GHz per operator to support the full range of 5G use cases being envisioned. However, there are concerns that, in practice, this target may not be reached, especially if regulators apply overly restrictive usage conditions to protect other services.

Beyond making spectrum available for 5G access, governments and regulators also need to make suitable provisions to support 5G backhaul. The significant capacity demands of 5G means there will be demand for higher frequency microwave backhaul bands which are better able to support the wider channels 5G needs. Currently the V-band (60 GHz) and E-band (70/80 GHz) are expected to be play an important role.

FIGURE 2.2.2

SPECTRUM ALLOCATIONS IN THE 3.5GHZ BAND[25] (SOURCE: GSMA INTELLIGENCE)



Note: the UK amounts exclude the 40 MHz already owned by Three UK through a prior company acquisition.

21. The second digital dividend is the 700 MHz band in Europe, the Middle East and Africa and the 600 MHz band in the Americas and Asia-Pacific
22. 'European Commission stakes out 700 MHz band for 5G' – Telecom TV (2016)
23. Leading towards Next Generation "5G" Mobile Services' – FCC (2015)
24. The proposed range is based on typical availability of 400MHz spectrum in the 3.5 GHz range, divided by, generally, 4 operators per country.
25. As at 1 January 2019

2.2.4.4 Spectrum Pricing

Spectrum should be affordable to encourage network investment

Spectrum pricing represents a critical concern for mobile operators as early 5G auctions have already highlighted failures which risk negatively impacting deployments. Governments and regulators should assign 5G spectrum to support their digital connectivity goals rather than as a means of maximising state revenues. Effective spectrum pricing policies are vital to support better quality and more affordable 5G services.

Spectrum prices are increasing with final prices paid rising 3.5 fold in the 4G era (i.e. 2008-2016) with some outliers 700% above the global average. While high spectrum prices occur in all types of market, it is notable that prices are three times higher in developing countries compared with developed countries once GDP is accounted for. High spectrum prices have been linked to more expensive, slower mobile broadband services with worse coverage and so present a profound threat to the success of 5G. They are also linked to irrecoverable losses in consumer welfare worth billions of dollars worldwide that comfortably outweigh additional treasury revenues from the higher prices.

The causes of very high prices are typically policy decisions that appear to prioritise maximising short term state revenues over long-term socio-economic benefits of mobile services. The GSMA recommends the following best practice for ensuring policy decisions do not artificially inflate spectrum prices and thus jeopardise the success of 5G:

1. Avoid limiting the supply of 5G spectrum, publish long-term spectrum award plans and hold open consultations. 5G requires significant amounts of spectrum so artificial limitations on the amount offered or inappropriate lot sizes risk inflating prices.
2. Set modest reserve prices and annual fees, and rely on the market to determine spectrum prices.
3. Avoid creating unnecessary risks in the auction design that put the success of operators' 5G services in jeopardy forcing them to overbid.
4. Consult with industry on licence terms and conditions and take them into account when setting prices.
5. Auctions must be well designed and implemented to be an effective award mechanism. However, they should also not be regarded as the only award mechanism. (An auction best practice policy paper is available on the GSMA website[26]). Administrative approaches can be more suitable when regulators and the national mobile operators can agree a mutually beneficial split of 5G spectrum.
6. There is no single best approach to estimating the value of spectrum and international benchmarks should be used with caution.
7. Spectrum caps and set-asides distort the level playing field, may jeopardise the success of commercial 5G services and can be costly for the entire ecosystem[27].
8. Spectrum pricing decisions should be made by an independent regulator in consultation with industry

2.2.4.5 Spectrum Fragmentation Risk

Support for 'private' 5G should not jeopardise spectrum availability for 'public' 5G

Regulators must be careful not to undermine the availability of sufficient spectrum for 'public' 5G networks, in seeking to support vertical players who may want to deploy their own 'private' 5G networks. In particular, as 5G should optimally be deployed in 80MHz to 100MHz blocks in the 3.5GHz range, many markets will not have enough spectrum if governments fragment the available spectrum to allocate for private 5G networks.

For example, some regulators are keen to encourage private 5G networks by setting aside spectrum for verticals or through spectrum sharing mechanisms. Both approaches risk limiting the spectrum that is available for public 5G services which will result in slower services, reduced capacity and risks driving up spectrum prices through artificial scarcity.

More widely, set-asides for verticals can lead to inefficient spectrum usage of priority 5G bands. Verticals are unlikely to use the spectrum very widely across countries, so national set-asides are likely to go unused in many areas. Instead, mobile operators can provide customised 5G services for verticals who can then benefit from network slicing, small cells, wider geographical coverage, as well as the larger and more diverse spectrum assets, as well as deployment experience, at mobile operators' disposal.

26. https://www.gsma.com/spectrum/wp-content/uploads/2016/11/spec_best_practice_ENG.pdf
27. https://www.gsma.com/spectrum/wp-content/uploads/2014/11/The-Cost-of-Spectrum-Auction-Distortions.-GSMA-Coleago-report.-Nov14.pdf

Voluntary spectrum sharing approaches are preferable to set asides as they can be used to support all potential 5G users, including verticals. For example, MNOs can be permitted to lease their spectrum assets so that verticals can build their own private 5G networks. This approach also overcomes the issue of synchronising public 5G networks with private 5G networks in adjacent bands which may limit which 5G use cases can be supported.

2.2.4.6: National spectrum planning

Put in place spectrum policy measures to support long-term 5G network investment and address national operators' requirements

It is vital that spectrum is made available in a way that encourages operators to invest heavily in mobile networks and supports quality of service. This will require a significant amount of long-term exclusively licensed spectrum (e.g. over twenty years) with a predictable renewal process that is planned years (e.g. over five years) in advance of expiry.

All mobile licences should be technology neutral – without additional cost – so operators can speed up wide area 5G rollouts using existing infrastructure while also improving spectrum efficiency. A 5G spectrum roadmap should be published outlining exactly what bands will be made available and in what timeframes so operators can plan their investment strategy and value spectrum effectively.

All 5G spectrum plans should be subject to consultation with 5G stakeholders to ensure spectrum awards and licensing approaches consider national technical and commercial deployment plans. For example, decisions around licence area sizes (e.g. national versus localised) and coexistence measures including rules surrounding network synchronisation will have a major bearing on network investment, deployment plans and the viability of various 5G use cases.

2.2.5 Regulatory costs

Policymakers need to ease the financial demands of 5G by bringing down regulatory costs and fees

Operators are in the difficult position of committing significant new investments for the rollout of 5G without any real certainty of how, or when, a return can be expected. Governments, in support of their own digital policy goals, should therefore take meaningful action to ease the cost burden faced by the mobile industry to deliver 5G services.

In addition to reasonable spectrum costs, further steps should be taken in many areas, such as reducing or eliminating mobile-sector taxes on both operators and customers; easing tax on energy for 5G; and lowering administrative and siting fees. Policymakers are also encouraged to allow voluntary spectrum pooling between operators to help drive faster services and maximise spectrum efficiency.

Spectrum sharing (with entities other than mobile network operators) is gaining traction in some countries. This may have an impact on the amount of spectrum mobile operators can reliably access to maximize the full potential of 5G services in terms of very-high throughputs, low latency (etc). Spectrum sharing frameworks support multiple users in a given band and enterprises in some vertical sectors are calling on regulators to ensure they can access 5G spectrum without relying on mobile operators. Some regulators, most notably the FCC in the 3.5GHz band, are looking to create shared spectrum bands. These approaches could limit the amount of spectrum available to mobile operators for high-quality 5G services.

To deliver affordable, widespread and high-quality mobile broadband services, mobile operators require affordable and predictable access to sufficient radio spectrum. High spectrum prices have been linked to more expensive, lower-quality mobile broadband services and may limit 5G roll-out an take-up. Spectrum auctions should allow the market to determine spectrum prices. Governments should prioritise rapid, high-quality 5G service rollouts over revenue maximisation when awarding 5G spectrum.

2.3 Market Readiness

KEY TAKEAWAYS

- **Market readiness, starting with 4G maturity, is crucial to determine the timing of 5G launch. This varies by market and will make or mark the success of 5G in each market.**
- **The 5G competitive landscape will remain fierce. Policymakers must continue to ensure a level playing field among competitors that supports the industry's ability to invest.**
- **Markets with greater scale can better influence the global trajectory of 5G development, and are also able to achieve low unit costs of network rollout and economies of scale.**
- **The availability and capability of 5G phones from 2019 will be a pivotal moment that will drive customer adoption of 5G.**
- **An interesting lesson from the launch of 4G is that being the first-to-launch does not guarantee sustainable competitive advantage.**
- **Another lesson from 4G is that when an operator delays launching for too long (>12 months after its rivals), it faces a decline in revenues as competitors gain market share.**
- **Given revenue uncertainty, many operators will maintain their CAPEX envelopes and focus on a demand driven approach that addresses hotspots in urban areas with a clear capacity need or to support enterprise customers' requirements.**
- **Operators should have a clear roadmap to shut down 2G/3G networks to limit network operations complexity and support spectrum refarming.**
- **The idea of leapfrogging to 5G from 2G/3G and without deploying 4G, is tantalising. But it will be very difficult due to technical, commercial and regulatory challenges.**
- **With a major shift in architecture away from traditional models and competencies, operators need collaboration and new skills to unlock 5G era opportunities.**

2.3.1 Market readiness and timing

The timing of 5G deployment is dependent on market readiness

Assuming that the technology for 5G is ready and the market is ready, operators will need to evaluate what they need to get right on their 5G journey. Some of the key questions to consider:

- How mature is my 4G customer base and what will they be prepared to pay for 5G?
- What is the state of my current network coverage and capacity?
- Do I have the right skills and expertise, and if not, what new partner relationships are required?
- What is the right operational model for the 5G era?
- What new opportunities does 5G create?
- When would customers need 5G capabilities?
- Does a market have pro-investment and innovation policy and regulatory framework?
- Are operators financially healthy to support 5G investments?

Some of these questions are explored further in this section.

2.3.2 4G maturity trigger

4G market maturity and affordability will trigger a push to 5G

5G is a question of 'when' and not 'if' for most markets and operators. The decision on when to launch 5G will be based on triggers that are localised for each market, given the different stages of 5G readiness across markets.

For example, a looming capacity crunch for mobile broadband or an identified enterprise need in a market are credible triggers for 5G launch. Ericsson[28] reports that average smartphone data usage by 2023 will range from 7GB/month in in Sub-Saharan Africa to 48GB/month in North America.

Even if the 5G launch trigger has not been reached, users and policymakers in highly developed mobile markets with a focus on technology leadership will expect 5G to be available soon. Many markets with at least 80% 4G coverage and 60% smartphone adoption will fall in this category.

Customers' ability and willingness to pay a premium for 5G services will be an important consideration in most markets. Any operator expectation on charging a premium for eMBB will need to be tested, given that over the last ten years, customers have used ever growing amounts of data over faster connections, while ARPU has stagnated and even declined in many developed markets.

28. https://www.ericsson.com/en/mobility-report/reports/june-2018

2.3.3 5G competitive landscape

Competition will remain fierce in the 5G era

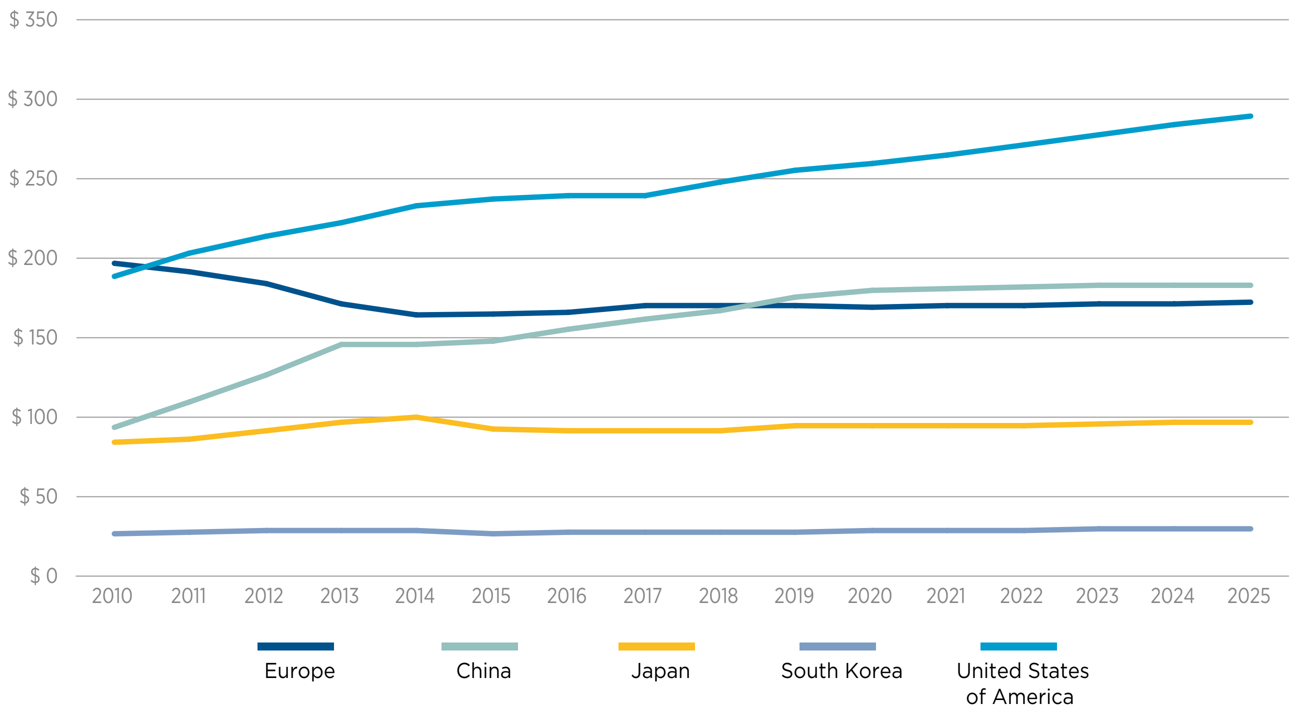
The competitive environment going into the 5G era remains challenging in many markets around the world. This is unlikely to abate anytime soon and intense intra-operator competition will remain a big market force for the foreseeable future. Many operators are also increasingly competing with non-operator companies, for example in TV and content services where operators have made acquisitions (e.g. AT&T's acquisition of Time Warner) as well as IoT, where some operators aim to expand beyond connectivity and provide vertical solutions.

Competition has been instrumental in driving costs down, developing innovative products and services, and expanding coverage globally. Operators will continue to play their part in ensuring that the mobile industry remains a source of value creation and growth driver for the global economy.

A supportive policy framework and a level playing field between competitors is vital in enabling a market environment that supports the ability of the industry to invest in 5G. When these conditions are less ideal, or supportive, industry financial health may be negatively impacted. For example, a comparison of selected countries and regions outlined in Figure 2.3.1 below suggests Europe was the only region in the world where revenues during the 4G era fell. This may undermine the capacity of the operators in the region to pursue an aggressive 5G rollout strategy.

FIGURE 2.3.1

MOBILE REVENUES AND FORECASTS IN $ BILLIONS FOR SELECTED COUNTRIES AND REGIONS (SOURCE: GSMA INTELLIGENCE)



2.3.4 5G and benefits of scale

Size and economies of scale are beneficial to 5G commercialisation

Telecoms is a capital intensive industry and having sufficient scale can provide huge benefits for all stakeholders in a market. Markets with sufficient scale can better influence the global trajectory of 5G development and are also able to achieve low unit costs of network rollout (i.e. economies of scale). These will create significant incentives for early 5G rollout.

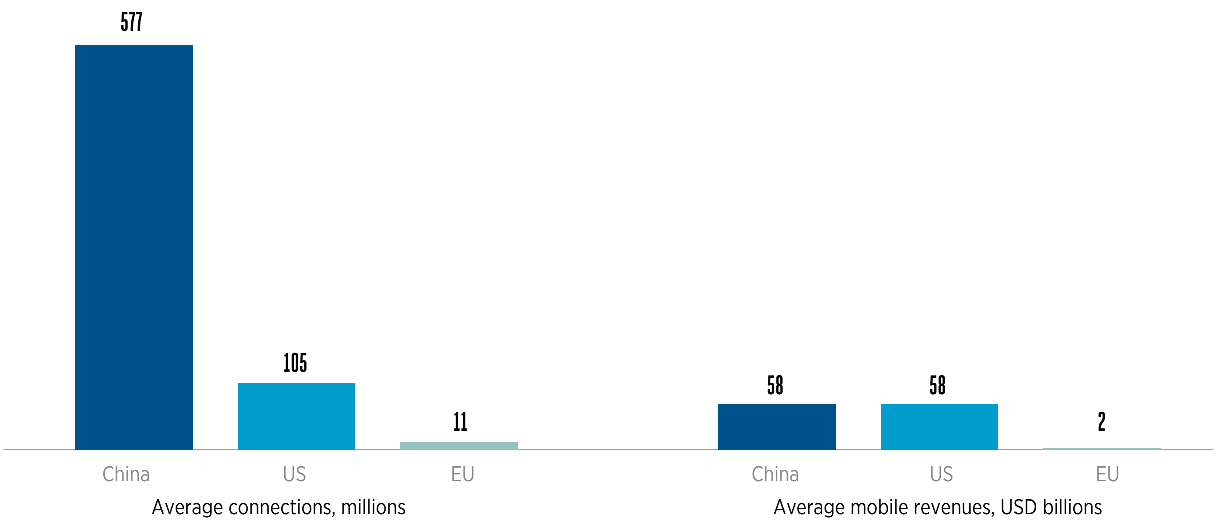
Figure 2.3.2 illustrates the lack of scale for operators in the EU. Each of the market-leading operators in China and the US (accounting for more than 95% of all connections) has an average of at least 100 million connections and generates an average of $58 billion in annual revenues.

In contrast, leading operators in the EU have an average of 11 million connections and $2 billion annual revenues. With sufficient scale, operators in China and the US have considerable financial muscle to support 5G deployment and a large base of customers to drive down the cost per connection for 5G.

To mitigate this, operators in individual markets that are subscale can consolidate, collaborate or align their 5G strategies to achieve better economies of scale. This can be in-country (e.g. through network sharing or consolidation) or across borders (e.g. harmonising the use of spectrum and timing of auctions). This is a task for all stakeholders in the market, including policymakers and operators. The announcement of the Nordics 5G corridor is an example of a collaboration that facilitates technology and spectrum harmonisation, and improves the incentives for network launch[29].

FIGURE 2.3.2

AVERAGE CONNECTIONS AND MOBILE REVENUES FOR OPERATORS IN CHINA, EU AND US (FY 2017) (SOURCE: GSMA INTELLIGENCE)



29. https://www.government.se/press-releases/2018/05/new-nordic-cooperation-on-5g/

2.3.5 Success factors for 5G handsets

New features, affordability, battery life and safety will drive adoption of 5G devices

While early 5G devices will be mostly customer premises equipment (CPE) for Fixed Wireless Access (FWA) or wireless routers, the availability of 5G phones from 2019 will be a pivotal moment that will drive customer adoption of 5G.

The smartphone market has matured, leading to a lengthening of the smartphone replacement cycle. In this reality, connection speed alone is unlikely to be a sufficient driver for mass-market upgrade to 5G devices as users will wait to see if the new or improved features warrant replacement of the smartphones every 12 to 18 months. The device ecosystem, including 5G devices, is hoping for an 'iPhone moment', similar to the new customer experience created by the iPhone in 2007.

There are also disincentives that could deter customers. Affordability is a major concern, given early indications that the wholesale cost of 5G handsets, when they are introduced in 2019, will be more than $750 and that only 9% of Chinese customers buy phones with wholesale prices of over $500[30]. The implication is that high device prices could threaten the economies of scale from China that ought to accelerate global 5G rollout.

In addition, battery capacity, performance and safety for early 5G handsets will be a key success factor. Adoption will be seriously impacted if early 5G handsets cannot last 24 hours on one charge, or if customers need to switch off 5G in order to make the battery last longer. Concerns about safety of 5G handsets will also be notable, whether as a result of battery safety, fire hazard or avoiding electromagnetic radiation. In September 2017, the GSMA produced the paper "5G, the Internet of Things (IoT) and Wearable Devices - What do the new uses of wireless technologies mean for radio frequency exposure?" to provide more clarity on EMF concerns in the 5G era.

30. https://news.strategyanalytics.com/press-release/devices/strategy-analytics-5g-hype-cycle-about-run-hard-truth-subsidies-needed

2.3.6 Lessons from 3G/4G: first mover advantage

First mover advantage does not guarantee sustainable competitive advantage

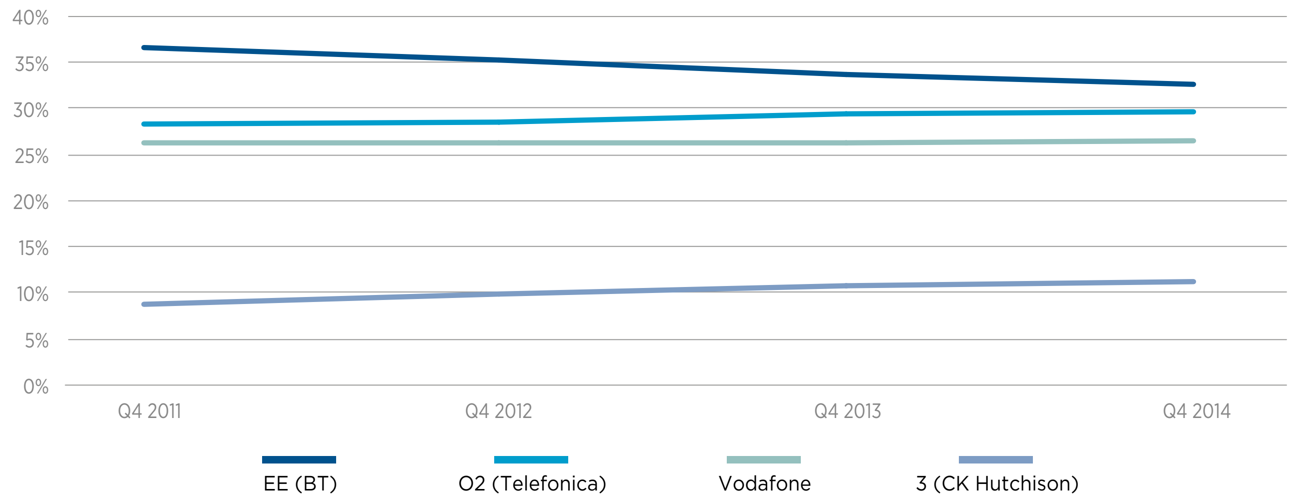
GSMAi analysis of operator KPIs during 3G and 4G deployment periods suggests that being first to launch a new cellular technology in a market does not always result in an increase in financial performance. In terms of ARPU, revenue or market share of connections, no correlation was observed either that proves a clear benefit of launching first. For example, EE launched 4G in the UK in Q4 2012, ten months ahead of other UK operators, yet its market share continued to decline (see Figure 2.3.3 below).

There are at least four likely explanations as to why being the first mover did not bring any significant upsides. First, operators that launch first in a market often do so on a limited scale (e.g. in selected key cities) with the intention to be the first for marketing/PR reasons. Second, in most cases the gap between the first mover's and competitors' launches was less than a year, therefore not enough to bring a sustainable competitive advantage. Third the first mover spends time and money debugging the system for others. Fourth, the first mover pays a premium for infrastructure and devices.

Long-term market share trends are rather dependent on other factors such as competitors' strategy or tariff plans.

FIGURE 2.3.3

4G ERA MARKET SHARE EVOLUTION IN THE UK (SOURCE: GSMA INTELLIGENCE)



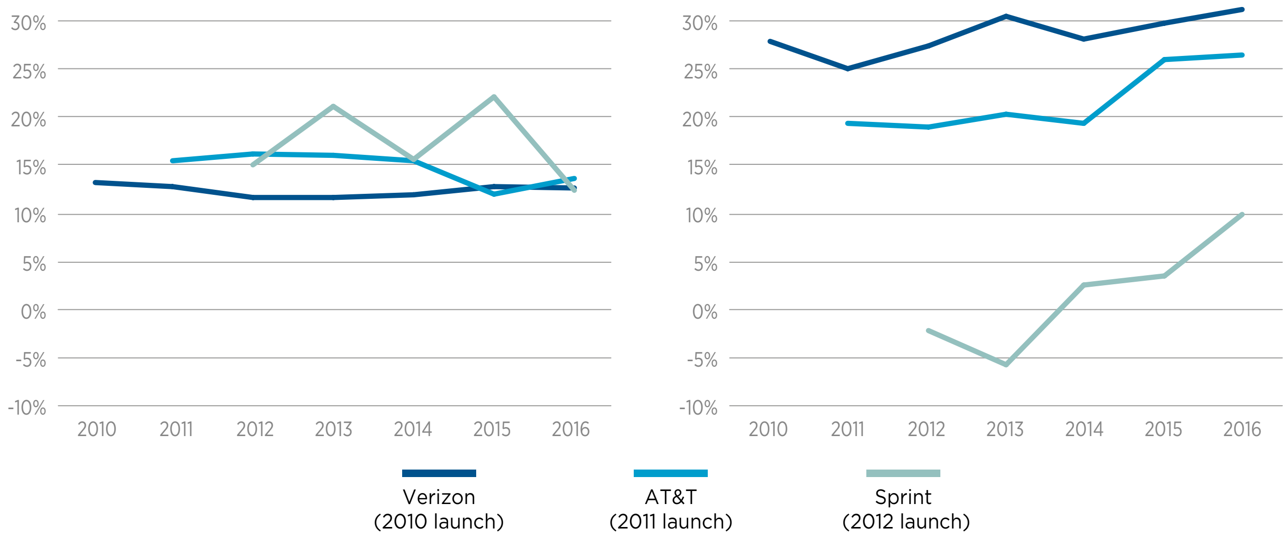
2.3.7 Lessons from 3G/4G: late mover risks

Late movers risk capex spikes to catch up with early adopters

While being the first to launch a new generation technology does not necessarily bring sustained competitive advantage, being late to the market can have serious implications for an operator. When an operator delays launching a new technology for too long (for example, by more than 12 months) after its rivals, the obvious impact is that the operator faces a decline in revenue as competitors gain market share with a superior offer. Moreover, the operator is often forced to catch up with an aggressive technology rollout to regain competitiveness. Figure 2.3.4 illustrates how this dynamic played out in the US for 4G roll out.

FIGURE 2.3.4

CAPEX AND CASH FLOW EVOLUTION IN THE US (SOURCE: GSMA INTELLIGENCE)



2.3.8 Lessons from 3G/4G: optimal rollout plan

A progressive and consistent rollout plan is optimal for 5G

The lesson from 3G/4G network rollouts is that a progressive and steady rollout plan, launching around the same time as rivals, is optimal. Operators which adopt this approach may, in the short term, experience a slight increase in capex and a slight decrease in operational free cash flow (OFCF). This may happen in a competitive context that necessitates higher investment levels to meet market-wide network coverage. In the long run, capex levels will fall to pre-launch levels as investment is focused on continued densification, maintenance and upgrading of the network. The examples of Bell Canada and Rogers in Canada in Figure 2.3.6 (below), illustrate the point.

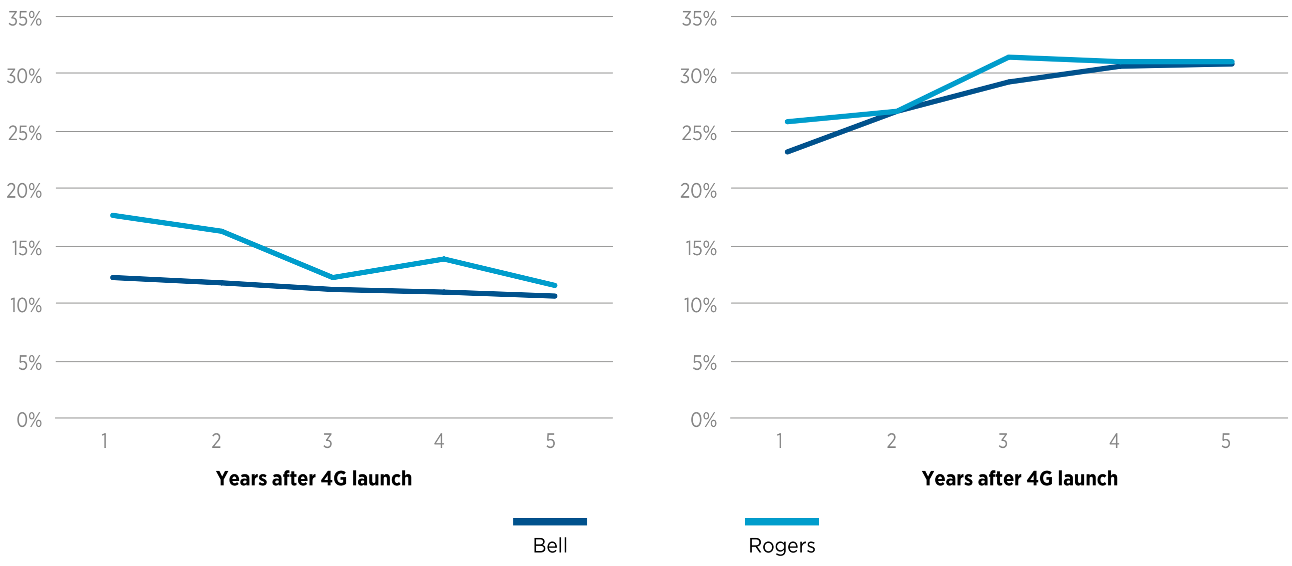
Much as the lessons from 3G/4G rollouts are useful, the CAPEX constraints that operators are facing today will be the important consideration in 5G deployment.

CAPEX dynamics over time are closely linked to revenue, and revenue growth for leading operators has been stagnating in recent years.

Looking at the 5G monetisation potential during the next five years, many operators feel that a clear revenue increase based on the currently-known 5G use cases remains to be proven. Therefore, many operators will maintain the CAPEX envelope, which means that 5G rollout will most likely be gradual (at the pace of the regular equipment upgrade/replacement cycle), starting in 2018 and lasting seven to ten years. Early deployment will be very much need/demand driven, addressing hotspots in urban areas with a clear capacity need or to support enterprise customers' needs.

FIGURE 2.3.5

CAPEX AND OFCF EVOLUTION IN CANADA (SOURCE: GSMA INTELLIGENCE)



2.3.9 Operational complexity with 2G/3G/4G/5G

Operators should have a clear roadmap to shut down 2G/3G networks

The prospect of running a combined 2G/3G/4G plus 5G network will pose an operational challenge to operators in many markets. The initial headache with 5G will come from the complexity of managing legacy networks, the need for integrating legacy networks with the new 5G network, and the resources and expertise required to address these challenges.

In the early 5G era, some operators may be able to count on multi-mode common platforms that are able to manage all access types (2G, 3G and 4G) plus 5G scenarios (NSA + SA) from a core perspective.

However, operators need to develop a clear roadmap for shutting down legacy 2G and/or 3G networks before commencing mass market 5G rollout, if they haven't done it yet. Such a roadmap could have an implied bonus when spectrum can be refarmed for 5G rollout – although there are sometimes regulatory barriers to this happening.

A key requirement before rationalising 2G/3G networks is adopt All-IP communications services to replace circuit-switched communications. In addition, interconnection and roaming of these All-IP communications services is essential because having inbound roamers and international communications traffic using CS services forces the operator to retain CS infrastructure.

The GSMA has developed the Network Economics Model and worked with the industry to detail several case studies that illustrate how operators have executed a 2G or 3G network shutdown or ease down[31].

2.3.10 Leapfrogging to 5G

Leapfrogging to 5G from 2G/3G, without deploying 4G, is possible but challenging

The prospect of leapfrogging 4G will be difficult for most operators because of technical, commercial and regulatory challenges.

A 4G network is a requirement for operators planning to launch NSA 5G. While a leapfrog from 3G to SA 5G is technically feasible, there are many complications. These include the challenges of managing voice handover; managing spectrum harmonisation; maintaining device interoperability; and the need to wait for the later maturity of SA 5G. It also means carrying over the complexities of the Circuit Switched 3G network into the 5G era, and the risk of undermining the simplicity inherent in migrating to 5G's service-based architecture (SBA).

Commercially, a leapfrog to 5G from 2G/3G will likely require a costly outlay on a greenfield, nationwide deployment of 5G, and with no fallback and no inbound roaming. It also raises the danger that some investments (e.g. spectrum), made in anticipation of 4G rollout, could become 'stranded assets'. Given the momentum towards a 4G-to-5G migration, devices and equipment for 3G-to-5G migration will struggle for economies of scale, potentially making them costlier.

Voice is a regulated service that operators will be expected to support for the foreseeable future. In markets where lots of voice traffic is still on 2G, over devices on 2G mode, it will be difficult to skip 4G and migrate to 5G without failing to fulfil the regulatory obligations on voice. Unless an operator wants to continue supporting 2G or 3G into the future, there is a need to firstly migrate voice traffic and usage to 4G (i.e. VoLTE), monetise any 4G spectrum and then plan a migration path to 5G.

31. https://infocentre2.gsma.com/gp/pr/FNW/NE/Pages/Default.aspx

2.3.11 Collaboration and new skills for 5G

Operators need collaboration and new skills to unlock 5G era opportunities

5G era opportunities will require new domain expertise including data science, analytics, machine learning etc., and an architectural rethink of how a network is deployed and run, including new approaches such as virtualisation. Operators will either have to develop these competencies in-house, or they will need to source them externally, establish partnerships, or bring in new talent in order to address these new opportunities.

Some of the new skills will be required to address the enterprise opportunity in particular. 5G offers huge opportunities for operators in the enterprise segment, but they must address the big challenge of building the C-level relationships to connect and understand the actual needs of enterprises, and build the solutioning capabilities to address those needs. For instance, in most enterprise use cases, operators will be competing with system integrators and other service providers (e.g. platform providers) on how best to serve enterprise needs. Often, these rivals will have deep understanding, borne out of existing relationships with enterprises.

However, as Sections 3.4 and 3.7 show, operators can make a difference with 5G and addressing the enterprise opportunity will also influence how and where 5G networks will be built. Unlike 2G/3G/4G, where operators built networks and waited for customers to come onboard for connectivity solutions, 5G networks may have to be built to address specific enterprise needs in specific locations.

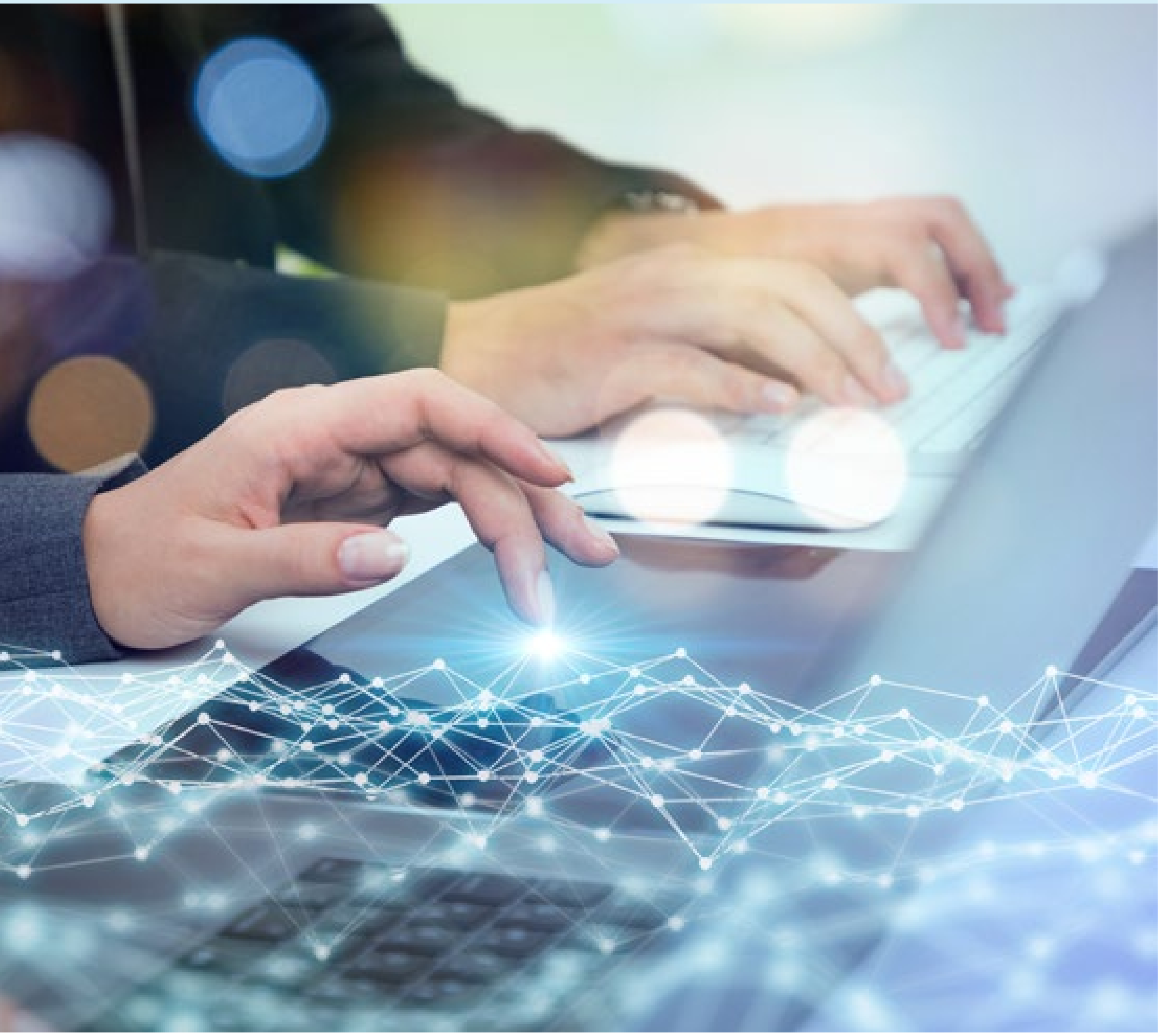
This will necessitate close collaboration between operators and enterprises to understand the best ways of deploying the network. Some operators have already begun engaging with enterprises and this will increasingly become a necessity for most operators.

For more details on operator relationships with enterprises, please go to Section 3.4: What do enterprises want, and Section 3.7: Enterprise opportunity.

2.4 The BEMECS Framework

KEY TAKEAWAYS

- **The BEMECS (for Basic, Economic, Market, Enterprise, Consumer, Spectrum indicators) framework is an evaluation tool for 5G market readiness.**
- **There are 40 indicators in the BEMECS tool which can be used to appraise the 5G market readiness for 160+ countries.**
- **The BEMECS tool uses a traffic light system (red, amber, green) to evaluate market readiness for 40 indicators.**



2.4.1 Introducing the BEMECS framework

Analytical tool for evaluating 5G market readiness

Expectations across society on what 5G will deliver and how revolutionary it can be, are very high. However, the readiness of each market for 5G is a multi-factorial reality and different markets are at different stages of maturity and readiness.

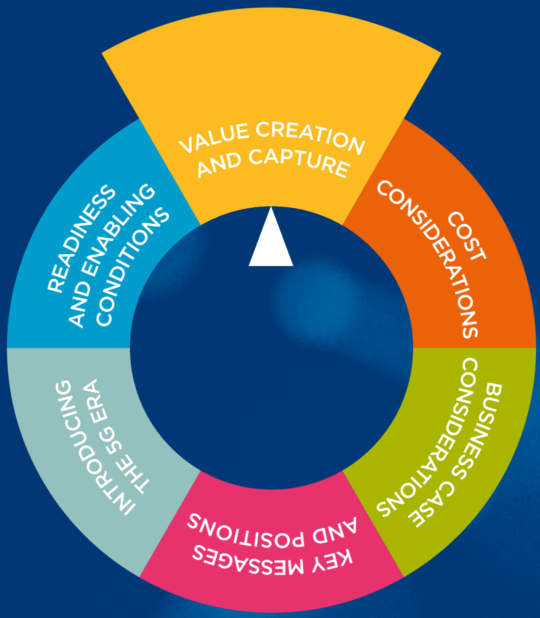
The GSMA has developed the Basic, Economic, Market, Enterprise, Consumer, Spectrum indicators (BEMECS) framework to provide an evaluation tool for the 5G market readiness of different countries. The BEMECS framework tool covers more than 160 countries and uses a traffic light system (Green, Amber, Red) to analyse the 40 indicators included, as summarised in Figure 2.4.1 and explained in full in Table 7.3.1.

The BEMECS framework aims to encompass the different perspectives from which 5G readiness can be analysed. For example, it covers indicators that are endogenous to the mobile telecoms industry (e.g. 4G and Smartphone penetration), which derive from the *in situ* competition in the industry. It also covers exogenous indicators (e.g. GDP/capita, literacy rates), which act as external variables that will ultimately shape 5G readiness. Likewise, BEMECS covers demand-side indicators (e.g. 'Household computer penetration' and 'Ratio of ARPU and GDP/Capita') and supply-side indicators (e.g. number of operators in a market and FTTx penetration).

FIGURE 2.4.1

BEMECS FRAMEWORK INDICATORS

BASIC INDICATORS	ECONOMIC INDICATORS	MARKET INDICATORS	ENTERPRISE INDICATORS	CONSUMER INDICATORS	SPECTRUM INDICATORS
Region	GDP (real)	Total Subscribers	IoT Penetration	AffoGDP rdability: ARPU/per capita	<1GHz availability
GSMA Region	GDP Growth Rate (Real)	Average Download Speed (Mbit/s)	Registered Websites per 1000 people	Affordability: Device ASP/GDP per capita	1-6GHz availability
Population	GDP Growth Rate (Constant)	Number of Operators	Published Apps per 1000 people	Literacy Rates	>6GHz availability
Population Density	GDP Growth Rate (PPP)	4G Penetration	Population with Tertiary Education	Mobile Social Media Accounts	
Urbanisation	GDP (real) Per Capita	Mobile Connections Penetration	Ease of Doing Business	Personal Computer Penetration	
		Smartphone Penetration	Published Apps in National Language	FWA Opportunity	
		Unique Subscribers Penetration	E-Government Availability		
		Fixed Broadband Penetration			
		Average ARPU (2017-2018)			
		FTTx Penetration			
		ARPU Growth (2018-2023)			
		Internet Backbone Penetration			
		Mobile Revenue Growth/GDP Growth			
		Electricity Availability			



3 5G Value Creation and Capture

Chapter 3 looks at the promise and opportunity of 5G, examining what customers and enterprises are anticipating from the technology and how it will deliver a variety of new revenue streams.

Readers will get an insight into some of the new opportunities unlocked by 5G, along with an understanding of the key enablers of 5G value creation.

3.1 The 5G Opportunity

KEY TAKEAWAYS

- **The 5G opportunity is clear. It will support a wider set of use cases, with varying requirements in terms of speed, latency, number of connections and mobility.**
- **The potential economic contribution of 5G to society is clear. A TMG/GSMA study estimates it at $2.2 trillion contribution to global GDP and $588 billion in worldwide tax revenue by 2034.**
- **Operators have a clear opportunity to benefit from 5G and the 5G use cases will enable a broader set of monetisation opportunities for operators and the wider ecosystem.**
- **Given the aspiration to support enterprises using 5G, operators' share of the 5G value will depend on their ability to support the digital transformation of other industries.**

3.1.1 The 5G opportunity framework

5G is inevitable and with the right conditions, it will flourish and create opportunities across society

5G is inevitable. For users, operators, vendors and policymakers, 5G is the next step in the industry's steady progress towards providing a better mobile experience. In that sense, 5G is a matter of when and how, and not if, it will happen.

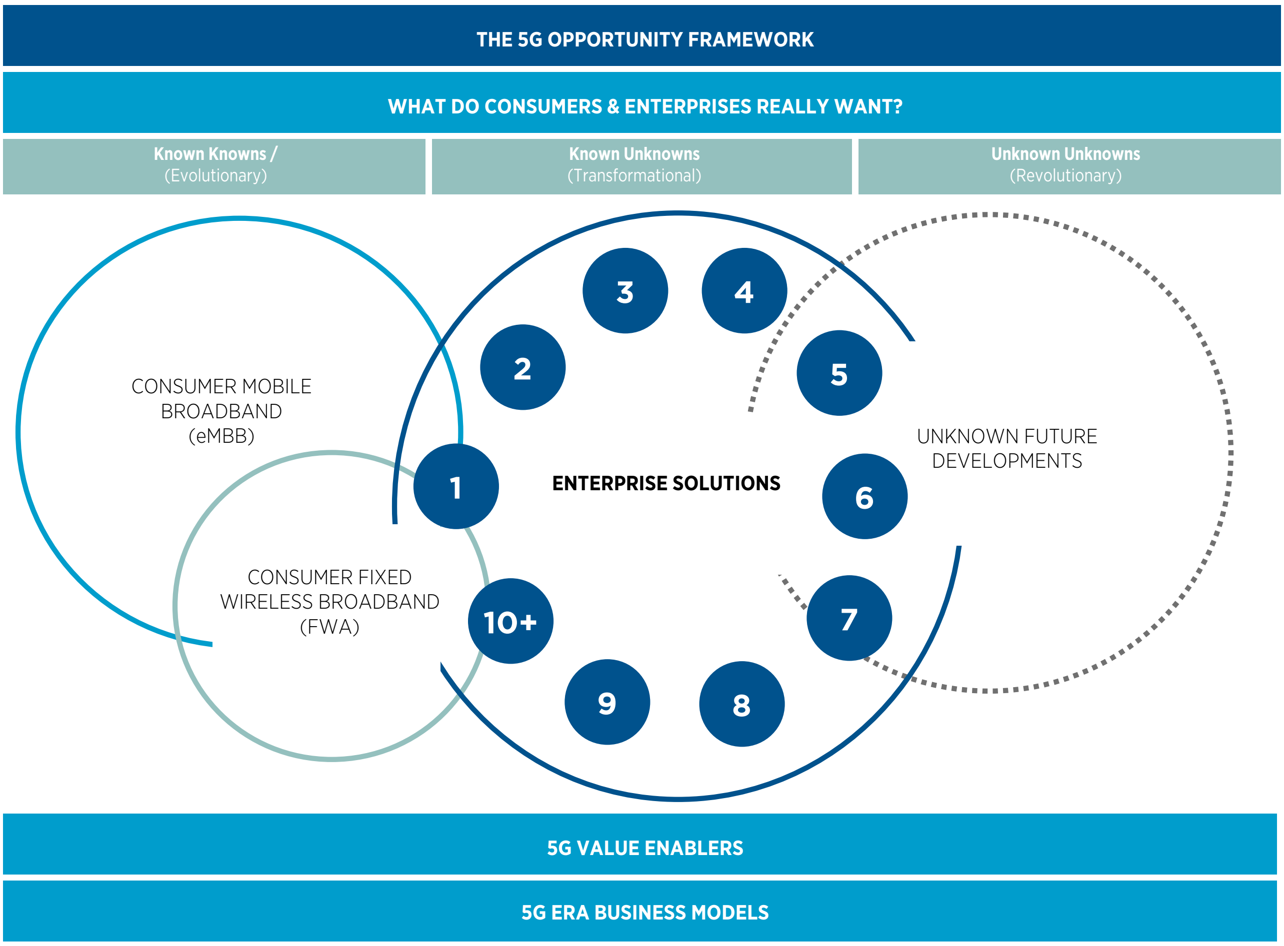
From an operator's perspective, 5G promises to structurally reduce the cost of operating future networks, while providing new functionalities and unlocking a new wave of innovative services. 5G will support a wider set of use cases, with varying requirements in terms of speed, latency, number of connections and mobility. These use cases will enable a broader set of monetisation opportunities

5G opportunities range from the known knowns of enhanced mobile broadband (eMBB) and fixed wireless access (FWA) to known unknown opportunities (e.g. in IoT) in many different enterprise markets. Given the course of technological development, 5G is also set to underpin revolutionary market opportunities, such as those based on artificial intelligence and cloud-based services.

Figure 3.1.1 introduces the 5G opportunity framework, highlighting the evolutionary, transformational and revolutionary opportunities for the 5G era.

FIGURE 3.1.1

THE 5G OPPORTUNITY FRAMEWORK



3.1.2 Economic benefits of 5G

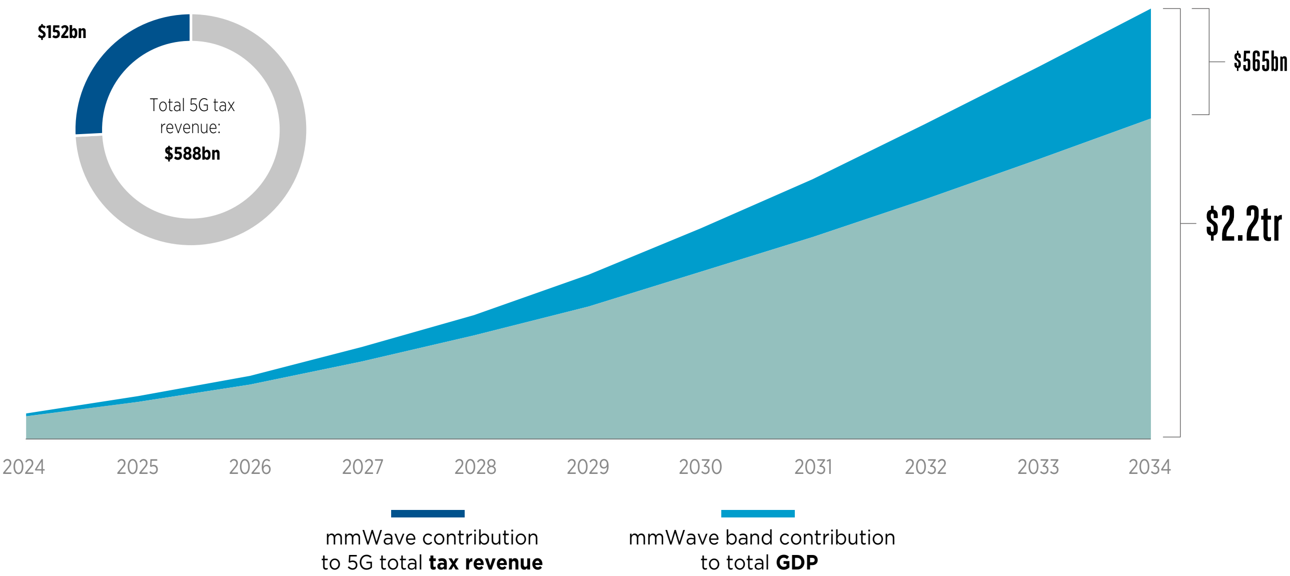
5G will yield $2.2 trillion in GDP and $588 billion in tax revenue during 2020 – 2034

5G will generate massive value for the global economy. This is underpinned by earlier studies (e.g. by World Bank[32]) that show strong relationships between broadband availability and economic growth. The GSMA's Mobile Economy report also shows strong GDP contribution by the activities of the mobile telecoms industry.

The December 2018 GSMA/TMG study[33] estimates that 5G will provide important economic benefits of $2.2 trillion in global GDP and $588 billion in worldwide tax revenue cumulatively over the period from 2020 to 2034, as outlined in Figure 3.1.2, below. Millimetre Wave 5G use cases will make up an increasing proportion of the overall 5G contribution to global GDP, achieving around 25% of the cumulative total by 2034, which amounts to $565 billion in GDP and $152 billion in tax revenue.

FIGURE 3.1.2

ECONOMIC CONTRIBUTION OF 5G (SOURCE: TMG, GSMA)



32. http://pubdocs.worldbank.org/en/391452529895999/WDR16-BP-Exploring-the-Relationship-between-Broadband-and-Economic-Growth-Minges.pdf

33. https://www.gsma.com/spectrum/wp-content/uploads/2018/12/5G-mmWave-benefits.pdf

3.1.3 5G revenue projections

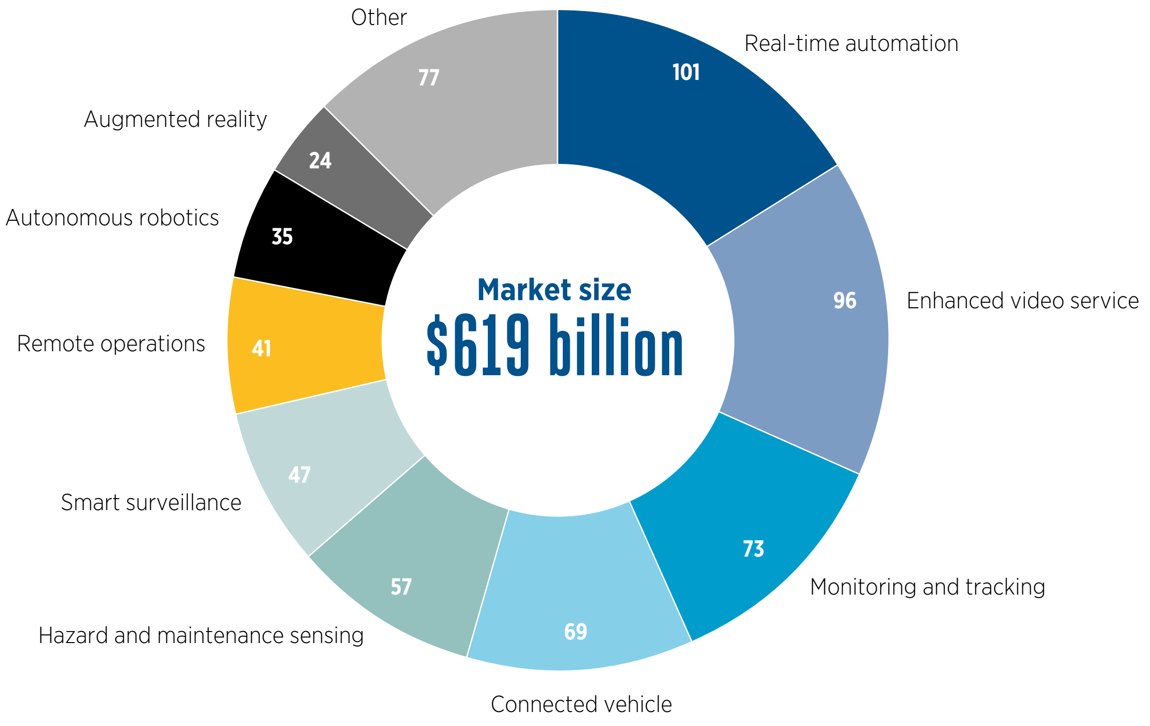
The incremental 5G opportunity is in digital transformation of industries

A major question for operators and industry stakeholders is how much of the $2.2 trillion 5G economic contribution to GDP is addressable by operators. An Ericsson study[34] in 2017 suggested that operators have the ability to address an additional revenue opportunity of $204 billion to $619 billion by 2026 from ten industries (see Figure 3.1.3). ">$400 billion" is used throughout this study as a reference for the enterprise opportunity. Another study, from Huawei[35], explored the opportunities from their top-ten 5G use cases, showing for example, that there is an operator addressable market opportunity of $93 billion for Cloud AR/VR.

These studies assess the scale of the opportunity that operators can unlock to capture their share of the value in the 5G ecosystem. For 5G to avoid becoming a technology show, it must deliver on its promise to accelerate the digital transformation of other industries.

FIGURE 3.1.3

5G BUSINESS POTENTIAL PER CLUSTER[36] (SOURCE: ERICSSON)



34. https://www.ericsson.com/assets/local/networks/documents/report-bnew-17001714.pdf
35. https://www-file.huawei.com/-/media/CORPORATE/PDF/mbb/5g-unlocks-a-world-of-opportunities-v5.pdf?la=en
36. https://www.ericsson.com/en/networks/trending/insights-and-reports/5g-challenges-the-guide-to-capturing-5g-iot-business-potential?alild=1206580

3.2 5G Value Capture

KEY TAKEAWAYS

- There are three opportunities for operators to create and capture value in the 5G era.
- First, 5G will enhance the core business of communications and data services. It will boost its capabilities, and make it more efficient and profitable.
- Second, 5G will deliver new 5G use cases, which operators can either monetise directly, use to enrich the core offering or can be spun off.
- Third, operators can capture value by investing in ecosystem innovations or partnerships that can help to 'pull through' 5G adoption or that can benefit from a more connected society.

3.2.1 5G Value capture for operators

Operators need to look beyond the core business to identify where and how to capture value in the 5G era

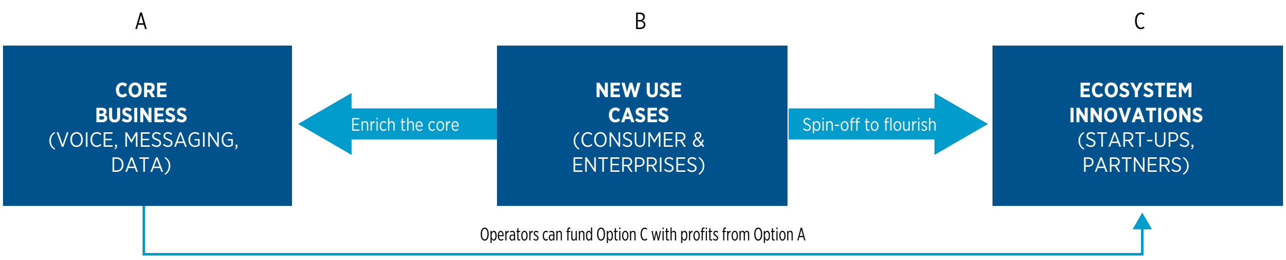
Operators have three sets of recognisable opportunities to capture value in the 5G era, as outlined in Figure 3.2.1. The first is in enhancing the traditional core business of communications and data services to consumers and enterprises. Operators are already experts in this area, and will evolve their current commercial models into the 5G era.

The second set of opportunities for operators is in new 5G use cases. The industry has focused a lot of effort on activities, pilots, and test beds to conceptualise, develop and commercialise new 5G use cases. Many of these are aimed at industry verticals, in keeping with the expectation that 5G will transform industrial verticals. Some new use cases will have synergies that enrich the core business (e.g. Cloud AR/VR) while some will be independent from the core business and could be spun off to flourish as independent businesses (e.g. drone delivery).

The third set of opportunities lie in ecosystem innovations or partnerships that can help to 'pull through' 5G adoption or that can benefit from a more connected society. Pull-through innovations (e.g. AR/VR entertainment) encourage customers to upgrade to 5G and their growth invariably leads to faster, and more profitable, 5G adoption. Innovations that grow as mobile connectivity improves (e.g. music streaming) are also good candidates for capturing value in the 5G era. While several operators already make such investments, the key is to explicitly link these ecosystem investments and partnerships as part of the value capture opportunities in the 5G era.

FIGURE 3.2.1

THREE VALUE CAPTURE OPPORTUNITIES FOR OPERATORS IN THE 5G ERA



3.2.2 5G and the 'Core' operator business

The 5G era vision is to offer differentiated services: the reality is, firstly, to deliver 5G at low cost

5G has the potential to both bring growth in new business areas and improve profitability in operators' core business. Figure 3.2.2 provides an illustration of these two options.

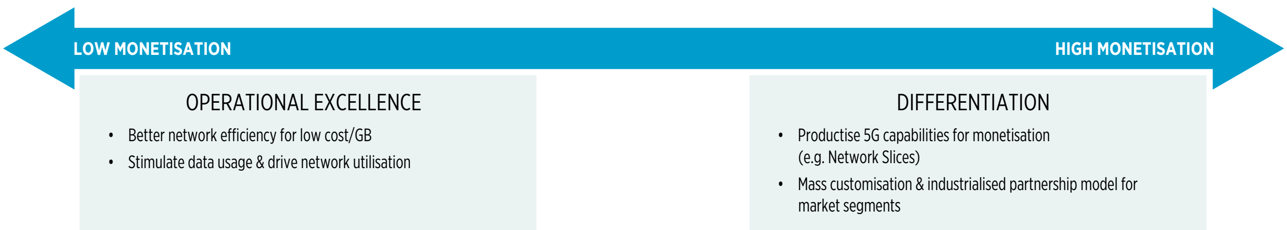
Using 5G to improve profitability of lower-growth business segments is primarily about making the core business of connectivity more efficient with better utilisation of the network. This is the minimum expectation for any operator seeking to launch 5G.

Operators seeking a higher-growth 5G strategy will need to devise a robust roadmap that is based on offering differentiated services to different market segments. This will require commercialising 5G capabilities such as low latency and security, and monetising them, potentially through APIs or a platform model. Based on the technological, market and operator 5G readiness, this high growth scenario is less likely to happen in the first years of 5G deployment.

Operators pursuing the higher growth model need to act now to prepare the market; understand the needs of the ecosystem; test and evaluate new use cases; and strike partnership deals.

FIGURE 3.2.2

OPERATIONAL EXCELLENCE VERSUS DIFFERENTIATION STRATEGIES FOR 5G



3.2.3 5G and new use cases

Operators should seek new use cases that can either earn new revenues, enrich the core offering or can be spun off

While there is less of the euphoria to find a 5G 'killer app' as was for 3G, there are still high expectations that operators will identify new use cases in the 5G era to drive revenue growth. In practice, any new use case can be used in three ways by operators.

First, operators should always seek to find new products and services that can bring in new revenue streams within the core business. Premium content is a typical example, and Cloud AR/VR is a big potential opportunity in the 5G era.

Second, operators can use new 5G services to enrich and embellish their core offering. Most customers, whether consumers or enterprises, are buying the core product of connectivity from operators. However, operators can offer new 5G services to increase the bundle price, incentivise upgrades, reward loyalty, minimise churn or even expand their offering.

Third, with strong cash flows and a professionalised workforce, operators are large enough to invest in innovations and efficient enough to execute on these investments. Some innovations that start off as internal projects will turn out not to have strong synergies with the core business. These products and services ought to be spun off so that they can thrive without being constrained by the operator's internal processes.

3.2.4 The ecosystem investment/innovation opportunity

Operators should use their Corporate Venture Capital (CVC) arms to invest in start-ups that can 'pull through' 5G

Most operators already work closely with start-ups to find and fund promising innovations. Overall, operator corporate venture capital (CVC) is on the rise in the wider TMT sector, demonstrated by an increasing number of deals and associated funding over the last few years. GSMA analysis[37] of many operators' CVC shows they invest in start-ups that support extension of core assets or a move into new business lines altogether, e.g. media, content and fintech (see Figure 3.2.3). Operator CVC activity is also on the rise in developing markets, where many local start-ups face scarce funding options and struggle to reach scale.

Collaboration can take different forms and models, based on the depth of collaboration and the financial commitment required from the operator. These include in-house tech hubs, start-up investments (through CVC, direct equity investments and joint ventures) and commercial agreements including OTT reselling partnerships.

While these CVC activities will continue and grow in the 5G era, there is an opportunity to reimagine some of the investments as an extension of the 5G value capture mechanism. These are investments (e.g. AR/VR solutions) that, while not directly linked to the core operator business, help to create demand for 5G. Value capture from these investments will not come from the usual direct channels. Rather they will help to drive adoption of 5G, providing an indirect route to creating and unlocking value in the 5G era.

FIGURE 3.2.3

OPERATOR CVC INVESTMENT SECTORS 2016 – 2018

Over the past three years operator CVC funds have invested in a huge range of sectors and sub-sectors, demonstrating the wide breadth of operator innovation interests

Only selected sectors shown in this chart

37. https://www.gsma.com/mobileeconomy/wp-content/uploads/2018/05/The-Mobile-Economy-2018.pdf

3.3 What do consumers want?

KEY TAKEAWAYS

- **Consumers will remain the biggest beneficiaries of 5G and their views and expectations is a good barometer of how 5G will develop.**
- **Insights from a GSMA Intelligence's survey of 36,000 consumers in December 2018 suggests the following key consumer expectations:**
  - **Faster speed is the top consumer expectation**
  - **Consumers expect wide 5G coverage**
  - **Expectations vary on whether 5G will bring innovative new services. Overall, 25% of respondents expect it but this rises to nearly 50% in Korea.**
  - **Some customers flagged lower service costs as an expectation for 5G, potentially capping the opportunity for revenue growth.**
- **Given consumer apathy (particularly in Europe and Japan), operators need to do a better job of focussing the 5G message to drive demand.**

3.3.1 Consumer engagement

5G insights from 36,000 respondents in 34 markets

GSMA Intelligence's December 2018 consumer survey, which covered 34 markets and 36,000 respondents, included a sub-set of respondents in developed markets and what they expect 5G networks to deliver.

The top-level results will not surprise: consumers expect faster networks and better network coverage. Digging a little deeper reveals some of the 5G challenges operators face in terms of customer awareness, operator relevancy, and strategic focus.

Importantly, the survey reveals significant variations between countries, highlighting the success of early 5G marketing efforts for some, and the need for others to refocus the 5G narrative to be clearer on its early applications and benefits.

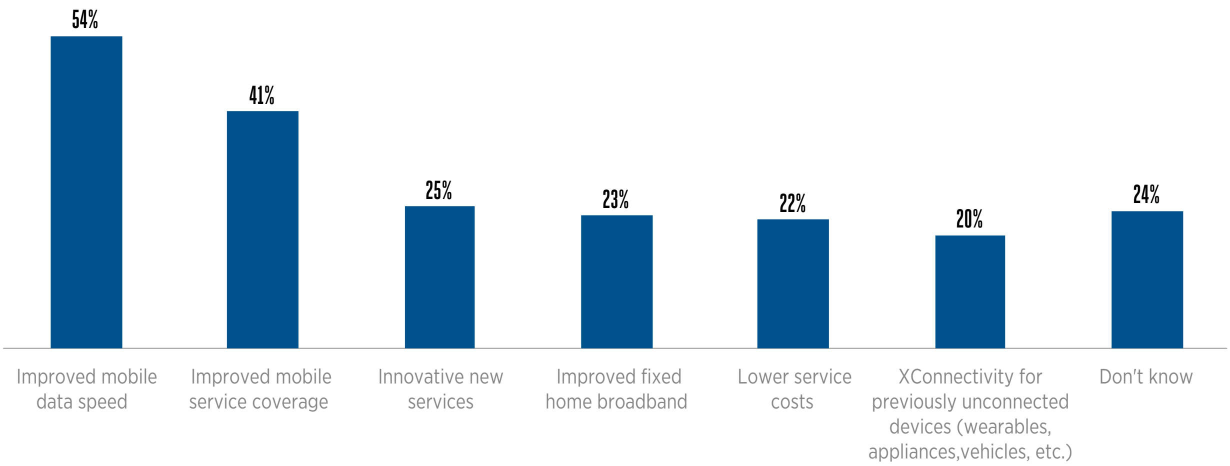
3.3.2 Key survey insights

3.3.2.1 Faster speed is the top consumer expectation
Faster mobile data speeds were the top 5G expectation by consumers across all surveyed countries, with the exception of Japan where it was a close second. That speed came top in itself is not surprising: network operators have long been promoting speed as a key tangible value driver in consumers' eyes.

It's only natural that early marketing efforts will focus on it as one of the key differentiators against LTE. The margin of expectation of faster speed versus other factors underlines its importance for consumers: it is 13 percentage points higher than improved coverage and approximately 30 percentage points higher than any other factors (see Figure 3.3.1). While it's unclear whether consumers will pay extra for faster 5G speeds, driving awareness and delivering on this standout expectation will be a key factor for operators' drive to 5G adoption.

FIGURE 3.3.1

CONSUMER EXPECTATIONS OF 5G (SOURCE: GSMA INTELLIGENCE)



Q: As you may or may not be aware, new 5G networks will be introduced over the next year, promising to deliver advanced capabilities over today's 4G networks. From what you know of 5G, which, if any, of the following would you expect 5G networks to deliver?

N= 15,000 respondents in 16 countries. Respondents could select multiple answers, chart shows % of respondents. Survey fieldwork was completed in 2018

3.3.2.2 Consumers expect improved 5G coverage

Improved coverage was the second most frequent consumer 5G expectation, but also had the highest variation across countries (17% in Japan versus 50% in the US, for example). 5G coverage expectations may end up being the trickiest for operators to fulfil given the different propagation properties of spectrum bands identified for 5G use and likely early rollout strategies, which will focus NSA deployments within urban areas using existing tower infrastructure.

The 600 MHz and 700 MHz bands can be used to extend 5G services widely, including in rural areas. However, the limited amount of spectrum available means the fastest 5G services will not be possible in those bands alone.

3.3.2.3 Consumers are unaware of new 5G use cases

Only 25% of respondents in the survey expect 5G to bring innovative new services. This is despite 5G's enhanced technological capabilities relative to LTE and the focus of its development (showcased in the media and in early trials) on the new services that it will enable, such as autonomous cars and augmented reality.

As smartphone innovation plateaued some time ago, this may reflect operators beginning to drop off the innovation radar in consumers' eyes: their expectations around 5G suggest a decoupling of the link between service innovation and new network technologies.

3.3.2.4 5G messaging needs to be clearer

Almost a quarter of respondents expect 5G to drive improvements to fixed home broadband (even in markets where no 5G fixed-wireless network plans have been announced). An additional quarter did not know what it would deliver. A broad section of consumers are still unaware of what 5G will offer, pointing to a lack of clear and focussed messages from the mobile industry. The fact that 5G has so many potential applications does not help: if the industry is unable to put forward a clearer proposition to consumers then it further relegates operators to just providing more and faster pipes.

3.3.2.5 Customers expect lower service costs in the 5G era

While 5G will deliver lower cost per bit, the capital cost of deployment to achieve this is significant and operators should make appropriate plans given consumer propensity to spend more on 5G, coupled with the cost-orientated, pro-competitive regulatory climate leading into the 5G era.

That a sizeable proportion of respondents in some European markets flagged lower service costs as an expectation for 5G is worrying (e.g. 32% in Spain and 28% in Germany, versus only 16% in the US and 14% in South Korea) and symptomatic of the regulatory approach to date. Japan was the outlier in terms of non-European markets with similar expectations (33% of respondents), in fact it was their primary expectation, however this may well lessen later this year following NTT DOCOMO's announcement in October 2018 that it plans to cut mobile charges by between 20% and 40%[38].

3.3.2.6 Korean consumers' expectations stand out

South Korean expectations of 5G stand head and shoulders above most other markets. While consistent on expectations of faster speeds and improved coverage, Korean consumers also demonstrated the highest expectations that 5G would deliver innovative new services (45%) and connectivity for previously unconnected devices like wearables, appliances, and devices (38%).

This reflects the drive with which Korean operators and regulators have approached 5G: from the first live trials at the Korean Winter Olympics, to agreements to launch simultaneously to avoid excessive marketing costs and to share deployment costs, it has been a focussed and pragmatic approach that has fed consumer expectations.

38. https://www.mobileworldlive.com/asia/asia-news/docomo-to-cut-back-on-smartphone-bundling-by-april/

3.3.3 Lessons for operators

3.3.3.1 Consumer expectations play to operators' strengths

The top two consumer expectations (faster speeds and better coverage) are a network operator's core capabilities, aligning exactly with the current business model and the structure of its operations.

Delivering on these two expectations will have direct positive impact on an operator's perception in its own market, and the overall reputation of the industry. Failing to deliver on these will also have implications especially as the demographic breakdown of the survey data shows that millennials have higher expectations, particularly around improved network speeds (+6 percentage points) and coverage (+4 percentage points).

3.3.3.2 Optimise capex envelope to boost network speeds

Given that the top consumer expectation is of faster speeds, operators should look to blend new 5G radio upgrades to existing sites with incremental improvements to remaining LTE sites (LTE Advanced Pro, Carrier Aggregation, Multi MIMO etc.) to deliver the most cost-effective impact.

3.3.3.3 More focussed messaging required

Operators should consider strengthening consumer messaging to drive demand prior to service launch. South Koreans have the highest expectations for 5G, followed by other markets targeting early (2019/20) launches. Beyond Japan, where respondents on the whole tend to be more reserved, European markets really stand out in terms of low expectations. Given the general lack of consumer awareness, operators should look to build awareness of the broad range of 5G benefits that among speed include latency, capacity and resilience, showcasing these benefits with tangible new use cases that consumers can relate to.

3.4 What do enterprises want?

KEY TAKEAWAYS

- While consumers will be the biggest beneficiaries of 5G, the enterprise segment offers the biggest incremental opportunity for operators in the 5G era.
- In a Q4 2016 survey of operator CEOs, nearly 70% of respondents indicated that they view the enterprise segment as the most important 5G era opportunity for the industry.
- In Q4 2018, the GSMA conducted a series of interviews with enterprises to understand the technical and business requirements of enterprises in the 5G era.
- Key takeaways were as follows:
  - Enterprises to use massive IoT and 5G to expand their role in the value chain.
  - Private 5G network deployments by enterprises using unlicensed spectrum and, where available, their own spectrum, will accelerate due to the perceived benefits of improved security, reliability and strategic control
  - Enterprises see 5G as ‘good to have’, but not yet a ‘must have’
  - 5G capabilities are seen of interest, but business models are unclear
  - Enterprises are focused on business outcomes, and flagged the historic challenges of working with operators
  - SMEs were more willing to allow operators to take a role beyond connectivity.
- There are five key lessons for operators from the enterprise interviews:
  - Operators need to focus on providing horizontal enablers to create common capabilities that can be offered across multiple industrial use cases
  - As SMEs are more willing to consume operator plug-and-play services, operators should create a catalogue of services that SMEs can choose from
  - There is an industry need to better articulate the 5G capabilities and value proposition to enterprise customers (incl. FWA, network slicing, MEC and IoT)
  - Operators must address the risk of marginalisation in IoT; operators want to move up the value chain but enterprises see them as connectivity providers
  - Enterprises are increasing the number of partners in the digital ecosystem; Operators should seek to grow their relevance to avoid being disintermediated.

3.4.1 5G enterprise opportunity

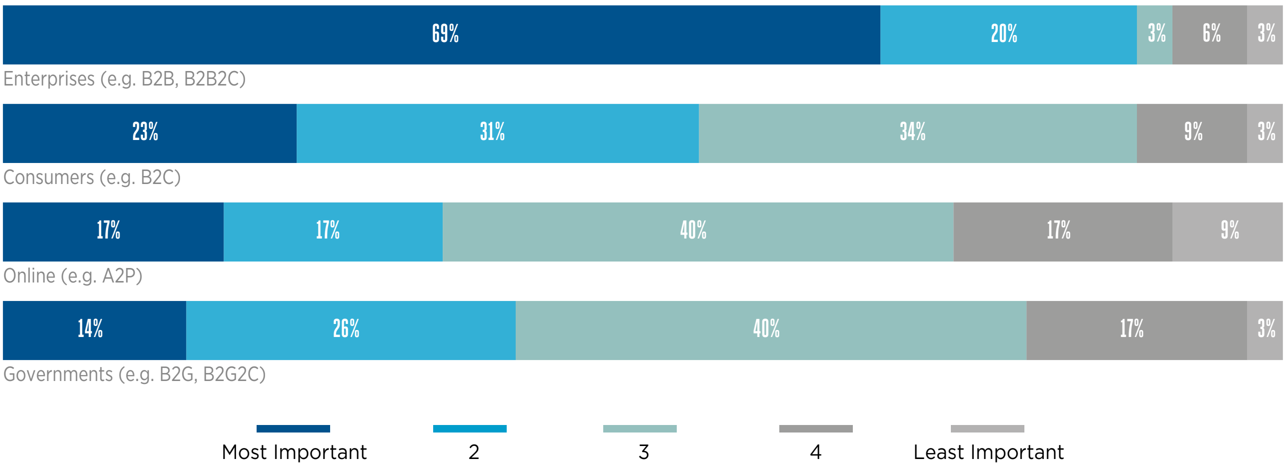
The enterprise segment will be the biggest source of incremental 5G revenues

With the growing maturity of the consumer mobile segment, the enterprise market has an elevated importance in the 5G era. Two GSMA surveys underline the importance of the enterprise segment to future operator opportunities. In the GSMA global survey of 750 operator CEOs in fourth quarter 2016, nearly 70% of respondents indicated that they view the enterprise segment as the most important opportunity for the mobile industry in the 5G era (see Figure 3.4.1).

FIGURE 3.4.1

WHERE WILL NEW OPERATOR REVENUES IN 5G COME FROM?

(SOURCE: CEO 5G SURVEY; GSMA; FEBRUARY 2017[39])



The GSMA 5G engagement study with operators in April 2018 indicated that the industry has an aspirational target to generate 40% of revenues from enterprises five years post 5G launch (NB: over 85% of respondents expect to generate more than 15% of revenues from enterprises five years post 5G launch). 5G will bring new capabilities and the flexibility to serve the specific needs of different enterprise customers.

3.4.2 Enterprise engagement

30 enterprises in 8 vertical sectors shared insights on 5G

The GSMA conducted 30 interviews with enterprise companies across different regions and verticals between October and December 2018, as well as a select number of operators, to fully understand the technical and business requirements of enterprises in the 5G era and beyond.

39. https://www.gsmaintelligence.com/research/?file=0efdd9e7b6eb1c4ad9aa5d4c0c971e62&download

FIGURE 3.4.2

INSIGHTS FROM ENTERPRISES ACROSS EIGHT KEY SECTORS (SOURCE: GSMA)

1. AUTOMOTIVE / MOBILITY	2. MEDIA & CONTENT	3. PUBLIC / SMART CITY	4. HEALTHCARE
5. MANUFACTURING	6. ENERGY & UTILITIES	7. SOFTWARE & TECH	8. MOBILE OPERATORS

FIGURE 3.4.3

1. AUTOMOTIVE AND MOBILITY

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- Connectivity and high bandwidth to provide both a **seamless service and high QoS** for various services from infotainment, navigation etc
- Low latency and high bandwidth can support **platooning** which help increases fuel efficiency and reduces number of drivers
- In the future, low latency and high bandwidth can support **remote driving and remote support (e.g. vehicle maintenance)** which can open a new generation of services / cost savings
- **Network slicing** provides road / infrastructure managers the ability to have flexible networks and better manage their infrastructure (allocate slices for specific functions)

NEW BIZ MODELS ENABLED

- **Data-based business models** open up to car manufacturers (traffic information, data analytics) to monetise data assets with other stakeholders who may value the information e.g. insurance companies, fleet managers

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- **Network slices will require clear SLAs** – for the road managers, they could choose to look for alternative networks
- **Closer relationship** between telcos and car manufacturers will be required

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- **“Pan-regional networks”** – some demand for connectivity to be provided by operators on a regional rather than national level (instead of using roaming intermediaries)
- Road infrastructure managers request a **revisit of existing business models** (installing hardware on the roads and subscribing to services with data limits is not sustainable)
- Potential for **PPP** with governments / smart cities but highly dependent on market

FIGURE 3.4.4

2. MEDIA AND CONTENT

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- **Transmitting high volume, high definition videos / drones for transmission** in real time for disaster response requires high bandwidth and low latency
- **VR for live-broadcasting and interactive experiences** – using the smart phones to share videos in real time with the community opens up immersive experiences
- **Enhancing commerce for retailers** – using VR to enhance the customer experience for shopping / car-parking / getting into their offices etc
- **Cloud gaming** – requires low latency and high bandwidth of 5G. The role of edge computing key to be able to process large volumes of data – this means the VR/AR headset itself does not have to be as high quality
- 5G can be a lower cost **alternative to satellite**
- **5G for content production** (transporting cables for filming can be cumbersome and expensive – wireless equipment is of interest to media companies)

NEW BIZ MODELS ENABLED

- **Advertising** opportunities for the media / content provider (e.g. immersive retail)
- Most likely be a **revenue share model** with the multiple parties involved for new services

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- Players in media & content are more willing to experiment around use cases for 5G
- Live content requires low latency, high bandwidth and more reliability
- Media and content players need operators to collaborate better and agree on common APIs for developer communities

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- When working with smaller ecosystem players, these companies value the **reach and marketing spend** that can be accessed through partnerships with mobile operators
- Most likely be a **revenue share model** with the multiple parties involved for new services
- Certain operators will have ambitions to take a more proactive role higher in the media value chain e.g. proprietary platforms
- Cloud computing is key to handle the large volumes of video traffic – this could provide an opportunity for operators to operate cloud / CDN for media players

FIGURE 3.4.5

3. PUBLIC / SMART CITY

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- **Connected vehicles** for police – link with traffic lights for example
- **Mass digitisation of certain public services – e.g. police officers with smartphones** and enable them to send high quality video and voice
- **Smart city management**
- **Network slicing** – provide higher security and reliability for mission critical services

NEW BIZ MODELS ENABLED

- Public sector – less about new business models as such more about **cost efficiencies, security and reliability**
- Enterprise either have private network or would consider **getting private network** but very expensive

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- Need **guarantee of service**
- Need **prioritisation of network for emergency services – at a similar cost to existing services**
- Want governments to regulate **MNOs providing data for emergency services** (e.g. crimes and location data of phones)
- For 5G want **cheaper and more reliable** connectivity

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- **Operators have the potential to re-sell services** provided to the public sector to other enterprise segments e.g. prioritisation services at premium to enterprises

FIGURE 3.4.6

4. HEALTHCARE

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- **Training** junior doctors for surgery using AR/VR – this requires low latency, high bandwidth
- **Wires in surgery rooms** could be replaced with wireless equipment but requires low latency and security
- **Remote diagnostics** is currently in use but could be enhanced greatly by 5G for real time diagnostics and high definition video
- **Robotics** is another use case – surgery is still nascent but for pharmaceutical dispense or support diagnostics could help save costs (low latency, eMBB)
- Not 5G specific but **AI and running data analytics** across medical records such as CT scans can help with prioritisation

NEW BIZ MODELS ENABLED

- Less about new biz models – more about cost optimisation and offering a best experience for patients and also for the physicians

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- 5G has to offer the **same latency as wired networks** - no interruption and no error in connectivity as safety is the most paramount importance
- **Lower price of cellular connectivity for diagnostic devices** and as high performance as fibre

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- Operators could provide **cloud storage / data centres** and outsource it to other parties who are not large enough to have their own – operators are looking into diversifying revenue in healthcare
- **Smart governments are looking for innovation partners and PPP** models for healthcare use cases

FIGURE 3.4.7

5. MANUFACTURING

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- **Wirelessly connecting a large** number of devices in a secure and economic fashion (cables very expensive)
- **Enabling virtual control of machines** with low latency provided through 5G – lead to cost optimisation as less CPUs needed on one floor
- **Telemetry / exchanging information** between large number of interconnected devices in real time – cloud computing can enable this as well as eMBB and mMTC to transmit the information in real time in high resolution
- **Network slices** can be reserved for specific functions and allow for lower cost infrastructure

NEW BIZ MODELS ENABLED

- Providing **service capabilities** to customers based on data analytics coming through connected devices (e.g. predictive maintenance) even offering **cloud computing**
- **Innovation of products** based on networked equipment and machines

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- Minimum requirement for 5G is to deliver **similar latency to fixed network** for mission critical applications
- **Backward compatibility** with past generation devices
- Communicate clearly that **NB-IoT and LTE-M** will be supported by 5G and provide clear deployment and technology support timeframes

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- **Cybersecurity** could be a potential area where MNOs could play a role as it is a big concern when it comes to data analytics from mass number of sensors
- Potential for operators to **leverage global reach** and help provide **"Out of the box connectivity"**
- Potential for operators to become **data platform provider**s but will be limited to certain markets (e.g. data storage, analytics etc)

FIGURE 3.4.8

6. ENERGY & UTILITY

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- **Edge computing** will be required when enterprises want to scale the number of devices and require platforms and analytics which can deal with that amount of data in real time
- 5G could provide a **substitute for the last mile**
- **Microrobotics** – perform inspection of sensors and share information real-time to prevent malfunctions (mMTC, low latency) and save costs
- **Management of complex virtual plants** of the future

NEW BIZ MODELS ENABLED

- **Cybersecurity** is a both threat and opportunity – large volumes of information flowing through devices and cloud – open to collaboration with other stakeholders
- Already **running or / looking to run private network** for more control and reliability

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- Communicate transparently how long certain technologies will be **supported on the field**
- **Backward compatibility** with past generation devices
- **SLAs** could help boost adoption of 5G
- Managing **cybersecurity** becoming important with the volumes of data - "veracity of data coming from wireless technologies"
- Difficult to see that 5G **can compete with fibre for latency** and therefore deployment may be difficult for mission critical missions
- Would like to understand from operators **value proposition of network slicing and MEC**

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- Openness to working with operators regarding **cybersecurity / trusted data**
- Certain markets show deep collaboration where **operators provide platforms** for energy management
- Potential role to audit the certification of **IoT devices**

FIGURE 3.4.9

7. SOFTWARE & TECHNOLOGY

ENTERPRISE

USE CASE ENABLED BY 5G & KEY BENEFITS

- **Next generation work sites** will be enabled by 5G – not just the communication but networked work sites and equipment
- **Network slices and personalised networks** will provide different industries more flexibility but require SLAs and security
- Low latency will allow an **real-time interpretation** of actions that were not possible before which will open up a suite of new services and seamless experiences
- **Edge computing and 5G** bring robotics in reality

NEW BIZ MODELS ENABLED

- Potential for someone to play **a role in aggregation of offerings or hosting platforms** as the ecosystem becomes more complex – software providers see themselves as playing this role
- **AI and the cloud** would become a big opportunity in the 5G era for software providers
- Big enterprises want to deploy **private networks**

MOBILE OPERATORS

KEY REQUIREMENTS NEEDED FROM MNOS

- **Collaboration** with the rest of the ecosystem – especially in use cases such as smart homes / cities where there a wide rate of players
- Robotics require **high bandwidth connectivity, security and SLAs**
- MNOs should focus more on an **end-end service delivery** which is not well practiced currently
- Industry need for **policies around 5G access network sharing**

NEW BIZ MODELS ENABLED / FUTURE POTENTIAL ROLE

- MNOs may need to look at new biz models – **not charging by data** used but other metrics e.g. CPUs / number of clicks / per session
- **Close collaboration with tech players** who offer services dependent on cellular connectivity could boost revenue – especially with co-development of certain services

3.4.3 Key interview insights

There are six key insights from the enterprise interviews

FIGURE 3.4.10

ENTERPRISE INSIGHTS

WHAT ENTERPRISES HAVE TOLD US...	
1	**Enterprises to use massive IoT to expand role in value chain**
2	**Private network deployments by enterprises will accelerate**
3	**5G seen as ‘good to have’, not yet a ‘must have’**
4	**5G capabilities of interest, business models unclear**
5	**Enterprises are focused on business outcomes**
6	**SMEs require more end-end support**

3.4.3.1 Enterprises to use massive IoT to expand role in value chain

Manufacturing, production and energy enterprises have the greatest awareness of 5G and its potential capabilities.

For these enterprises digital transformation, Industry 4.0 and addressing operational complexity are key strategic priorities. Some enterprises had advanced plans to capture incremental revenues in the future such as providing services based on data analytics (e.g. manufacturing companies directly providing predictive maintenance, cybersecurity as a service) but also innovating products based on networked equipment and machinery.

These enterprises expect 5G to further enhance these opportunities. Wirelessly connecting a large number of devices in a secure and economic way, remote control of networked machinery, telemetry of information and network slices to lower cost of infrastructure are considered to be the key benefits of using 5G.

3.4.3.2 Private network deployments by enterprises will accelerate

Several large enterprises in the manufacturing, production industries and public sectors interviewed for this study already own their own spectrum, and have either deployed private networks or are looking to do so. Security, reliability and strategic control are considered the key drivers to deploy privately. In select cases, the enterprises work with operators on their private deployments, but in others they have disintermediated the mobile operator completely to run their own private networks.

The smaller enterprises cite that, although private networks would be beneficial, the costs involved and limited expertise in network management were barriers to deploying private networks. Enterprises not included in this study, such as Rio Tinto (a mining conglomerate in Australia), Ocado (UK retailer) and Hamburg Port Authority have also deployed private LTE networks.

A large vendor has reported that it has deployed over 660 private LTE networks. With greater 5G spectrum flexibility and growing experience and confidence with private mobile networks we may see an increasing number of enterprises deploy privately in the future.

3.4.3.3 5G seen as 'good to have', not yet a 'must have'

Enterprises are aware of the attributes of 5G and expect it to provide higher reliability and security at a lower cost. Enterprises are mostly aware of the attributes 5G offers such as high bandwidth and low latency which they expect to provide an enhanced experience and lower cost of existing services.

Several enterprises are exploring use cases for network slicing and edge computing. Enterprises indicated that network slicing could be used to provide more flexible networks, increased reliability and can allow for infrastructure simplification when slices are reserved for specific functions. For edge computing, enterprises anticipate the ability to process larger volumes of data faster, which can lead to innovation of both devices and services.

These findings are supported by the results of the 2018 GSMA Intelligence IoT Enterprise Survey, which measures IoT adoption by enterprises across 14 countries and eight verticals. When asked which 5G capabilities would make it compelling to deploy 5G for future IoT deployments, 74% of enterprises stated that higher data transfer speeds would make 5G compelling; 49% cited network slicing, 41% edge computing; and 31% low-latency services. It is interesting to note that there is little variance in the responses from enterprises across different verticals.

5G was highlighted as a potential alternative network technology for more expensive modes of connectivity such as fibre and satellites in rural areas. In an industrial setting, wirelessly connecting a mass number of devices in a secure and economic way was seen to be a key advantage, however it was noted that in fact for most use cases existing technologies for IoT networks, 4G and fibre were seen as good enough. There were some question marks by enterprises whether 5G could ever compete with, or replace fibre.

The key technological needs from enterprises focuses on latency (similar to fibre for mission critical applications), reliability of service and security (particularly with the volumes of data coming from the mass of devices connected). Backward compatibility with past generation devices was one of the most frequently mentioned requirements from operators, even going as far as operators potentially taking a larger role in auditing the certification of IoT devices. Several enterprises raised the question of costs related to 5G, particularly in public and health sectors and where cost optimisation was a greater priority than revenue generation.

3.4.3.4 5G capabilities of interest, business models unclear

A number of new use cases enabled by 5G mentioned in the interviews focus on the media industry. The low latency and high bandwidth offered by 5G will improve the nascent VR/AR/XR experience for end users, proliferate usage and open up new revenue opportunities (e.g. immersive reality platforms). The role of edge computing and the ability to process larger volumes of data faster is valuable across the media value chain, from broadcasting (real time broadcasting of content) all the way to hardware innovation, as AR/VR headsets do not have to be as high-quality when content can be processed at the edge.

Media players expressed the most willingness to engage operators, especially on discussions on revenue sharing for new service opportunities in the future, and were least concerned about cannibalisation of players' traditional business. Media players, as technical innovators, are open to collaboration and experimentation with operators.

Media players saw the value of operators not only providing eMBB and uRLLC, but also the VR/AR/XR platforms, and the cloud compute/storage and analytics required. Although business models were not clearly articulated, players in the media space are exploring potential revenue share models based on new services or advertising models with mobile operators.

3.4.3.5 Enterprises are focused on business outcomes

The most urgent enterprise requirements are business oriented, such as providing clear SLAs and lowering the cost of cellular connectivity. Clear communication around how long technologies would be supported in the field (e.g. legacy technologies such as 2G), the value and definition of network slicing (business benefits rather than technical definitions) and edge computing were also highlighted across various verticals.

The challenges of working with operators was also highlighted by enterprises (e.g. speed of deployment, complexity of organisations and openness to collaboration with the ecosystem). Mobile operators need to focus on end-to-end service delivery and horizontal enablers such as APIs, analytics platforms that can be built across verticals while bearing in mind the specific functionalities and services for specific verticals.

3.4.3.6 SMEs require more end-to-end services support

Across all verticals, SMEs were much more willing to allow operators to take a role beyond connectivity than the larger enterprises. Already, there are several cases where operators provide/are looking to provide various platforms, cloud services and analytics for smaller enterprises.

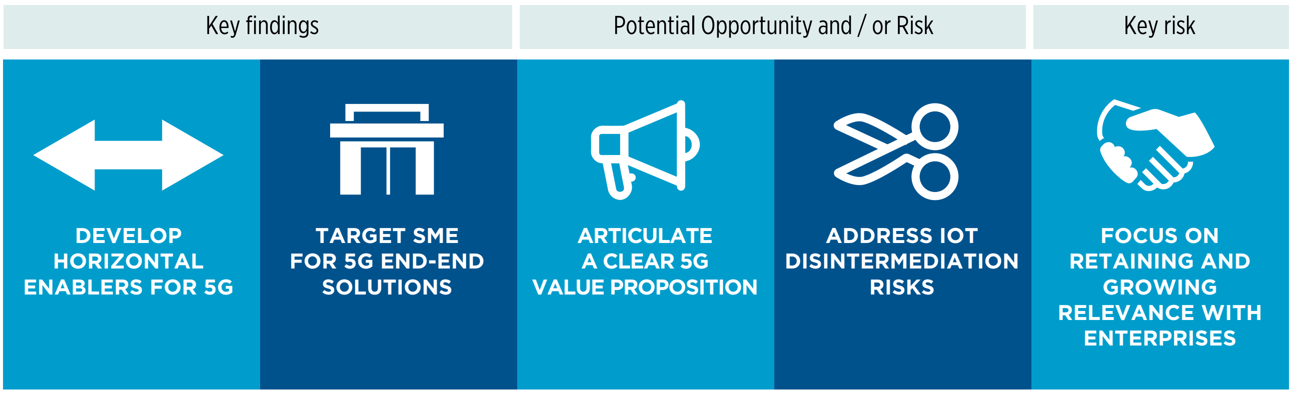
In APAC, operators are even taking a large role in marketing and business development by supporting national and international expansion for smaller partner companies. Several enterprises also commented on their willingness to have operators provide connectivity bundled with their services and expressed an interest in collaboration around cybersecurity.

3.4.4 Lessons for operators

There are five key lessons for operators from the enterprise interviews

FIGURE 3.4.11

KEY OPERATOR TAKEAWAYS



3.4.4.1 Develop horizontal enablers for 5G

5G opportunities exist across different industries, but building vertical-specific competencies requires substantial investment in acquiring expertise, relationships and assets. Operators need to focus on providing horizontal enablers to create common capabilities and services which can be offered across multiple industrial use cases. This could allow operators to offer and sufficiently scale services beyond connectivity and generate a positive business base.

3.4.4.2 Target SMEs for end-to-end solutions

The SME segment emerges as an area where there is demand for operators to play an end-to-end role in 5G. Non-network assets such as marketing and business development are just as valuable to these players as is connectivity, which can unlock new interesting business models for operators. As SMEs are more willing to consume operator managed services, generating a catalogue of services that businesses can choose from could be a potential opportunity for operators.

As one example, SMEs are a prime target for network-as-a-service capabilities. 5G and network slicing will allow operators the capability to offer SMEs hyper-targeted network-as-a-service, allowing them to consume network slices with differentiated QoS, latency and throughput according to use case and customer. Although targeting the SME segment alone may not generate a positive business case for 5G due to the complexities of SME needs and size of opportunity, it could be a chance for operators to experiment with new use cases and business models, which could be replicated further as can be seen by several innovative operators in APAC.

3.4.4.3 Articulate a clear 5G value proposition

There is an industry need to better articulate the 5G capabilities and value proposition to enterprise customers (including FWA, network slicing, edge computing and IoT technologies). The perceived lack of clarity on technology migration (timelines but also how legacy technology works with new technology) delays enterprise investment in devices and potential take-up of service. Enterprises typically lean towards implementation of technology that is available currently, that will be supported in the future or is more economical (e.g. enterprises preferring LoRa over NB-IoT).

The lack of clarity leads to differences in opinions on the potential for a particular technology: for example, operators are very positive about the potential opportunity of FWA for enterprises in the 5G era whereas verticals showed relatively low levels of awareness on the benefits. It should also be emphasised that there was a high level of confusion from enterprises regarding NB-IoT and LTE-M: the mobile industry needs to clearly communicate that NB-IoT and LTE-M will be supported by 5G.

The 5G era also presents an opportunity for operators to innovate on business models. Several operators in APAC and in the Middle-East have embraced government-led digitisation initiatives to engage both public and private sector enterprises in discussions to explore new business models for the 5G era. Innovation of business models could include ways of how to monetise connectivity in different ways (e.g. automotive industry looking for one-stop regional roaming services, charging data by CPU/number of clicks etc.), monetising non-traditional services (e.g. outsourcing cloud and data centres, cybersecurity, platforms) and effectively monetising specific enterprise needs (e.g. using 5G as a back-up solution for enterprises that have a critical reliance on connectivity, in the same way that 4G is offered to enterprises by operators today).

3.4.4.4 Address IoT disintermediation risks

Operators must address the risk of marginalisation in the massive IoT opportunity. Many operators recognise that expanding their role within the value chain is imperative to generate a positive business case for 5G and are looking to play a role in data processing, cloud operations, data storage, analytics services and other digital services. Enterprises, however, very much see the role of the operator restricted to providing faster, more reliable and secure connectivity in the future and creating the standards for technology rather than working on integration and service design.

Operators are not only at risk of missing out on opportunities further up the IoT value chain: there is a threat of connectivity disintermediation, particularly from utility/manufacturing enterprises and the public sector which have deployed proprietary networks to have more control over their networks and isolation. With fully virtualised networks in the future, the large cloud players become increasingly strong competitors to mobile operators in providing connectivity. Amazon's announcement of a partnership to deliver a cloud-based private LTE network solution based on CBRS is a perfect example of this trend.

Other enterprises interviewed have revealed that they are exploring options for private networks, however, this could potentially be an opportunity for mobile operators. For example, operators could consider managing private networks on behalf of these types of players. By opening up network capabilities via APIs and leveraging network slicing, this would provide enterprises the control they are looking for while avoiding the cost of investment and risks of operations without having to build up in-house know-how in network deployment and management.

Several operators and vendors are already adopting a graded approach to test the viability of slicing by rolling out private LTE networks and/ or campus networks. A number of demos at MWC 2019 showcased the usability of such networks in practice – a welcome advance from previous discussions at the conceptual level. Notably Deutsche Telekom and Osram launched Campus Network, based on a 'dual slice' that combines a public and a private LTE network on a common platform to enable a smart factory use case and Telefonica highlighted its LTE-Enterprise (LTE-E) solution which has been developed for industrial environments in partnership with Ericsson, ASTI and Geprom.

3.4.4.5 Focus on retaining and growing relevance with enterprises

Digitisation and increasing complexity of the ecosystem will only increase the need for operators to understand and meet the needs of enterprises. There is a risk that operators may be facing disintermediation from managing the direct relationship with enterprises as other technology players see this as a potential role they could play in the 5G era.

Technology providers position themselves as better able than operators to manage the complexities and relationships with enterprises. They believe that AI, cloud and big data are large opportunities to grow revenue and as ecosystems become increasingly complex, they believe they could also play the aggregator role to minimise the difficulties in working with mobile operators. This trend mirrors that of the approach aggregators have taken in working with operators in digital services (payments, identity and messaging) and looks to be replicated in the enterprise space.

3.5 The eMBB Opportunity

KEY TAKEAWAYS

- Enhanced mobile broadband (eMBB) is the default, and earliest, 5G use case. This includes mobile data, video and IP communications services (i.e. VoLTE, RCS).
- 5G will provide the capacity for at least 100GB per month per customer to cope with growing video traffic.
- Low latencies approaching 1 millisecond will support new use cases in gaming, critical communications, remote control of devices and industrial automation.
- Monetising extra network capabilities will help to stabilise 5G era ARPU.
- Additional capacity from 5G will encourage bigger/unlimited bundles, and may trigger a shift to a different pricing paradigm e.g. speed-based tiering.

3.5.1 eMBB products & services

eMBB is the biggest early use case

In the 5G era, many operators will be aggressively targeting the lucrative vertical market - including using customised technologies like NB-IoT etc. However, for most operators the early use case for 5G will be to provide mobile broadband services directly to customers. This will be primarily through enhanced mobile broadband (eMBB) and, in some cases, fixed wireless access (FWA). The prospect for eMBB is evolutionary to the current business of operators and will progressively improve the mobile internet experience of the more than 5 billion mobile phones users in the world.

3.5.1.1 Data

eMBB is the de facto productisation of mobile data and is used for accessing apps; email; viewing web pages; watching videos; updating software; and any internet-based activity on a mobile device. 5G, as has been the case for previous generations of mobile technology, will deliver faster downlink/uplink speeds and lower latency. This will in turn enable improved experiences and a wider range of use cases.

3.5.1.2 Video

Video is saturating 4G networks and 5G will bring much better performance for video services. In the 3G era, the predominant way of consuming video was via downloads. Thanks to the boom in streaming services, 4G networks support a lot of streaming (e.g. Netflix). Early projections with AR/VR, 4k/8k video and 360 degree videos suggest that 5G video content will be immersive, consuming an even higher proportion of the overall data traffic.

Figure 3.5.1 outlines four types of video products that operators should evaluate for 5G.

- Internet Video: while operators are unlikely to charge customers more for internet video, the lesson from 4G is that while customers will not pay for internet video directly, they will pay more for a 5G that offers superior experience for video.
- Premium video: operators, where viable, can offer premium/exclusive video content to paying customers. This is a lucrative opportunity. Ampere analysis forecasts that OTT video revenues (including pay-TV, subscription video, video-on-demand) will generate revenue of $46 billion in 2019 compared to cinema box office revenues of $40 billion.
- Video Communications: thanks to OTT services such as WhatsApp and WeChat, video calling is no longer a novelty. However, carrier-grade ViLTE remains an interesting proposition for the 5G era and should be actively considered.
- Video enablers/APIs: Operators should consider developing video enablers/APIs to promote development of inter-operator video services. This is the major driving force for the GSMA's 5G Cloud XR Forum[40].

Broadcast / Multicast technologies and approaches can also be used for efficient content distribution of video and other high capacity content (incl. software updates).

FIGURE 3.5.1

FOUR 'VIDEO' TRAFFIC TYPES FOR THE 5G BUSINESS CASE

	Types of video traffic	Key consideration for operators
1	**Internet / OTT Video**	**Monetise as part of data bundle**
2	**Premium / exclusive Video Content**	**Few opportunities & for mostly 'cash rich' operators**
3	**Video Communications**	**Expand 'Green Button' to include video calling**
4	**Video Enablers / API** (e.g. Cloud AR/VR)	**Identify & standardise common video APIs**

40. https://www.gsma.com/newsroom/press-release/gsma-launches-new-industry-wide-initiative-to-support-development-of-operator-edge-cloud-ar-vr/

3.5.1.3 IP Communications

The traditional role of operators in providing communications services will continue in the 5G era, even if most customers no longer pay for metered voice/messaging services, and even if operators are to share that role with other providers.

Accordingly, the GSMA proposes that 5G era networks should continue to offer, and build on the full set of IMS-enabled communication services that are already available in 4G. The expectation is that Voice over New Radio (VoNR), packaged as an enriched communications proposition to customers, will replace legacy communications services and will become the base assumption for 5G networks.

3.5.2 eMBB drivers

3.5.2.1 Bigger Capacity

5G will provide the capacity for at least 100GB per month per customer

The biggest early value for society from 5G will come from the ample capacity it will provide for digital services, owing to better spectral efficiency and capacity.

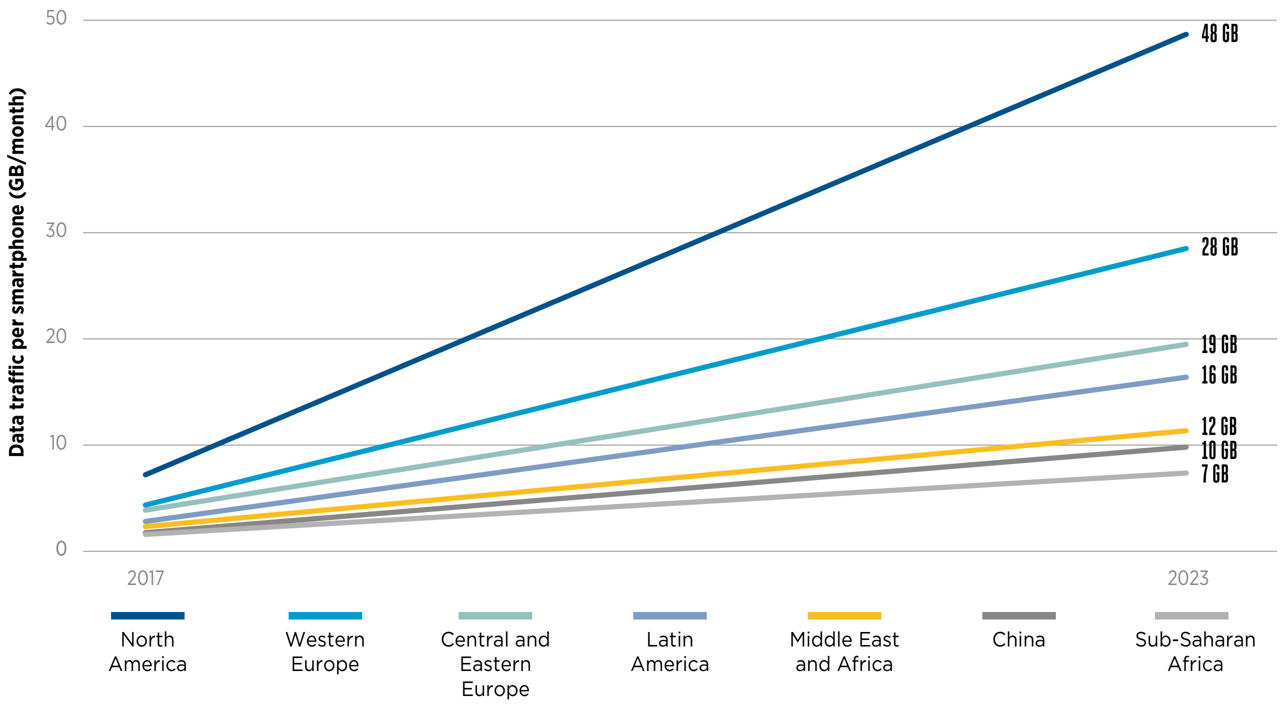
Smartphone data usage growth is continuing on an impressive trajectory both in developed and in developing countries (see Figure 3.5.2). Some operators (e.g. in affluent Middle East markets) report usage in excess of 40GB per customer per month, primarily from video consumption.

Yet, with limited scope for advancements of 4G beyond LTE Advanced Pro and limited availability of spectrum in its operating range (below 6GHz), the supply of additional capacity is expected to be one of the strongest drivers for the launch of 5G.

A typical user in the 5G era could be consuming more than 100GB/month of mobile data. (As a reference, an AR/VR or 8k video stream at 50Mbps for 1 hour uses about 175GB). Countries where usage trajectory is already pointing to the 100GB/month usage level, or cell sites with such traffic demands, are best positioned for early 5G upgrades.

FIGURE 3.5.2

AVERAGE DATA TRAFFIC PER SMARTPHONE (SOURCE: ERICSSON)



3.5.2.2 Lower cost/bit

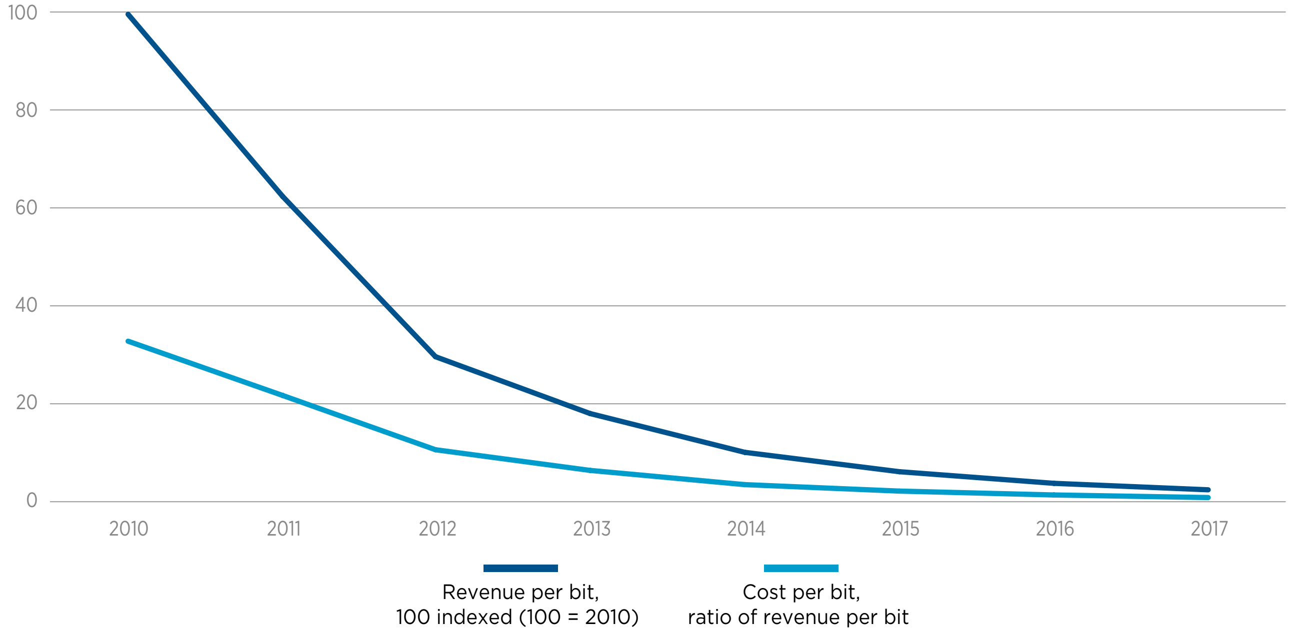
Cost versus revenue per GB trends will further drive the market to unlimited data bundles in 5G

5G will continue the trend in mobile data pricing that was seen in the 4G era where bigger network capacities, and the convergence of the revenue/GB and cost/GB curves (see Figure 3.5.3), have led to the re-emergence of unlimited data bundles. This is a major change in the business model of operators and the underlying assumptions that define the operator business model.

Given the increased efficiency and capacity in 5G, higher-priced unlimited data bundles can help to increase profitability for the industry. However, depending on market conditions, it could also lead to deflationary pricing and its concomitant implications.

FIGURE 3.5.3

REVENUE/GB VERSUS COST/GB FOR MOBILE DATA (SOURCE: GSMA INTELLIGENCE)



3.5.2.3 Low latency

5G's low latency will support new use cases

A design goal for 5G is to support low latencies of up to 1 millisecond. Potential use cases in gaming, critical communications, remote control of devices and industrial automation have been suggested. However, there are question marks whether these services will need low latency of 1 millisecond and if such low latency can be found everywhere. For example, some of the big content providers insist that they only design their services to work within the current capabilities of the widely-provided network.

While the scepticism is understandable, the lesson of 4G shows that generally lower latencies can have profound impact on service development. For example, 4G's low latency and bigger capacity has accelerated the development of services that rely on real-time feedback and notification (e.g. online gaming).

If this trend is replicated in the 5G era, new, currently unknown services could emerge, especially focusing on factory automation, robotics and haptic/tactile interactions. Ultra-reliable low latency communication and time-sensitive networking, enabled via a combination of 5G and wireless edge, will be required for time-critical Industrial IoT manufacturing processes. Such processes include closed-loop robotic control, machine-human interactions, automated guided vehicles, as well as AR and VR.

3.5.2.4 Digital ID

A mobile linked ID will support operator's role in the digital value chain in the 5G era

Digital ID is increasingly becoming a 'must-have' asset across society. As more countries, particularly in the developing world, continue to implement their digital transformation strategies, proving one's identity digitally will become increasingly fundamental to participation and inclusion[41].

Mobile ID, anchored on the phone number, is an integral component of the eMBB proposition and can be used to support government efforts to accelerate the roll out of digital identification systems. With more than 5.1 billion unique subscribers globally, mobile networks connect people as no other technology before, providing access to a vast array of life-enhancing services. Given this scale, the mobile industry has a unique opportunity to bring the benefits of digital technology and digital identification. It will also support efforts to deliver one of the key targets of Sustainable Development Goal 16: "by 2030, provide legal identity for all, including birth registration.

3.5.2.5 Affordability of handsets & smartphones

The cost of 5G handsets is a critical determinant of eMBB demand and could necessitate subsidies

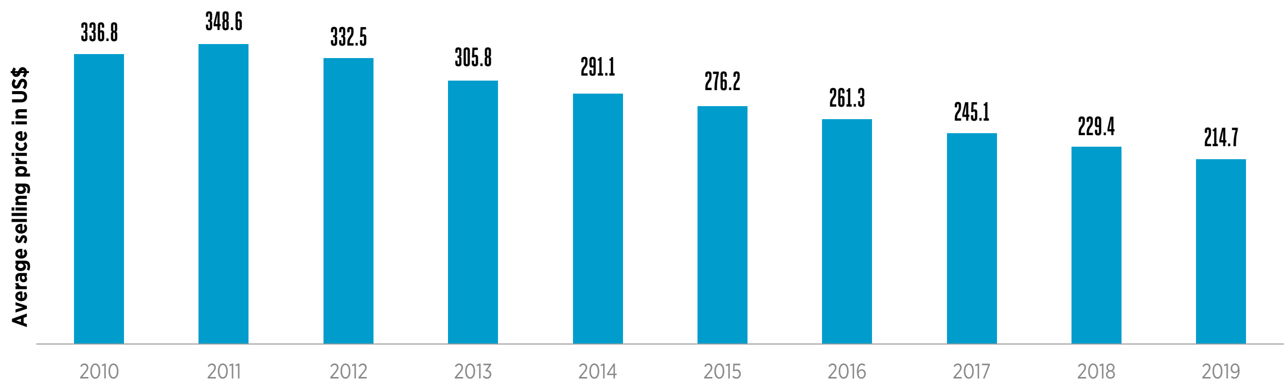
Two interrelated factors will push device availability and affordability to a top agenda for 5G. Firstly, in the early years, and especially where the NSA option has been used, the experience of eMBB will not be significantly different from that of 4G MBB. Secondly, early 5G devices will experience a premium over traditional 4G devices for device vendors to recoup the R&D investment. The confluence of these two factors could slow the uptake of 5G as customers balk at paying a premium for 5G devices when there is little differentiation from 4G eMBB.

This is a critical consideration especially for operators who are expecting the consumer market demand to singularly bankroll the deployment of 5G. Therefore, it is critical that 5G support is introduced not only in the expensive flagship models, but also in the affordable segment to entice more customers to eMBB. Some operators may also opt to sustain or even increase the subsidies for 5G devices in other to drive demand

Overall, as the projections for average selling price of smartphones in 2019 is substantially less than the value in 2011 (see Figure 3.5.4), there is little appetite for more expensive devices. Hence 5G devices for eMBB need to be affordable to drive the demand.

FIGURE 3.5.4

WORLD SMARTPHONE AVERAGE SELLING PRICE (SOURCE: STATISTA)



41. https://www.gsma.com/mobilefordevelopment/programme/digital-identity/access-mobile-services-proof-identity-global-policy-trends-dependencies-risks/?utm_source=YT&utm_medium=reportreferral

3.5.3 eMBB economics

3.5.3.1 Stabilise ARPU

Monetising extra network capabilities will help to stabilise 5G era ARPU

While overall operator revenues have been growing, the per connection revenue has been consistently declining in all countries in the world for the past ten years. Some of this downward trend is because of connecting lower-spending customers (e.g. low income customers) or lower-usage connections (e.g. IoT connections), as well as fierce competitive pressures.

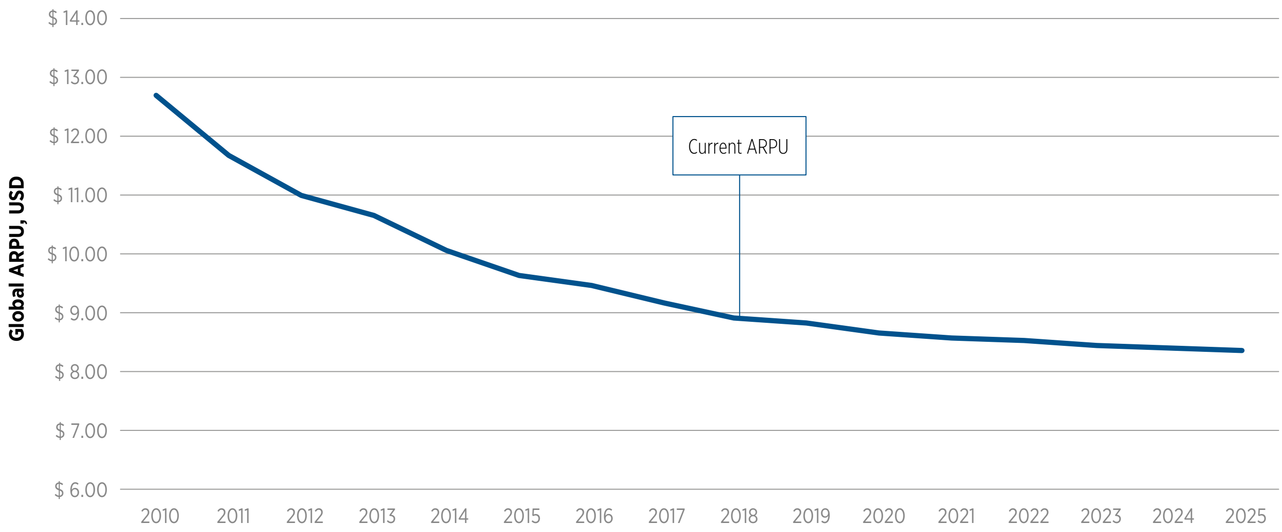
In line with the trend that has begun as 4G matures (see Figure 3.5.5), there are two main factors that will help to stabilise, or even reflate ARPU in the 5G era globally.

First, the rebalancing of tariffs towards data and away from traditional voice and messaging has arrested the voice/messaging revenue cannibalisation from OTT alternatives. A 2014 Ovum study suggested operators could lose $386 billion between 2012 and 2018 unless they rebalanced their tariffs from metered voice to metered data[42]. This rebalancing is nearly complete in post-paid-heavy countries (e.g. Japan/South Korea), and is picking up in prepaid-heavy countries.

Second, operators are succeeding in selling bigger data bundles to customers in many markets. This will continue in the 5G era, and together with other ancillary revenue sources (e.g. antivirus or roaming or devices), will help to nurture ARPU back to stability or growth for some operators.

FIGURE 3.5.5

MOBILE ARPU WILL STABILISE IN THE 5G ERA (SOURCE: GSMA INTELLIGENCE)



42. https://www.telecomasia.net/content/telcos-lose-386b-ott-voip-ovum

3.5.3.2 Capacity glut and big bundles

Capacity glut in the 5G era may encourage big deflationary data bundles

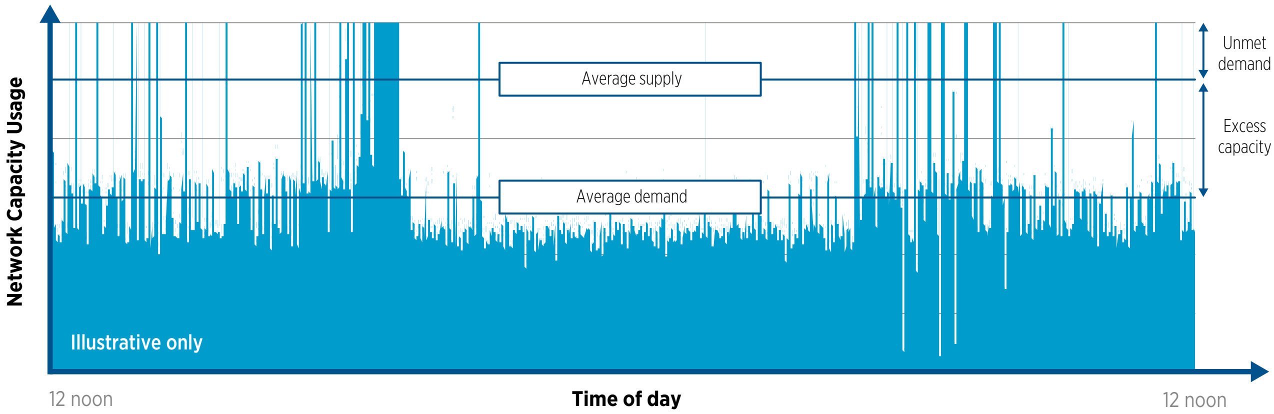
Operators face a constant, unending competitive pressure to add more capacity to their networks. This is driven by the need to accommodate growing data usage on smartphones, and the need to serve additional devices. But the biggest driver is to provide enough peak capacity to cover spikes in data usage. Operators in every market are competing to assure customers that their mobile data connections will perform well during peak hours, such as at a bus/train station during rush hour or at a stadium during a sports game.

But this additional capacity has consequences. As Figure 3.5.6 shows, the continuous addition of extra capacity to provide for the 'unmet demand' increases the 'average supply' of network capacity above what is needed to cover for 'average demand'. The resultant 'excess capacity' has become a key battleground, as operators try to monetise this capacity with bigger, and increasingly unlimited, data bundles.

This trend is already in full swing in many developed markets for 4G services and would carry on into the 5G era. In some places, it has provided an upsell opportunity, but concerns remain that the quest to monetise excess capacity is stoking deflationary pricing.

FIGURE 3.5.6

DEMAND VARIATION FOR MOBILE NETWORK CAPACITY – 24 HOURS (SOURCE: KINGS COLLEGE LONDON[43])



43. https://nms.kcl.ac.uk/nishanth.sastry/pubs/obiodu-5GWorld18.pdf

3.5.3.3 Usage vs. speed-based pricing

Widespread adoption of big bundles may trigger a shift in pricing

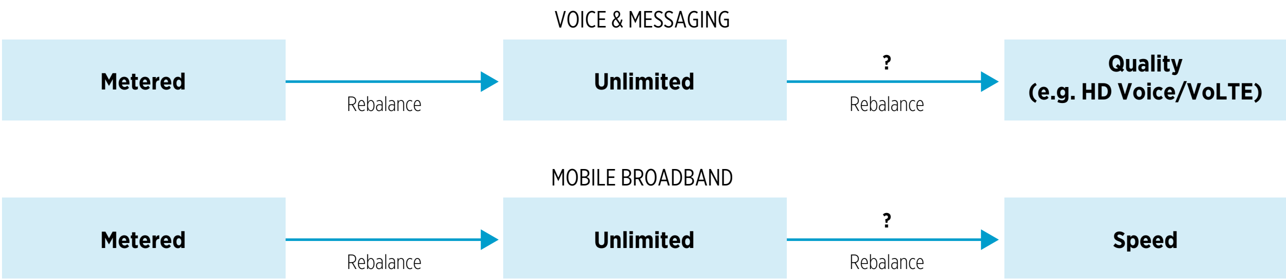
An imminent consequence of the move to abundant and unlimited mobile data bundles is that operators lose the ability to price differentiate with data usage. This switchover from metered to unmetered broadband has happened for many fixed broadband customers in developed markets. Internet Service Providers have shifted from data usage based pricing to speed tiers pricing as a differentiating factor between basic and premium services to users.

This trend is likely to occur for mobile broadband in the 5G era as operators offer ever bigger data bundles beyond what customers are able to use up in a day or month.

However, rebalancing to another paradigm pricing is not without its challenges as is evident from the failure to rebalance to quality-based pricing for HD Voice and VoLTE (see Figure 3.5.7). Technical challenges and the ability to put together a compelling value proposition are often obstacles. For example, a survey of a representative sample of 978 households in the US in 2016 suggests that households' do not value speeds of over 100Mbps highly[44].

FIGURE 3.5.7

EVOLUTION OF PRICING FOR EMBB SERVICES



44. https://prodnet.www.neca.org/publicationsdocs/wwpdf/91917tpi.pdf

3.6 The FWA opportunity

KEY TAKEAWAYS

- **Fixed Wireless Access (FWA) is a by-product of excess eMBB capacity and enables operators to address new & existing broadband opportunities.**
- **There are four clear FWA use cases: broadband for the unconnected; broadband to compete with fixed alternatives; backup broadband and base station backhaul.**
- **FWA is important for other strategic reasons too: additional incentive to deepen fibre capillarity, to boost product portfolio for mobile-only operators; or to avoid new FWA entrants distorting the market.**
- **The GSMA has mapped FWA opportunities for 160 countries: Blue Ocean markets, Red Ocean markets and Desert markets.**
- **While the FWA opportunity varies considerably across geographies, there are always potential "oases" of opportunities.**

3.6.1 FWA products & services

Operators can address new & existing broadband opportunities with 5G FWA

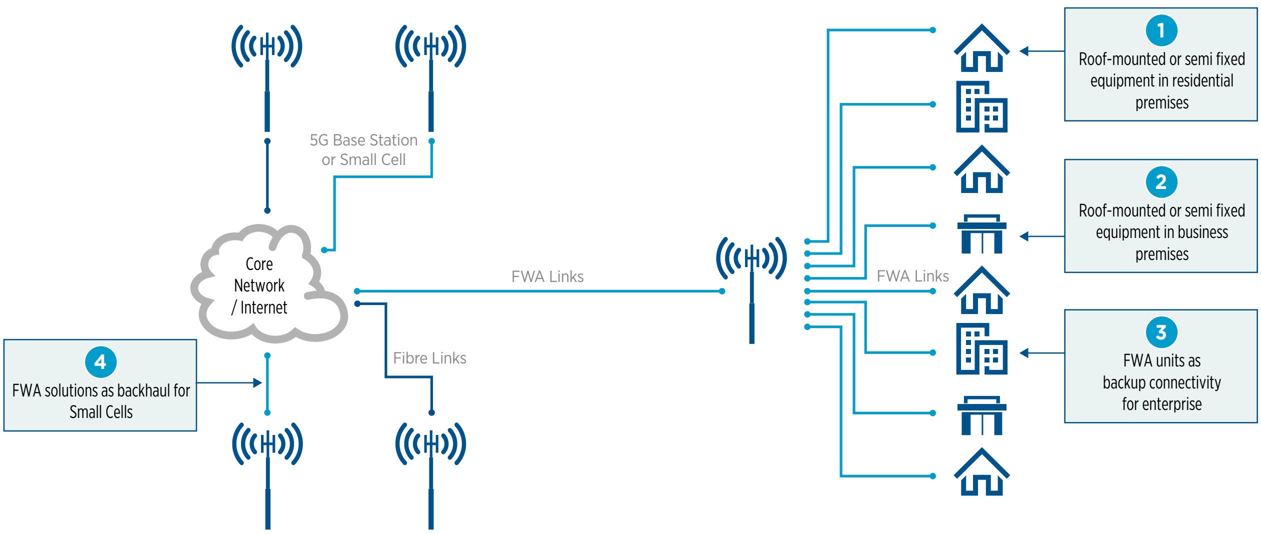
Fixed Wireless Access (FWA), a wireless link that provides connectivity to objects that are stationary or nomadic, will receive a boost thanks to improved 5G capabilities. FWA is not a new product idea, but 5G FWA is positioned as superior to previous attempts to deploy FWA-like services using proprietary wireless technologies (e.g. LMDS, iBurst), alternative cellular technologies (e.g. WiMAX) and default cellular technologies (e.g. 3G, 4G).

Many operators expect to deploy 5G FWA early in the 5G era to provide for broadband in rural/sub-urban regions, or to provide a competitively-priced alternative to fixed broadband. This opportunity exists, but is by no means universally addressable by operators in all markets. As such, 5G FWA needs to be viewed as an opportunity that is highly dependent on local realities, such as the 2018 launches in the US.

There are four primary FWA products that operators can offer globally, as shown in Figure 3.6.1. Also, as the FWA opportunity is not universal, this section frames the discussion based on the different market scenarios in terms of attractiveness for FWA.

FIGURE 3.6.1

FWA PRODUCT OFFERINGS FOR OPERATORS



3.6.1.1 Broadband for the unconnected

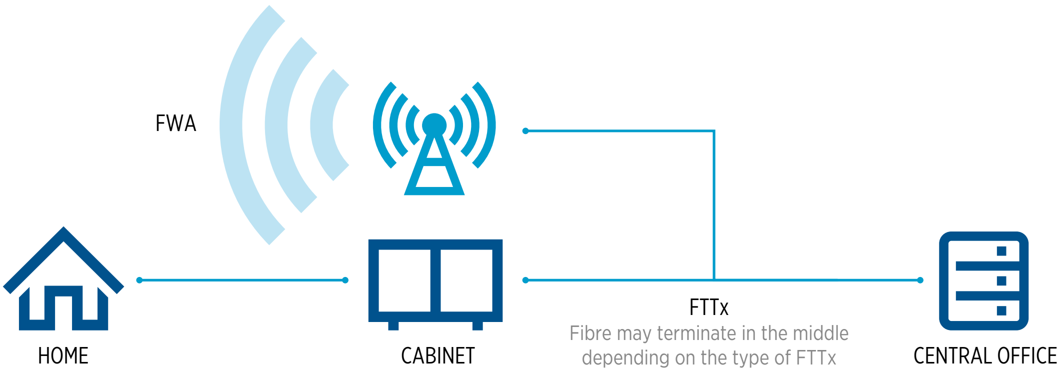
Operators can address stationary broadband demands including premises that were not connected previously or are connected with only legacy copper/DSL broadband, time-limited (e.g. seasonal) broadband demands and IoT demands. This is the strongest opportunity for 5G FWA.

For mobile-only operators, FWA is an opportunity to enter into new broadband markets, gaining access to new value pools.

For many fixed/mobile operators with a commitment to provide high-speed broadband services to rural and suburban premises, FWA offers a competitive cost economics compared to greenfield FTTx deployments, especially in developing regions where low fibre penetration and costly civil works for fibre densification favours wireless connectivity. Huawei estimates the capex per subscriber range at between $500 and $1000 for FTTx versus $100to $400 for FWA[45]. This is based on calculations for 4G FWA and 5G may work out to be even cheaper.

FIGURE 3.6.2

FWA IS A LOWER COST ALTERNATIVE THAN GREENFIELD FTTX



3.6.1.2 Broadband competition

The idea of 5G FWA competing with fixed broadband is a polarising proposition. The attraction is that 5G NR provides an experience that enables operators to offer a high-performing, competitive broadband service for customers.

The clear opportunities are to address customers still reliant on legacy copper/DSL broadband products, and scenarios where the cost of newly deploying FTTx is prohibitively high. However, the idea that already-installed FTTx can be replaced with FWA is largely unproven. Unless the FWA service is priced to woo customers, there is little evidence from anywhere that FWA offers a superior customer proposition – based on speed/performance - to FTTx.

3.6.1.3 Backup broadband

As businesses increase their dependence on the internet, their need for a reliable backup will grow. This is a currently underestimated opportunity and may turn out to be the most profitable FWA product for operators. The rationale is straightforward. Market or regulatory forces are pushing businesses to ensure that there is very little downtime in their operations. Faced with the costly option of running a leased line into their premises, a 5G FWA option will prove much more cost effective. Already some operators have begun offering such services in the market using 4G FWA (e.g. BT Assure in the UK).

3.6.1.4 Base station backhaul

The option of using 5G FWA as a backhaul for 5G base stations is still under development, but could well prove to be an important use case for FWA. Using Integrated Access Backhaul (IAB), an advanced beamforming technique that concentrates radio waves in a specified direction for long-distance transmission, operators can use FWA to provide backhaul for 5G macro and small cells. NTT DOCOMO and Huawei demonstrated IAB in early 2018[46] and 3GPP is considering Integrated Access Backhaul (IAB) as a possible 5G NR standard.

45. https://www-file.huawei.com/-/media/corporate/pdf/news/4g-wireless-broadband-industry-white-paper.pdf?la=en&source=corp_comm

46. https://www.nttdocomo.co.jp/english/info/media_center/pr/2018/0522_00.html

3.6.2 FWA drivers

3.6.2.1 Monetising excess network capacity

Excess network capacity is the biggest enabler for FWA

FWA is an opportunity for operators to monetise their excess network capacity by creating new product lines. These include broadband products for the unconnected, for competing with fixed broadband propositions, and for backup, in both developed and developing markets. In a study of European operators, Rewheel argues that the excess capacity on mobile networks will push operators to go after fixed-to-mobile broadband substitution[47]. This is already happening in markets such as Finland and Austria.

3.6.2.2 'Pull through' driver for fibre

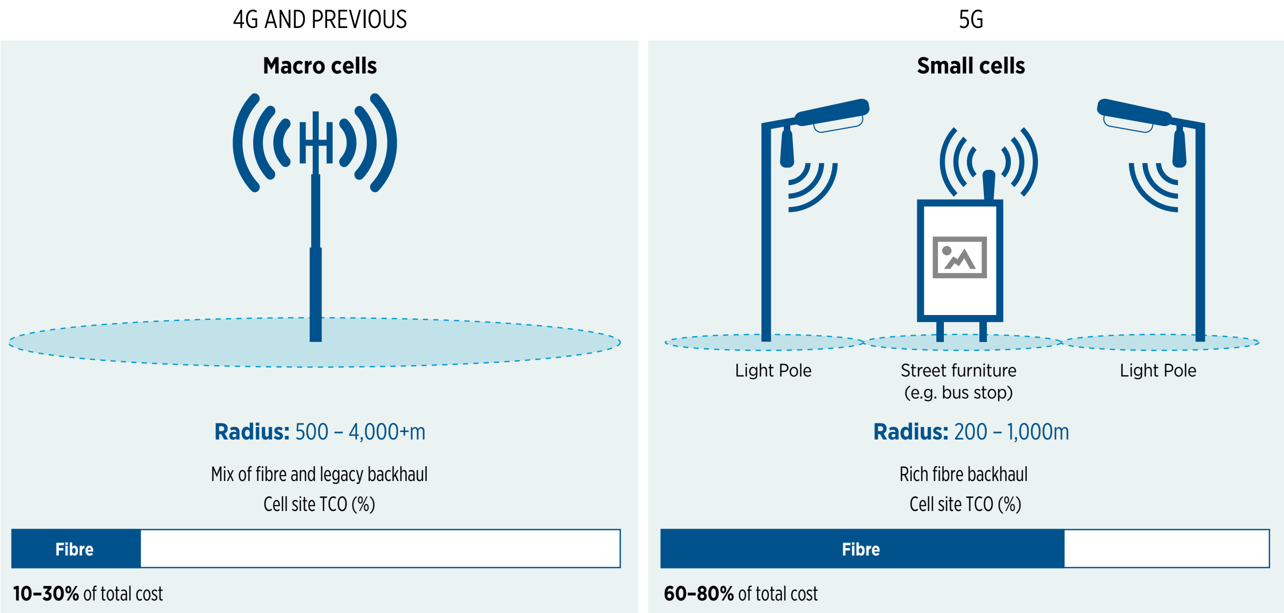
FWA provides an additional incentive to deepen fibre capillarity in the 5G era

The cost of deploying additional fibre infrastructure to support 5G rollouts is a concern for operators in some markets, especially if the deployment is for small cells on mmWave spectrum. A Solon Consulting study, based on the US market, suggests that fibre could make up between 60-80% of total cost of a 5G mmWave base station compared to 10-30% for a typical 4G macro cell (see Figure 3.6.3).

Accordingly, the opportunity to productise and market FWA will act as a driver for fibre investments. This can be as part of a fibre + FWA hybrid bundle. FWA can provide an additional revenue stream for base stations that are already connected by fibre. And for base stations that are still connected by microwave, the prospect of FWA will provide the incentive to switch from microwave to fibre backhaul.

FIGURE 3.6.3

FWA AS AN INCENTIVE TO DEEPEN FIBRE USAGE IN 5G (SOURCE: SOLON CONSULTING)



47. http://research.rewheel.fi/downloads/Capacity_utilization_fixed_mobile_broadband_substitution_potential_2017_PUBLIC.pdf

3.6.2.3 'Strategic competition' with fixed broadband

Cost and strategic leverage will inform many FWA launches

There is an ongoing industry debate on the merits of using FWA to compete with existing fixed broadband propositions. This will likely play out in at least two ways.

First, in a greenfield context, rolling out FWA is significantly cheaper than FTTx. The per subscriber capex estimates are $500-$1000 for FTTx versus $100-$400 for FWA, so it is attractive to opt for 5G FWA if it can provide a customer experience that is close to FTTx. Operators who are driven by this cost analysis will justify FWA based on its lower total cost of ownership.

Second, operators with small or no fixed broadband market share could use FWA to boost their product portfolio and strengthen their competitive position. This may be more so in markets where fixed-mostly companies (e.g. cable companies) are seeking to enter the mobile market in the 5G era. For this, the strategic benefits of launching FWA may not be immediately evident and may be indirect.

3.6.2.4 Competing with new FWA entrants

Operators should take the lead to chart the roadmap for FWA hotspots

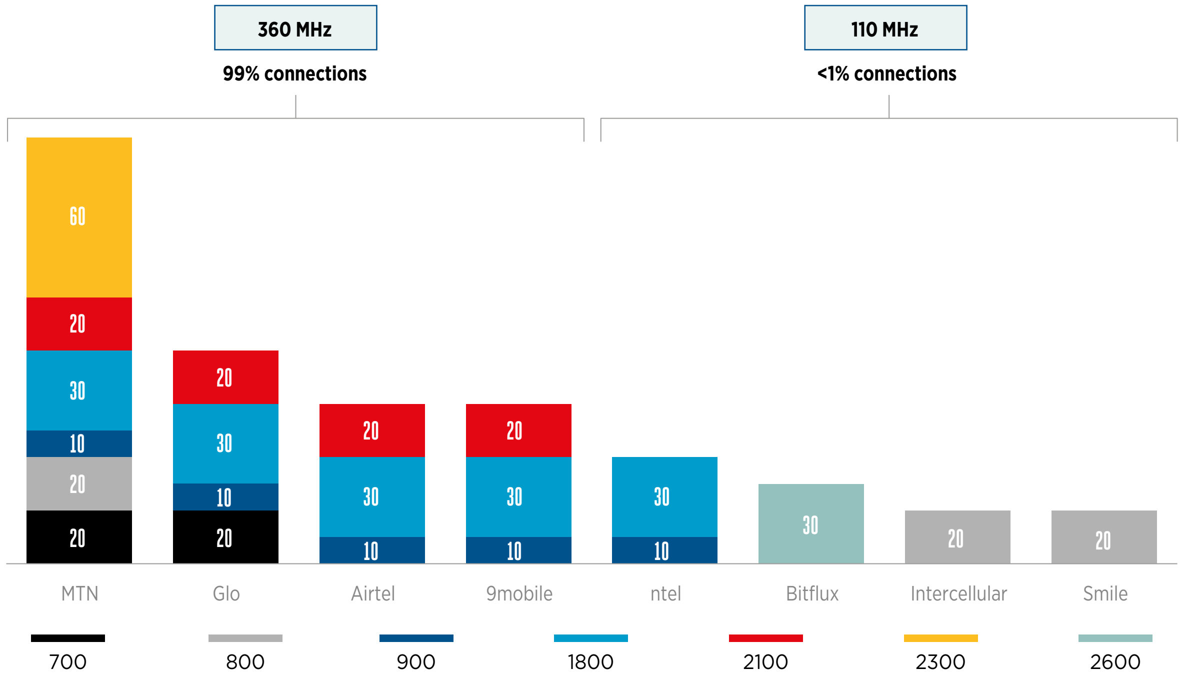
Past experience suggests that operators may not be alone in the race to win valuable 5G spectrum for FWA. A number of new entrants have competed for, and won, spectrum for 3G and 4G FWA services in the past. For example, UK Broadband won around 120MHz of 3.5GHz spectrum in the 2013 UK 4G auctions, while new entrants, such as Smile, Surfline and Afrimax, have been assigned significant amounts of sub-1GHz spectrum in markets across Africa, sometimes ahead of established service providers.

Most of the new entrants have struggled to scale up: those in developed regions have been constrained by well entrenched fixed broadband infrastructure and weak performance of 3G and 4G FWA, while a lack of resources and capability for large scale deployment is the primary limitation for those in developing regions. Nonetheless, their activities impact operators' ability to deploy 4G networks cost-effectively and, in many cases across Africa, distort value in the 4G market with deflationary pricing.

Operators must not risk a repeat of the 4G spectrum fragmentation, and its consequences, in the 5G era. To capitalise on the 5G FWA opportunity and avoid value erosion, operators should take the lead in proactively defining the 5G roadmap for their market, as opposed to taking a reactionary approach to potentially value-eroding events.

FIGURE 3.6.4

SPECTRUM FOR NEW FWA ENTRANTS IN NIGERIA (2018) - NEARLY A QUARTER OF ASSIGNED SPECTRUM IS HELD BY OPERATORS WITH A COMBINED MARKET SHARE BELOW 1% (SOURCE: GSMA INTELLIGENCE)



3.6.2.5 Affordability of FWA devices

Adoption of 3GPP's 5G specifications for FWA enables production of FWA devices to scale

The success of mobile communications, especially GSM (Global System for Mobile communications), stems from the fact that it is globally interoperable and enjoys global economies of scale. Unlike other technologies, GSM enabled devices and network equipment to be manufactured at global scale, reducing the cost of adoption for both operators and subscribers.

This also applies for FWA using 5G. If FWA customer premises equipment (CPEs) is based on 3GPP's 5G specification, the operators will be able to enjoy global economies of scale in production of CPEs. Furthermore, products based on 3GPP specifications have been developed by a robust ecosystem consisting of numerous vendors. 3GPP specifications also are peer-reviewed by number of experts, ensuring that mistakes and errors are minimized. This means that the operator will not only benefit from the potential cost reduction, but also have numerous alternatives in procuring its CPEs. Operators will then be in a position to adopt more competitive pricing for end users.

Device rental models can also be beneficial for both customers and operators. For example, FWA customers can benefit if the CPE is rented as it would be easier for operators to upgrade the CPE while potential upsell of services can also be possible with the upgrade.

3.6.3 FWA economics: opportunity mapping

GSMA mapping of ‘oasis’ of FWA opportunities and limitations

There are several metrics that can be used to map the relative mass market FWA opportunity in different countries. On the supply side, home density vs. population density provides a comparison on how costly it can be to provide mass market FWA coverage. Spectrum choice (mmWave vs. 3.5GHz) determines the size of the cells for FWA coverage and the resultant cost of covering a given area.

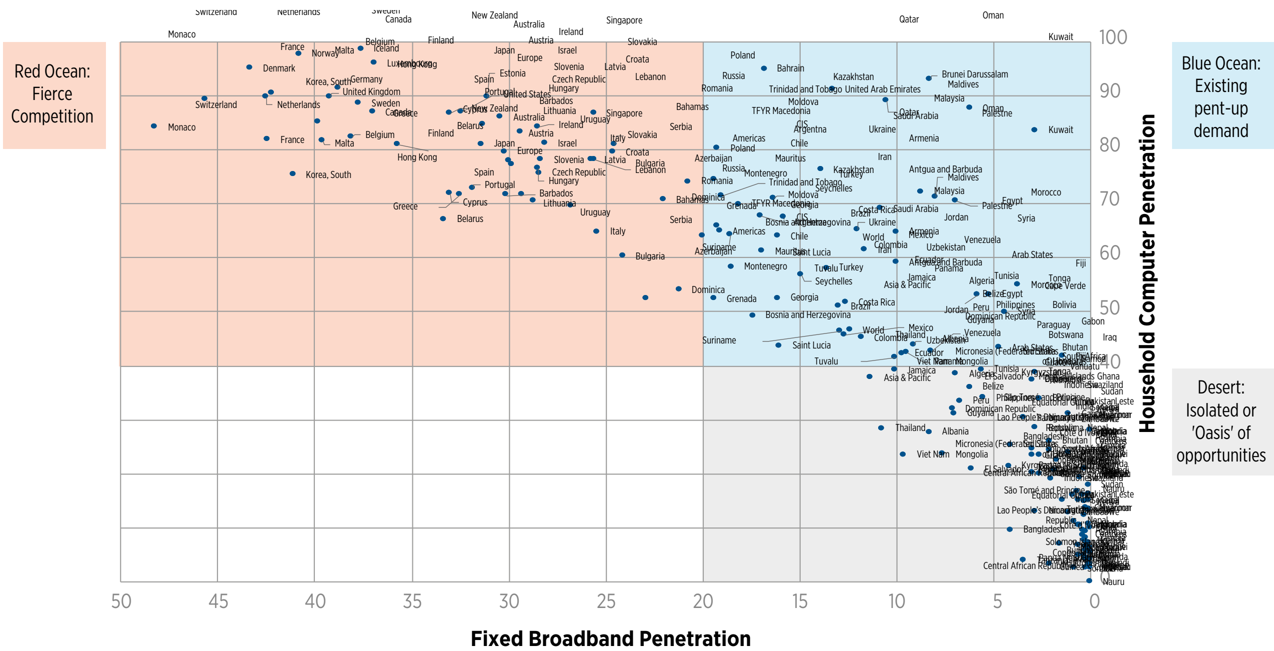
But the demand side provides more helpful metrics to assess the addressable FWA market opportunity. As a broadband proposition to stationary and nomadic uses, FWA will be ‘competing’ with: 1. non-consumption of home broadband; and 2. alternative home broadband services.

For (1), the proportion of households with a computer is a good indicator of an appetite for home broadband. Customers who can neither afford computers nor decide against having a computer are unlikely to be willing FWA customers. For (2), in households with computers, the level of fixed broadband penetration in each country will show the level of pent-up, addressable demand for FWA.

Figure 3.6.5 charts 160 countries on household computer penetration and fixed broadband penetration, and shows that for FWA, most markets can be categorised as either Red Ocean, Blue Ocean or Desert. However, regardless of which category a country is in, there will always be ‘oasis’ of opportunities for FWA.

FIGURE 3.6.5

FWA MASS MARKET OPPORTUNITY FOR 160 COUNTRIES (SOURCE: GSMA)



The GSMA has used the ITU’s data for 2017 to develop this analysis to cover 160 countries. Readers are invited to use more current data for their respective markets for more accurate predictions

3.6.3.1 Mostly 'Blue Ocean' markets

Operators should explore playing in these markets

Blue Ocean markets present a sizeable, and relatively uncontested, mass market opportunity for home broadband (i.e. analogous to a peaceful-looking blue ocean). These are markets with at least 40% household computer penetration but less than 20% fixed broadband penetration.

These markets are attractive for 5G FWA because affordability and usability for residential customers is high. Likewise, the enterprise opportunities for FWA, especially for SMEs, will broadly mirror the consumer market opportunity.

Good examples are found in Middle East countries such as Saudi Arabia (69% household computer penetration; 11% fixed broadband penetration) and Kuwait (84% household computer penetration; 3% fixed broadband penetration).

3.6.3.2 Mostly 'Red Ocean' markets

Operators should only play in these markets for broader strategic reasons

Red Ocean markets present a fiercely competitive opportunity for home broadband (i.e. analogous to a bloody, shark-infested ocean). These are markets with household computer penetration of over 40% and over 20% fixed broadband penetration.

Although these markets are sizeable to be addressed by FWA, they are highly competitive because either the fixed broadband ARPU is already at a price that makes FWA pricing uncompetitive or the existing fixed broadband providers will fight to defend their market share. However, FWA, as a backup broadband for enterprises could provide attractive.

Examples of Red Ocean FWA markets are in most developed markets in Europe, North America and North East Asia.

3.6.3.3 Mostly 'Desert' markets

Operators should seek out and play in 'oasis' opportunities in these markets

Desert markets offer only a small, mass market FWA opportunity because of low affordability and usability (i.e. analogous to a dry, barren desert with isolated 'oases' of greenery). These are markets with household computer penetration of less than 40% and less than 20% fixed broadband penetration. Customers in these markets will likely stick to using their smartphones for internet access, and as a hotspot for computer internet access.

However, there will be selected residential and enterprise opportunities, especially in affluent neighbourhoods and business districts which can prove particularly lucrative. Operators in these markets should focus on making a compelling FWA proposition to customers in these locations early, else these customers will seek alternative broadband solutions for their needs.

Examples of Desert FWA markets are in many developing markets in Africa and South East Asia.

3.7 The Enterprise Opportunity

KEY TAKEAWAYS

- 5G will bring new capabilities and the flexibility to serve the specific needs of different enterprise customers. This could be worth $400 billion per annum to operators by 2025.
- There are broadly four enterprise offerings by operators: basic connectivity; differentiated connectivity; beyond connectivity and managed solutions.
- Operators should seek ways to capture incremental value from commoditised basic connectivity; hence the need for differentiated connectivity (e.g. network slicing).
- Operators can sell more third-party products as part of beyond connectivity; they can also work as co-innovators with their customers to build customer-relevant solutions.
- 5G will be a key enabler of the 4th Industrial Revolution, as technology is seamlessly embedded within society and especially in commercial and industrial processes.

3.7.1 Enterprise products & services

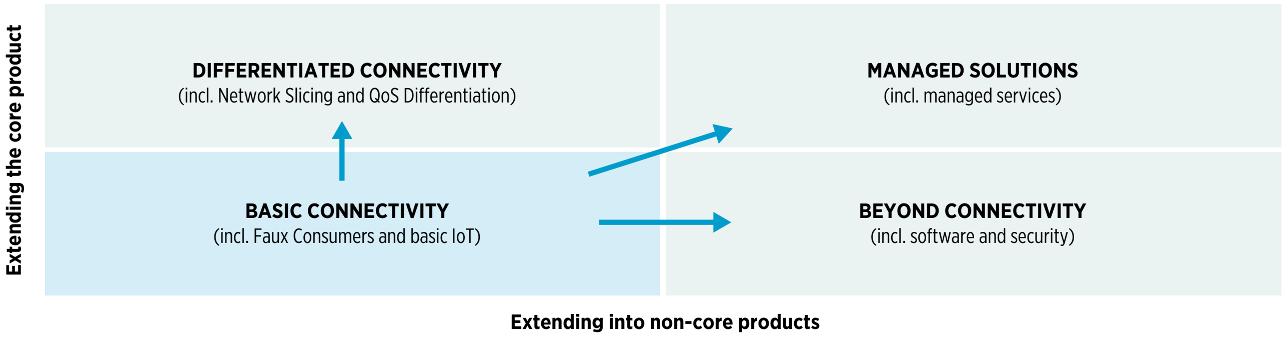
Enterprises will be the biggest source of incremental revenue in the 5G era

5G will bring new capabilities and the flexibility to better serve the specific needs of different enterprise customers. Operators can leverage these new capabilities to unlock a sizeable new revenue opportunity that GSMA estimates could be worth up to $400 billion per annum by 2025 (including the IoT segment).

To fully capture this opportunity, operators will need to tailor their value propositions to large organisations (including municipalities and government agencies) as well as small and medium enterprises (SMEs). While operators are primarily purveyors of connectivity products, they can offer enterprises four different offerings positioned around the core connectivity offering as shown in Figure 3.7.1.

FIGURE 3.7.1

OPERATOR ENTERPRISE OFFERINGS IN THE 5G ERA



3.7.1.1 Basic Connectivity

Operators should seeks ways to capture incremental value from basic connectivity

Operators will continue to offer basic connectivity to enterprises in the 5G era using the core eMBB proposition or, for fixed/mobile operators, fixed broadband offerings. This is generally a strong business for operators and can be quite profitable in areas with unique infrastructure. With the growth in IoT services, operators have the opportunity to cultivate the market for billions more IoT connections.

However, whether as the default option or as a backup, connectivity is largely commoditised and the basic connectivity offering for enterprises is largely undistinguishable from the consumer proposition. This lack of distinction muddles efforts to segment the market appropriately, resulting in many SMEs being served as if they are residential customers (i.e. faux consumers).

In the 5G era, operators should step up efforts to capture incremental value from basic connectivity. This could come through special SLAs (differentiated connectivity) or by bundling additional services (beyond connectivity).

3.7.1.2 Differentiated Connectivity

Operators can better monetise connectivity using a bespoke or customised connectivity offering

Both fixed and mobile operators have, since the early 1970s, sought to offer differentiated connectivity to enterprise customers. With this, operators seek to offer different quality-of-service (QoS) to different customers at different price levels.

Table 3.7.1 (below) provides a brief review of 15 differentiated connectivity capabilities that have been introduced in the telecoms industry since 1974. Several of these capabilities (e.g. Leased Lines, ATM) have been productised and marketed to enterprises for several years. However, there have also been historical challenges in selling differentiated connectivity.

This context will shape the introduction of network slicing and other 5G differentiated connectivity offerings. Given that enterprises already indicate their lack of clarity on the 5G proposition, operators need to be clear that they are solving a specific business need for a customer instead of pushing network slicing as a technology.

3.7.1.3 Beyond Connectivity

Operators will develop new solutions, sell more third-party products/services/solutions and develop platforms for APIs

Operators already offer several non-connectivity products and services to enterprises and these will grow in the 5G era. Many of these propositions are complementary to connectivity (e.g. devices, cloud/backup storage, security) while some are supplementary to connectivity (e.g. IT support, business apps, web hosting).

In the 5G era operators will extend their beyond connectivity propositions in three additional ways. Firstly, they will leverage their deep knowledge about the needs and behavior of the customer, plus management of the network infrastructure to develop new products and services.

Secondly, they will deepen their role as resellers of non-operator products and services (e.g. insurance, fraud detection, business productivity software [e.g. Office 360, Salesforce]). Importantly too, and as was evident in the enterprise engagement, the SME market will welcome operators providing end-to-end services. These businesses have limited budgets and will opt for plug-and-play products from operators that can simplify their tasks.

Thirdly, in a push to expand their role in the value chain, operators will develop platforms/market exchanges to commercialise network APIs and platform enablers. This is one of the main lessons from the enterprise engagement, highlighting the need for operators to develop horizontal enablers that can be used to serve customers in different industry verticals.

TABLE 3.7.1

SELECTED DIFFERENTIATED CONNECTIVITY MECHANISMS (1974 – 2018)

Name	Description	Fixed vs Mobile	Year introduced	Market status
Leased Lines		Fixed	1974 (ITU)	Moderate usage and revenues
X.25		Fixed	1976 (ITU)	Little evidence of current usage
IP TOS	Internet Protocol Type of Service	Fixed	1981 (IETF)	Little evidence of current usage
ATM	Asynchronous Transfer Mode	Fixed	1988 (ITU)	Decreasingly used with negligible revenues
Frame Relay		Fixed	1990 (ITU)	Decreasingly used with negligible revenues
IntServ/RSVP	Intergrated Services	Fixed	1994 (IETF)	Little evidence of current usage
DiffServ	Differentiatiated Services	Fixed	1998 (IETF)	Little evidence of current usage
MPLS	Multi Protocol Label Switching	Fixed	2001 (IETF)	Widely used (Grandview Research forecasts $46.3 billion by 2020)
Carrier Ethernet		Fixed	2001 (MEF)	Widely used (Ovum forecasts $22.5 billion by 2020)
QCI	QoS Class Identifier	Mobile	2008 (3GPP)	Mostly for VoLTE only
SD-WAN	Software Defined Wide Area Network	Fixed/Mobile	2014 (-)	Growing usage (Gartner forecasts $1.3 billion by 2021)
SCM	Smart Congestion Mitigation	Mobile	2015 (3GPP)	Used by emergency services
ACDC	Access Control for general Data Connectivity	Mobile	2016 (3GPP)	Little evidence of current usage
5QI	5G QoS Indicator	Mobile	2017 (3GPP)	Not yet launched
Network Slicing		Mobile	2017 (3GPP)	Not yet launched

3.7.1.4 Managed Solutions

Operators to position as co-innovators with their customers in the 5G era by offering managed services

Operators are increasingly entering the market to create and manage a range of connectivity plus solutions for customers. The benefit of this approach is that operators can co-innovate with their customers. For example, by applying data science and AI tools to IoT customer data (e.g. fleet management company), an operator can help the customer to identify new business opportunities or more efficient ways of running their business.

An important opportunity in the 5G era will be to manage 5G private networks that several large enterprises seek to deploy. As history shows that businesses generally benefit from outsourcing connectivity solutions as a non-core function, operators will need to put together a compelling value proposition that could include leased spectrum, equipment, and management.

Designing and building technology solutions for large enterprises is a market traditionally dominated by large system integrators, especially in developed markets. Operators will have to compete in this market by upskilling themselves and building up their brand to achieve market recognition and reputation. Operators in developing markets, with less system integrator competition, have a stronger opportunity in this space.

3.7.2 Enterprise drivers

3.7.2.1 The declining ARPU trap

Operators need the enterprise market to stabilise declining consumer ARPU

The mobile industry has faced a declining ARPU for a long time. This is now an established long-term trend, highlighting how challenging it has been for operators to increase their share of the consumer wallet. Using 2007 as a base, in the ten years to 2017 unique subscriber ARPU declined by an average of 6% per year, as shown in Figure 3.7.2

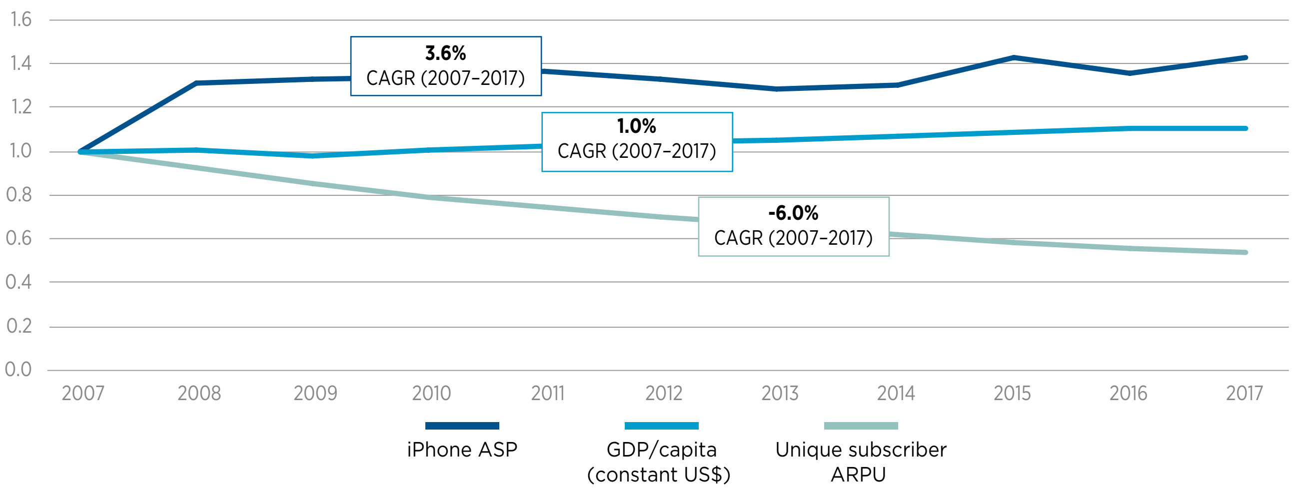
By contrast, over the same period global GDP/capita grew by 1% annually, and the average selling price of the iPhone grew by 3.6% annually. This means consumers were getting richer and were willing to pay more for other products and services in the telecoms ecosystem, but were paying less for mobile services.

Stabilising, and then reversing this persistently declining ARPU trend would be a major success for the 5G era, and the enterprise opportunity may be key to achieving this.

FIGURE 3.7.2

ARPU GROWTH VS GDP/CAPITA AND IPHONE ASP 2007 – 2017

(SOURCE: ASYMCO, WORLD BANK, GSMAI, GSMA ANALYSIS)



3.7.2.2 5G and the Fourth Industrial Revolution

The biggest geopolitical driver for 5G is as an enabler for the Fourth Industrial Revolution

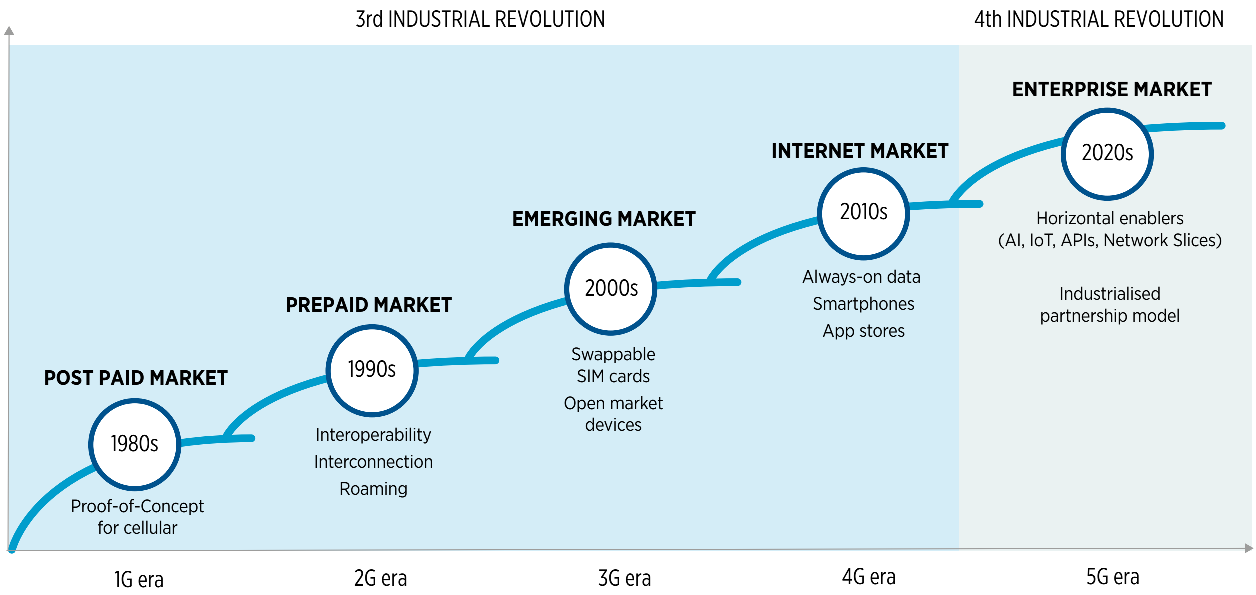
Some operators face an immediate and direct demand from geopolitical forces to deploy 5G to support the transformation of society and vertical industries.

This aspiration is captioned as the Fourth Industrial Revolution or Industry 4.0, a time when technology is seamlessly embedded within society and especially in commercial and industrial processes. Political commentary often puts 5G together with advances in robotics, AI, quantum computing, IoT, 3D printing, autonomous navigation etc. as the emerging technological forces that will power Industry 4.0.

As Figure 3.7.3 shows, operator products and services were integral to the Third Industrial Revolution from the 1980s as technology evolved from analogue electronic and mechanical solutions to the digital versions that are prevalent today. This was the era of the Personal Computer (PC), internet, smartphones and Machine-to-Machine devices.

FIGURE 3.7.3

5G AND THE 4TH INDUSTRIAL REVOLUTION



3.7.2.3 Private 5G networks: the market opportunity

Operators need to be ready to support private 5G cellular networks

5G will be the first mobile technology generation to be designed from the outset to operate in unlicensed, shared[48] and traditional licensed spectrum. This means that not owning licensed spectrum will not be the barrier to mobile network operation that it once was.

As a result, the introduction of 5G will create opportunities for new players to enter the market to provide private cellular services in a localised environment. One estimate is that $5 billion will be spent on private mobile networks per year by the end of 2021[49].

This is an opportunity for operators to deploy private networks for key enterprise customers, or to sublet licensed spectrum to them. However, enterprises may also choose to roll out their own 5G networks, either directly or through partners[50]. These enterprises include private venues, municipalities, utility companies, port authorities and manufacturers who want to deploy cellular-based IoT solutions and other broadband communications.

48. Unlicensed spectrum includes the 2.4 GHz and 5 GHz "Wi-Fi" bands. Shared spectrum is typically a band that is occupied by an incumbent but that is made available to others in areas and at times when it is not being used (e.g. a prominent example is the US' CBRS sharing plan in the 3.5 GHz band.)

49. According to an SNS Telecom & IT study (2017)

50. E.g. German Industry wants to setup their own 5G networks & several US companies/groups are campaigning to the FCC for terms which will suit private mobile networks in the 3.5 GHz band.

3.7.3 Enterprise economics: operator revenue mix

Overall 5G era revenues can grow by 33% if a hypothetical operator can grow its enterprise revenues to 40% while maintaining its consumer revenues

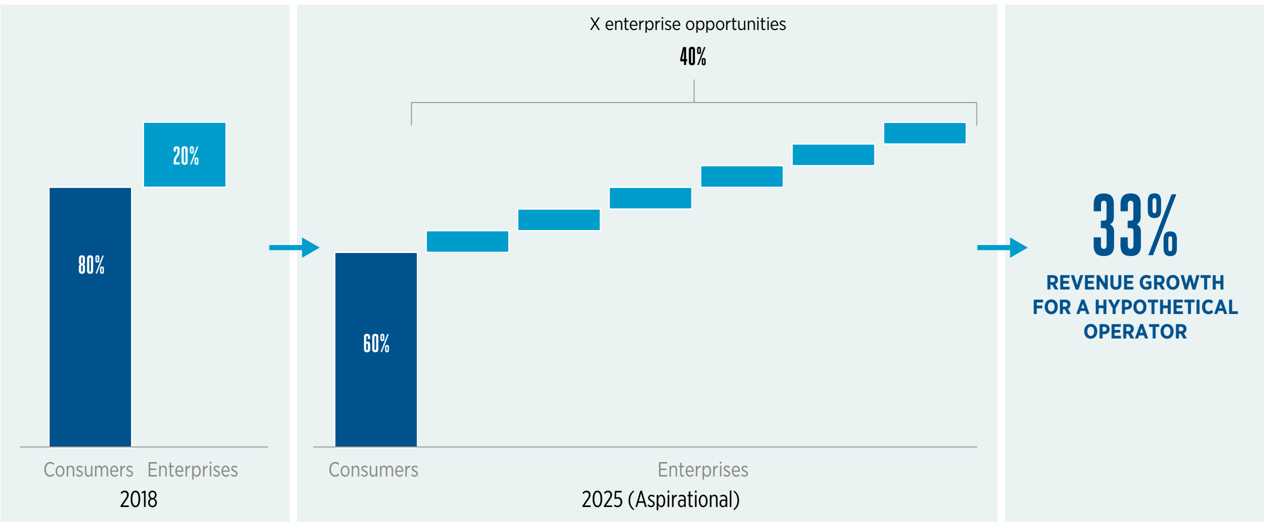
Faced with a maturing consumer market, the enterprise segment offers an opportunity for operators to continue growing revenues in the 5G era, which can lead to a changing mix of revenues.

An industry rule of thumb suggests that operators currently seek to generate 80% of revenues from consumers and 20% from enterprises. To make progress in the 5G era, operators will need to aim to grow their absolute revenues by maintaining their current consumer revenues (in absolute terms) while growing their enterprise revenues to an aspirational target of 40% of the total. A hypothetical operator going from 80/20 to a 60/40 revenue split, could see revenues in the 5G era grow by 33%.

Unlike the consumer market where operators rely on a single proposition based on mostly basic connectivity products (voice, messaging and data), there is unlikely to be a single enterprise opportunity that will deliver 40% of revenues. Instead, operators will rely on serving multiple enterprise opportunities using a common set of horizontal enablers (see Figure 3.7.4).

FIGURE 3.7.4

THE OPERATOR REVENUE MIX IN THE 5G ERA



3.8 Enterprise Opportunity - IoT deep dive

KEY TAKEAWAYS

- **Many IoT applications are well supported on the existing 4G networks, and NB-IoT and LTE-M are already part of the 5G family.**
- **5G will enhance the IoT opportunity by providing more capacity for scale, for critical IoT, and by supporting enhanced quality of service and lower latency.**
- **To compete effectively in IoT, operators should plan to provide IoT connectivity solutions enhanced with additional capabilities, such as MEC, AI and security.**

3.8.1 IoT products & services

5G will support a wide variety of machine-related, IoT use cases

Internet of Things (IoT) is set to become a major contributing factor to the increase of productivity by enhancing and automating business and manufacturing processes via secure connectivity. Many IoT applications are well supported on the existing 4G networks, but some can also benefit from enhanced 5G capabilities for massive IoT by providing more capacity for scale; for critical IoT; and by supporting enhanced quality of service and lower latency.

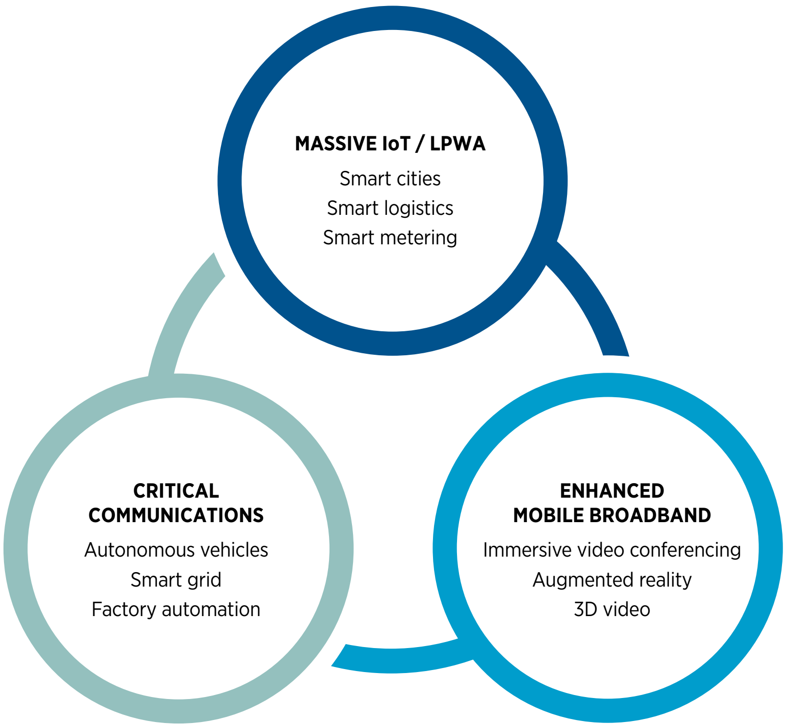
A boost of capacity supported by 5G will be particularly important, as the large-scale IoT deployments will drive a massive growth of IoT connections. Two thirds of the 3.6 billion IoT connections in 2025 (up from 1.1 billion at the end of 2018 as per GSMA Intelligence forecasts) will be used by smart industry and automotive verticals: 5G is already incorporated into the roadmaps for connected vehicles, transport, manufacturing and robotics.

These new IoT connections are set to make use of numerous new 5G functionality: ultra-reliable low latency communication and time sensitive networking, enabled via a combination of 5G and wireless edge, will be required for time-critical industrial IoT manufacturing processes, including closed-loop robotic control; machine-human interactions; automated guided vehicles; as well as AR and VR, for example, for machine maintenance.

Public and private businesses will use input from secure IoT connectivity overlaid with artificial intelligence, cloud computing and advanced analytics to monitor and interpret data from diverse assets, production lines and complex machinery in real-time to anticipate faults, manage infrastructure and mitigate risks.

FIGURE 3.8.1

MOBILE IoT IN THE 5G FUTURE



3.8.2 IoT drivers

3.8.2.1 NB-IoT and LTE-M as futureproof IoT

Investment into NB-IoT and LTE-M today is already an investment into 5G massive IoT

Massive IoT connectivity based on low power wide area (LPWA) networks will become a less expensive, less complex and an energy-efficient foundation for building future intelligent 5G managed services.

One of the most important enterprise considerations for any technology investment is its durability and the openness of its ecosystem. The majority of IoT business cases require a long-term deployment of connected sensors and devices that can be managed remotely and can last for many years without replacement. With the first 5G networks now being planned, some potential customers for NB-IoT and LTE-M have been hesitant to deploy the technology, believing 5G could make it obsolete.

In reality, the opposite is true: 3GPP has agreed that the LPWA use cases will continue to be addressed by incorporating LTE-M and NB-IoT as part of the 5G specifications, so confirming the long term status of both LTE-M and NB-IoT as 5G standards. Massive IoT is expected to be backward compatible, with software upgrades that would support transition to massive IoT without disrupting the IoT business case.

3.8.2.2 IoT 'long tail' as a driving force

"IoT out of the box" will drive the long tail of industrial and consumer applications

The early adoption of IoT has been driven by large enterprises, but the large-scale deployment will accelerate when IoT becomes ingrained in the long tail of industrial and consumer applications and services, many of which are developed by small- and medium-size enterprises. Adoption of cellular IoT solutions in this segment will be driven by the mobile industry's ability to support open innovation, and open source prototyping and development.

The foundation for diverse IoT applications is laid on the existing 4G networks, where LPWA NB-IoT and LTE-M technologies already support the functionality of massive IoT and private LTE networks are used by enterprise customers. The launch of SA 5G networks will enhance the LTE functionality and give extra boost to the growth of IoT applications.

3.8.3 IoT economics

3.8.3.1 Competition in the IoT ecosystem

Operators will differentiate with a secure, neutral service IoT proposition

Operators will not be alone in competing for the industrial IoT market. Firstly, mobile IoT will coexist and compete with other access technologies such as Wi-Fi, LPWA networks and satellite. Secondly, the management of private 5G networks is equally attractive to systems integrators, enterprise-focussed vendors, and enterprise customers themselves.

To compete effectively, operators should plan to provide IoT connectivity solutions enhanced with additional capabilities, such as MEC, AI and security-as-a-service that can cater to both the short-range and long-range Industrial IoT network requirements. Operators' unique proposition is in secure management of diverse 5G connectivity options, combined with a variety of services such as cellular grade security and analytics, moving from providing data services to control services.

Importantly, operators do not need to wait until 2020. Their portfolios of managed enterprise IoT services can be built using 4G IoT, and later enhanced and expanded with 5G building on the established enterprise relationships and opening new value-added revenue opportunities.

3.8.3.2 IoT value chain

Operators will increase their role in the IoT value chain in the 5G era

New network capabilities will create more IoT opportunities for operators, in addition to the many IoT use cases that can and are being addressed using today's existing technologies. A typical example of the value chain for an IoT service is illustrated in Figure 3.8.2

For operators, the IoT opportunity is about adding many more connections, as well as capturing value from parts of the IoT value chain beyond connectivity. Connectivity revenues represent the main opportunity for operators in IoT today and this opportunity will continue to grow as billions of additional connections are brought on stream. By 2025, however, GSMAi forecasts the share of connectivity revenue in the total IoT revenue will decline to 17%, while Service Enablement, including Applications and Platforms, is forecast to generate 57% of the total, and Professional Services and Business Solutions 26%.

This "Forward Integration" opportunity should see operators take on more roles in enabling IoT services, and where feasible, offering IoT business solutions. Among these are analytics/Big Data, real time control/telematics, and autonomous driving capabilities. The new roles are outlined in Figure 3.8.3, and analysed in detail in the GSMA report titled "Opportunities in the IoT: Evolving roles for mobile operators."

Likewise, operators could backward integrate and take advantage of opportunities in new areas.

FIGURE 3.8.2

OPERATOR ROLE IN THE IOT VALUE CHAIN

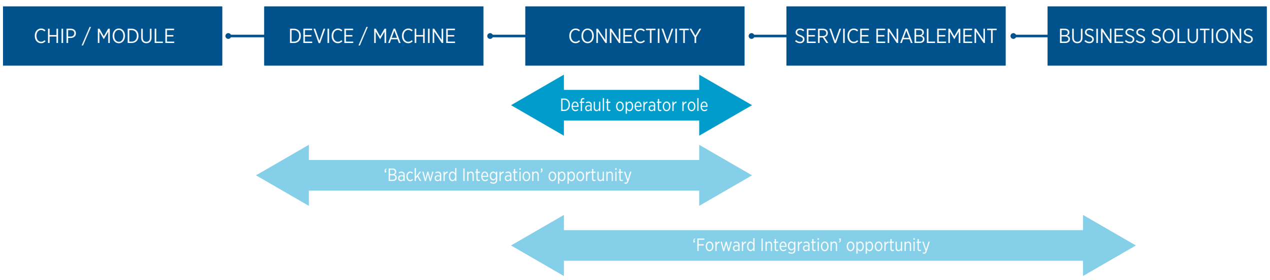
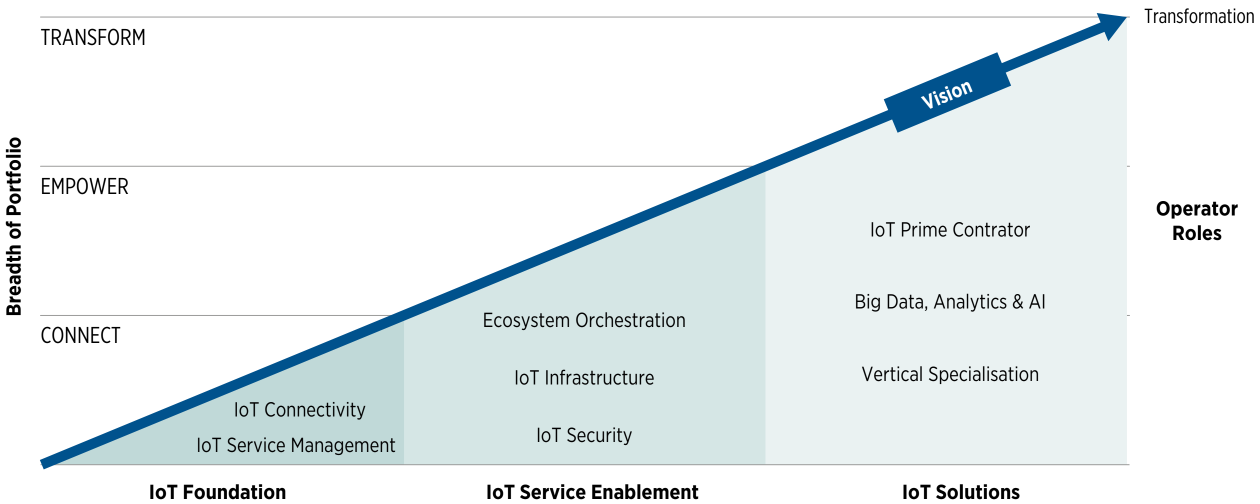


FIGURE 3.8.3

OPERATOR ROLE TRANSFORMATION



3.9 5G Value Enablers – Resilient Networks & Services

KEY TAKEAWAYS

- Resilience will be a major strategic and business enabler in the 5G era and will play out in different ways for different services.
- Operators will need to create value propositions to customers based on clear understanding of service availability and reliability.
- 5G networks should recognise that different use cases may require different service levels, especially during atypical operating scenarios.
- Operators need tools and processes to reassure customers that 5G will deliver on its value proposition and SLA.
- Operators need a secure way to authorise devices and to block devices en masse.

3.9.1 Importance of resilience

The economic cost of poor Internet connections can be as high as 30% of annual telecoms revenues

Studies show that the cost, to society, of poor internet connection can be high and many 5G era use cases could fail to materialise if operators cannot assure network and service resilience. A 2015 UK study by Daisy Group suggests that the cost to the economy can be as high as £11billion, equating to about 31% of the total annual revenues of the UK's fixed and mobile operators. This is the context to the importance of resilience to creating and capturing value in the 5G era.

A resilient system provides and maintains an adequate level of service in normal and abnormal operating scenarios, including in the event of a fault. In this context, resilience is an all-encompassing concept and covers other attributes such as reliability; availability; survivability; consistency; quality management; Six Sigma, etc. It also covers the traditional approaches from systems, safety and reliability engineering.

Many operators have already embraced the Total Quality Management (TQM) methodologies that came from the manufacturing industries (e.g. operators now routinely use Six Sigma to improve their service delivery and business processes). While much of the focus on resilience has been at the service level, the 5G era will need a similar push at the network level to fully enable value creation and capture for operators.

Resilience will be a major strategic and business enabler in the 5G era and operators will need to create value propositions for customers based on clear understanding of service availability and reliability. For example, Table 3.9.1 illustrates the different levels of network availability and the type of use cases that can be supported.

It is important to stress that operator-run 5G networks using licensed spectrum will already be more resilient than alternative networks run on unlicensed spectrum or managed by organisations without the scale or competence to run critical infrastructure.

This section groups the considerations for network and service resilience into predictive resilience, preventive resilience and corrective resilience.

FIGURE 3.9.1

DESIGNING NETWORKS TO MINIMISE DOWNTIME

	"Two Nines"	"Three Nines"	"Four Nines"	"Five Nines"
Availability	99	99.9	99.99	99.999
Downtime				
Per Year	3.65 days	8.77 hours	52.60 minutes	5.26 minutes
Per Month	7.31 hours	43.83 minutes	4.38 minutes	26.30 seconds
Per Week	1.68 hours	10.08 minutes	1.01 minutes	6.05 seconds
Per Day	14.40 minutes	1.44 minutes	8.64 seconds	864.00 milliseconds
Use cases (Ideal for...)	Email, Web browsing	IoT	Pay TV	Voice, autonomous navigation

3.9.1.1 Network resilience and the philosophy of communications networks

Resilience is integral to the technical designs of mobile networks, but it is at 'best effort' level only

There is an ongoing paradigm shift in the underlying philosophy of telecoms networks. Since the internet went mainstream in the early 1980s, and prior to the 5G era, it has typically been assumed that networks can deliver 'best effort' connectivity over variable quality networks.

Resilience will be key in the 5G era as the mobile network is being explicitly asked to support ultra-reliable and critical systems. This is a key selling point for 5G and is reflected in the identification of Ultra Reliable and Low Latency Communications (URLLC) as one of the key pillars of the 5G opportunity. 3GPP has also specified that the reliability of the 5G network should be such that there is a 1-10^(-5) success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1ms.

3.9.2 Predictive resilience: designing for resilience

Network and service design should be 'fit for purpose' for each use case

Operators consider a lot of factors in designing and provisioning mobile networks and services. These have been explored in detail in the 5G Readiness chapter. The outcome of these considerations is that the network is dimensioned to cope with peak usage, and most customers can expect to receive the same experience. These considerations will not change, in general, in the 5G era. However, operators should consider at least two adaptations to ensure that 5G era networks and services system are designed for resilience.

First, as is clear from the enterprise interviews, some users are not sure of the 5G value proposition and may not rely on it for their product roadmap (e.g. driverless cars). This suggests a need for clearer messaging on what 5G will deliver and what it will definitely offer for selected use cases.

Second, the operation of 5G era networks should recognise that different use cases may require different service levels, especially in atypical operating scenarios. This is the promise of network slicing, to offer a differentiated experience to different use cases such that each use case is optimally addressed. Operators have begun adapting their propositions in the 4G era using static categories (e.g. IoT devices that upload data during off-peak only). In the 5G era, network automation should make it possible to dynamically provision different levels of services.

3.9.3 Preventive resilience: frameworks to assure resilience

Operators need tools and processes to reassure customers that 5G will deliver on its value proposition and SLA

Regardless of the robustness of its design and provisioning, 5G era networks will at times be challenged to deliver on their designed promise. These challenges could be accidental (e.g. equipment failures, bugs in software, natural disasters, human errors etc.) or malicious (e.g. hacking, software viruses, unauthorised access, vandalism, theft etc.). In many ways, the overall resilience of 5G systems will be determined by the resilience of its weakest component.

For some emerging 5G use cases (e.g. for the healthcare industry), operators will be tasked with providing assurances and stringent Service Level Agreements (SLAs) for customers. Likewise, policymakers and insurers will be keen to know what policies and processes operators have in place to assure security of 5G era systems.

Other stakeholders in the 5G ecosystem will benefit from a clearly articulated industry view on how to deliver preventive resilience to support the 5G value proposition. Accordingly, this calls for concerted efforts to develop common QoS and SLA frameworks for different industry verticals and use cases.

3.9.3.1 Access control for resilient networks

Operators need a secure way to authorise devices and to block devices en masse

A robust identity, authentication and authorisation framework is integral to providing preventive resilience for 5G era systems. Assets need to be correctly identified and authenticated to the right services, while ensuring that devices are restricted from using services they are not entitled to. Services should also have an ability to recognise a subscriber and to compare the security capabilities required, and then respond in near real time. The subscriber may move between networks and services within these networks meaning the security parameters may alter.

In addition to restricting services, it may be necessary for an operator to block devices when the 5G era system is compromised or attacked. This is the case when numerous devices send data traffic to a specific target, resulting in a distributed denial of service (DDoS) attack.

3.9.3.2 Supply chain risks in the 5G era

Supply chain resilience and control will be required in 5G due the complexity of the ecosystem

While there may not be as many players in the market during early 5G deployment, new opportunities in the 5G era could extend existing relationships and create new supplier relationships for operators. This is emerging to be a major consideration for preventive resilience in the 5G era, and can assume strategic and geopolitical dimensions.

Accordingly, operators need to understand their place within the end-to-end supply chain for each service and where ultimate accountability, responsibility and liability fall. The supply chain applies to suppliers providing any aspect of a specified service; this may be 5G components, service management, software utilisation, device ownership and numerous other aspects of service delivery.

A notable example of supply chain risk is that the failure to risk-assess supply interlinks may result in data leakage through insecure Network Exposure Functions (NEF) and Application Programmable Interfaces (API). Industry standards such as ISO 2800, 2700 and 3100 address supply chain and risk management controls.

3.9.5 Corrective resilience: business continuity and disaster recovery

In the event of a fault, 5G systems will need to quickly return to normalcy

When a fault or failure does occur, customers will need assurances that operators will quickly identify, isolate and rectify the fault so that service can continue. This expectation will only grow in the 5G era as critical systems and services become increasingly dependent on the mobile network.

Proper business continuity planning recognises the potential risks that can hamper 5G service delivery to customers, support customers in assessing the impact to their day-to-day operations and mitigate the risks, and provide assurances on minimising the downtime.

A starting point towards corrective resilience is to build in redundancies to provide fallback options for selected use cases. This multi-connectivity approach could evolve to become a major part of the 5G value proposition for enterprise use cases.

For example, connections for emergency and critical services could rely on a fall-back connection in the event of a fault. This is the explicit requirement from a team of surgeons exploring the opportunity for remote surgery in the US[54]. While low latency is being touted as the enabler for remote surgery, the surgeons note that they could perform surgeries with worst case latencies of up to 250 milliseconds. However, they dread the unreliability of the connectivity and would require dedicated networks with multiple connectivity options to assure resilience.

54. https://www.theguardian.com/technology/2018/jul/29/the-robot-will-see-you-now-could-computers-take-over-medicine-entirely#comment-118850420

3.10 5G Value Enablers: Horizontal APIs

KEY TAKEAWAYS

- **Horizontal APIs provide the interface between the 5G network and the needs of enterprises in different industry verticals.**
- **3GPP has taken a big step towards harmonising horizontal APIs for the 5G era, providing a common global structure for exposing network and service capabilities to third parties.**
- **Capability exposure, platformisation and developer ecosystems are the ingredients for a successful API ecosystem.**

3.10.1 Importance of APIs

As the interface with industry verticals, APIs are the vehicle for mass customisation in the 5G era

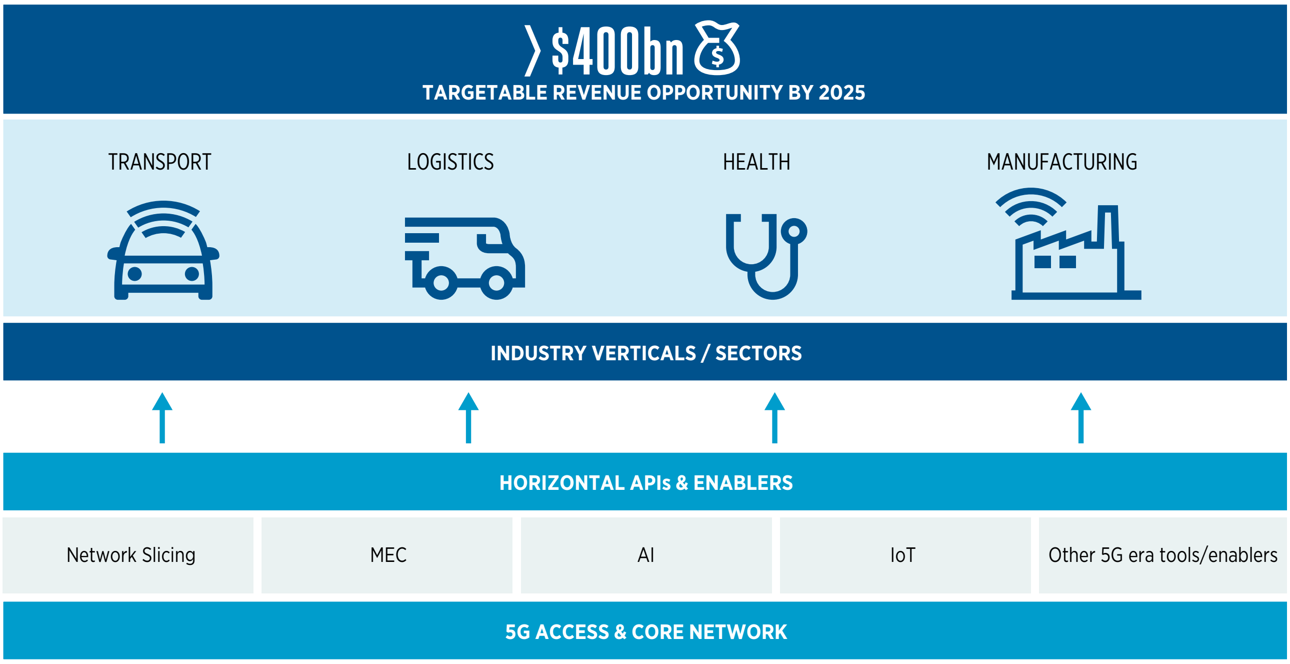
The telecoms industry, like other sectors since the Industrial Revolution of the 19th century, has ridden on the back of a mass-produced service to deliver transformational success to society. This worked also because the service produced was similar to every customer, allowing operators to drive scale and market penetration fast. In the 5G era, such mass produced services will continue to be the main proposition for consumers and many enterprises.

However, if 5G is to become embedded deeper into industrial processes in other sectors and unlock the more than $400 billion revenue opportunity, then offering only the default service proposition will no longer be enough. Enterprises, especially those across different industries, often require bespoke solutions and operators have traditionally sought to work with large enterprises to customise their mobile proposition.

Horizontal APIs provide the interface between the 5G network and the needs of enterprises in different industry verticals. In practice, APIs will provide a more efficient tool to customise, on a larger scale, the 5G proposition to the needs of both large and the vastly greater pool of smaller enterprises. This is the 5G mass customisation opportunity.

FIGURE 3.10.1

HORIZONTAL API AS THE VEHICLE FOR MASS CUSTOMISATION IN THE 5G ERA



3.10.2 Technical landscape for APIs

3GPP has taken a big step towards harmonising horizontal APIs for the 5G era

The technical landscape for APIs in the 5G era is a lot more promising than in previous mobile generations. In its recent releases 3GPP provided a means to securely expose and discover the services and capabilities provided by 3GPP network interfaces, via horizontal APIs. These are the Network Exposure Function (NEF) and the Service Capability Exposure Function (SCEF).

When successfully implemented, these will provide a common global structure for exposing network and service capabilities to third parties. This will allow operators to enable new services, provide better SLAs and ensure better quality of service (QoS) that feature as key enterprise requirements for operators.

Another technical evolution of the API landscape in the 5G era is that the APIs will be using established IT principles to deliver on the 5G Service Based Architecture. These will simplify the retrieval of data, management of devices by the customer of the network and allows operators to design better services. Some of these principles include:

- Use of HTTP/2 (Hyper Text Transfer Protocol 2) adopted as the application layer protocol for the service based interfaces
- TCP (Transmission Control Protocol) adopted as the transport layer protocol, and TLS (Transport Layer Security) for security. UDP (User Datagram Protocol) yet to be defined but will be added in future 3GPP releases.
- JSON (JavaScript Object Notation) adopted as the serialisation protocol.
- REST-style (Representational State Transfer) service design whenever possible.

3.10.3 APIs, platforms & commercialisation

Capability exposure, platformisation and developer ecosystems are the ingredients for a successful API ecosystem

APIs are not new in the telecoms industry, and are already widely used across the internet economy where billions of API-based transactions are made with minimal commercial agreements. However, the history of APIs in the telecoms industry and beyond offers three insights on what is needed to ensure that APIs in the 5G era are successful.

First, the foundation for every successful API is that it provides a standard interface to expose network or service capabilities to third parties. While it is possible to design and develop bespoke APIs for every use case for each customer, it is much more efficient to agree standard industry-level common APIs which can be used globally. Crucially too, history shows that these APIs start off for internal use before being commercialised for external use.

Second, potential users of APIs may not want to set up contractual relationships with the 800+ operators in the world for each individual API. Instead, they prefer a market exchange which provides a hub for API exchanges and interconnections. Owners/managers of the platform become the interface between operators and the API users.

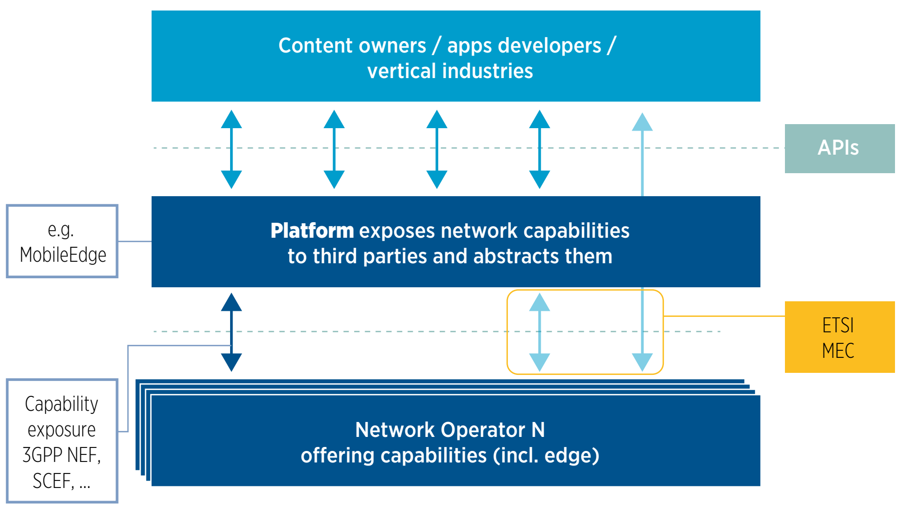
Third, APIs can only thrive in the market if there is an active ecosystem of developers who are building new products and services based on the APIs.

SMS is an example of a very successful API, with good capability exposure, established platforms and market exchanges, and a healthy developer ecosystem. This is now being evolved into RCS.

Figure 3.10.2 is an example of the interlinks between APIs, platforms and platform providers for the 5G era.

FIGURE 3.10.2

APIS – STANDARDISATION, PLATFORMISATION, COMMERCIALISATION



3.11 5G Value Enablers: Operator Cloud

KEY TAKEAWAYS

- **The Operator Cloud will combine the best of both cloud and edge to enable the 5G 'Service Delivery Model'.**
- **Edge computing in 5G networks will be delivered as Multi-access Edge Computing to reduce latency.**
- **An Operator Cloud can help operators to save up to 2% of capex by improving operational efficiency and customer experience.**
- **If operators can create competitive global platforms for edge/cloud services, this could unlock a new revenue opportunity of up to $100bn.**

3.11.1 Importance of the Operator Cloud

The Operator Cloud will combine the best of both cloud and edge to enable the 5G 'Service Delivery Model'

The Operator Cloud (see Figure 3.11.1), a distributed cloud/edge infrastructure, is central to the new 'Service Delivery Model' of the 5G era and how operators can create value for their customers. 5G is a cloud-native platform that will support a plethora of network microservices.

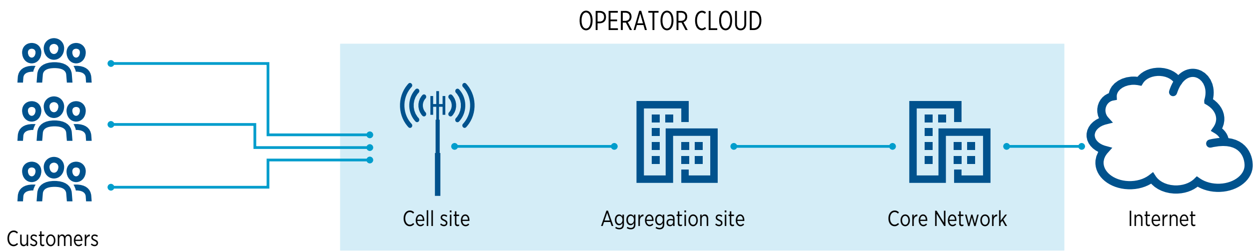
Operators are much smaller than existing cloud providers and need to manage a cloud infrastructure that will deliver the flexibility and scalability of today's internet services. Likewise, the existing cloud providers will need to move services closer to the edge to deliver low latency capabilities. Co-locating their equipment or hosting their application in the Operator Cloud is an option.

To realise this, the Operator Cloud needs to incorporate the best properties of cloud-based service delivery while also leveraging edge-computing technologies. The ultimate goal is to cost-effectively provide a resilient network to deliver the consistency, reliability, latency and compliance expectations of customers in the 5G era.

In practice the Operator Cloud will support and optimally distribute computing and intelligence capabilities, between the core network and the access network. This will enable high bandwidth and ultra-low latency access to cloud computing/IT services at the cloud and edge to be accessed by applications developers and content providers.

FIGURE 3.11.1

THE OPERATOR CLOUD IS A DISTRIBUTED EDGE/CLOUD INFRASTRUCTURE



3.11.2 The case for MEC

Edge computing in 5G networks will be delivered as MEC

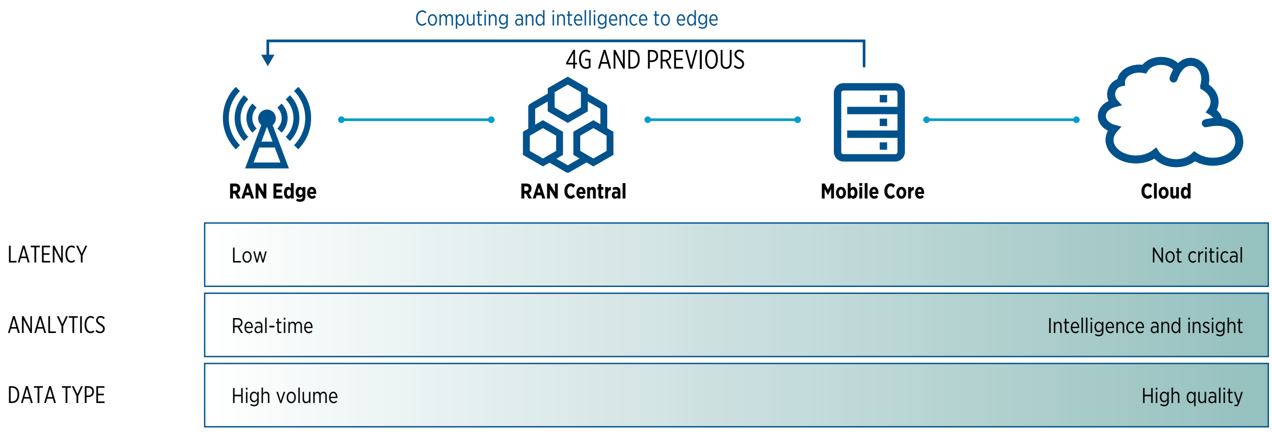
Edge Computing, architected as Multi-access edge computing (MEC) for mobile networks, is most suitable for use cases that require at least one of the following: low latency; real-time analytics; and high volume data transfers (see Figure 3.11.2). As edge computing reduces the physical distance of communications nodes, latency can be reduced significantly while allowing real-time analytics to take place. Having the core functionality at the edge also allows a more efficient transfer of massive volumes of data.

On the other hand, use cases that are not very delay sensitive, where intelligence and insight are more important than real-time analytics, and where high quality data is preferred over high volume of data would be more cost effectively addressed using traditional core/cloud approach. Therefore, while MEC provides operators with new capability to address new use cases, it is important for the operator to consider all of its infrastructure and capabilities to be ready to address all 5G use cases.

Section 4.5, in the 5G Cost Considerations chapter, explores the cost aspects of deploying MEC in a global operator's 5G network and recommends that MEC should be integrated into the 5G business case and investment plan. MEC APIs standards are being developed by ETSI.

FIGURE 3.11.2

MEC VS CLOUD – A REQUIREMENTS PERSPECTIVE



3.11.3 Drivers for the Operator Cloud

Operators are one of many possible providers of a distributed cloud/edge infrastructure

The distributed edge/cloud infrastructure space is attractive to operators and other players because of the possibilities it enables. Other potential providers include existing CDN players; select enterprises (e.g. airports, malls etc.); businesses with distributed real estate (e.g. supermarket chains); government/local authorities (e.g. libraries); and tower companies. Each of these alternative providers may opt to play in the distributed cloud/edge market, especially if enabled by either technology or regulation.

Operators have two distinct capabilities that give them an advantage. Firstly, compared to others, operators can breakout traffic locally, with minimal effort, before it reaches the internet. Secondly operators are already active in managing a mass-market edge infrastructure for communications services.

Given these, there are four clear drivers for operators to play in this market: drive for operational efficiency; demand for improved customer experience; expectations on monetising 5G era network capabilities; and political forces.

3.11.3.1 Operational efficiency

An Operator Cloud can help operators to save up to 2% of capex

Incorporating an Operator Cloud provides operational efficiency opportunities for operators, potentially saving up to 1.8% of the capex that would have been used for backhaul and core network upgrades. This is based on locally breaking out more than 30% of the video content to a local storage location[55]. If applied globally, this could be worth up to $3.2 billion for the industry according to GSMA's analysis.

Given the growing prevalence of video traffic on the network and the rising dominance of a few large content providers, the opportunity to locally breakout and cache popular video traffic is growing.

3.11.3.2 Customer Quality-of-Experience

Poor customer experience creates an annual 'revenue-at-risk' of more than $60billion for the industry

Customers often cite poor quality of experience (QoE) as one of their key complaints about operators' services. Therefore, the mechanism for using the Operator Cloud to improve customer QoE is clear.

About 20% of customer sessions can be predicted to suffer considerable QoE degradation at the access network, according to network measurement specialists Teragence. This is partly because congestion at the RAN affects cloud-hosted videos more than edge-hosted videos. The result is that edge-hosted videos start to play faster and stall less than cloud-hosted videos.

Poor customer experience promotes churn, putting operator revenues at risk. If this was to put 5% of revenues into competitive play, this could put more than $60 billion of global industry revenue at risk (based on GSMAi's forecast for mobile services revenues in 2020).

3.11.3.3 Monetising new capabilities

Over $100 billion of new revenue opportunities can be enabled by the Operator Cloud

With the Operator Cloud, operators have a great chance to monetise the new network capabilities that will be enabled by the 5G system. Some of these will be basic storage and compute functionalities and many others will be based on building a platform to support apps. If the storage and compute opportunity matches revenue projections for content delivery networks (CDNs), this could amount to over $30 billion by 2022[56]. Likewise, a 30% share of app revenues by 2022 could be worth over $70 billion to operators[57].

These opportunities require operators to create global platforms for edge/cloud services and applications. But operators face huge challenges to achieve global scale for their platforms, especially given previous experience (e.g. with WAC and OneAPI). Therefore, new approaches will be key to unlocking the opportunity. One example is MobiledgeX's approach to creating a global operator platform.

55. https://mavenir.com/sites/default/files/2018-12/Mavenir-MEC-at-the-edge-vMBC-WP.pdf
56. https://www.marketsandmarkets.com/Market-Reports/content-delivery-networks-cdn-market-657.html
57. http://www.businessofapps.com/data/app-revenues/

3.11.3.4 Political forces

Someone will have to provide the infrastructure for existing and emerging socio-political uses

Political headwinds in several countries will push the need for a localised cloud/edge infrastructure. This may be to satisfy data sovereignty laws, provide cyber security, prepare for a future where broadcast TV is replaced by Internet TV etc. For example, the General Data Protection Regulation (GDPR) in Europe already homogenises data protection policy across the European Union, promoting the need to store EU' citizen's data with geographic restrictions.

Operators are often key providers of digital infrastructure in most countries and would be expected to provide the infrastructure for such politically-motivated platforms.

3.11.4 Operator Cloud: infrastructure vs. innovation strategy

Value creation and capture with the Operator Cloud is firstly about an 'infrastructure strategy'

A common refrain in the industry about the Operator Cloud, edge computing and MEC is that they present a chicken and egg dilemma. Operators seek a robust business case with clearly identified revenue sources and sizes before embarking on the journey to deploy the distributed edge/cloud infrastructure. While this may look like the prudent thing to do, it creates inertia for action and can lead to operators foregoing the opportunity completely.

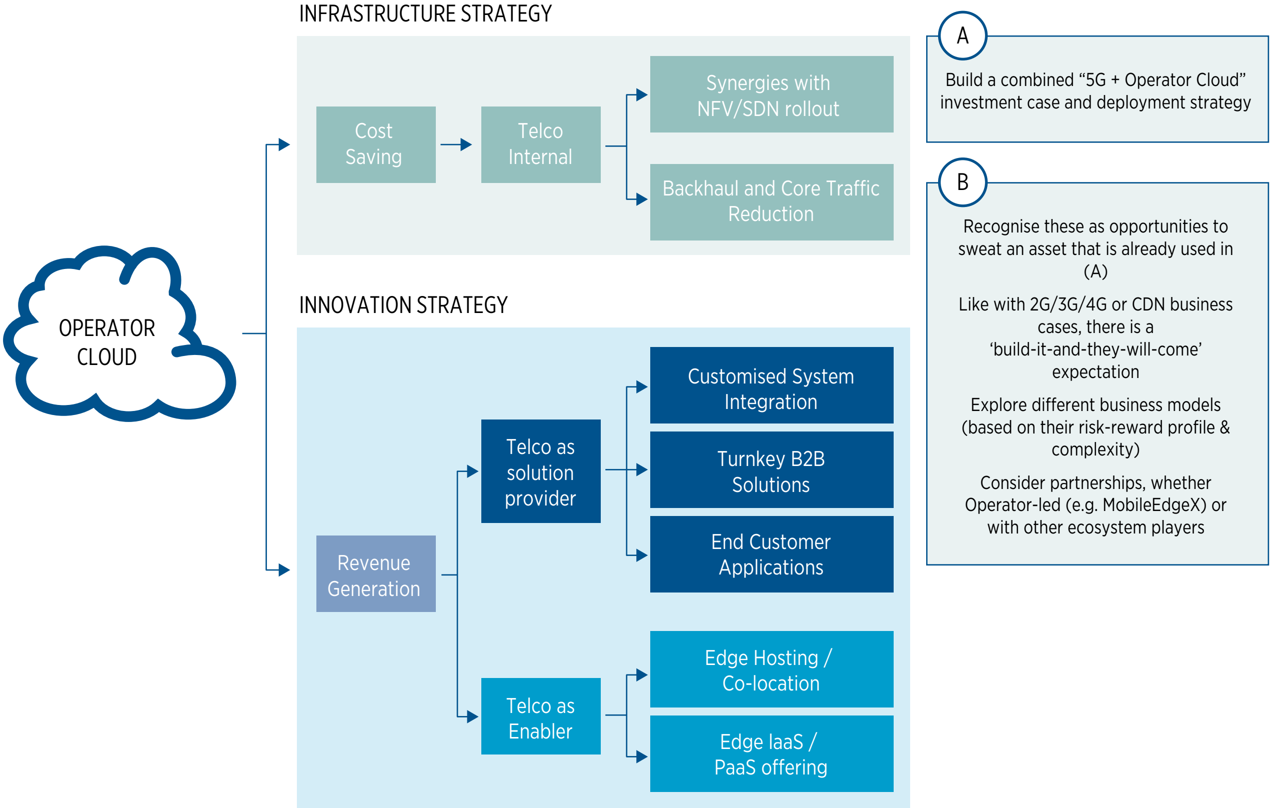
An alternative approach is to consider the Operator Cloud, firstly as part of the infrastructure strategy of an operator. Under this approach, the Operator Cloud is progressively rolled out together with 5G network build out. Operators also begin to use it for backhaul relief and to improve the QoE for customers.

Under this approach, operators can satisfy their own operational and customer experience needs, and then address new opportunities without needing to impose an unachievable ROI hurdle. Figure 3.11.3 shows the contrast between the infrastructure strategy vs. the innovation strategy.

FIGURE 3.11.3

OPERATOR CLOUD AS, FIRSTLY, AN INFRASTRUCTURE PLAY

(SOURCE: GSMA ANALYSIS, ADAPTED FROM DEUTSCHE TELEKOM)



3.12 5G Value Enablers: Network Slicing

KEY TAKEAWAYS

- **Network Slicing offers the biggest commercial innovation opportunity in the 5G era.**
- **It enables operators to create pre-defined, differing levels of services to both their own customer segments and different enterprise verticals.**
- **For Network Slicing to succeed as a commercial solution for enterprises, the industry needs to deliver on four key ingredients:**
  - **Aligned technical standards**
  - **Clear guidelines on how to engage the ecosystem and potential customers from enterprises**
  - **The implementation roadmap for Network Slicing should be well documented early enough to ensure broader industry consensus on how to implement slicing**
  - **The business model for Network Slicing should be anchored in the reality of what is achievable rather than hype**
- **Upselling Network Slicing capabilities to existing customers ought to be an easier opportunity than targeting new customers.**

3.12.1 Importance of Network Slicing

Operators can use Network Slicing to address in-house opportunities or to explore the enterprise opportunity

Network Slicing offers the biggest commercial innovation opportunity in the 5G era. It will enable operators to create predefined, differing levels of services for different enterprise verticals, enabling them to customise their own operations. As noted by Ericsson[58], Network Slicing will give operators more value levers to achieve simpler resource management, deliver better customer experience, provision new services with a shorter time-to-market, and unlock the wider enterprise market.

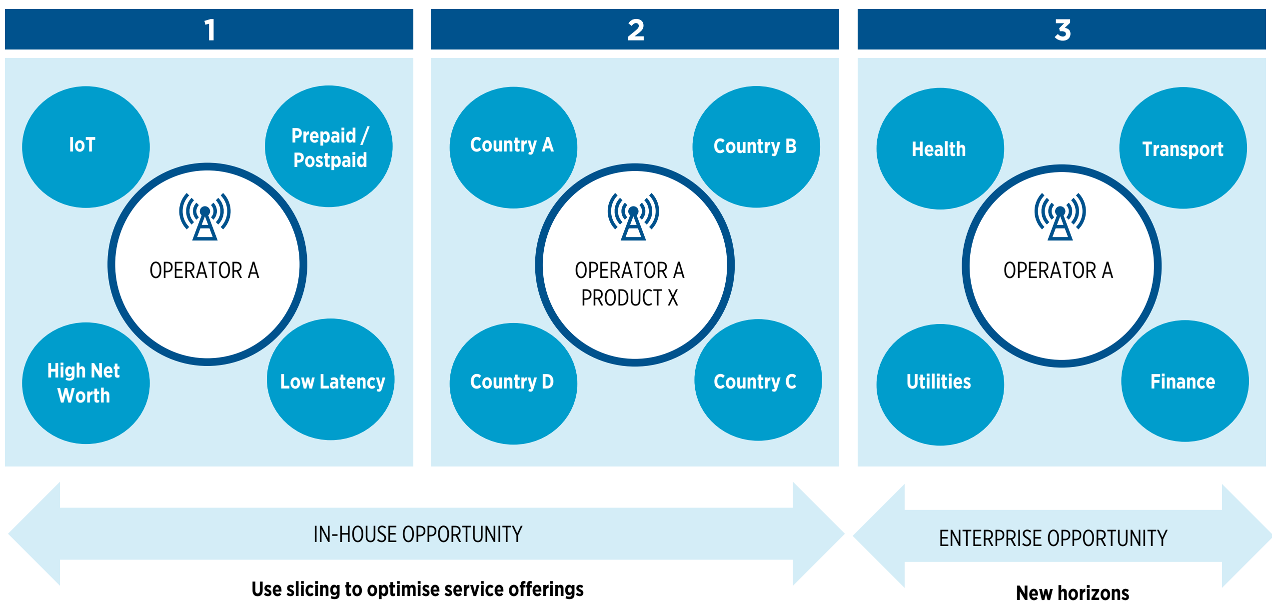
Figure 3.12.1 highlights three focus areas, in two categories, for Network Slicing.

For the in-house opportunity, an operator can dedicate separate slices to existing customer segments. This will provide an end-to-end segmentation beyond what can be achieved by segmenting based on SIM cards, or within the billing or customer care systems. A home operator can also offer 'roaming slices' to foreign operators, enabling them to tailor services for their roaming customers.

But the big, new opportunity for operators is to use Network Slicing to tap into new horizons in the enterprise space. Network Slicing is one of the 5G era enablers for operators to tap into the over $400 billion enterprise revenue opportunity. Operators, with the right device capabilities, operators can create slices for different enterprise segments and tailor these slices to their needs.

FIGURE 3.12.1

NETWORK SLICING USE CASES



58. https://www.ericsson.com/en/networks/insights/economic-study-5g-network-slicing

3.12.2 Network Slicing: prerequisites for success

Technical standards, ecosystem engagement, a clear implementation roadmap and a clear business model are the ingredients for success

For Network Slicing to succeed as a commercial solution for enterprises, the industry needs to deliver on four key ingredients.

First, the technical standards need to be ready to avoid the proliferation of proprietary solutions. This will help to minimise complexity in the implementation, create common interfaces, assure global interoperability and deliver service continuity and roaming.

Second, the industry needs clear guidelines on how to engage the ecosystem and potential customers from enterprises. A starting point is to be sure that the industry's Network Slicing value proposition is clear and that potential customers understand them.

Third, the implementation roadmap for Network Slicing should be well documented early enough to ensure broader industry consensus on how to implement slicing. The GSMA has published *"Network Slicing: Use Case Requirements*[59]*"* to support in providing clarity on slicing templates, APIs etc. that will be needed to achieve global commercial scale.

Fourth, the business model for Network Slicing should be anchored in the reality of what is achievable. Accordingly, operators and their customers need commercial templates and proof-of-concepts to showcase the reality and marketability of Network Slicing.

59. https://www.gsma.com/futurenetworks/wp-content/uploads/2018/07/Network-Slicing-Use-Case-Requirements-fixed.pdf

3.12.3 Network Slicing: Go-to-Market Strategy

Upselling Network Slicing to existing enterprise customers may prove easier than selling to new enterprises

Selling Network Slicing may be a new experience for mobile operators and sales teams will have to come up to speed quickly on how to sell the proposition. A helpful place to start is to learn from how enterprise sales teams in fixed telecoms have sold similar products such as leased lines, ISDN, Managed WAN, Ethernet VPN, etc. Based on this, a three-stage go-to-market strategy would help operators to unlock the Network Slicing opportunity.

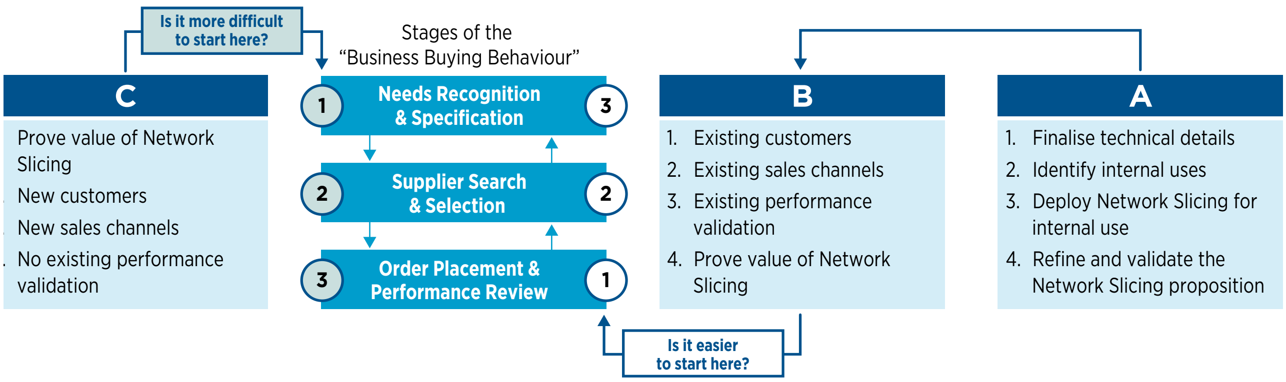
In the first stage, operators should productise and deploy Network Slicing for internal use to prove its validity. This option offers a low risk opportunity to experiment to validate the proposition and refine it ahead of rollout to commercial customers.

For the second stage, operators should seek to upsell Network Slicing capabilities to existing enterprise customers. Operators already have existing enterprise customers and based on the typical buying behaviour of business customers, upselling Network Slicing capabilities to these customers ought to be an easier opportunity than targeting new customers. These customers can then become proof points and advocates for the new capabilities.

In the third stage, operators can now target to sell Network Slicing to new enterprise customers. This is the last group of customers to target as they often require a proven solution and seek market validation before they buy. Figure 3.12.2 illustrates that the go-to-market strategy for Network Slicing will be easier if it follows the reverse order on the stages of the "Business Buying Behaviour".

FIGURE 3.12.2

STAGES OF THE NETWORK SLICING GO-TO-MARKET STRATEGY



3.13 5G Era Business Models

Please refer to the Legal Notice for context before reading this section

KEY TAKEAWAYS

- 5G era business models need to focus on what the customer wants and values. This is the only way for operators to create and capture value in the 5G era.
- Operators will evolve their existing business models into the 5G era and then develop new ones to capture value from 5G assets, capabilities and attributes.
- There is a lot of talk about new business models for 5G. While that is true for some use cases and scenarios, existing business models will still dominate in the 5G era.
- Operators have a wide choice of business models to choose from. But it is likely that a combination of these 6 business models will dominate. These include subscription, usage-based, bundling, differentiated pricing, platforms, and outcome-based models.
- Other models that could also play a role include ad-funded, sponsored, rental and managed services models.

3.13.1 Evolving the cellular business model

5G era business models need to focus on what the customer wants and values

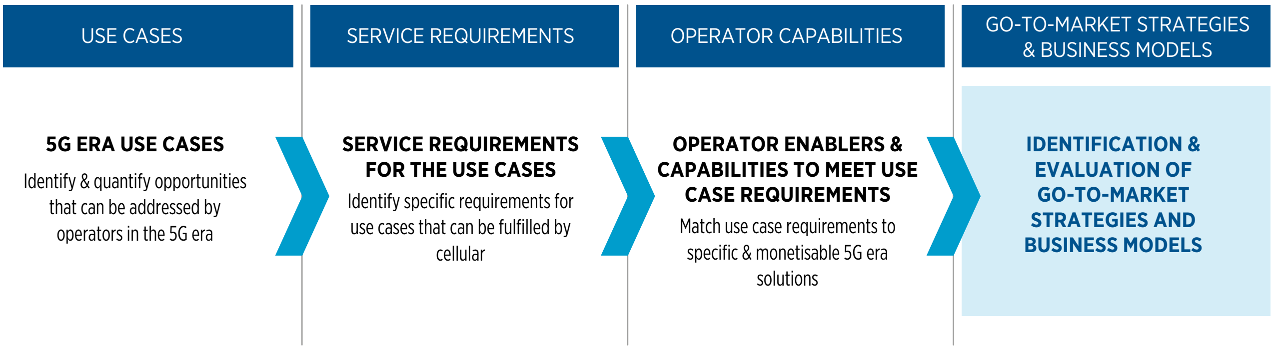
Operators receive lots of advice on how to create new business models for 5G. Much of it promotes the view that without new business models, operators may struggle to create and capture value in the 5G era. This is the 'disrupt or be disrupted' paradigm and *"Re-inventing your business model*[60]*"* offers insights that operators can use to explore how disruptive new entrants might be for the industry.

But the reality is more nuanced, and new business models are more likely to coexist with existing practises well into the 5G era. Drawing on lessons from the management theorist Peter Drucker, a starting point for evaluating 5G era business models ought to be an understanding of who the customers are, and what the customers value.

Figure 3.13.1 illustrates this customer-centric view. It considers operator business models for the 5G era by first evaluating potential 5G use cases, then understanding the service requirements for them, moving to identifying operator capabilities to address the requirements, and then finally the go-to-market strategies for market success.

FIGURE 3.13.1

CUSTOMER-CENTRIC ROADMAP FOR 5G ERA BUSINESS MODELS



60. https://hbr.org/2008/12/reinventing-your-business-model

3.13.2 5G assets and capabilities

5G will create new and enhance existing operator monetisable attributes

5G business models will be anchored on the monetisable assets and capabilities of operators. 5G will create several new ones, improve several existing ones, and potentially undermine some too. This is the context that will shape the evolution of 5G era business models.

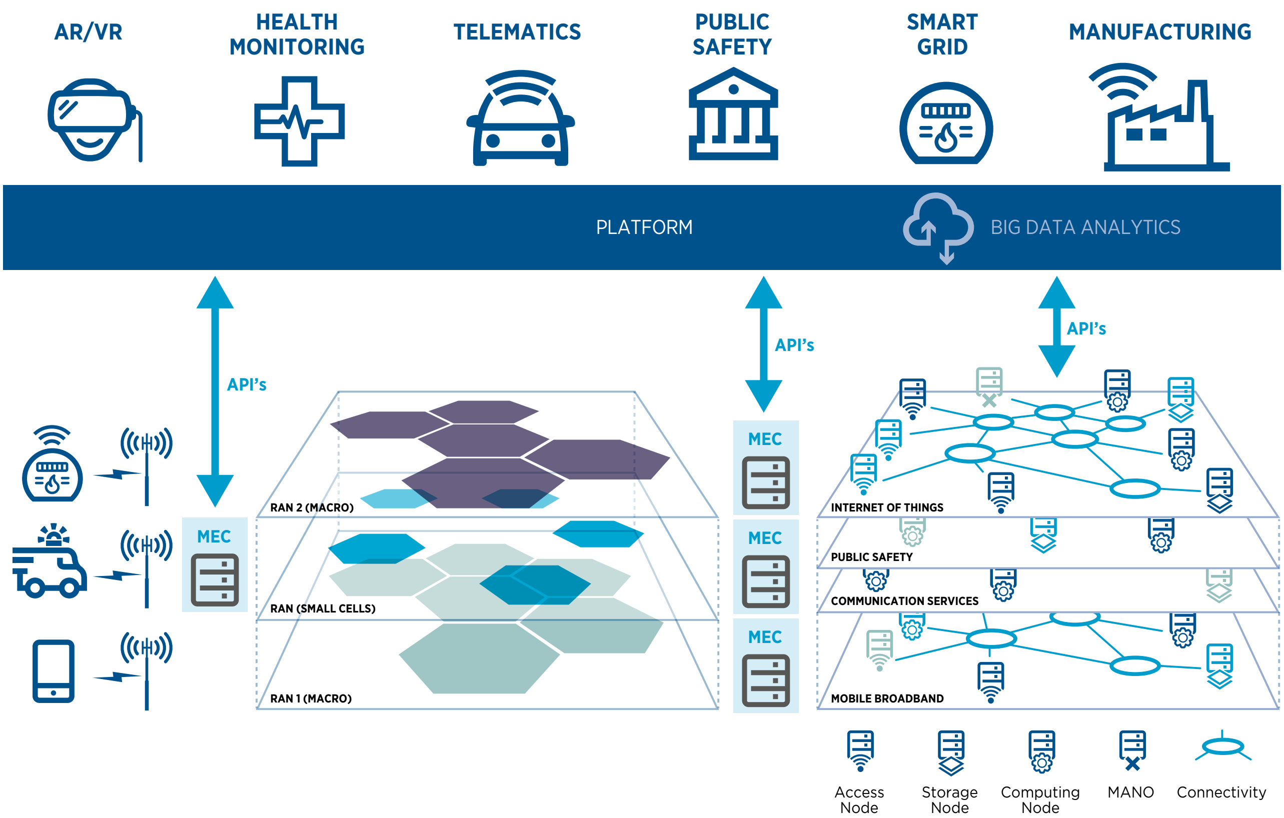
New 5G era monetisable attributes include network slicing and Edge computing, two attributes at the centre of creating new value in the 5G era. Also, for the first time in the history of the cellular industry, 5G could make 'uplink characteristics' a distinct monetisable attribute. This is feasible because the abundant 5G capacity could make it possible for operators to productise 'uplink' in the same way that 'downlink' has been productised for over 20 years. This will be valuable for the Cloud AR/VR opportunity.

Existing attributes that will be improved include speed, latency, and security. Operators will have a chance to offer enhanced versions of these to consumer and enterprise customers.

While each of these assets, attributes, capabilities could be offered to customers individually, Figure 3.13.2 shows that operators can offer a more compelling proposition if these are integrated into, and sold as a platform proposition.

FIGURE 3.13.2

OPERATOR ASSETS AND CAPABILITIES CAN BE INTEGRATED INTO A PLATFORM PROPOSITION



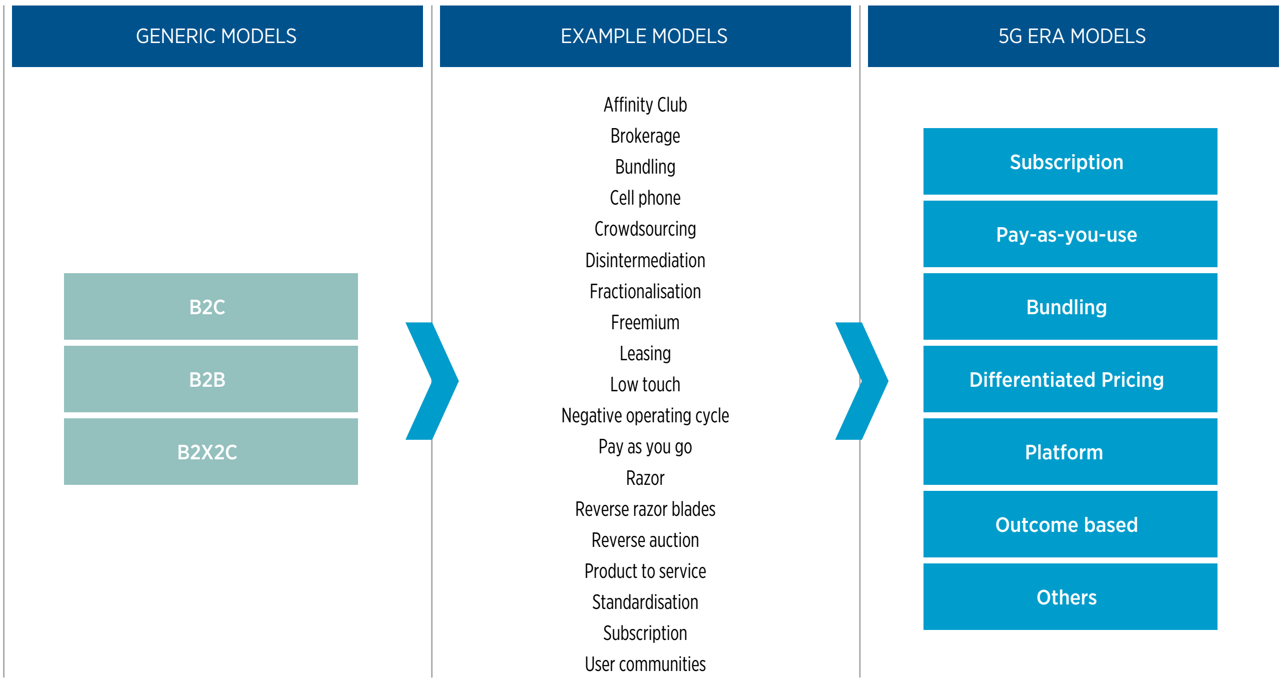
3.13.3 Six key business models

Six business model choices will dominate for operators in the 5G era

Whether it is for Business to Consumer (B2C), Business to Business (B2B) or Business to Business/Government to Consumer (B2X2C) opportunities, operators have a broader set of business model options in the 5G era. In practice, operators will combine elements of the six business models outlined in Figure 3.13.3 to meet most customer expectations. This section focuses only on six 5G era models. Readers should refer to *"Seizing the White Space: Business Model Innovation for Growth and Renewal*[61]*"* for more information on the rest of example models.

FIGURE 3.13.3

5G ERA BUSINESS MODELS FOR OPERATORS



61. https://books.google.com/books/about/Seizing_the_White_Space.html?id=3AzNGapxmXMC

3.13.3.1 Subscription models

Established business model for predictable revenues in the 5G era

Subscription is an established business model in the telecoms industry and will continue in the 5G era for both consumers and enterprises. Most operators in developed markets have already moved to subscriptions including unmetered voice and messaging, and some have begun a shift from metered data to subscriptions for big data bundles.

Subscriptions can be post-paid or prepaid depending on the credit worthiness of customers in a market. The former is for customers who settle their bills at the end of the month while the latter is for customers who pay for the subscription before using it. In this context, 'prepaid' is different from 'pay-as-you-go' which is explored in sub section 3.13.3.2.

The main benefit of a subscription model for operators in the 5G era is that it creates a strong, predictable revenue stream. Accordingly, many operators will seek to move customers onto 5G subscriptions as soon as possible.

3.13.3.2 Usage-based or pay-as-you-use models

Directly monetise incremental usage

The usage-based model has traditionally been used to serve low income customers who prefer tighter control of their spend. As customers settle into regular habits, many cost conscious customers also prefer to move to pay-as-you use models to manage costs. While such customers may not be the early adopters for 5G, operators should nonetheless evolve their pay-as-you-use proposition to ensure they are addressing all of the market, and to prepare for new opportunities.

One such new opportunity is in upselling new 5G era products, services or solutions to customers. For example, if operators develop a cloud AR/VR proposition and can offer, say, 300 minutes of AR communication, the question will arise on how to monetise this. Should operators offer a package of 300 AR/VR minutes for customers taking up a new subscription, or should they allow customers to pay-as-they-use any incremental AR/VR minutes?

The main benefit of a pay-as-you-use model in the 5G era is that it enables a direct link between incremental usage and revenues. Conversely, its main disadvantage, especially in markets where 5G services will be sold as such, is that it leads to less predictability and greater variability of revenue streams, and makes planning difficult for operators.

3.13.3.3 Bundling models

Can be used to enrich, embellish, encircle or upsell the core data proposition

Bundling is a catch-all term and has traditionally being used for products and services that enrich, embellish, encircle or upsell a core proposition. Bundling does not exist as a standalone business model but it combines subscription and pay-as-you-use models for multiple products.

As emphasis shifts from voice to data, data has now become the core proposition and most of the operator bundles in the 5G era will focus on what can be added to improve the appeal of the data bundle. Basic voice and messaging are now included in many data-led bundles and the cost of 5G devices could affirm the need for handset subsidies to encourage adoption. Operators will also be adding roaming services, security solutions, fixed broadband and increasingly exclusive or premium content (e.g. Netflix, Spotify) into the bundle.

The main benefit of a bundling model in the 5G era will be to encourage customers to subscribe or increase their usage in a pay-as-you-use model. For this, operators will need to understand customer habits and preferences so as to decide what to include in the bundles. Immersive media content is an early candidate for the 5G era service to be added to the bundle.

3.13.3.4 Differentiated pricing models

Economically optimal to match demand, supply and ability to pay

Operators have always sought to differentiate the capability (e.g. QoS) of the core proposition and market it to different customers for different prices. This has often been offered as a superior product (e.g. leased lines for businesses) or inferior product (e.g. low-cost sub-brands).

This will continue into the 5G era and could become central to unlocking incremental value in 5G. For example, network slicing in the 5G era would give mobile operators the opportunity to market differentiated value propositions for mobile connectivity in a similar way that fixed operators have sold leased lines, ATM, Carrier Ethernet and MPLS for decades.

The main benefit of differentiated pricing is that it is the most economically optimal way for operators to match demand and supply, allowing customers to pay for the product and the capability they need, when they need it.

3.13.3.5 Platform business models

Ideal to create two-sided and asymmetric revenue streams; need APIs to see the platform and an industrialised partnership strategy to woo developers and users

The platform model is the most publicised option for operators in the 5G era. Its advocates promote it as the only approach for operators to develop new ecosystems by bringing together buyers and sellers of 5G era products, services and attributes. Platform owners are able to charge a fee per transaction to one or several parties (two-sided models), use a freemium model to attract users and can use APIs to standardise a previously personalised service to lower cost.

Given their central role as the managers of the market exchange, platform owners can enter new markets by offering subsidies to customers, and then capture value in the core business. This asymmetric business model is the basis of how many internet companies have grown (e.g. Amazon with books, Facebook with news, Google with directory services, Apple with apps).

The main benefit of the platform model is that it creates new value or revenue streams from two-sided and asymmetric sources. And if operators want to become platform owners in the 5G era, at least at the national rather than international level, there are two key success factors.

First, they must ‘seed’ the platform with new products and services. Operators can do this by exposing the capabilities they already have and make sure they are well known to the community. Horizontal APIs is the major interface for operators to harmonise the technical, commercial and policy positions on the most frequently used features.

Secondly, operators must design the platforms to support many customers. This means that the platform cannot just be reserved for a few deep-pocketed enterprises. Instead, operators need an ‘industrialised’ model that encourages thousands or even millions of customers to engage the platform seamlessly. This is the major lesson from the Apple App Store and Google Play.

3.13.3.6 Outcome-based models

Ideal for embedded connectivity and for product-to-service propositions

Outcome-based business models may become more prominent in the 5G era as managed mobile connectivity becomes a critical enabler of select enterprise products and services. Outcome-based models are also the focus of a broader shift from technology to business outcomes in enterprise technology sourcing, where technology and service providers begin to contract with a focus on business level outcomes instead of seeking pure technology centric SLAs. GSMA Intelligence has explored how such outcome-based thinking can be used for IoT[62].

The rapidly growing involvement of business buyers in technology purchases such as IoT is one of the key drivers for the future growth of outcome-based pricing. Stakeholders such as CMOs and CFOs often want to see a closer link between the technology services they buy and the business outcomes they seek. Linking a portion of the contract revenues to business centric SLAs such as product shipments, customer net adds, churn and even revenues; in addition to the technology SLAs such as speed, latency and reliability, focuses the minds of operators and other technology providers on clients' broader business issues, rather than looking narrowly on the delivery of a pure technology service.

The key challenge with pure outcome-based pricing is that it ties a provider's contract revenues to the business operations and results of the client, not all of which are under the control of the provider. This makes pure outcome-based pricing a challenge to execute well even for the largest IT services players such as IBM and Accenture, which have been engaged in such deals for IT outsourcing services for over a decade. Hence operators need to proceed with outcome-based pricing with care, and start with tying only a very small proportion of contract revenues (e.g. in an IoT engagement) to business specific outcomes, or SLAs.

The main benefit of the outcome-based model is that it is an opportunity for operators to become embedded deeper into the enterprise market and tap into a bigger share of the revenue pool.

3.13.3.7 Other business models

- Ad-funded model: a model often talked about, but it is difficult to see how operators can rely on the ad-funded model for their business in the 5G era.
- Sponsored model: a model where a business subsidises a service in order to provide other services (e.g. Facebook's Internet.org). It has received a lot of attention given its implications for net neutrality and has so far not delivered on its earlier promise[63]. It is a model to watch for in the 5G era.
- Rental model: an unsophisticated model for operators to rent out their assets in return for a recurring fee. For consumers, this could be applicable to expensive 5G devices whereas for enterprises, this could be providing physical space at the operator central office or cell site for businesses to install their own equipment.
- Managed services model: a model where the operator acts as an integrator or consultant to businesses and is paid for project delivery.

62. Outcome based business models for IoT: https://www.gsmaintelligence.com/research/2018/11/outcome-based-pricing-in-iot-high-risk-high-return-bet/706/
63. Internet Regulation, Two-Sided Pricing, and Sponsored Data: http://chairgovreg.fondation-dauphine.fr/sites/chairgovreg.fondation-dauphine.fr/files/attachments/Sponsored_data_FinalJIO403.pdf

3.13.4 Cloud AR/VR: an example of a 5G era business model

There are four possible business model combinations for Cloud AR/VR

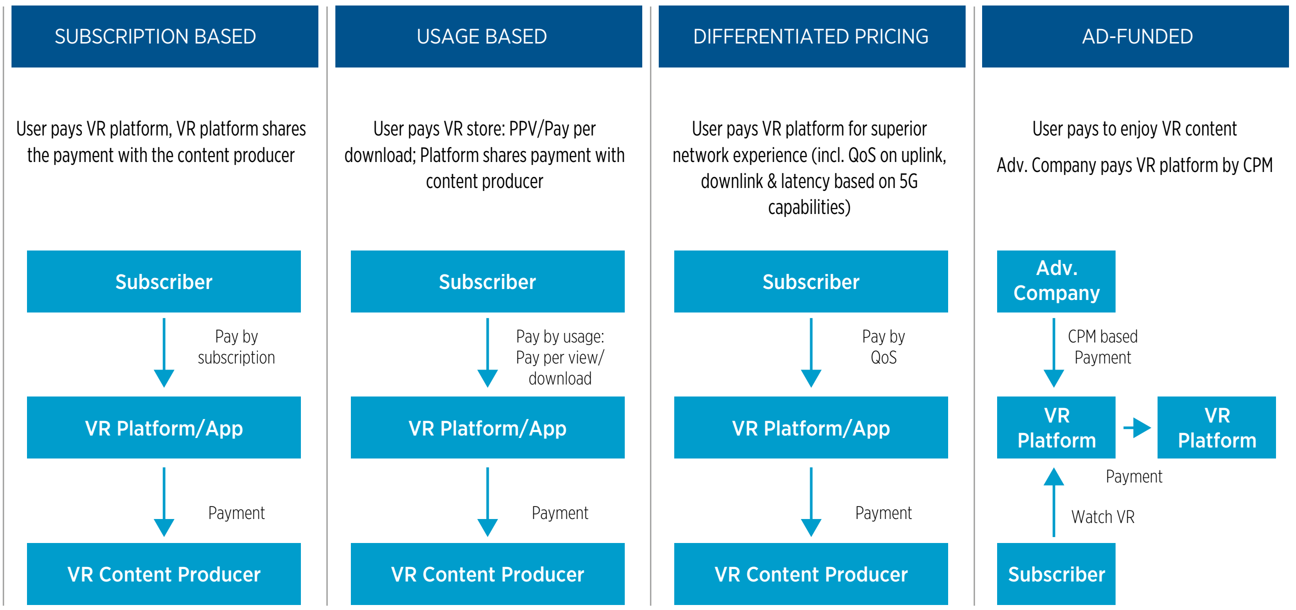
Cloud AR/VR is emerging as one of the early 5G era opportunity for operators. Huawei notes that this market will be worth $292 billion by 2025 and the operator addressable market value will $93 billion (about 30% of the total).

Customers can use Cloud AR/VR via a thick client with sufficient computational resources on the device, or a thin client with most of the computational task offloaded to the cloud/edge. Figure 3.13.4 illustrates the different types of business models that could be used for cloud AR/VR.

FIGURE 3.13.4

BUSINESS MODEL OPTIONS FOR CLOUD AR/VR IN THE 5G ERA

(SOURCE: GSMA ANALYSIS, ADAPTED FROM HUAWEI)



4 5G Cost Considerations

Chapter 4 examines cost evolution in the 5G era, outlining how innovations in 5G network architecture, capability and ownership will introduce more drivers of cost into the operator business model.

Readers will gain a better understanding of the costs of building and operating 5G networks, including granular insights into the major economic opportunities and challenges.

4.1 Cost Considerations

KEY TAKEAWAYS

- **Cost dynamics in 5G will not only be influenced by traditional network factors (e.g. capacity and coverage), but also new factors such as network flexibility and ownership.**
- **The impact of some of these new cost factors can be foreseen or are already being put into practice in 4G networks e.g. network virtualisation.**
- **However, the impact of some cost factors cannot be foreseen. Examples include network ownership (e.g. Private 5G networks) and new network management approaches (e.g. AI-based automation).**

4.1.1 Cost considerations framework

Cost drivers with known and unknown impacts will coexist and shape the 5G business case

5G networks are distinct from previous generations because of the level of heterogeneity, flexibility and automation that is inherent in their design. Therefore, cost dynamics of 5G networks will not only be influenced by traditional factors (e.g. capacity and coverage), but also new factors such as network flexibility and network ownership.

Some of these new themes can be foreseen or are already topical in 4G networks. NFV/SDN are already being adopted to provide flexibility for 4G networks. Likewise, there are active industry discussions on how to introduce edge computing into the network architecture to provide low latency capabilities. However, while there is a lot of enthusiasm for these transformational factors, their impact on the cost of 5G network rollout and operations in practice is less clear.

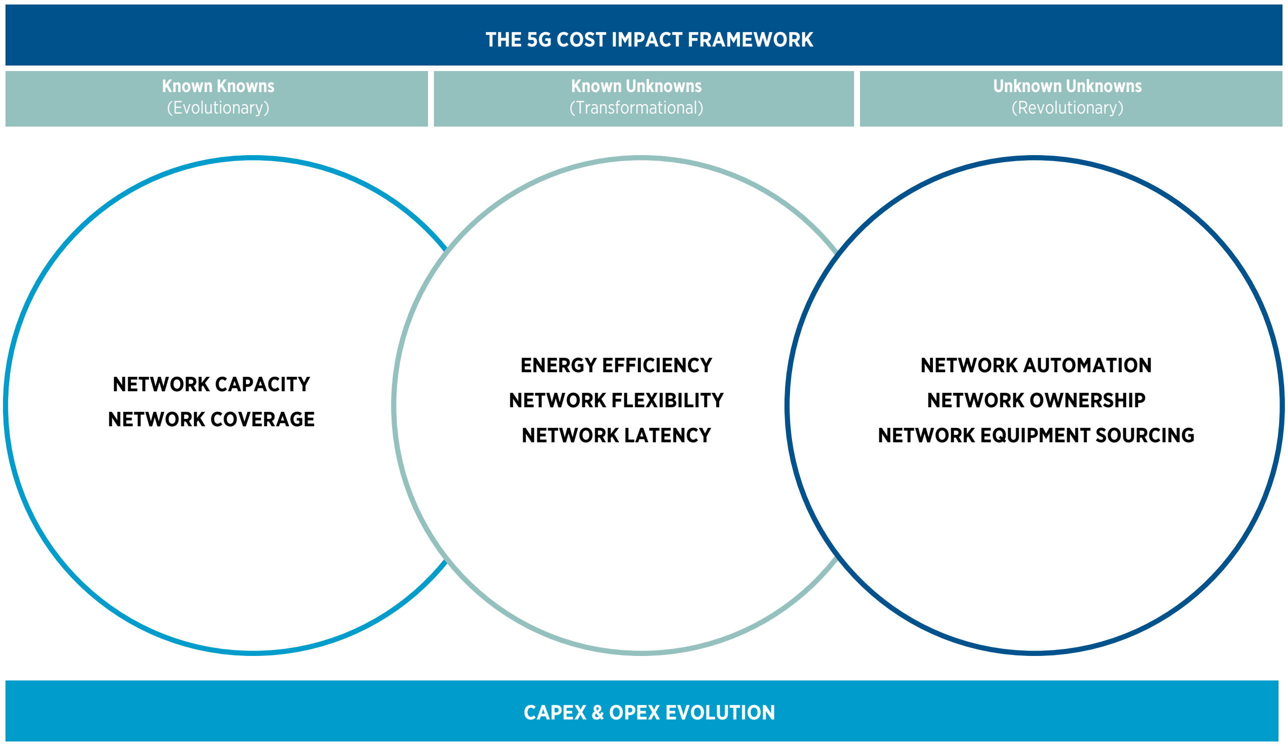
An even bigger set of unknown unknown impact factors exist for 5G rollout and operation. Much of the industry consensus has been shaped by infrastructure competition among operators, with networks built by established equipment vendors and managed by an army of network engineers. But a revolution is looming which will see the introduction of new models of network ownership (e.g. Private 5G networks), new ways of building networks (e.g. using Open Source concepts) and new network management approaches (e.g. using AI-based automation).

This chapter uses a novel theme-based (could also be intent-based or outcome-based) approach to explore the main cost drivers for 5G, instead of the typical technology-focused approach. Figure 4.1.1 contextualises the impact of these different themes into a known known, known unknown and unknown unknown framework. The benefit of this approach is that it focuses on the business goals that need to be addressed rather than fixating on the technicalities of the underlying technology.

The GSMA seeks to bring better understanding of the impact of these drivers and the Future Network's Network Economics programme has developed several case studies in this area[64].

FIGURE 4.1.1

COST IMPACT & CONSIDERATIONS FRAMEWORK FOR 5G BUSINESS CASE



64. Network Economics programme https://www.gsma.com/futurenetworks/network-economics/

4.2 Network Capacity

KEY TAKEAWAYS

- There are four main considerations for network capacity: spectral efficiency, spectral capacity, spectral reuse and backhaul.
- With 4G spectral efficiency close to the theoretical maximum, the spectral efficiency gains from 4G to 5G will be smaller than the gains from 3G to 4G.
- As spectral efficiency gains reach a peak with 5G, increasing the bandwidth of the communications channel (spectral capacity) increases data throughput.
- 5G will require network densification (spectral reuse) to meet both coverage and capacity objectives. Both macro cells and small cells will grow in the 5G era.
- Demand for higher capacity backhaul will grow in 5G. While fibre remains the ideal, higher capacity microwave options could deliver a lower cost alternative.

4.2.1 Network capacity drivers

Spectral efficiency, spectral capacity, spectral reuse and transport are the four key drivers

The importance of spectral efficiency and spectral capacity stems from the Shannon-Hartley Theorem which determines the theoretical maximum capacity of a cellular system. Spectral efficiency dictates how much data can be carried per unit of bandwidth of a communications channel at a time given the ratio of signal to unwanted noise. Spectral capacity is determined by the number of spectrum channels in use.

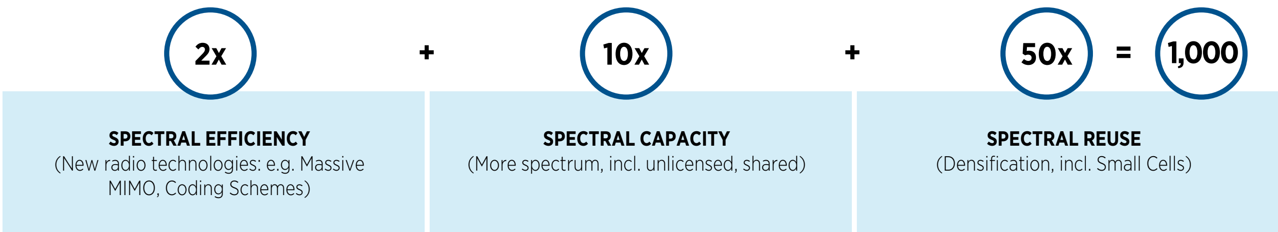
Spectral reuse (e.g. with network densification) makes it possible to use the available spectrum channels many more times. A good analogy is lighting multiple candles alongside an existing lit candle. As more candles are lit, the overall luminosity is increased without changes to the luminosity of the original candle.

Densification is the most important determinant of access network capacity. As noted in *5G Network Capacity: Key Elements and Technologies*[65] and *Mobile Broadband Transformation: LTE to 5G*[66], if 5G is to deliver a 1000x improvement over 4G, then spectral reuse will account for 40-50x. But densification cannot continue *ad infinitum* and interference eventually puts a limit to how many times a cell can be split. Continuing with the candle analogy, at some point, diminishing returns sets in and adding more candles will 'burn' rather than illuminate. Figure 4.2.1 summarises the spectral factors that will drive capacity for 5G networks.

The transport network determines the rate of transferring traffic from the cell site to the core network. It can be backhaul or fronthaul depending on which nodes of the radio access network are connected through the transport.

FIGURE 4.2.1

THREE 'SPECTRAL' OUTCOMES THAT DEFINE NETWORK CAPACITY-HYPOTHETICAL VALUES TO REALISE A 1000X CAPACITY INCREASE



4.2.2 Spectral efficiency

5G spectral efficiency gains will be smaller than the improvements from 3G to 4G

The industry is getting closer to peak theoretical performance, for a single communications channel, thanks to constant improvement in spectral efficiency. 4G-delivered capacity is close to reaching this Shannon bound (for one communications channel), hence 5G will use new approaches to increase spectral efficiency further.

So while 5G will improve spectral efficiency with further incremental radio innovations, it pushes the limits further by leveraging more than one channel of communications, with techniques such as massive MIMO and beamforming. In addition, efficient coordination of adjacent cells to minimise interference will also enhance the spectral efficiency.

However, given that 4G spectral efficiency is close to the theoretical maximum, the spectral efficiency gains from 4G to 5G will be smaller than the gains made in the transition from 3G to 4G.

65. https://ieeexplore.ieee.org/abstract/document/6730679
66. http://www.5gamericas.org/files/2214/7257/3276/Final_Mobile_Broadband_Transformation_Rsavy_whitepaper.pdf

4.2.3 Spectral capacity

More spectrum bandwidth equals greater network capacity

As spectral efficiency gains reach a peak with 5G, increasing the bandwidth of the communications channel increases traffic capacity. This is the crux of the industry's focus on securing wider spectrum bands for 5G. In this context, higher spectrum bands (e.g., 3.5GHz bands and mmWave bands) are great 5G options as they offer from 80MHz to 1,000MHz contiguous bandwidth for 5G use per operator depending on spectrum band considered.

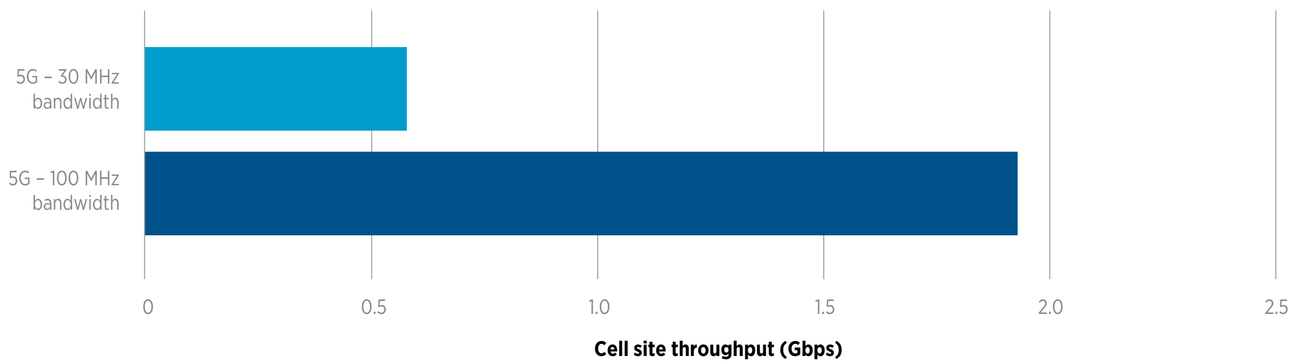
Furthermore, higher order MIMO and massive MIMO provides even more data throughput than conventional radio systems, and would be more efficient when used in large contiguous bandwidth. This highlights the importance of contiguous bandwidth and hence the role of higher spectrum bands in meeting 5G network capacity.

Even where regulators do not allocate full contiguous bandwidth, mid-to-high spectrum bands offer much more bandwidth than the 20MHz bandwidth typically allocated in 4G. For example, for C-Band, awards to date have shown that the available bandwidth varied significantly, from the 80-100MHz awarded to Korean operators, to the 20-50MHz awarded to UK operators. These mean that average cell site throughput would vary from 0.6Gbps to 2.0Gbps, as outlined in Figure 4.2.2 below. In the 5G era, many operators will be aggressively targeting the lucrative vertical market - including using customised technologies like NB-IoT etc.

Of course, disjointed spectrum bands can also be aggregated using carrier aggregation technology, whereby up to five disparate 20MHz spectrum bands can be aggregated as a single data pipe of up to 100MHz bandwidth – a single 100MHz block offers a more uniform capacity or user experience though. Carrier aggregation is also used in 4G today, so it is not unique to 5G.

FIGURE 4.2.2

THEORETICAL MAXIMUM CELL THROUGHPUT FOR 30MHZ BANDWIDTH AND 100MHZ BANDWIDTH CASES



NB: Actual throughput will be significantly less

4.2.4 Spectral reuse: network densification

Number of cells will grow to 18.4 million by 2025 to meet 5G requirements

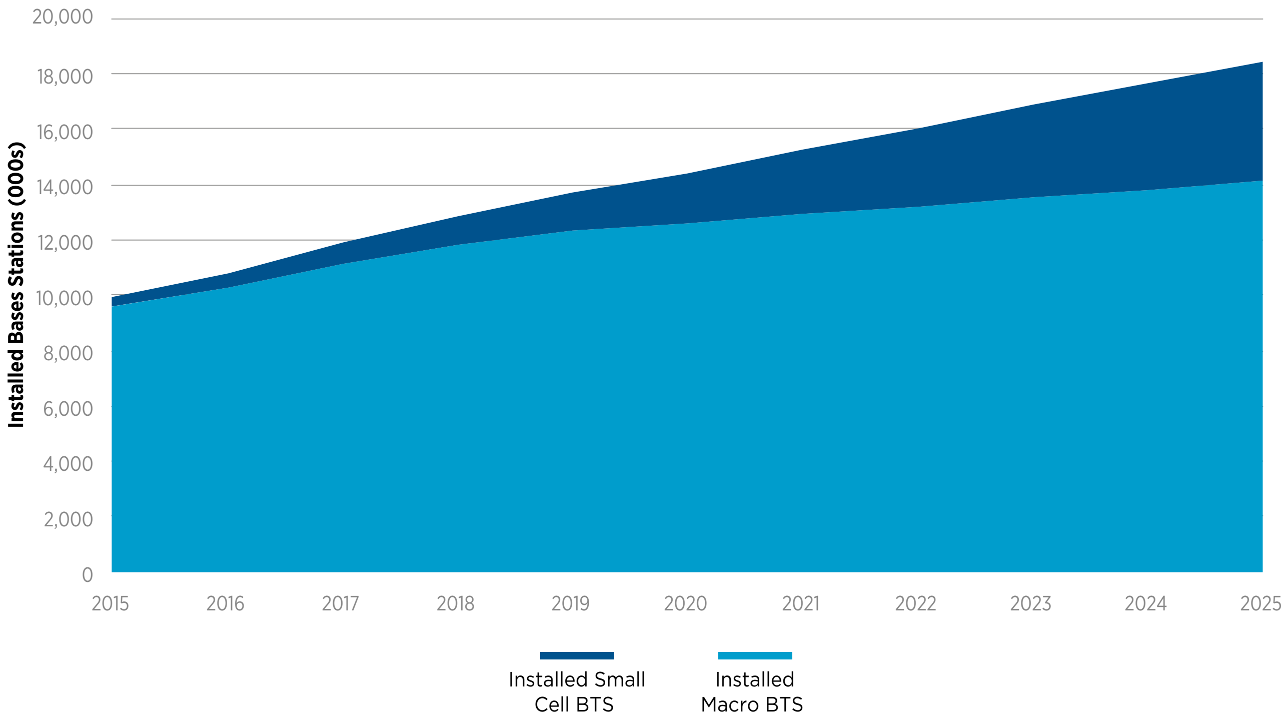
5G will require network densification to meet both coverage and capacity objectives. However, one of the biggest cost uncertainties is the level of network densification needed.

ABI Research estimates that the number of wireless cells will grow by at an average annual rate of 5.7%, from 11.8 million in 2017 to reach 18.4 million by 2025. This will be driven by the need for more capacity, the use of higher band spectrum, continued growth in 4G networks, and new 5G cells to deliver new capabilities.

The cost of adding new sites varies from country to country and from operator to operator. The modelling in Chapter 5 explores the incremental cost of 5G based on the hypothetical cost of new macro and small cells in different regions and for different operator archetypes.

FIGURE 4.2.3

INSTALLED CELL SITES BY CELL TYPE SOURCE: ABI RESEARCH



4.2.4.1 Macro cells will grow steadily

The number of macro cells will grow by 3% on average annually from 11.1 million in 2017 to reach 14.1 million in 2025 (Source: ABI Research, see Figure 4.2.3). Macro cells are the primary means for operators to reach their customers and will still be important in the 5G era despite the growth of small cells. They provide large coverage ranges (1 ~ 20km), delivered via high power cell sites combined with tall towers/masts.

Macro cells coordinate the small cells and connectivity to the core network, and are critical for effective small cell deployment and operation. In addition, macro cells are appropriate for use cases that require significant coverage, but not necessarily high capacity requirements (e.g., high data rate or low latency).

4.2.4.2 Small cells will grow rapidly

Small cells will grow by 25% on average annually from 0.7 million in 2017 to reach 4.3 million in 2025 (Source: ABI Research). Small cells are low-powered radio access nodes or base stations operating in licensed/unlicensed spectrum that have a coverage range from a few metres up to a few hundred metres.

Small Cells will be essential for mobile usage inside buildings, where over 80% of mobile usage occurs in developed markets, as shown in Figure 4.2.3. Therefore, dense urban areas will see significant increase of small cells in the 5G era, while sparsely populated areas can be covered by densifying macro cells.

4.2.5 Transport (Backhaul/Fronthaul)

Backhaul is a key 5G cost driver

Network densification raises the need for high capacity and reliable transport solutions, in addition to the cost of extra sites. While transport for 'fronthaul' (connections from the antenna to their controllers) will grow in importance in the 5G era[67], by far the biggest transport requirement will be for backhaul and this is a key consideration in the 5G business case modelling in Chapter 5.

Operators will face a challenge of backhauling the rapidly growing 5G mobile data traffic from varied environments, such as urban; suburban; rural; offices; residential homes; skyscrapers; public buildings; tunnels etc., regardless of whether it is from macro or small cells. In fact, there is a potential risk of a 'network bottleneck' if higher 5G access network capacity is not matched with a commensurate increase in transport (especially backhaul) capacity.

67. Mobile Backhaul Options report (GSMA/ABI Research) https://www.gsma.com/spectrum/wp-content/uploads/2018/11/Mobile-backhaul-options.pdf

4.2.5.1 Backhaul requirements per site

5G networks will require more capacity for backhaul than 4G networks. Ericsson estimates the vastly different bandwidth and latency requirements of 5G NR versus 4G in Table 4.2.1. While the actual 5G requirements will differ depending on the size of the site, access spectrum and network types, it is clear that the demand for higher-capacity backhaul will grow in 5G.

TABLE 4.2.1

4G AND 5G BANDWIDTH AND LATENCY REQUIREMENTS (SOURCE: ERICSSON)

	Interface	Bandwidth	Latency
LTE	CPRI	1-10Gbps/sector	75µs
	S1/NG	1-2Gbps/site	30/5ms
NR	eCPRI	10-25Gbps	75µs
	F1	1-10Gbps	5ms
	S1/NG	1-10Gbps	30/5ms

4.2.5.2 5G backhaul options analysis

Fibre and microwave will be the dominant 5G backhaul technologies

5G operators have diverse set of backhaul technologies at their disposal: fibre, satellite, wireless links and even copper. As shown in Table 4.2.2, while fibre is the ideal backhaul option for 5G, several microwave options can and will be used to support 5G cell sites at a lower cost. Copper and satellite will be niche solutions suitable for indoor/rural scenarios where fibre and wireless links may not be feasible.

- Fibre provides stable connection with high bandwidth capable of addressing future 5G demands with its cost steadily decreasing with rollout innovations, increasing competition and growing economies of scale. These advantages made fibre one of the primary backhaul solutions in 4G, but its relatively high cost means that it has so far been used sparingly.
- Copper-line may be suitable for small cells in indoor settings using Ethernet over existing copper, which tend to be insufficient to meet requirements of 5G cells. Copper-line was the primary backhaul solution in 2G/3G, but has not been mainstream in 4G with high traffic demand. Copper-line also do not scale easily as DSL throughput is inversely proportional to distance, thus limiting the reach of copper-line to be used. Another drawback is the price of copper that makes the line expensive and vulnerable to theft in some nations.
- Geosynchronous (GEO) satellites, at about 36,000km from earth, traditionally serve as the niche backhaul solution for mobile operators in remote areas or as the emergency communications link. Whilst satellite can have extensive coverage, limitations in bandwidth and latency limit its backhaul application. Some start-ups plan to launch thousands of satellites at LEO (Low Earth Orbit), where satellites are only 1,500km away from Earth instead of 36,000km for traditional satellites. The technology, however, has not yet matured and therefore may not be suitable for major backhaul solution in the early 5G era. In terms of costs, satellite comes at greater variability in pricing, which is more closely linked to usage than capacity, unlike other technologies.
- Wireless links using microwave (7-40GHz), V-band (60GHz), E-band (70/80GHz), W-Band (75-110GHz) or D-band (110-170GHz) are attractive backhaul options as their cost can be a quarter of leased fibre, and the cost can be reduced further by using PMP (point-to-multipoint) configuration. Higher spectrum band links can be complementary to microwave for 5G backhaul, as they provide higher capacity, but at shorter range. Microwave backhauling would also grow in the 5G era as a result of daisy-chaining several small cells to a fibre-connected small cell.

TABLE 4.2.2

COMPARISON OF 5G MOBILE BACKHAUL TECHNOLOGY OPTIONS (SOURCE: ABI RESEARCH)

Segment	Microwave (6-40 GHz)	V-Band (60 GHz)	E-Band (70/80 GHz)	Fiber-optic	Copper (Bonded)	Satellite
Future-proof Available Bandwidth	Medium	High	High	High	Very Low	Low
Deployment Cost	Low	Low	Low	Medium	Medium/High	High
Suitability for Heterogeneous Networks	Outdoor Cell-site / Access Network	Outdoor Cell-site / Access Network	Outdoor Cell-site / Access Network	Outdoor Cell-site / Access Network / Core	Indoor Access Network	Rural only
Support for Mesh/Ring Topology	Yes	Yes	Yes	Yes where avaialble	Indoors	Yes
Interference Immunity	Medium	High	High	Very High	Very High	Medium
Range (Km)	5-30,++	1~	~3	<80	<15	Unlimited
Time to Deploy	Weeks	Days	Days	Months	Months	Months
License Required	Yes	Light License/ Unlicensed	Licensed/Light License	No	No	Yes

4.2.5.3 Economics of fibre backhaul

Incumbent operators with fibre assets have a backhaul cost advantage

Operators with incumbent fibre deployment have superior economics in backhaul deployment, while new entrants are better off with microwave links or leased fibre rather than deploying their own fibre infrastructure. This conclusion is based on an analysis of the ten year NPV (Net Present Value) backhaul costs per site for different fibre ownership scenarios and microwave scenario outlined in Figure 4.2.4 below.

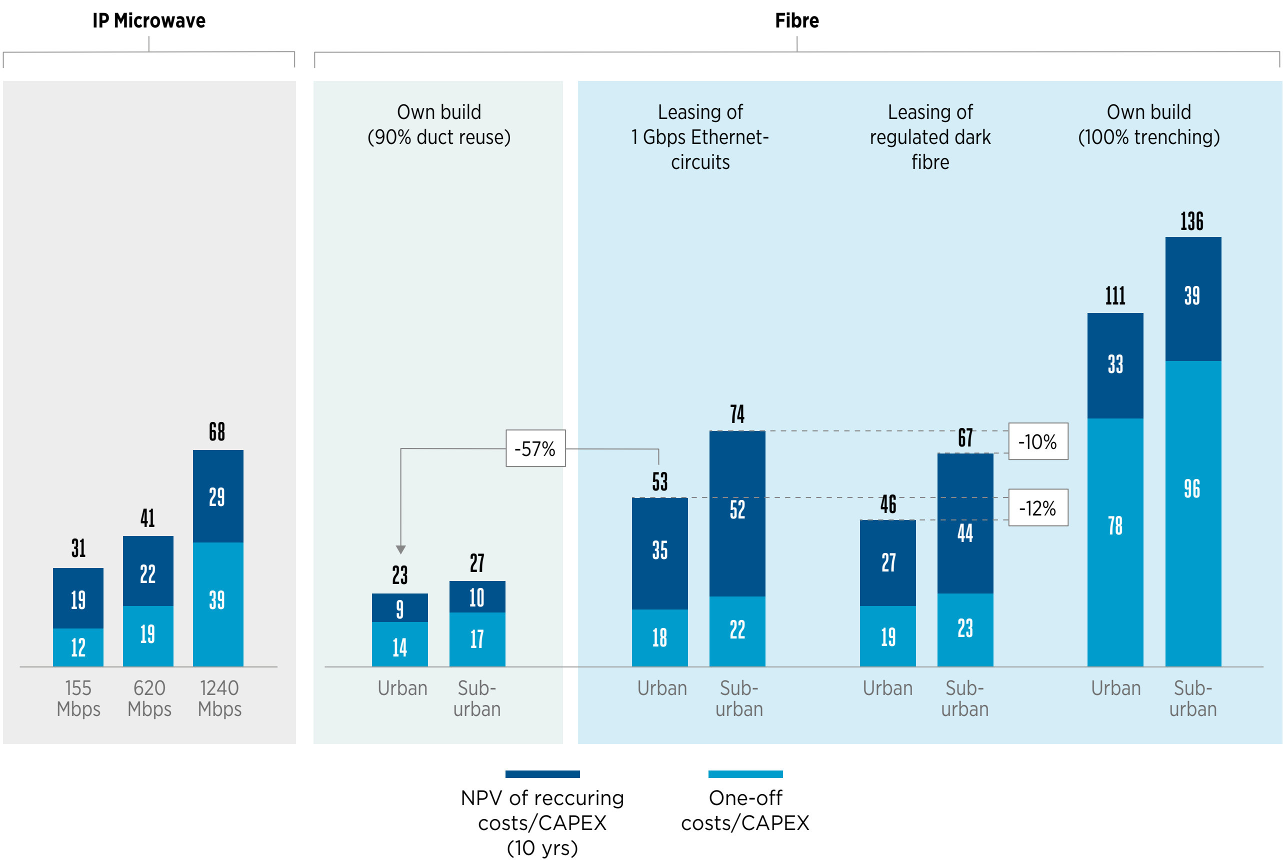
Most of the cost of deploying a fibre backhaul are due to civil works (trenching, building the ducts, deployment of physical cables). There is a clear opportunity for incumbent operators of leveraging FTTH fibre deployments using vacant fibres when available, or adding some extra fibres for additional applications or future purposes (e.g. corporate services or mobile backhaul) in planned deployments.

The analysis shows that when the operator already owns fibre and reuses 90% of its ducts, the cost is 57% less than that of leasing 1Gbps Ethernet circuits for urban scenarios and 63% less for suburban scenarios. Leasing a regulated dark fibre can reduce the cost by 12% and 10% respectively for urban and suburban scenarios when compared to leasing 1Gbps Ethernet circuits.

When new entrants deploy their own fibre, the cost is five- to six-times more than an incumbent's fibre cost and almost double the cost of leasing 1Gbps Ethernet circuits. Compared with deploying microwave capacity of 1,240Mbps, leasing Ethernet-circuits or regulated dark fibre require equivalent cost, while it is significantly cheaper than a new entrant building their own fibre.

FIGURE 4.2.4

BACKHAUL ECONOMICS PER SITE (10-YEAR NPV OF COSTS IN EUR): FIBRE VS. IP MICROWAVE (SOURCE: OFCOM, BT OPENREACH, BERNSTEIN)



Note: WACC: 10%; GBP/EUR: 1.2; urban/sub-urban cell site distance from aggregation point: 750m/1250m; average competitor MNO site distance from nearest fibre entry point: 25% of total circuit length

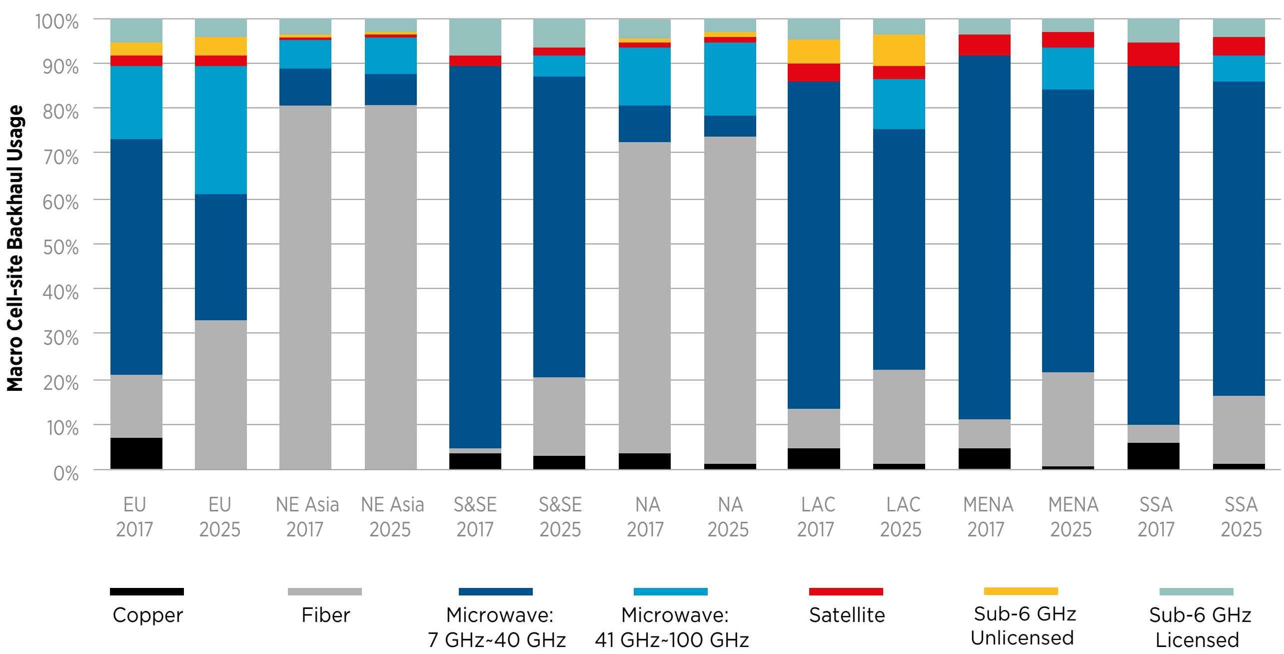
4.2.5.4 Macro cell backhaul options

The higher capacity requirements of 5G will drive adoption of fibre and microwave links in higher spectrum bands (V-band and E-band). As a result, most macro cell backhaul will be delivered by microwave links, followed by fibre, with some significant regional variations. Satellite will provide coverage in remote areas.

The uptake of macro backhaul will be closely linked to regional regulatory context and fibre penetration, as shown in Figure 4.2.5. In regions with relatively higher fibre penetration (e.g., North East Asia and North America), fibre will remain the dominant choice for macro backhaul, as reusing existing fibre infrastructure is the most economic option compared to deploying new microwave links. On the other hand, wireless links will be prevalent in regions with relatively low fibre penetration, while fibre adoption will grow in these regions to accommodate capacity demand.

FIGURE 4.2.5

MACRO BACKHAUL BY METHOD - REGIONAL (SOURCE: ABI RESEARCH)



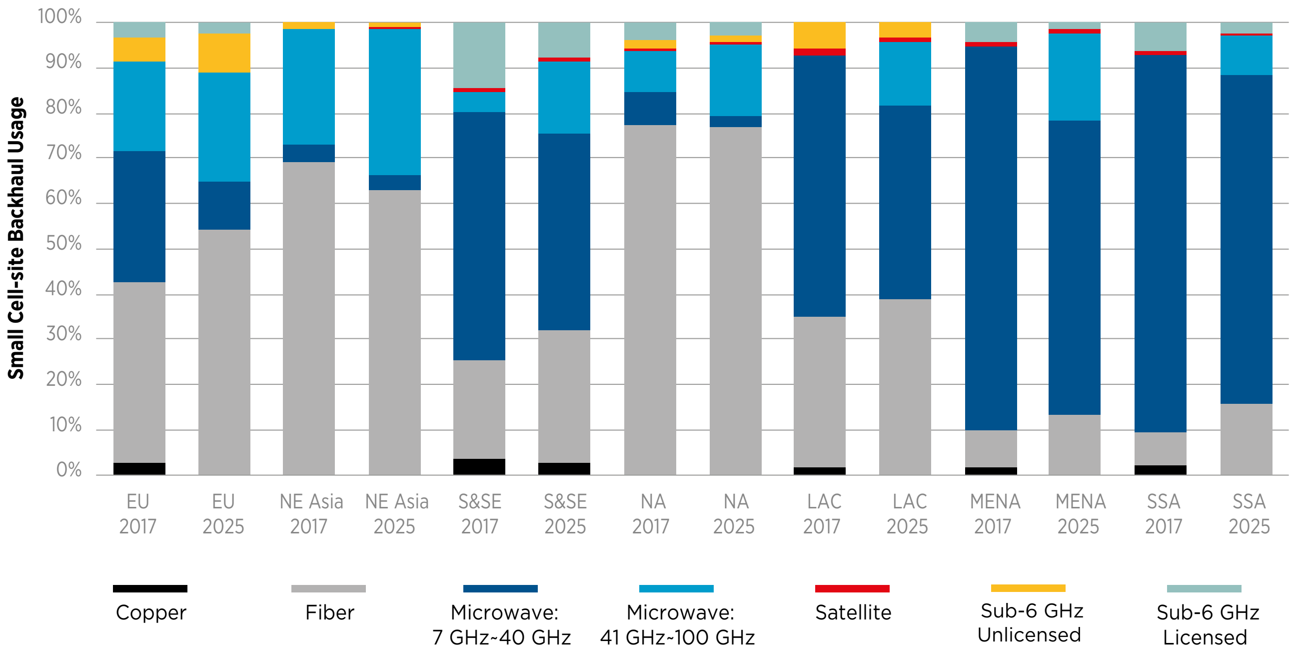
4.2.5.5 Small Cell backhaul options

While market and regulatory context also play a role, fibre will be much more prevalent in small cell backhaul, compared to macro cells. This is because small cells are mostly targeted to address hotspot scenarios in large urban centres where there is more likely to be existing fibre connections and wireless links require control terminals to be placed at small cells making small cells heavier and more spacious.

In developed nations, where cities tend to have higher fibre penetration (e.g., Europe, North East Asia and North America), fibre will remain the dominant choice for small cell backhaul while wireless links will be more prevalent in developing nations (see Figure 4.2.6 below).

FIGURE 4.2.6

SMALL CELL BACKHAUL BY METHOD - REGIONAL (SOURCE: ABI RESEARCH)



4.3 Network Coverage

KEY TAKEAWAYS

- Sub-1GHz bands (e.g. 700 MHz band) is the first of three bands for 5G. Its signal propagation is excellent, making it suitable for rural and wide area coverage.
- The 1GHz-6GHz bands (e.g. 3.5GHz) come with large bandwidths for capacity to support a very high number of 5G devices. It is suitable for urban macro cells.
- Spectrum above 6GHz (e.g. mmWave) can provide very high data rates. But as it is more susceptible to attenuation, it is most suitable for urban hotspots, including FWA.
- Early deployments of 5G will focus on providing capacity relief in congested areas and high-traffic locations, largely in urban and suburban areas.
- As with 2G/3G/4G, the operator business case for 5G rural roll-outs is challenging (e.g. rural uses up 79% of the hypothetical total capex to deliver 50Mbps across the UK).

4.3.1 5G spectrum coverage range

Operators will use different 5G spectrum bands for different coverage needs

The three different spectrum bands for 5G are suitable for different coverage ranges as shown in Figure 4.3.1.

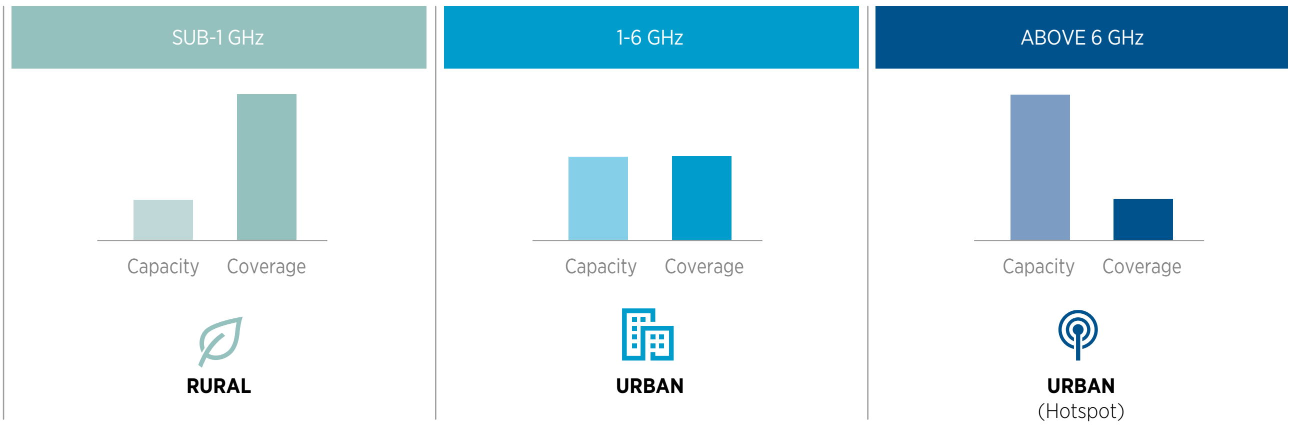
First, the sub-1GHz bands (e.g. 700MHz band) can cover large areas. While this spectrum band cannot provide high data rates because of narrow spectrum availability/allocations, signal propagation is excellent, making it suitable for rural coverage.

Second, the mid-range spectrum bands (1GHz-6GHz bands), such as the 3.4GHz to 3.8GHz band, come with large bandwidths to provide the necessary capacity to support a very high number of 5G devices. Although at shorter range than lower spectrum bands, this band provides higher data rates and therefore is well suited to urban macro cells but could extend more widely.

Third, higher spectrum bands (6GHz or above) such as the mmWave bands can be used to provide very high data rates that come with the very large contiguous bandwidth of spectrum available in those bands. The downside with this spectrum band is that the mobile signal reach is very limited and more susceptible to attenuation than other bands. Therefore, this band is often associated with urban hotspots and FWA.

FIGURE 4.3.1

5G NR SPECTRUM BANDS AND COVERAGE/CAPACITY PROVIDED



4.3.2 Network coverage: hotspots

5G will initially be deployed in hotspots

Early deployments of 5G will focus on NSA (Option 3 of the possible 5G configurations) to provide capacity relief in congested areas and high-traffic locations. This is to be expected given that the higher spectrum bands to be used by 5G NR can provide ample capacity. The NSA option ensures that this 5G configuration is integrated with 4G networks.

Even with SA (Option 2), the higher spectrum band of 5G NR makes it more suitable for places that experience capacity crunch with 4G rather than places that are already reasonably addressed by 4G. Therefore, 5G SA rollouts will also begin with addressing the hotspots in dense locations (e.g., stadiums, airports and train stations).

While the 3.5GHz band looks set to be the most common band used, early maturity of mmWave technologies and available devices will encourage the use of mmWave in early 5G hotspots.

4.3.3 Network coverage: urban

Cities are central to 5G deployment strategies

Cities are centres of excellence, with a high concentration of technology-savvy and relatively affluent users. Given these socio-political realities, operators need to work together with other stakeholders to showcase large-scale deployment and commercialisation of 5G in cities.

In *Delivering the Digital Revolution: Will mobile infrastructure keep up with rising demand?*[68], the GSMA and BCG evaluated the mobile broadband infrastructure needs of the world's megacities. The analysis examined four big-city archetypes, each with its own network infrastructure needs, and was based on the stage of development of the cities and projected traffic density (defined by gigabytes per square km). This is illustrated in Figure 4.3.2

Figure 4.3.3 shows that the four megacity archetypes often face similar network capacity challenges and need continuous upgrade of their infrastructure to support high traffic density (gigabytes per square km) in dense urban areas.

However, the cost of upgrading urban networks to 5G will vary across cities based on their unique circumstances and characteristics. An analysis conducted for the UK shows that, in a hypothetical plan to deliver 50Mbps to the entire country, network costs for urban centres is only 2% of the total and suburban 19% of the overall capex.

68. https://www.gsma.com/publicpolicy/delivering-the-digital-revolution

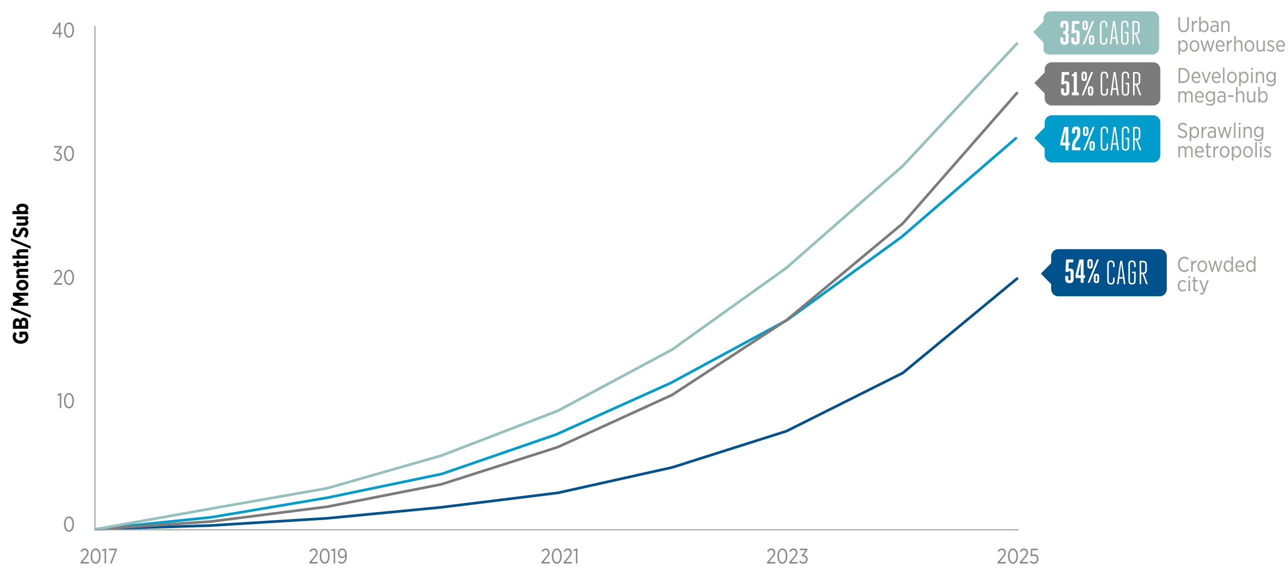
FIGURE 4.3.2

NETWORK DEPLOYMENT VARIES IN FOUR MEGACITY ARCHETYPES (SOURCE: BCG, GSMA)

		Lower costs of sites relative to ARPU. **DEVELOPED**	Higher costs of sites relative to ARPU, less developed infrastructure and higher demand growth. **DEVELOPING**
DENSE	Due to limited site-to-site distance and high traffic density, the limitations of the macro network are reached quicker and **more small cells are required**	**URBAN POWERHOUSE** Examples: New York, Tokyo, Seoul	**DEVELOPING MEGA-HUB** Examples: Shenzhen, Shanghai, Sao Paulo, Mumbai
SPARSE	Due to the lower traffic density, the limitations of the macro network are reached later and **fewer or no small cells are required**	**SPRAWLING METROPOLIS** Examples: Paris, London, Los Angels	**CROWDED CITY** Examples: Manila, Lagos, Lima

FIGURE 4.3.3

MOBILE DATA TRAFFIC GROWTH IN MEGACITIES (SOURCE: BCG, GSMA)



MOBILE DATA TRAFFIC IS EXPECTED TO GROW RAPIDLY WITH CAGR BETWEEN 35% AND 54% UNTIL 2025

4.3.4 Network coverage: rural

Closing the rural - urban broadband gap is a key socio-economic challenge

Building resilient broadband infrastructure is a key goal for society (UN Sustainable Development Goal 9) and 5G, coexisting with 4G well into the 2030s, will be the bedrock for providing high speed, next generation broadband services to communities. However, operators will be challenged by economics.

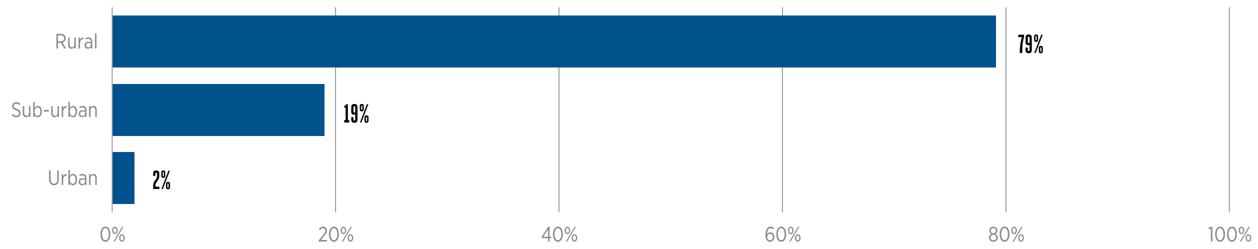
Figure 4.3.4 shows that in a hypothetical plan to deliver 50Mbps 5G services across the UK, the rural regions will account for 79% of the total capex. Yet rural regions are often unviable because there are not enough revenue-generating users. For example, the average cellular revenue per rural square mile in the US is $262 whereas the average cellular revenue per urban square mile is $248,000, as noted in *Is anyone out there? 5G, rural coverage and the next 1 billion*[69].

To remain central for all society, whether urban or rural in both developed and emerging markets, it is suggested that all stakeholders plan for 5G in a way that avoids widening the digital divide, as outlined in *Will 5G see its blind side? Evolving 5G for Universal Internet Access*[70]. This should also include use of universal service funds to solve network coverage in remote areas.

3GPP has taken a supporting step, recommending the 600MHz and 700MHz bands as 5G NR spectrum. 3GPP has also introduced mechanisms to support cells of 'up to' 100km in radius[71].

FIGURE 4.3.4

SHARE OF CAPEX TO DELIVER 50MBPS IN THE UK (SOURCE: OUGHTON AND FRIAS[72])



69. http://www.comsoc.org/ctn/anyone-out-there-5g-rural-coverage-and-next-1-billion
70. https://arxiv.org/pdf/1603.09537.pdf
71. TS 22.261
72. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/577965/Exploring_the_Cost_Coverage_and_Rollout_Implications_of_5G_in_Britain_-_Oughton_and_Frias_report_for_the_NIC.pdf

4.3.5 Network Coverage: transport links

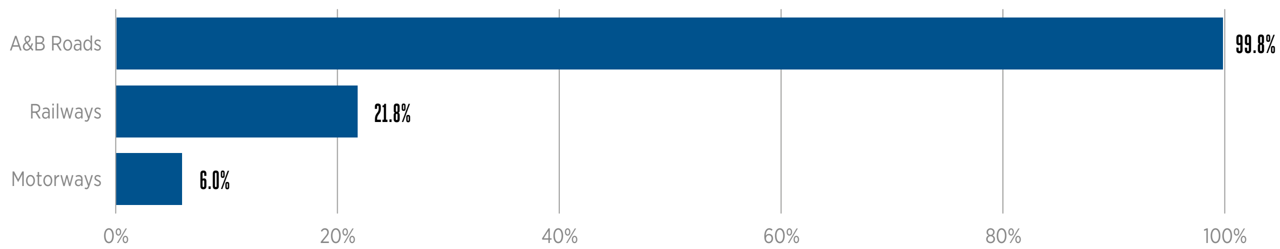
5G network rollout will trace the route of major transport networks

5G along transport routes will provide connectivity for autonomous/assisted navigation (e.g. driverless cars), productivity-boosting activities (e.g. commuting rail workers) and infotainment (e.g. passenger entertainment in cars). This is similar to how the 2G/3G networks traced the road networks. While 4G initially sought to match the 2G/3G footprint, it soon became clear that it also needed to trace the rail networks to deal with data usage by rail commuters.

Using estimates of capex for covering the road and railway networks in the UK with 5G in *Exploring the cost, coverage and rollout implications of 5G in Britain* by Oughton and Frias (see Figure 4.3.5), GSMA calculates that it could take the equivalent of 22% of annual mobile capex to cover the railway network of a major developed country with 5G. On the roads, GSMA calculates that it will take 6% of annual capex to cover the Motorways (multi-lane, inter-city roads) and 99% to cover A and B roads (A roads are major roads below the rank of Motorways while B roads are mostly minor inner-city and rural roads).

FIGURE 4.3.5

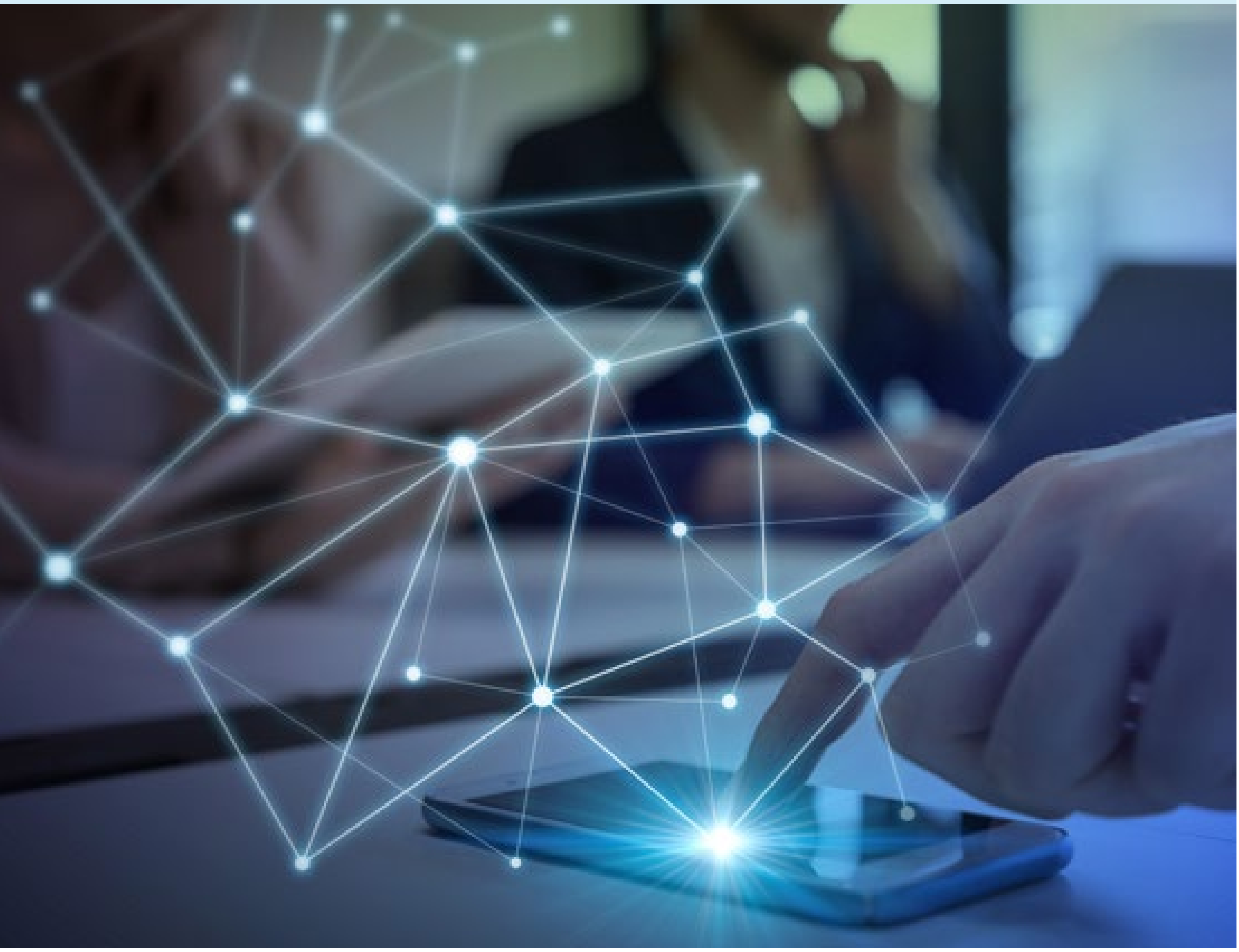
HYPOTHETICAL COST OF 5G COVERAGE OF MAJOR UK TRANSPORT LINKS AS A PERCENTAGE OF TOTAL ANNUAL CAPEX (SOURCE: OUGHTON & FRIAS; GSMA ANALYSIS)



4.4 Network Flexibility

KEY TAKEAWAYS

- 5G era networks will be flexible and modularized by design with technologies such as NFV / SDN, network slicing, and Cloud RAN.
- Virtualisation can generate significant cost savings, but it comes with a number of complexities. There is a risk that it may even end up costing same as before.
- On network slicing, common attributes need to be agreed by the industry to minimise the complexities and ensure interoperability.
- A Kings' College London study demonstrated the potential for network slicing, whilst highlighting required key enablers (automation, templates and interoperability).
- Cloud RAN can enable significant savings with some vendors reporting substantial capex and opex savings over a 5-year period vs. traditional approach.



4.4.1 Flexibility in 5G era networks

A flexible mobile architecture in the 5G era will shake up the industry

5G era networks will be flexible and modularised by design with technologies such as network slicing, SDN/NFV, cloud RAN and Open RAN. At a basic level, these changes in mobile network technology and architecture seek to reduce costs and provide flexibility for customised services tailored for major customers. However, they are also likely to have more profound impact on the mobile industry in two ways.

Firstly, there are concerns that virtualisation and softwarisation promise a lot, but can be quite challenging to implement, and may ultimately cost the same as physical networks in the long term. Some operators note that virtualisation does not deliver a cost advantage for them for existing services. However, expectations for cost savings is stronger for new services where a virtualised architecture can offer better scaling for the traffic demand than the traditional architecture, hence resulting in lower capex/opex.

Second, whilst the solutions for greater network flexibility enables a wider ecosystem of players and hence more competition among suppliers, this architectural change makes it difficult to isolate responsibility, role and issue associated with specific network elements. This is the focus of the Network Equipment Sourcing section.

Three key enablers of flexibility for 5G networks are considered: NFV/SDN, network slicing, Cloud RAN.

4.4.2 NFV/SDN

NFV/SDN technologies bring flexibility and cost savings, but at a price

Network virtualisation is not a 5G-specific cost issue as it has already begun on 4G networks. However, it is a prerequisite to deploying and operating a 5G network because 5G networks are virtualised and cloud native by design.

As Figure 4.4.1 shows, NFV enables network functions to be isolated as software that can run over Commercial Off-The-Shelf (COTS) hardware. NFV enables cost reduction, faster time-to-market and a broader ecosystem with more specialist market players. SDN is where network control planes and user planes are separated, and the control plane is centralised. Centralising the control plane enables the network to make globally optimised routing decisions, makes the network flow programmable to fit specific requirements and also broadens the ecosystem with layer decoupling.

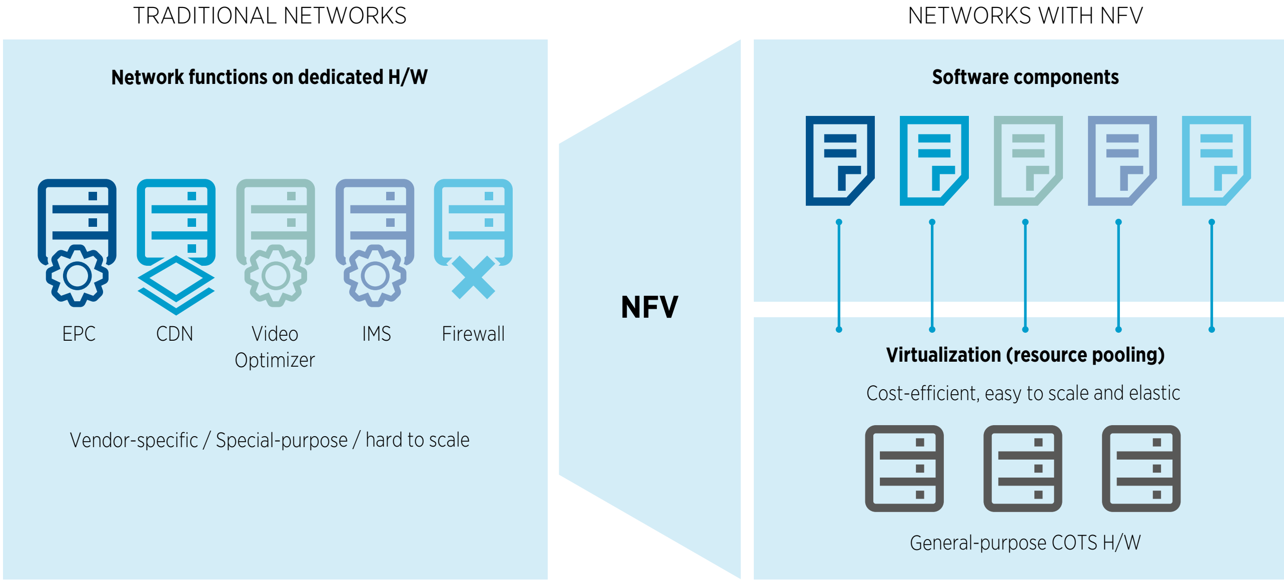
Therefore, SDN can enable a programmable transport network, which is able to create multiple and isolated transport slices. The transport resources can be dynamically allocated to different clients, interconnecting virtualized and physical network functions distributed geographically, which are likely to be located across different network domains. SDN is also able to provide network programmability through standardized APIs and networks resources abstraction, in order to obtain the required operational flexibility and dynamicity required for 5G, at the speed of signaling network control protocols propagating to the networks. Additionally, the centralized control plane capabilities of SDN provide E2E visibility of network resources for establishing and maintaining an optimized connectivity.

Experience from operators who have virtualised their 4G EPC networks is that virtualisation can generate cost savings of 40% of Total Cost of Ownership. This comes from the use of COTS, reduced time to market, and reduced need to over-provision network capacity and redundancy. Nevertheless, the complexities associated with decoupling the layers and increasing the vendor combinations must not be overlooked in virtualising the network and the operator will need to balance the long-term cost savings and short-term investment required.

Operators should, therefore, note that virtualising the network is not just an engineering challenge, but a people challenge: whatever the eventual cost benefits that virtualisation may bring, it is going to get more expensive in the short-term.

FIGURE 4.4.1

TRADITIONAL NETWORKS TO VIRTUALISED NETWORKS



4.4.2.1 Lessons from the IT industry on virtualisation

The mobile telecoms industry can look at the lessons from the IT industry which has been deploying virtualisation technologies for over 30 years. Virtualisation has helped organisations manage and shift IT resources from mundane tasks to strategic projects that create value for the business.

In a research study with 30 customers in a variety of industries, VMware, a key player in the virtualisation space, found that the operational impact of virtualisation on IT operations resulted in:

- 94% of respondents realising operational savings with virtual infrastructure for both one-time and day-to-day tasks
- one-time tasks of provisioning, decommissioning and migrating servers from one data centre to another each took at least 75% less time with virtualisation.
- performing the specific day-to-day tasks of hardware maintenance, rolling back from unsuccessful patches and rolling back from unsuccessful configuration changes each took at least 75% less time with virtualisation.
- The simplification and automation of ordinary IT activities can dramatically reduce routine management and maintenance tasks and their associated labour hours, saving organisations energy that can be reapplied to new business efforts and enabling companies to improve productivity and service availability, while reducing operating costs.

Appendix 7.4, co-authored by VMware, provides a detailed analysis of the virtualisation journey for the IT industry and how the mobile telecoms industry can apply the same lessons for 5G.

4.4.3 Network slicing

Common attributes need to be agreed by the industry to minimise complexities of network slicing

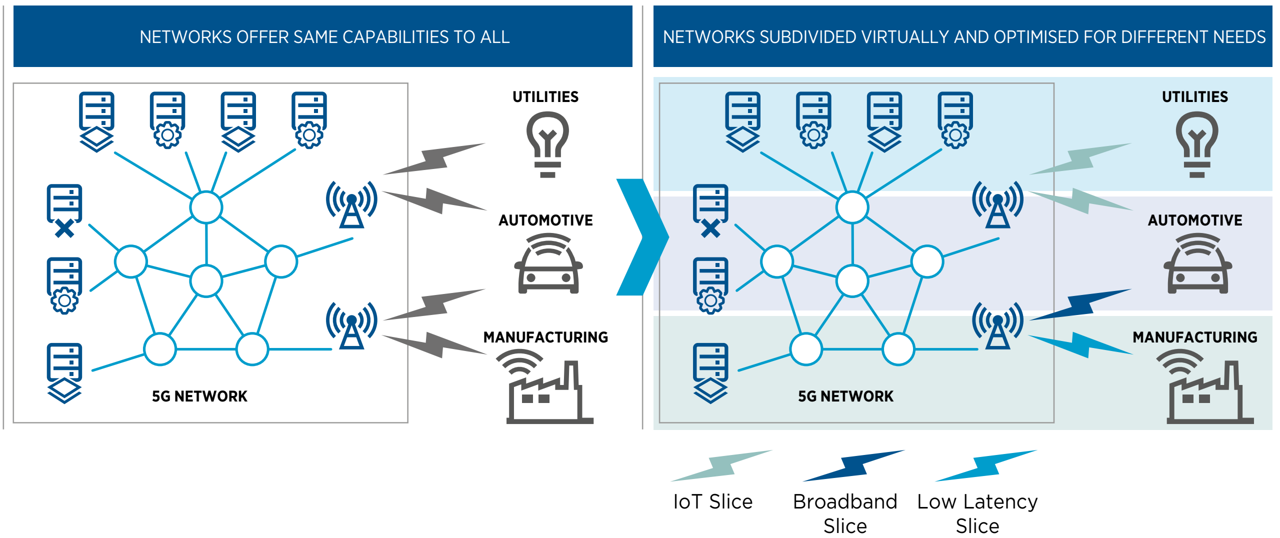
Enabled by NFV and SDN, Network Slicing enables the creation of two or more virtual networks with different performance parameters over a single physical network infrastructure, so each of the virtual/logical networks can serve a specific purpose. Conceptually, it can be depicted as slicing a physical network into many networks to serve specific use cases (see Figure 4.4.2). With network slicing, operators can address a variety of different client requirements, especially enterprises, with one physical network.

Network slicing, however, also comes with complexities in the context of interoperability and roaming. A customer using one network when switching to another network will expect a comparable, if not the same, experience. In this context, standardising a general set of attributes that characterise different network slices would be beneficial (e.g. the Generic Slice Templates (GST) defined by the GSMA Network Slicing Templates Taskforce).

The GST is an industry-agreed list of all the necessary slicing parameters. This does not mean that values of the parameters need to be agreed, but rather the attributes would be agreed such that a slice provided by an operator is easily emulated by another operator when the template is transferred, providing a baseline and reference for potential customers.

FIGURE 4.4.2

CONCEPT OF NETWORK SLICING



4.4.3.1 The investment case for network slicing

The Investment case will be much easier if it is only marginal to the broader 5G investment case

For network slicing to deliver on its promise, it needs to be provisioned in a way that does not create a massive return-on-investment hurdle for operators. There are three considerations to make this happen.

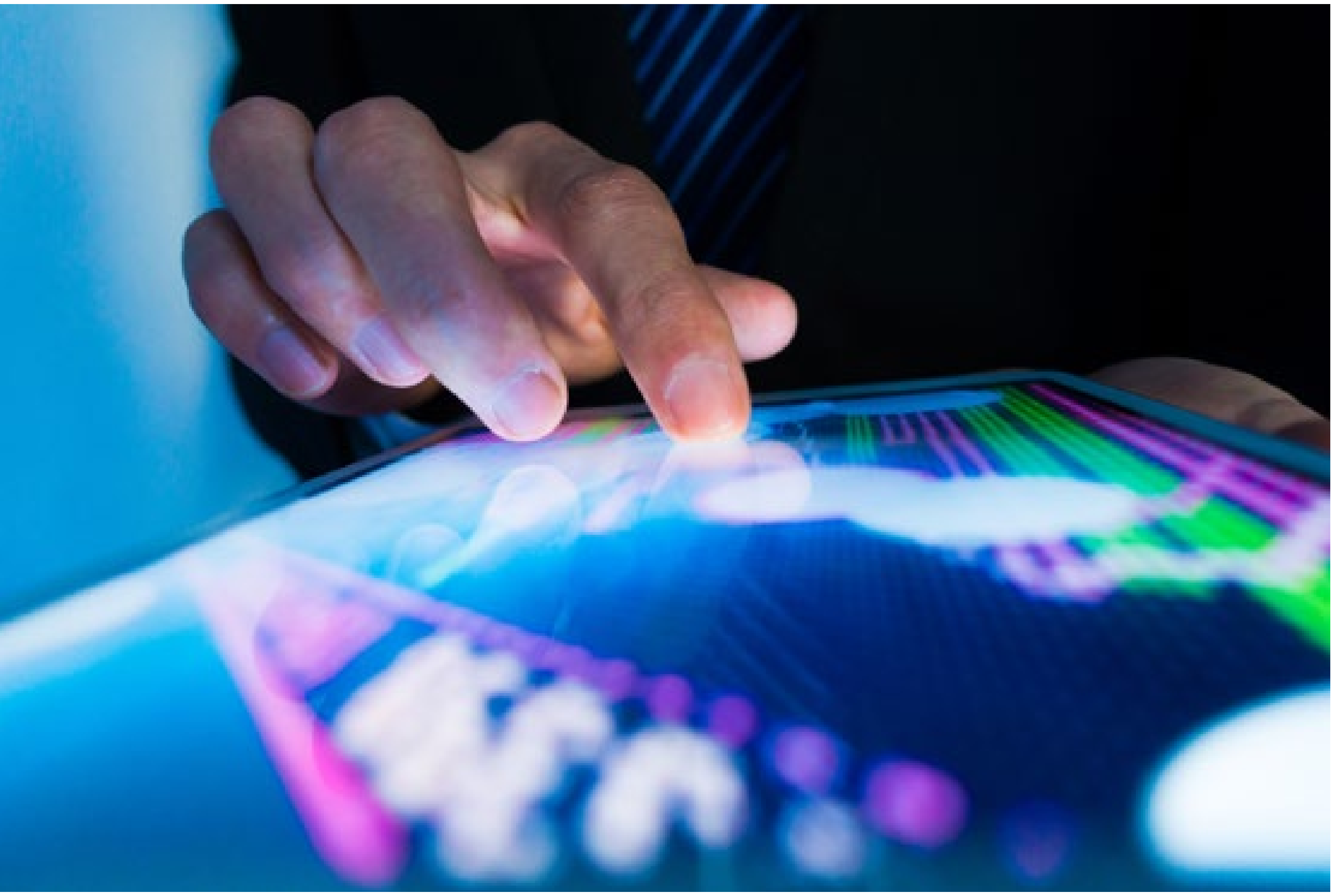
First, and as described above, is to minimise the complexities in its design and conceptualisation. Second, there is a need to drive economies of scale by focusing on a few slicing templates that can achieve wide adoption. Lastly, the investment case needs to be marginal to the broader 5G investment case.

As Figure 4.4.3 shows, responsibility to achieve these will depend on several stakeholders across the industry – Standard Defining Organisations (SDOs) such as 3GPP, industry groups such as GSMA and operators all have a role to ensure that the investment case does not impose a high barrier to the deployment and adoption of network slicing.

FIGURE 4.4.3

THE ROLE OF COLLABORATION IN THE INVESTMENT CASE FOR NETWORK SLICING

MINIMIZE COMPLEXITY TO KEEP COSTS LOW	DRIVE ECONOMIES OF SCALE TO REDUCE UNIT COSTS	MAKE INVESTMENT CASE MARGINAL TO THE 5G INVESTMENT
Standard Defining Organisations (SDOs)	GSMA, others	Operators



4.4.3.2 Lessons from a network slicing implementation

In 2017-18, King's College London together with the University of Surrey and the University of Bristol in the UK ran the world's first 5G end-to-end network slicing implementation.

A major goal of the study was to demonstrate the potential of network slicing in delivering low-latency applications over multiple operator networks, whilst relying on the interoperability of the participating operator's slices. The implementation involved intelligent cameras and real-time social media connections across London, plus innovative 5G music performances with artists in distributed locations.

One implementation tested was for a low-latency control of a drone, which is launched both from a local operator's core network and a remote operator's core network. In the latter case, a low-latency network slice is stretched from local operator's core network to the remote operator's core network, where the application server runs. While the proof-of-concept successfully demonstrated the feasibility of stitching together network slices across two operators' domains, it also demonstrated that manual configuration of a cross-operator slice is a time-consuming process requiring significant coordination.

Based on their experience, King's College London provide the following recommendations for operators:

- Network slicing should be an enabler for commercial value propositions and customers should not have to worry about its technical complexities.
- Granularity of network slices can vary, allowing for more differentiation and service creation. But increased granularity will increase cost of provisioning a slice.
- Network slicing can be used to provide a dedicated service to some customers, and a means to specify a set of QoS for some applications.
- Interoperability and inter-operator cooperation is critical because network slices for global businesses will require the orchestration of various resources from different parts of the network.
- Automation is essential and without it, network slicing will struggle for scalability.
- Network slicing templates, with predefined and optional fields, will help to bring down the cost and time to deploy, guarantee interoperability and enable automation of slice management on global scale.
- New business models and ways of working will emerge from network slicing and operators should get ready to play new roles (e.g. Infrastructure-as-a-service).
- The relationship between operators and end customers could undergo a fundamental change if verticals (e.g. automotive companies) leverage network slicing to reach directly to customers.

Appendix 7.5, commissioned by the GSMA, provides the full analysis from Kings College London's experience of network slicing.

4.4.4 Cloud RAN

Network virtualisation makes it possible to deploy Cloud RAN to unlock capex and opex savings

Cloud RAN is a radio access technology where some components of the radio access network are virtualised and centralised so that one physical location handles hundreds of cells, reducing the cost and complexity of operating a cell site.

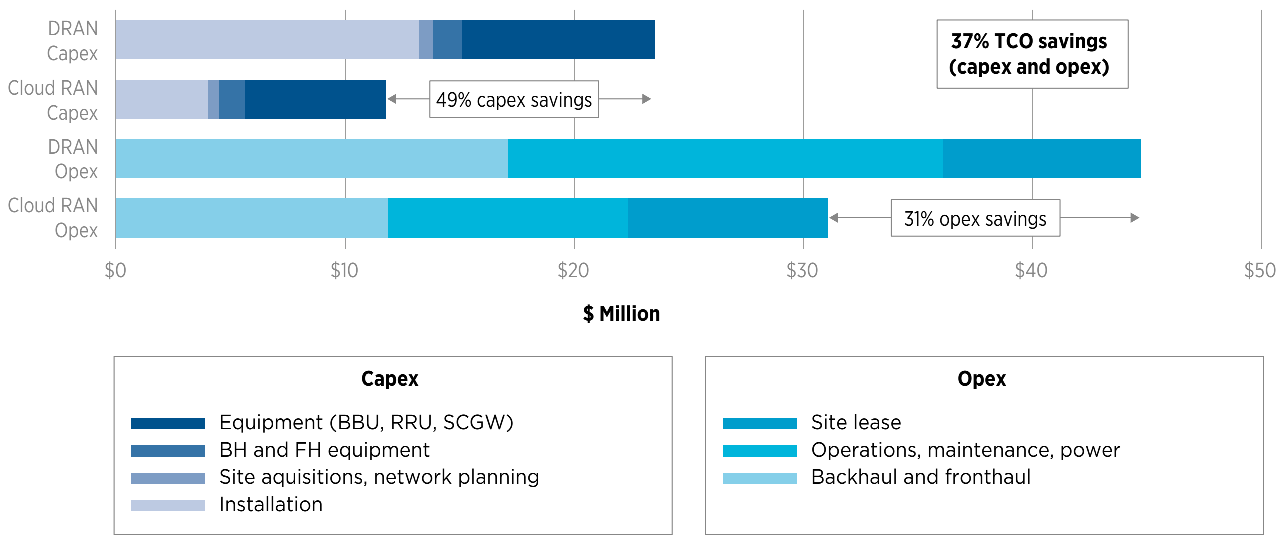
The Cloud RAN architecture is possible because virtualisation allows for the baseband processing to be done in virtual equipment running on generic hardware. The result is that fewer and lower cost COTS servers are used when compared to a distributed RAN (DRAN) architecture, today's predominant approach. The Cloud RAN also simplifies network management and enables resource pooling. The Cloud RAN architecture is highly suitable for the small cell era, where lower cost, flexibility and scalability are key operational factors.

Cloud RAN enables significant savings that would not have been possible with traditional configuration. For example, according to a Mavenir and Senza Fili Consulting study[73], Cloud RAN can yield 49% capex savings and 31% opex savings over a five-year period compared to the DRAN architecture – see Figure 4.4.4.

It should be noted that the CAPEX and OPEX savings above depends strongly on the availability of fiber and space for the baseband farms. Having to build or rent these may change the case significantly, as additional build/rent costs may offset the savings.

FIGURE 4.4.4

5 YEARS CUMULATIVE TCO FOR CLOUD RAN – CAPEX AND OPEX (SOURCE: MAVENIR, SENZA FILI CONSULTING)



73. https://www.mobileworldlive.com/wp-content/uploads/2017/11/20451-Mavenir-Whitepaper1.pdf

4.5 Network Latency

KEY TAKEAWAYS

- **Low latency is often cited as the key capability that operators will be able to monetise in the 5G era; but delivering it will inevitably increase the cost of the network.**
- **MEC (Multi-access edge computing) for mobile networks is the critical component to achieve low latency in mobile networks.**
- **GSMA estimates that the cost of adding a MEC server to every cell site in the world would be $140bn; limiting the roll-out to aggregation points reduces this figure to $5bn.**
- **Opex may be challenging for operators given on-site space and power constraints.**

4.5.1 Latency in 5G era networks

Given the constraints of physics, delivering low latency will be costly and trade-offs will be needed

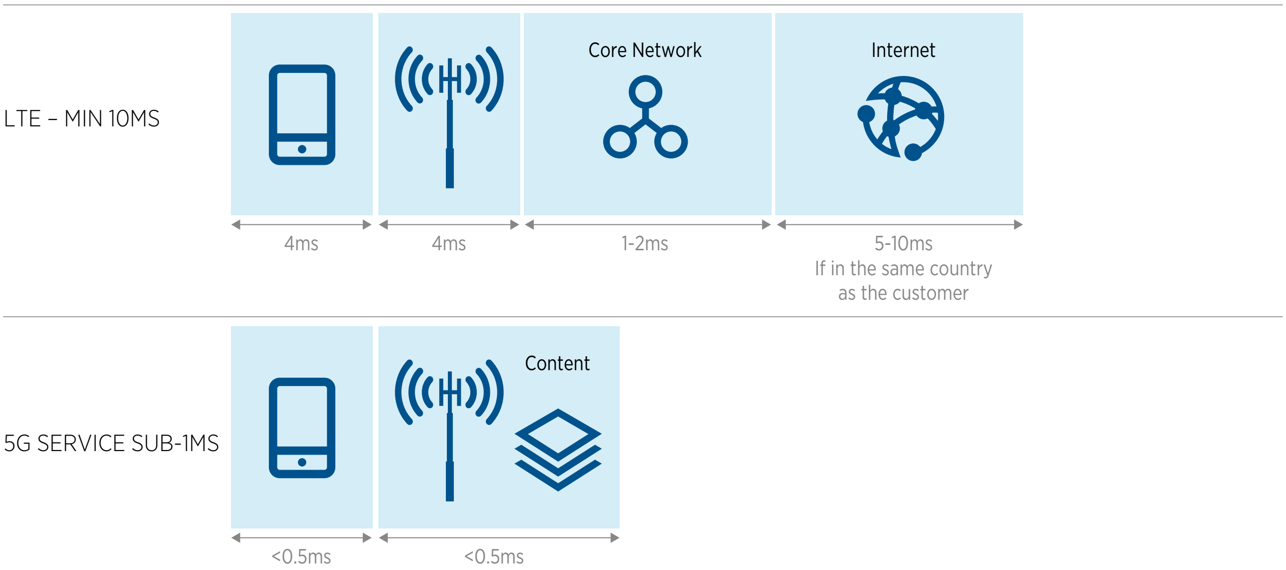
Low latency is often cited as the key capability that operators will be able to monetise in the 5G era. However, achieving low latency inevitably increases the cost of the network and operators will have to make trade-offs on where to invest, and when to promise low latency capabilities to customers.

Latency is primarily governed by the laws of physics (maximum theoretical speed c of 299,792,458 metres per second; 300 kilometres in 1 millisecond). Figure 4.5.1 shows the different sources of delay in actual networks. Latency is also affected by network topology (no of hops), protocols implemented in the transport network or network congestion). Industry estimates suggest that to deliver a content in 1 millisecond on real networks, the content needs to be less than 1 km away[74]. This would require widespread deployment of edge computing servers across the network, with its attendant cost implications.

Where the content is not owned by the serving operator (e.g. AR content from a social network), this also means that there has to be interconnection points at those edge computing servers so that third parties can host or cache their content. This is the rationale for exposing APIs for edge computing.

FIGURE 4.5.1

LATENCY PERFORMANCE FOR LTE COMPARED TO LATENCY REQUIREMENT FOR 5G



74. https://www.gsmaintelligence.com/research/?file=141208-5g.pdf&download

4.5.2 Enabling low latency: edge computing

The cost of MEC is linked to where the 'Edge' is

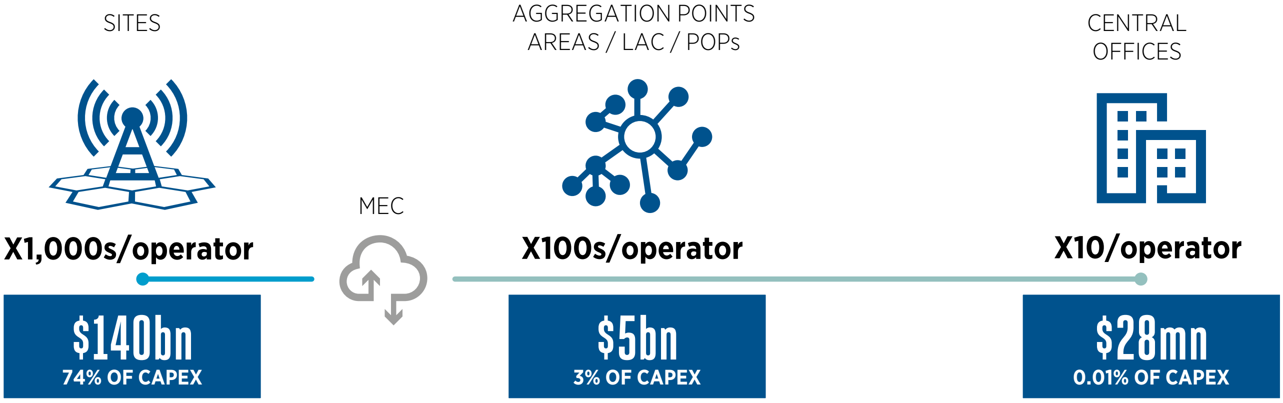
Edge computing, architected as MEC for mobile networks, is the critical component to achieve low latency in mobile networks. Its conceptual development aims for sub-1 millisecond latency, but its design architecture deals with the reality that not many services will need such low latency.

Accordingly, rather than push for MEC sites to be on every cell site, MEC is being designed to be deployable at alternative locations. The locations can be regional DCs (large central offices), local central offices and aggregation sites, where progressive approach will flow from the regional DCs all the way to aggregation sites. GSMA estimates (see Figure 4.5.2) that the cost of adding a MEC server at every cell site in the world will be $140 billion, about 74% of total industry capex in 2017. In contrast, putting MEC at aggregation points will cost $5 billion.

MEC opex may be even more challenging than capex for individual operators. Physical space at many cell sites is limited and energy to power the additional equipment may not be easily available. There will also be a higher risk of theft in some countries for MEC equipment, so security costs may rise. Unsurprisingly, there are discussions on sharing MEC sites, and there are also tower companies and start-ups (e.g. Vapor IO) who seek to build out the hardware for 'Edge' infrastructure and partner with operators to use it.

FIGURE 4.5.2

THE COST OF MEC AT DIFFERENT 'EDGE' LOCATIONS



4.5.3 MEC as part of 5G capex

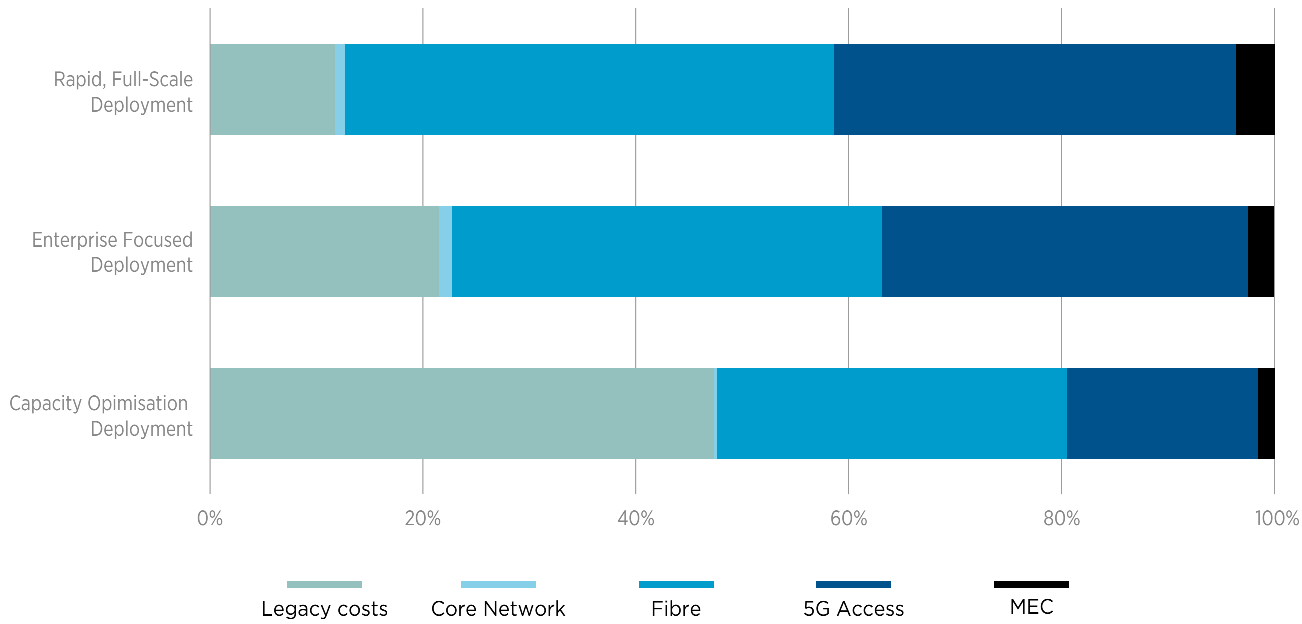
If operators are to build out MEC, then it should be integrated into 5G capex

The MEC business case is a chicken and egg quandary. There are not enough confirmed paying customers for MEC capabilities to meet the investment criteria for many operators. Yet, without a rollout of MEC, the business opportunity will not be developed.

GSMA's consideration of this is that MEC rollout should be included in the 5G business case and its cost should be integrated into 5G capex planning. The advantage of this approach is that MEC is progressively trialled and built out, without a big bang investment case. GSMA modelling suggests that for the three 5G deployment scenarios explored in Chapter 5, MEC, at the aggregation sites, will account for 2-4% of hypothetical 5G era capex (see Figure 4.5.3). Please refer to Chapter 5 for methodology and disclaimer.

FIGURE 4.5.3

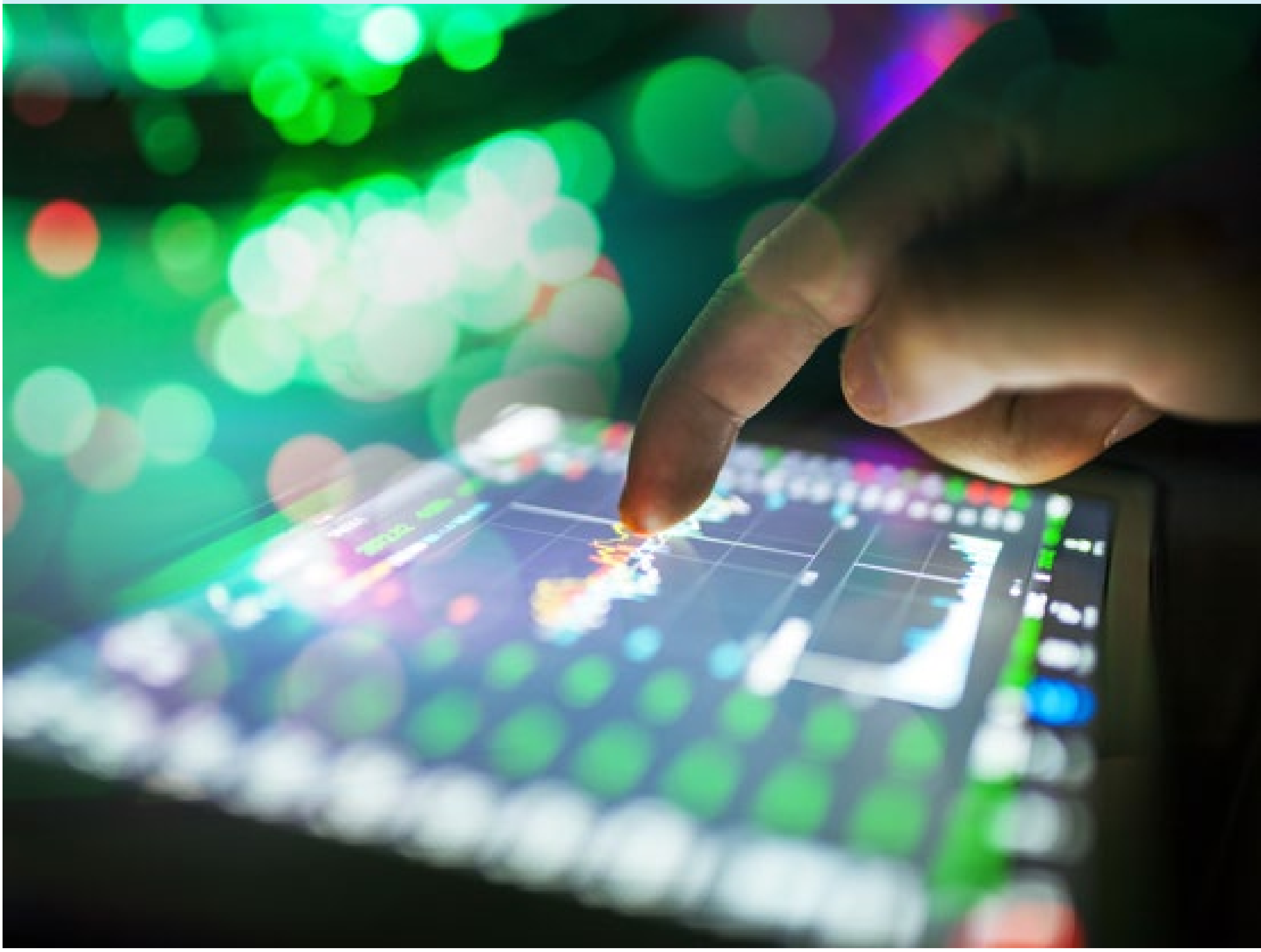
MEC COULD ACCOUNT FOR 2-4% OF 5G CAPEX IN A HYPOTHETICAL SCENARIO



4.6 Network Energy Efficiency

KEY TAKEAWAYS

- **Costs and growing global commitments to reduce greenhouse gas emissions require radical energy efficiency for 5G networks.**
- **5G promises to deliver up to 1,000 times as much data as today's networks, the infrastructure to deliver this may potentially consume up to 2-3 times more energy.**
- **Operators can deliver a greener 5G by using renewable energy sources and by adopting practices that increase energy efficiency.**
- **Solar energy is the key option for operators wishing to supply their own renewable energy, though in some markets (e.g. Nordics) wind energy solutions are preferred.**
- **5G era networks power management will be optimised as part of an intelligent infrastructure.**



4.6.1 Towards 'Greener' 5G era networks

Costs and global commitments to reduce greenhouse gas emissions call for radical energy efficiency for 5G networks

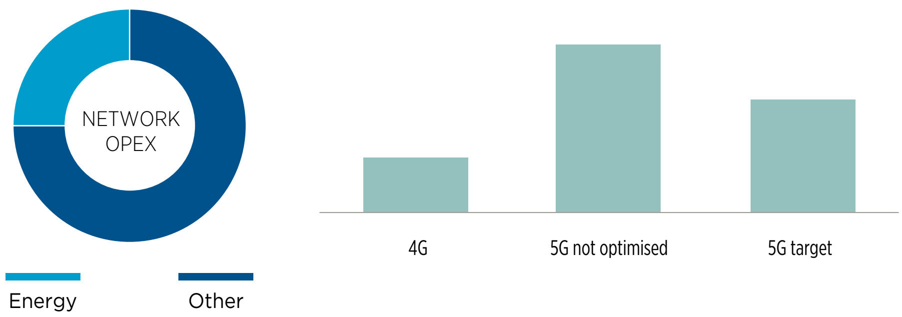
For many operators, energy consumption has historically being a major consideration as it is one of the highest operating costs, alongside employee remuneration (see Figure 4.6.1). But it is becoming even more important due to climate change and sustainability considerations. The potential increase in data traffic (up to 1,000 times more) and the infrastructure to cope with it in the 5G era could make 5G to, arguably, consume up to 2-3 times as much energy. This potential increase in energy, coming from greater number of base stations, commercial stores and office space; maintaining legacy plus 5G networks and increasing cost of energy supply – call for action.

The current reality is that overall energy usage by the telecoms industry needs to come down as the industry consumes between 2 - 3% of global energy currently[75]. Many national governments are mandating businesses to adhere to energy reforms (e.g. EU's 2030 climate and energy framework) with the global goal to reduce greenhouse gas (GHG) emissions, since 2014, by 30% in absolute terms by 2020 and 50% by 2030. The telecoms industry is not exempt from these pressures and the evolution to 5G is an opportunity to deliver a cleaner, greener telecoms footprint - indeed, 3GPP's 5G specification calls for a 90% reduction in energy use.

A growing number of operators have taken a leading role in sustainability and the use of renewables to meet or exceed these decarbonisation goals and these will expand in the 5G era. The many solutions to enhance network energy efficiency fall in two major groups: increasing the use of alternative energy sources to reduce dependence on the main power grid; and network load optimisation to reduce the energy consumption.

FIGURE 4.6.1

PROJECTED IMPACT OF ENERGY OPTIMISATION IN 5G NETWORKS (SOURCE: ORANGE)



75. http://mdpi.com/2078-1547/6/1/117

4.6.2 Network energy costs: industry debate

Energy consumption constitutes between 20 – 40% of network OPEX and there are two schools of thought on how this will evolve for 5G

There are two opposing schools of thought with regards to network energy consumption in 5G. Some stakeholders point to no overall net increase in the energy consumption of 5G networks by virtue of the equipment being more efficient. For example, Telia and Ericsson believe that the increase in energy usage will be offset by more efficient equipment resulting in no net increase in energy usage[76]. This view is also shared by Nokia[77], who in addition, in 2017 found that existing site equipment renewal delivered efficiencies of 44% which are expected to offset any increase[78].

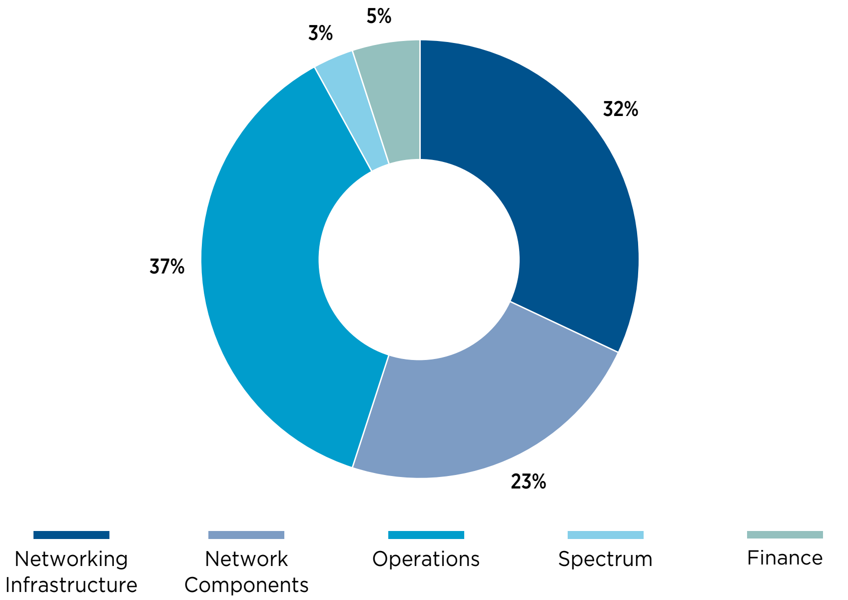
On the other hand, other stakeholders believe that the energy consumption of wireless networks will initially fall before picking up again. Huawei estimates that energy consumption will fall initially until "around 2021" (MDPI report). However, in the same way 5G data traffic (and network deployments) increase, so does energy usage. They calculate this increase to be at a rate of 5% p.a. from 2022 until 2025. Even this value is contingent on a breakthrough in "efficient 5G technologies", a delay of which could see global energy usage increasing by an additional incremental 30%.

In addition to the data load question, i.e., equipment will be able to handle more bandwidth with the same or lower energy consumption, this does not address the increase in cell sites with Huawei pointing to a doubling of network energy consumption. It is worth highlighting that issues of power capacity at existing sites, may also affect CAPEX and deployment times[79].

Figure 4.6.2 highlights the cost contributions and total cost of ownership (TCO) for a hypothetical operator in a developed market. It is based on the GSMA's Network Economics Model and has been developed to support operators in understanding the key value levers to deliver lower TCO.

FIGURE 4.6.2

TOTAL COST OF OWNERSHIP, BASED ON THE GSMA'S NETWORK ECONOMICS MODEL ESTIMATE FOR A HYPOTHETICAL OPERATOR IN A MOSTLY DEVELOPED MARKET



76. http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A1177210&dswid=5306
77. https://gsacom.com/paper/5g-network-energy-efficiency-nokia-white-paper/
78. https://www.nokia.com/sites/default/files/nokia_people_and_planet_report_2017.pdf
79. https://www.huawei.com/en/press-events/news/2018/10/huawei-first-5g-power-solution - more than 70% of the sites will face the challenge of insufficiency capacity of power, battery, distribution, and more than 30% of the sites need grid modernization, with inevitable CAPEX increases

4.6.3 Benefits of renewable energy

Renewable energy sources can be both good for the environment and cost effective

Operators are increasingly shifting their energy sourcing away from carbon sources towards green renewable technologies and alternative energy sources, such as photovoltaic modules and fuel cell generators as their cost continues to fall. Such non-carbon energy sources can exempt an operator from the burdens of carbon emissions regulation and enables the networks to be more resilient to natural disasters or power outages.

The optimal choice of renewable energy will differ depending on the context of the operator (e.g., fossil fuel costs in the nation, power outages, carbon emissions regulation), but alternative energy source solutions can be cost effective. This is important because energy costs from the central grid or by energy generators with fossil fuels is a major concern for operators: the former because the electricity needs depend on the utilities and the latter because carbon emissions are being regulated/taxed by some regulators.

4.6.4 Leveraging alternative energy sources

Energy sourcing and energy efficiency provide the path to a greener 5G

Operators have three options for alternative energy sourcing. First, operators may purchase green energy directly from their utility provider (often at a premium).

Second, they can use a third-party power purchase agreement (PPA) as a means to shift supply to renewables without the initial capex investment, agreeing to purchase energy from the solar or wind farm at a specific rate for a specific period of time e.g. 5-20 years.

Thirdly, operators can self-generate energy either at the base station with standalone or hybrid solar-based solutions, (which can be extended to off-grid scenarios); or with larger scale solar and wind farms, requiring capex investment.

4.6.4.1 Renewable energy: Self-supply options

Solar energy is the key option for operators wishing to supply their own renewable energy for their network, though in some markets (e.g. Nordics) wind energy solutions are preferred. Solar energy is a very attractive option in some regions, such as the Middle East or Africa – with average solar radiation ranging between 5 KWh/m2 and 7KWh/m2 – where output can be up to 1000GWh per country, per year.

Solar energy is becoming cheaper than traditional fossil fuels and is now either the same price or cheaper than new fossil fuel capacity in more than 30 countries according to a World Economic Forum report[80].

The GSMA expects that solar will play a key role in the 5G era. The construction of more solar parks, with a useful life of 20-30 years, will result in a gradual reduction of emissions for operators by incorporating more base stations and charging points in a growing network.

80. https://www.weforum.org/agenda/2018/05/one-simple-chart-shows-why-an-energy-revolution-is-coming-and-who-is-likely-to-come-out-on-top

4.6.4.2 Renewable energy: power purchase agreement (PPA)

To avoid the capex for self-supplied renewable energy solutions, operators can enter into a financial agreement where a developer designs, funds and installs a solar energy system on operators' property. Under PPA, mostly considered for solar and wind energy solutions, the developer sells the power generated to the host operator at a rate that is typically lower than the local utility's retail rate.

PPAs typically range from 10 to 25 years and the developer remains responsible for the operation and maintenance of the system for the duration of the agreement. As an example, a North American operator purchased over 800 megawatts (MW) of wind energy in the first six months of 2018, in one of the largest PPA in US corporate history. The carbon savings from this project is equivalent to taking more than 530,000 vehicles off the road each year or providing electricity for more than 372,000 homes per year.

The cost of production of renewable energy continues to fall, so operators should structure their PPAs to ensure they continue to benefit from future cost efficiencies over the duration of these contracts. PPAs should also factor in energy storage within the solution (e.g. concentrated solar power thermal energy storage) to ensure reliability and security of supply.

4.6.5 Optimising the network load

5G era networks will be optimised as part of an intelligent infrastructure

Network load optimisation is essential to ensure that total energy consumption is reduced. This is a prescient requirement for 5G era networks. Improving energy efficiency to consume less energy can be achieved through a multitude of solutions, including smart building, virtualising the core, and improving RAN efficiency through modernisation of legacy equipment and implementation of low-powered solutions.

While existing core networks enjoy the benefits of having well-established energy management systems (including remote management systems), the critical elements for access network infrastructure such as power systems, batteries, air conditioners, free cooling and generators (gen-sets) often do not come with holistic, well-developed energy management systems.

Remote monitoring and automation of management functions for the main site infrastructure elements allow operators to identify capex and opex reduction opportunities and develop energy efficiency strategies. Further energy efficiency gains will also come from network automation and using a shared network infrastructure.

4.7 Network Automation

KEY TAKEAWAYS

- Network automation, where technology is applied in network deployment and operation to reduce human effort, is not new.
- 5G era networks will need more automation because they are more complex; have a higher management workload to deal with more customers and data traffic; and the increasing sophistication of customers and types of services.
- Automation in the 5G era will either be based on the traditional approach (using pre-programmed rules to run processes) or based on AI or a combination of both.
- AI will enable cognitive functions that have not been possible before, supporting predictive maintenance, long-term network optimisation, network planning, security and deployment automation.

4.7.1 The age of network automation

Network automation can either use pre-programmed rules, or be based on AI or a combination of both

Network automation, where technology is applied in network deployment and operation to reduce human effort, is not new. Operators already have a degree of network automation implemented: e.g. specific network faults trigger an alarm to the operations staff and networks treat traffic automatically based on pre-set policies.

5G era networks will need more automation because they are more complex and have a higher management workload to deal with more customers and data traffic, and the increasing sophistication of customers and types of services. This trend is set to grow further in the 5G era, when billions of devices will be connected, potentially opening up new opportunities for both revenue growth and cost reduction.

While the overall impact of network automation is a big unknown for operators, there are two benefits that operators should seek to unlock. Firstly, automation is the logical step to dealing with growing network complexity, given the limitation of cost and finding personnel with the right expertise. Secondly, automation is the optimal means to deliver networks and services in a more agile way and with reduced provisioning times.

Network automation in the 5G era will either be based on the traditional approach (using pre-programmed rules to run processes) or based on AI or a combination of both.

4.7.2 AI-based network automation

AI will enable cognitive functions that have not been possible before

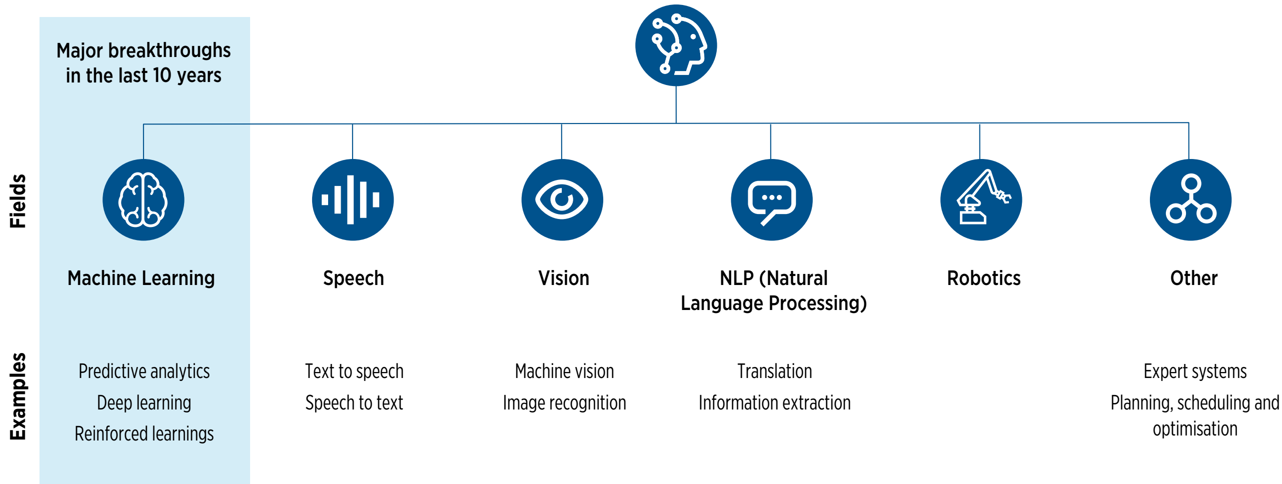
The growing maturity of machine learning and other AI technologies will dramatically expand the scope for network automation. AI enables learning algorithms that can take cognitive decisions on network operation that were previously taken by humans. This will be beneficial for predictive maintenance, long-term network optimisation, network planning, and network deployment automation.

The possibility of using AI for network automation is largely thanks to the drop in the cost of computing, the accumulation of large datasets, and the development of learning algorithms to process the datasets. AI is a broad term and covers different fields and techniques (see Figure 4.7.1). Examples include machine learning, speech, vision, natural language processing, robotics and finally to other fields such as optimisation. The most relevant fields for network automation are machine learning and optimisation.

In addition, AI can be used for network planning, to enhance the efficiency of the network and reduce cost of deployment. Speech, vision, natural language processing and robotics are also important but are not as related to network automation as the two fields mentioned above. However, operators should always be attentive to AI-driven innovations that can be utilised for network automation (e.g. image recognition of heat patterns within data centres).

FIGURE 4.7.1

THE DIFFERENT FIELDS OF AI



4.7.3 Network automation in action

Automation can either use pre-programmed rules, or use data to generate rules

Broadly speaking, most forms of network automation implement pre-programmed rules or implement new rules that have been informed by an analysis of large operational datasets. Accordingly, there are three network automation mechanisms for operators to consider.

Firstly, operators can, and should continue automating routine processes to streamline network element provisioning and management. These do not involve AI, and are based on delegating a computer or intelligent system to take action based on pre-configured parameters. This is the traditional approach to automation and, for example, would be needed to accelerate service provisioning for network slices in 5G.

Secondly, operators can apply AI in specific areas of the network. For example, some operators already apply machine learning to predict degradation of 3G/4G data traffic and optimise VoLTE, or to enhance carrier aggregation and balance the load in the RAN. Others use machine learning models, to predict failures in virtualised core network or software defined networks deployed in enterprise customers' premise.

Thirdly, operators can take a holistic approach and create a network operations platform that is AI-powered. This is achieved by developing in-house or adopting open source framework (or even the combination of the two). For example, an operator integrates open source in different layers (network cloud, edge computing system and AI marketplace) to form a full-stack AI platform.

4.7.4 Mechanism of AI-based network automation

Operators can use AI to automate network operations, improve network planning and strengthen security

AI can contribute to making the network more efficient and “intelligent” in three main areas: network operations; network planning; and network security.

Machine learning is most often applied to network operations. Examples include network monitoring, fault prediction, optimising self-organising networks (SON) and monitoring/predicting degeneration of quality of the network, but it can also be used for fraud prevention and troubleshooting.

Machine learning and other AI techniques can also have an important role in network planning as it did for network operations. Some operators already apply AI in planning and designing the radio access network, deciding where base stations can be installed to optimise cost and interference. Some operators also use AI to predict the best rollout route for network deployment. For example, machine learning models and computer vision can be used to determine best rollout routes in fibre deployments.

Mobile networks remain susceptible to security threats that can cost operators immensely (e.g., data breaches). AI can enhance the security of mobile networks by detecting anomalies of how devices behave in the network, providing prediction and recommendations to security experts.

4.7.5 Limitations of network automation

Automation, especially when AI-driven, has limitations

Operators should consider three types of limits in defining their automation strategy. Firstly, the usefulness of automation needs to be proven for each use scenario and operators should limit their use of automation to where there are clear business benefits. As was argued for in Automation and AI in *Telco Ops — A Reality Check*[81], while computer-driven automation promises a lot of efficiency gains, it will not always follow that automation is more effective than human action for some initiatives.

Secondly, the nature of AI could bring additional unpredictability to network operations if its closed loop system becomes a black box with little human understanding. This technology limitation may not be helpful for network and service provisioning, especially considering that operators need to provide assurances to customers to incentivise some 5G era use cases that require a highly reliable and resilient network performance.

Thirdly, for AI use cases, the data and the algorithms to extract insights from it, present challenges that operators need to prepare and plan for. These scenarios require huge datasets, and the data requires structuring to make it suitable for training an AI model. Also, the outcomes can, potentially, be biased based on the prejudices of its human handlers, and it can be difficult to explain and generalise its learnings.

81. https://www.sdxcentral.com/articles/analysis/automation-and-ai-in-telco-ops-a-reality-check/2018/08/

4.8 Network Ownership

KEY TAKEAWAYS

- **To manage costs in the 5G world, new network ownership models will apply at both the macro and small scale.**
- **The traditional infrastructure sharing model will continue into the 5G era, with passive infrastructure sharing and the use of tower companies becoming more widespread.**
- **The benefits of single wholesale networks are appealing but dangerous given the lack of wholesale competition and related pricing constraints.**
- **Aerial networks (e.g. LEO satellites) may provide backhaul for operators in remote/rural areas where economically justified.**
- **Given that it may be both physically difficult and aesthetically challenging to install multiple small cells on public infrastructure, neutral host small cells may be needed.**
- **Private networks are likely to proliferate in the 5G era; operators need to consider the most economically viable method to support them.**
- **Improvements to Wi-Fi (e.g. with Wi-Fi 6) could create a complement to 5G small cells and private networks.**

4.8.1 Evolution of network ownership and management

New network ownership models will apply at both the macro and small scale

The need to meet the throughput and coverage requirements for 5G era networks would, on paper, lead to higher costs. This is fuelling active discussions in industry, academia, financial and policy circles on how different forms of ownership and management of 5G-era networks, among other things, can reduce costs.

These discussions challenge the historical network ownership and management paradigm - where an operator owns and manages the network infrastructure it deploys/operates - that has prevailed across the industry for the past few decades. Crucially, they are also happening at the same time as the operator community is seeking to make the case for, and raise the funds, to invest in 5G.

Figure 4.8.1 outlines two aspects to these discussions: at macro scale, to provide coverage across populations and geography; and small scale, to provide capacity in hotspots and 5G corridors, network deployments.

Each of the seven approaches under consideration can reduce the cost burden for operators in deploying 5G era networks, but some of them inadvertently undermine the historical role of operators as the owners and managers of the public broadband infrastructure. The discussions, and how they will eventually play out, are major unknown considerations for operators.

FIGURE 4.8.1

LARGE SCALE VS SMALL SCALE NETWORK OWNERSHIP CONSIDERATIONS

MACRO SCALE: NATIONWIDE & COST EFFECTIVE FOR COVERAGE	VS.	SMALL SCALE: LOCALISED & COST EFFECTIVE FOR COVERAGE & CAPACITY
• Traditional Infrastructure Sharing (incl. TowerCos) • Neutral host: Single Wholesale Networks (SWF) • Aerial networks (incl. satellites, drones, balloons)		• Neutral Host: hotspots & 5G corridors • Private 5G networks • Wi-Fi 6 • Bring-Your-Own-Small Cells

4.8.2 Infrastructure sharing (incl. Towercos)

The traditional infrastructure sharing model will continue into the 5G era

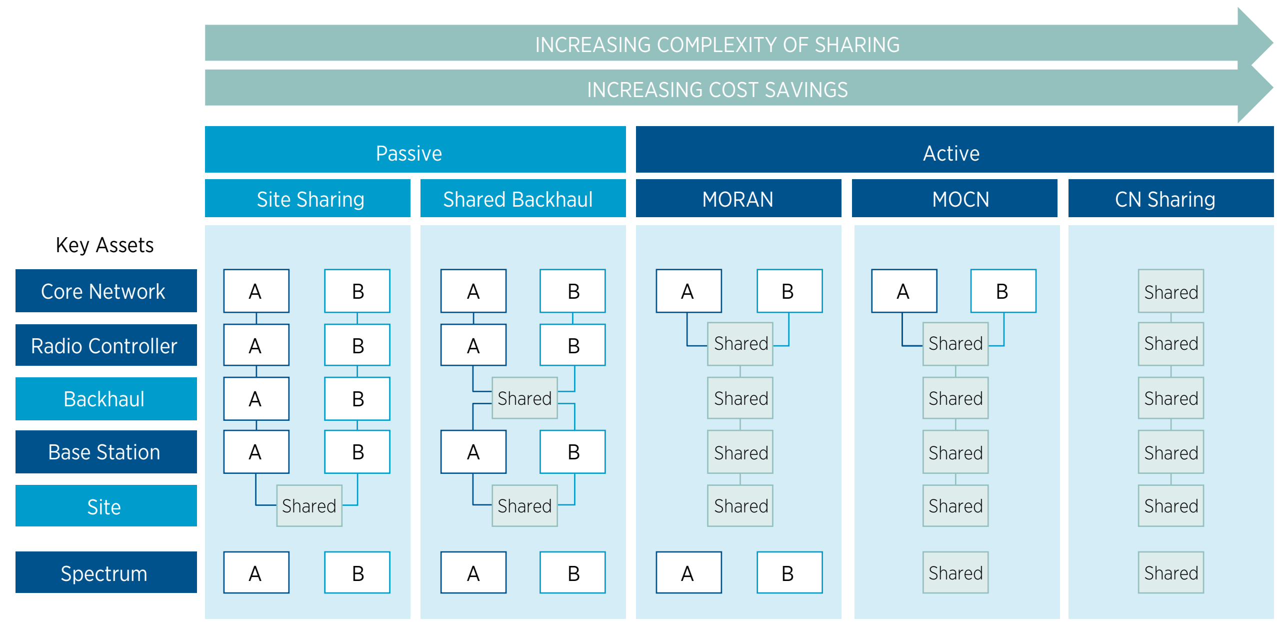
At the macro scale, many operators across the world will, most certainly, embark on more infrastructure sharing for 5G. This is expected given that many operators have achieved capex and opex savings from infrastructure sharing in 2G, 3G and 4G networks. The GSMA has detailed operator case studies showing capex and opex savings of up to 50% on shared infrastructure. The format of 5G era infrastructure sharing will follow the same pattern since in earlier versions of infrastructure sharing as shown in Figure 4.8.2.

The benefits of infrastructure sharing must be contrasted against the risks of hindering infrastructure competition that has served the industry so well. Two clear risks must be addressed. First, infrastructure sharing should not create a disincentive for operators to invest in providing adequate coverage to customers across all environments. Secondly, the need for resilience in 5G era networks means that network redundancy will remain a key consideration to assure overall system resilience.

As such, while some governments (e.g. South Korea[82]) are being proactive to encourage infrastructure sharing for 5G, it is important that governments have a regulatory framework that allows voluntary sharing of infrastructure among operators.

FIGURE 4.8.2

TECHNICAL CLASSIFICATION OF INFRASTRUCTURE SHARING



82. https://www.mobileworldlive.com/asia/asia-news/korea-operators-to-build-shared-5g-infrastructure/

4.8.2.1 Trends in infrastructure sharing

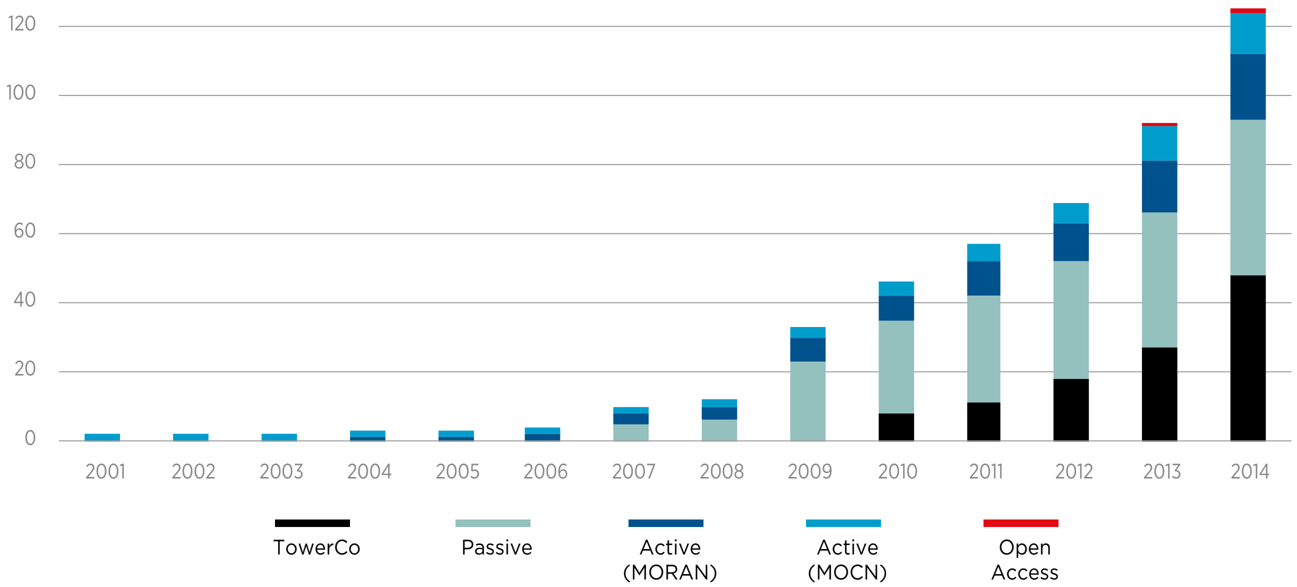
With densification of networks from 2G to 4G, more operators have adopted infrastructure sharing. Accordingly, infrastructure sharing has rapidly accelerated in recent years, growing from 12/15 publicly announced deals in 2008 to 120/125 deals in 2014, according to data from Coleago (see Figure 4.8.3).

The scope of deals has changed to passive infrastructure sharing and sharing of spectrum along with RAN (MOCN) is slowly but steadily increasing. The most prominent trend since 2010 is emergence of tower companies, where tower companies own, deploy and operate the infrastructure that tenant operators lease.

An obvious observation is that passive infrastructure sharing is gaining traction and that sharing of spectrum along with RAN (MOCN) is slowly but steadily increasing.

FIGURE 4.8.3

CUMULATIVE INFRASTRUCTURE SHARING DEALS (SOURCE: COLEAGO)



4.8.3 Neutral Host: Single Wholesale Networks (SWN)

Macro scale SWNs are tantalising but dangerous

A recurring question, given the merits of infrastructure sharing, is whether to combine all the networks into a Single Wholesale Network (SWN) or to build a single greenfield 5G network. This approach would reject the infrastructure competition model at a time when most countries have three operators and there is little enthusiasm to return to a single operator market.

For 5G, some governments have either publicly (e.g. US) or privately called for an SWN to ensure fast rollout of 5G. These would be built using some form of public-private partnership. Some other ecosystem players, e.g. tower companies, are also exploring moving up the chain to deploy their own, and operate 5G neutral hosts.

The GSMA has evaluated SWNs or Wholesale Open Access Networks (WOAN) extensively and noted that while the stated vision and goals are often ambitious, turning the vision into reality is difficult[83]. Experience from Rwanda (deployed an WOAN), Kenya, Russia, Mexico, South Africa and USA (SWN or WOAN considered), indicated a number of challenges and unmet targets. These include affordable price targets, lack of competition and challenges with hitting coverage targets.

4.8.4 Aerial networks (incl. LEO satellites)

Technology feasibility is clearer but economic viability is as yet unproven

There is a clear rationale for aerial networks. Given their elevated altitude, they can provide coverage for a much larger footprint, above and beyond what can be covered using terrestrial networks (see Figure 4.8.4). There is now improved technology (e.g. better launch rockets) and more funding for LEO satellites and drones (e.g. OneWeb and SpaceX plan to more than double to number of LEO satellites to over 20,000 by 2027, according to CelesTrak SATCAT[84]).

However, it is less clear how these systems can be commercially viable (cf. the commercial challenges of previous LEO constellations such as Iridium and Globalstar). For example, internal documents from SpaceX suggest a target ARPU of $62.50[85]. But GSMA Intelligence data indicates only Bahamas had an ARPU higher than $50 globally in 2018. IoT might be an option, focusing on verticals that need geographic coverage (e.g. driverless cars); require unit tracking across large distances (e.g. military vehicles, commercial trucking, shipping); or that operate in remote areas out of reach of land-based networks (e.g. offshore oil rigs, mining pits).

Aerial networks already act as partners or competitors to operators. As partners, they support operators to reach remote/rural areas at a lower cost, or fill in the gaps to address gaps in coverage for some verticals (e.g. connected cars).

83. https://www.gsma.com/spectrum/woan-report/

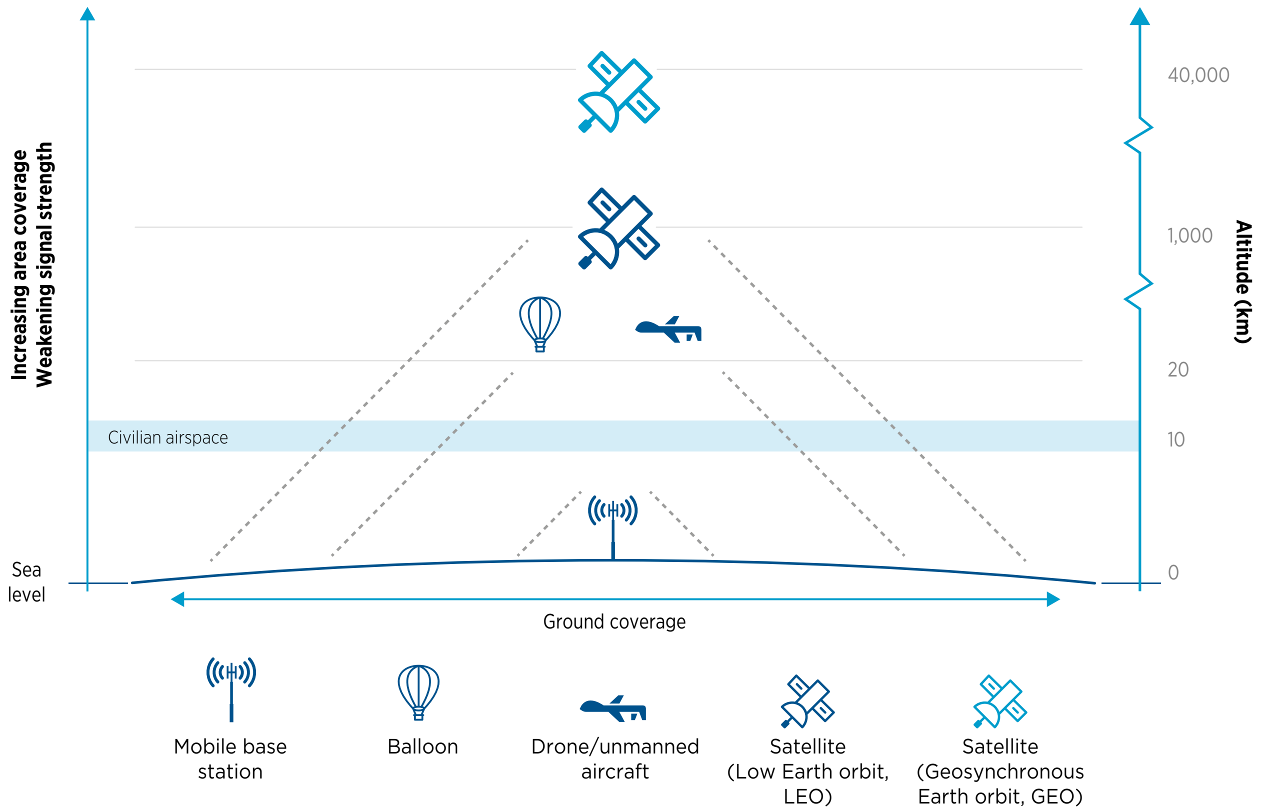
84. https://www.economist.com/briefing/2018/12/08/satellites-may-connect-the-entire-world-to-the-internet

85. https://www.gsmaintelligence.com/research/?file=b30810aee2588382d0b0d3b1302da031&download

FIGURE 4.8.4

AERIAL NETWORKS – WIDER AREA COVERAGE, WEAKER SIGNAL, LOWER CAPACITY

(SOURCE: GSMA INTELLIGENCE)



4.8.5 Neutral Host: hotspots & 5G corridors

Aesthetics, environmental and financial drivers for neutral hosts for 5G hotspots

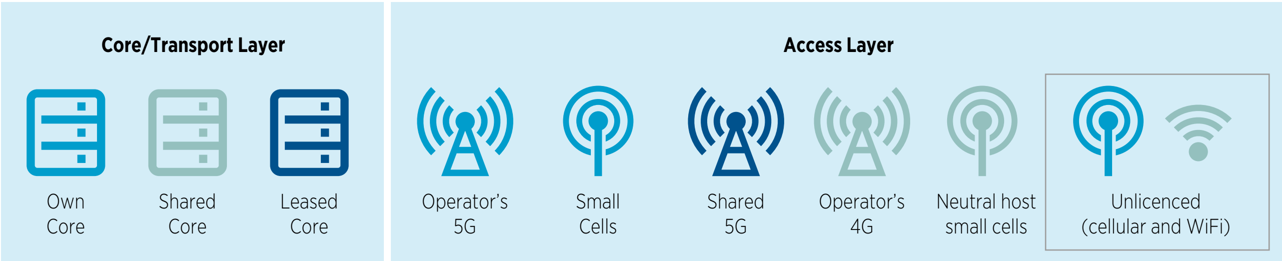
The need to provide ample capacity in hotspots or 5G corridors, with the option to use mmWave spectrum, means that small cells will be much more prevalent in the 5G era. Such small cells will often be deployed on public infrastructure such as lamp posts, bus shelters, or in the premises of large enterprises such as stadia and railway stations.

Given that many countries have at least three operators, it may be both physically difficult and aesthetically challenging to install multiple small cells on such infrastructure. As such, there is a need for broad industry discussions to determine the best way forward. For example the public sector or a private organisation can install a single neutral infrastructure on the lamp post and lease the access to it to all operators. They may also take form in public-private partnership, where the public sector may fund the deployment/operation of the network to assist the operators and enhance the quality of network infrastructure regionally.

Neutral host systems or Distributed Antenna Systems (DAS) are likely to become more popular for 5G hotspots (e.g. stadia, airports) and corridors (e.g. railway lines, motorways). Figure 4.8.5 shows the different combinations of own and shared infrastructure in a 5G system.

FIGURE 4.8.5

A NEUTRAL HOST SMALL CELL SYSTEM



4.8.6 Private 5G networks

Private networks will proliferate in the 5G era; operators need to consider how to support them

An enterprise providing a neutral host for a hotspot could decide to own the network and where possible, own or share the spectrum as well, creating a private 5G network. This is possible because 5G will be the first mobile technology generation to be designed from the outset to support unlicensed, shared[86] and traditional licensed spectrum. This means that owning licensed spectrum will no longer be a barrier to mobile network operation.

As a result, the introduction of 5G could create opportunities for new players to enter the market to provide private cellular services on a local scale. One estimate is that $5 billion will be spent on private mobile networks per year by the end of 2021[87].

There is an opportunity for operators to run private networks targeted for key enterprise customers, or to sublet licensed spectrum to them. This can be used to turn a cost (network densification to serve indoor customers) into an opportunity. However, enterprises may also seek to rollout their own private 5G networks, either directly or through partners[88]. These include private venues, utility companies, port authorities and manufacturers who may want to deploy cellular-based IoT solutions and other broadband communications.

86. Unlicensed spectrum includes the 2.4 GHz and 5 GHz "Wi-Fi" bands. Shared spectrum is typically a band that is occupied by an incumbent but that is made available to others in areas and at times when it is not being used (e.g. a prominent example is the US' CBRS sharing plan in the 3.5 GHz band.)

87. According to an SNS Telecom & IT study (2017)

88. E.g. German Industry wants to setup their own 5G networks & several US companies/groups are campaigning to the FCC for terms which will suit private mobile networks in the 3.5 GHz band.

4.8.7 Wi-Fi: the road to Wi-Fi 6

An improved Wi-Fi may be regarded as a complement to 5G small cells and private networks

For enterprises requiring a private 5G network on their premises, an improved Wi-Fi could be a complementary solution. Owing to the use of licensed spectrum, cellular systems can efficiently manage interference and provide mechanisms to deliver quality of service with high reliability and predictability especially in controlled environments such as a campus network. Conversely, currently adopted Wi-Fi solutions rely on unlicensed spectrum and have a much less developed quality of service framework, making these systems inherently unable to offer guaranteed services.

But these considerations will change as Wi-Fi 6 (previously known as 802.11ax) debuts in the market from around 2020. Wi-Fi 6 becomes the first Wi-Fi standard to adopt OFDMA (Orthogonal Frequency Division Multiple Access), a technology also adopted in LTE that will vastly increase the efficiency and quality of the data link, especially in dense deployments.

Given that the vast proportion of traffic in most developed markets flows through Wi-Fi, and the expectation that these will migrate to cellular in the search for higher quality, an improved Wi-Fi 6 could impact the cost dynamics for 5G small cells and private networks.

4.8.8 Bring-Your-Own-Small Cells (BYO-Small Cells)

Customers already bring their own Wi-Fi. Should they bring their own Small Cell?

As private networks proliferate in the 5G era for use in enterprise settings, it raises the prospect of a future for Bring-Your-Own-Small Cells (BYO-Small Cells) for residential premises.

The potential for BYO-Small Cells is that it begins to transfer responsibility for indoor coverage from operators to customers. Some variant of this model has already been unsuccessfully tried with earlier generations of femtocells. However, neutral host small cells and advances in self-organising networks could provide the breakthrough.

For cellular networks this could be the radio engineer's nightmare, but it is the model for Wi-Fi for many residential users. It is also the model for most other utility services (e.g. electricity, gas, fixed telephone/broadband) where the responsibility for the service provider ends at the boundary of the premises and the customer is responsible for internal wiring/piping.

4.9 Network Equipment Sourcing

KEY TAKEAWAYS

- The disaggregation of software from hardware and the decoupling of layers of the network should enable more players to become network equipment suppliers to operators.
- In practice, operators require carrier-grade performance for hardware and software and this could limit the number of OEMs that are able to provide the requisite accountability and performance assurances.
- Open source supply could offer new opportunities for innovation and cost reduction, but operators will need to adapt their approach to the very different philosophy of open source organisations.
- It will be important to establish well defined liability boundaries for service assurance in the disaggregated model and adapt operational procedures accordingly.

4.9.1 Open Source for flexibility: a dose of realism

In running carrier-grade networks, reliability and accountability are more important than flexibility

In theory, the disaggregation of software from hardware and the decoupling of layers of the network should enable more players to become network equipment suppliers to operators. This will bring more competition and lower prices into the ecosystem. For example, Mavenir notes that an operator with 10,000 cell sites would be paying less than 10% for COTS hardware and software licences for Baseband Unit (BBU) when compared to purchasing dedicated BBU appliances.

Adopting open architecture solutions can also provide operators with significant cost reduction through the use of open source and white-boxes as a supply alternative, or by using standardised interfaces (e.g. from Open RAN). This is especially true if the operators invest in or possess the engineering capabilities/resources to understand the knowledge of virtualization.

In reality, it is a big unknown if the decoupling of layers would bring as many new players to the ecosystem as expected and if this will lead to realisable cost savings over the long term. Operators require carrier-grade performance for hardware and software. But not many OEMs will be able to meet the performance requirements and not many are well capitalised (financially) to provide the requisite accountability and performance assurances.

Likewise, initial cost savings from outsourcing could be undone by complexities from hard-to-troubleshoot hardware and software, plus the need to maintain the engineering capability to deal with continuously changing configurations.

4.9.2 New lock-in phenomenon

The risk of vendor lock-in remains and operators must remain vigilant

Traditional OEM business model is based on a tightly integrated product where dedicated hardware appliances, licences for the software running on it and maintenance/support are sold, integrated and maintained as a package by the vendor.

However, the decoupling of layers does not mean that operators would no longer experience lock-in to a few vendors. Whilst it is true that operators would be able to extricate themselves from the lock-in of siloed products provided by traditional equipment vendors, operators are likely to experience lock-in to specific vendors in each layer.

For example, an operator would get most of its hardware from IT hardware firm A while software for control plane functionality would mostly rely on a software firm B. In each of these domains, the expectation of carrier-grade requirement limits the number of vendors that can participate in the ecosystem and only few vendors would be able to deliver the quality and support in the scale that operators require.

It is also important to highlight that there could be a lock-in to specific open source solutions when adopting open source de-facto-standards. The risk of lock-in grows if implementations rely on any specific solutions that prevents its interoperability with other elements not included in the open source project (e.g. CORD).

4.9.3 Mobile operators as system integrators

Operators will either outsource to a single vendor or need an 'army of engineers' to integrate the different open source hardware and software

With disaggregation of hardware and software, however, vendors will be focused on developing either software or hardware, and the integration of hardware and software will be, in most part, the responsibility of the operator. This is important to assure service recovery in the event of a network failure. For example, in the case of network fault, it would be difficult to identify the root cause and, crucially, where liability lies, as the number of possible combinations of hardware and software increases drastically. Even if the vendors have the responsibility for troubleshooting, it will take significant time to identify which vendor would be responsible for the cause.

Operators will, therefore, have to make a choice between becoming the integrator of the system or delegating the integrator role completely to one single capable vendor. For the former, operators will need to maintain "an army of IT and telecoms engineers" to perform and manage the integration in-house. For the latter, the operator will be establishing a "managed services" contract with the single vendor to operate and troubleshoot the network.

4.9.4 Proliferation of open source organisations

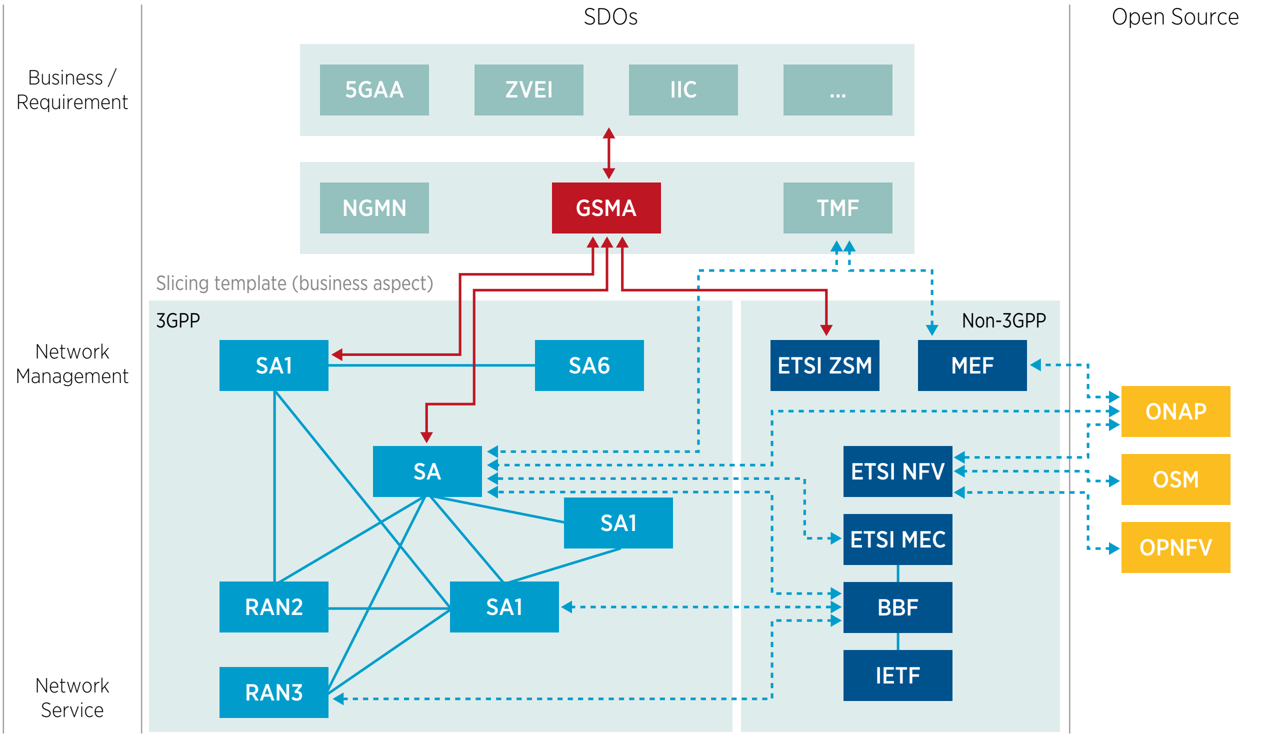
The standardisation landscape is becoming too fragmented

An important consequence of softwarising the network is that more organisations are involved in the standardisation landscape. Whereas traditional networks required standards from 3GPP, ETSI, IETF, BBF and sometimes IEEE to be implemented, the new network technologies required for disaggregation of software from hardware are standardised and developed in many other organisations.

Figure 4.9.1, for network slicing, is an example of the proliferation of new standardisation groups in ETSI (e.g., ETSI MEC and ETSI NFV) and various open source organisations. Consequently, tracking the progress of relevant organisations, studying the specifications/code and representing the operator's opinion in the organisations will become more complex and costly.

FIGURE 4.9.1

NETWORK SLICING STANDARDIZATION LANDSCAPE



4.9.5 Engaging and leveraging open source organisations

Operators need to adapt fast to the very different philosophy of open source organisations

There are four clear philosophical differences between the traditional standardisation approach and the open source approach.

4.9.5.1 Focus on implementation

Open source organisations focus on implementations. Whilst documents and specifications can be drafted to guide users of the technology, the ultimate form of contribution in open source organisations is lines of code and merely submitting requirements/requests does not drive the organisation forward. Also, while in the more traditional Standards Defining Organisations (SDOs), meaningful changes can only be realised through technical contributions (e.g., change request to technical specifications). Therefore, to drive open source organisations, operators need to possess the engineering capability to be able to interpret open source codes and to contribute code to the open source organisations.

4.9.5.2 Product liability

Open source organisations are not liable for the technology developed. Although purchase of licences may be required depending on the policy of the organisations, the open source organisations usually do not take responsibility for fault and issues that arise from the implementation of its technology in commercial networks. This means that mobile networks need to maintain engineering capability to verify the implementation and understand the open source codes to the extent that troubleshooting is feasible.

4.9.5.3 Changeability of code

The power of open source lays in the possibility for the user (i.e. the mobile operator) to make any changes to the code that is deemed necessary. It is probably only a handful of operators in the world that possess the skills and resources necessary to be able to leverage this asset: for most operators, the nature of the source code in their equipment (open or closed) will be immaterial.

4.9.5.4 Proliferation of organisations

As can be seen in the network slicing standardisation landscape, there are many organisations that develop the technology overall and coordination is necessary to maintain coherent and consistent development of technology. Therefore, the coordination of various SDOs and open source organisations is necessary. This would also minimise the potential issues that open source implementations may generate that would be problematic to resolve. Operators would have to coordinate these various standardisation organisations along with open source organisations by sending delegates and making relevant contributions.

4.10 Capex and Opex evolution

KEY TAKEAWAYS

- **There is no industry consensus for a major bump in capex for the 5G era and the funding envelope is expected to remain similar to 4G.**
- **Exponential growth in data traffic is the biggest 5G opex driver.**

4.10.1 5G Capex evolution

5G era capex will be incremental, with no significant bump for 5G

Having explored the cost considerations in this chapter, it is clear that, 5G is, and should be, targeted to be cost effective. Therefore, there is no industry consensus for a major bump in capex for the 5G era and the funding envelop is expected to remain similar to 4G.

This conclusion derives from several industry research studies, sentiment analysis from major global network vendors and mobile network operators, which largely conclude the use cases of 5G will revolve around eMBB in the early 5G era. Consequently, the expectation is that 5G era capex will grow incrementally, given that 5G capacity would be deployed incrementally, when and where needed, through this forecast period (2018-2025).

In most markets, capex will grow progressively, in line with operator revenue growth, rather than requiring a 'big bang' and will vary by operator/region due to varying levels of business maturity.

These considerations form the basis of the assumption used for the GSMA's hypothetical 5G business case model that is described in Chapter 5.

4.10.2 5G Opex evolution

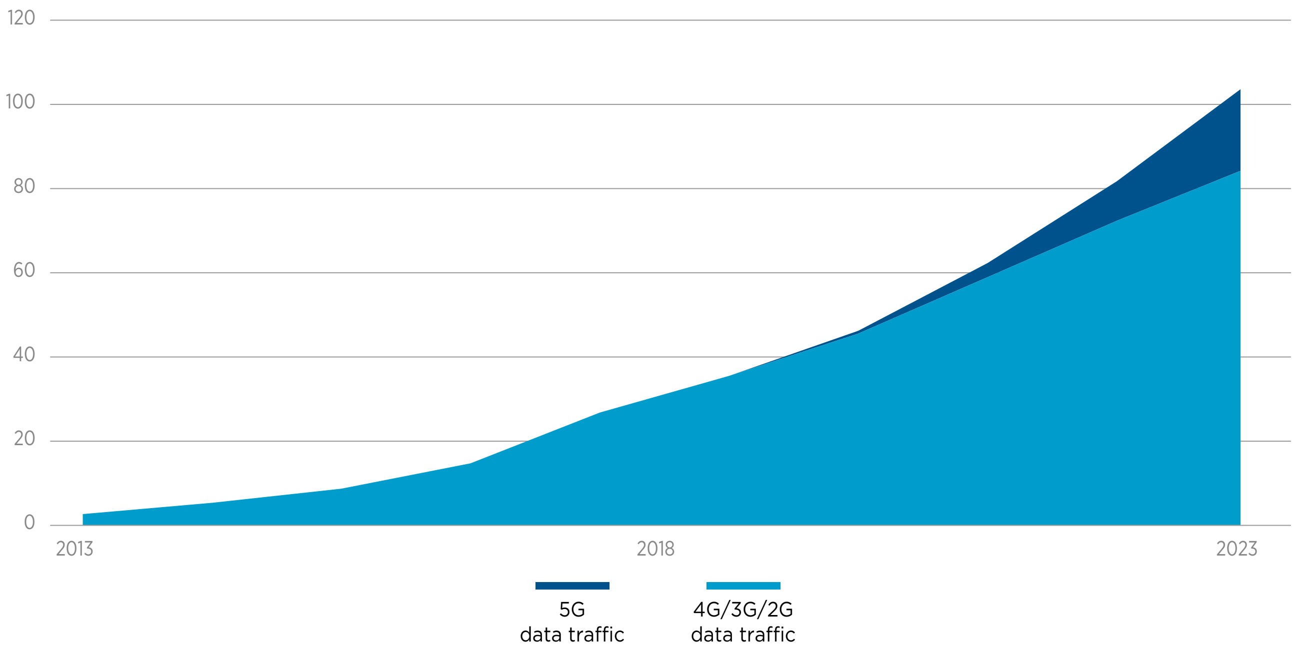
Exponential growth in data traffic is the biggest opex driver

Mobile network opex has been stubbornly high in recent years, whilst it is essential to the 5G business case that it falls. An Analysys Mason survey suggests that operators are seeking a 30% reduction in opex by 2025[89]. Yet, there is no single solution that will achieve this and operators will need to rely on a combination of tactics to deliver savings on this scale in the 5G era.

The most significant opex driver is the exponential growth in mobile data traffic. In Ericsson's latest Mobility Report, total mobile data traffic is expected to increase almost eight-fold by the end of 2023 (see Figure 4.10.1), with a CAGR of 39%. At that time, it is expected that 20% of global mobile data traffic worldwide will be carried by 5G networks, and the figure will be much higher in regions with early 5G deployments. This is 1.5-times more than the total of 4G/3G/2G traffic today.

FIGURE 4.10.1

GLOBAL MOBILE DATA TRAFFIC GROWTH (SOURCE: ERICSSON)



With the increased demand putting strain on network components and infrastructure, operators must realise a pragmatic and efficient approach to running networks. Network transformation strategies, with energy being a core focus, will be key to ensuring efficiencies. This assumption applies to the GSMA opex forecast for operators in developed or high/middle income countries but also Asia Pacific, where data consumption is expected to reach over a quarter of the global total.

Similar to the capex, these opex considerations form the basis of the assumption used for the GSMA's hypothetical 5G business case model that is described in Chapter 5.

89. http://www.analysysmason.com/Research/Content/Reports/5g-opex-strategy-rma16/

5 Business Case Considerations – Hypothetical Model

Chapter 5 examines the overall business case for 5G using GSMA scenario analysis across a number of different geographies and operator archetypes.

Readers will gain insight into how different rollout strategies will impact the overall economics of 5G.

Chapter 5 - including the model, scenarios and archetypes that inform it - is a general guide developed exclusively by the GSMA and does not make reference to any specific geographic market or operator.

Its cost and revenue assumptions have been developed using publicly available sources only. Neither the model, nor its constituent parts, have been validated by any operator or vendor.

The model is basic and does not include several major cost considerations such as spectrum, licensing conditions, impact of planning laws etc.

Accordingly, the model does not represent nor make reference to concrete plans or views of specific operators. In the same vein, the model cannot nor should be used to establish a benchmark regarding any particular operator.

Use of the model is at the user's discretion and, save for the changeable levers included in it, any modification of the model is forbidden without an explicit written permission from the GSMA.

5.1 5G Business Case Model: Setting the context

KEY TAKEAWAYS

- The GSMA 5G business case model supports operators in identifying the relevant elements to be taken into consideration in their decision making process about the type of investment they want to make in 5G networks.
- The model examines the business case to deliver at least a 5% increase in revenue and a 40% share of the revenues from enterprises.
- It is built for 8 operator archetypes in developing and developed regions, plus three deployment scenarios to reflect the speed of 5G rollout.

5.1.1 The objective for the model

The model will support operators on the question of: "How fast should I rollout 5G?"

Given the extensive analysis in the previous chapters of the book, the GSMA believes that 5G is inevitable: it is only a question of when, rather than if, operators will deploy 5G. Accordingly, the two pertinent question for operators to consider in their 5G rollout are:

1. When should I start 5G rollout?
2. How should I roll out 5G?

For the 'when' question, the economic, social and political drivers that will influence when an operator commences 5G rollout were explored in Chapter 2.

In particular, the BEMECS 5G Readiness framework provides a framework for identifying and evaluating the economic and market conditions that are favourable for commencing a 5G rollout.

For the 'how', the GSMA has developed this model to assist operators in evaluating if their unique operational realities can support a rapid 5G deployment or if 5G should be rolled out gradually in an evolutionary approach.

5.1.2 The objectives behind the model

The model sets the business case to deliver at least a 5% increase in revenue and a 40% share of the revenues from enterprises

Operators will have their own set of objectives to justify their 5G rollout plan. However, throughout the engagements with operators and other stakeholders, three particular objectives emerged.

First, given the challenges of low revenue growth for operators, a meaningful increase in revenue attributable to 5G will be expected. A 5% revenue increase mark is used in the model as the pragmatic and realistic minimum expectation for the 5G era.

Second, given the maturity of the consumer market, it is expected that the enterprise segment will drive the incremental 5G opportunity for many operators. Most operators do not currently get up to 20% of their revenues from the enterprise segment. However, if the enterprise 5G use cases (e.g. based on the Ericsson market sizing) are realised, an average operator could earn 40% of its revenues from the enterprise segment. The 40% share of revenues from enterprises is therefore used in the model as an optimistic expectation for the 5G era.

Third, the model has been designed with the assumption that the cost intensity (ratio of cost to revenue) will be unchanged into the 5G era. This means that there will be no extra capex for 5G, unless it is matched by a corresponding increase in revenues.

5.1.3 Methodology for the model

There are eight operator archetypes and three deployment scenarios in the model

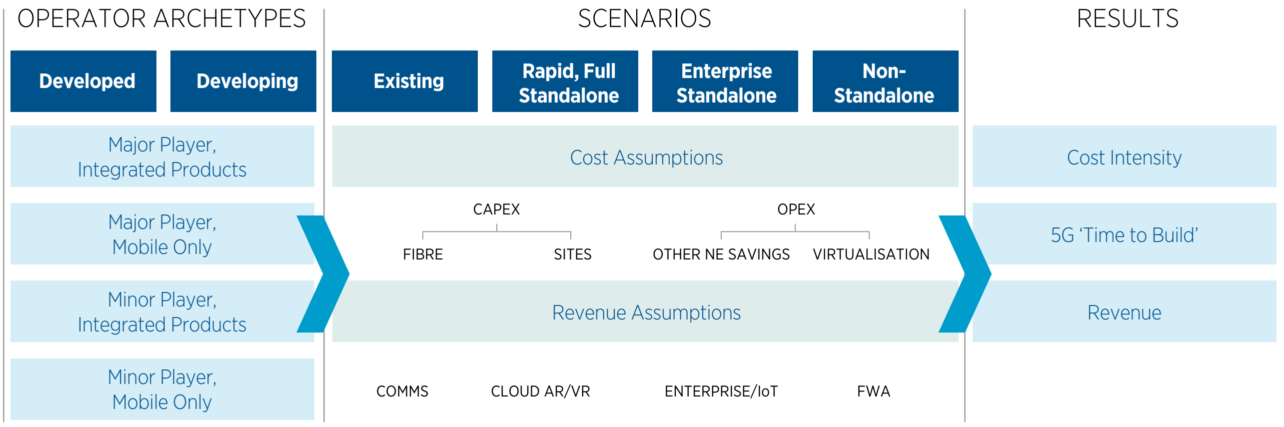
The model provides a stylised study of potential costs and projected revenues for select deployment options, or types. It sets eight operator archetypes in developing and developed regions, in three deployment scenarios that reflect variances in target segments and speed of 5G rollouts. The model combines existing and historical operator/market data (GSMAi, other) with additional 5G cost and revenue assumptions.

The model takes a stylised high-level scenario based approach in considering potential cost and revenue implications. The GSMA objective for this model is to provide an indicative support to operators in their own 5G business case modelling, rather than outline a specific, local and granular economic study.

Figure 5.1.1 provides a high level overview of the business case model developed by the GSMA.

FIGURE 5.1.1

HIGH-LEVEL STRUCTURE OF THE 5G BUSINESS CASE MODEL



5.2 Archetypes & Deployment Scenarios

KEY TAKEAWAYS

- The operator archetypes modelled are:
  - Major Player, Integrated Products
  - Major Player Mobile Only
  - Minor Player, Integrated Products
  - Minor Player, Mobile Only
- The deployment scenarios are based on the speed and purpose of the rollout:
  - Deployment Option A: Rapid, full scale deployment
  - Deployment Option B: Enterprise focused deployment
  - Deployment Option C: Capacity optimisation deployment

5.2.1 Operator archetypes

There are four different operator archetypes in the model and these are explored for both developed and developing regions

The model simulates the cost and revenue implications of three particular rollout scenarios for four operator archetypes, in both developed and developing regional contexts (see Figure 5.2.1). The purpose of including these is to evaluate the core considerations for operators regionally and locally, whilst attempting to represent as many GSMA operator members as possible.

FIGURE 5.2.1

OPERATOR ARCHETYPES FOR THE 5G BUSINESS CASE MODEL

Developed	Major Player, Integrated Products	Minor Player, Integrated Products
	Major Player, Mobile Only	Minor Player, Mobile Only
Developing	Major Player, Integrated Products	Minor Player, Integrated Products
	Major Player, Mobile Only	Minor Player, Mobile Only

5.2.1.1 Major Player, Integrated Products

An incumbent operator with market share (of subscribers) of more than 25% in its operating country; product portfolio consists of integrated products such as strong fibre products and bundled services.

5.2.1.2 Major Player Mobile Only

An incumbent operator with market share of over 25% in its operating country; products and services consist of core mobile only

5.2.1.3 Minor Player, Integrated Products

An operator with market share less than 25% in its operating country; product portfolio consists of integrated products such as strong fibre products and bundled services.

5.2.1.4 Minor Player, Mobile Only

An operator with market share under 25% in its operating country, products and services consist of core mobile only.

5.2.2 Deployment scenarios

The deployment scenarios are based on the speed and purpose of the rollout

The model sets three deployment scenarios to outline the approaches an operator could take based on its expectations for speed and purpose of 5G rollout. These scenarios are identified using industry expertise, operator survey data and historical studies related to previous generation rollouts.

The three deployment scenarios evaluate the investments/costs and revenue projections for the first five years of commercial launch of 5G. For these, the main top-level levers are the degree of investment in new sites and fibre backhaul; the urban vs. rural split; and the incremental ARPU from 5G era use cases.

Figure 5.2.2 summarises the key assumptions for the three deployment scenarios.

FIGURE 5.2.2

THREE 5G DEPLOYMENT SCENARIOS

A RAPID FULL-SCALE DEPLOYMENT	B ENTERPRISE FOCUSED DEPLOYMENT	C CAPACITY OPTIMISATION DEPLOYMENT
• 60% of 5G Subscribers impacted • 3GHz to 60% Urban sites; 40% Rural • No fall back to 4G • 100% Fibre • No site sharing, full virtualisation, no Network Economic savings • ARPU – Access only scenario and Full Service scenario	• 40% of 5G Subscribers impacted • 3GHz to 40% Urban sites • Fall back to 4G • 60% Fibre • Private partnerships site sharing; full virtualis-ation, limited Network Economic savings • ARPU – 30 - 40% Enterprise Revenue split (i.e. growth by 40%) by year 5	• 20% of 5G Subscribers impacted • 3GHz to 20% Urban sites; 20% Rural • Fall back to 4G • 40% Fibre • Part virtualisation; Network Economic savings (Infrastructure share, backhaul, energy) • ARPU – Access only scenario and Full Service scenario

5.2.4.1 Deployment Option A: Rapid, full scale deployment

For Option A, the model applies the estimates associated with the rapid build out of a 5G network which is independent of 4G systems and includes a new 5G core. This scenario will be the most investment-heavy for operators to consider, with assumed higher number of new sites, site upgrades and fibre investment.

5.2.4.2 Deployment Option B: Enterprise focused deployment

For Option B, the model explores the hypothesis that an enterprise targeted (SA) 5G deployment, supportive of enterprise specific use cases, can generate return on investment and/or does not deviate vastly from a sustainable cost intensity. This option still assumes a 5G core, but uses a lower level of infrastructure investment relative to Option A, but greater than Option C.

5.2.4.3 Deployment Option C: Capacity optimisation deployment

For Option C, the model starts with the assumption that initial 5G launches will focus on capacity and coverage enhancements for eMBB. Many elements of this 5G rollout build on 4G networks, rather than representing a complete departure, and that means operators can take an evolutionary approach to infrastructure investment.

Operators taking this approach may begin by upgrading the capacity of their existing 4G macro network by refarming a portion of their 2G and 3G spectrum, or by acquiring additional 5G spectrum when available. This way, they can align investments in 5G by also evolving to LTE and LTE-Pro features, such as 4x4 or massive MIMO.

5.3 Cost Model – Assumptions

KEY TAKEAWAYS

- **Key capex assumptions:**
  - **5G networks will require a much higher capillarity of fibre to meet capacity and latency requirements**
  - **5G will require a much denser network**
  - **Spectrum is a major capex consideration for operators when deploying 5G**
- **Key opex assumptions:**
  - **Savings from virtualisation in the IT industry suggest that operators could achieve similar benefits**
  - **Energy efficiency and backhaul relief will provide additional Opex savings**

5.3.1 Cost mechanics

Cost considerations for the 5G era will apply to both capex and opex

The model evaluates the major levers that drive the capex and opex dynamics in a 5G buildout. It provides a high-level calculation across the core scenarios of 5G commercial rollout based on an itemised list of cost levers. The purpose is to highlight potential cost differences between three rollout scenarios, for varying archetypal operators in the '5G era'. Figure 5.3.1 provides a summary of the major cost levers for the model, which are assessed in detail below.

FIGURE 5.3.1

SUMMARY OF THE CAPEX AND OPEX ASSUMPTIONS FOR THE MODEL

	CAPEX		OPEX (Cost Savings)		
	Fibre	Sites	Site Sharing	Virtualisation	Other NE Savings
(A) Rapid Full Scale Deployment	Fibre to 100% of sites	5G (3GHz) site upgrade costs; 60% of Urban sites; 40% Rural	None	Full – 100% of network	–
	Assumed Cost per site	3GHz new sites – 200% growth in Urban sites; 100% in rural			–
		Densification (Small Cells)			–
(B) Enterprise Focused Deployment	Fibre to 60% of sites	5G (3GHz) site upgrade costs; 40% of Urban sites; 5% Rural	Private Partnerships	Full – 100% of network	Backhaul – 10%, per site
	Assumed Cost per site	3GHz new sites – 100% growth in Urban sites; 50% in rural	30% site sharing reduction		Energy – 10%, per site
		Densification (Small Cells)			
(C) Capacity Optimisation Deployment	Fibre to 40% of sites	5G (3GHz) site upgrade costs; 20% of Urban sites; 20% Rural	60% site sharing reduction	Part – 50% of network	Energy – 20%, per site
	Assumed Cost per site	3GHz new sites – 20% growth in Urban sites; 10% rural			Backhaul – 20%, per site
		Densification (Small Cells)	Cumulative Opex saving of 30-40%*, per year		

5.3.2 CAPEX

5.3.2.1 Fibre

5G networks will require a much higher capillarity of fibre to meet capacity and latency requirements

To improve overall network capacity, operators must undertake large-scale fibre efforts to meet the capacity and latency requirements of existing and new cell sites. In particular, fibre is essential to support small cell deployment in urban areas. This invariably requires the use of fibre optics to minimise the time-to-market of massive small cell deployments, a major milestone for the roadmap to 5G.

The model assumes that for deployment Option A, 100% of sites will require fibre, i.e. assuming 20% of existing sites have fibre, another 80% is required; for Option B a total of 60%; and for Option C 40%. These will vary for developed and developing markets and the model accounts for that.

5.3.2.2 Sites

5G will require a much denser network

Network density growth is inevitable and a requirement in 5G, and the level of growth is dependent on data growth demands and anticipated scale of deployment. The model assumes variances in each scenario for:

- 5G 3.5GHz site upgrade costs – assuming 3.5GHz as the 'global' 5G spectrum band, the model includes the anticipated proportion of existing site footprint to be upgraded.
- 5G new sites – the number of newly built 5G cell sites/base stations required to maintain expected coverage and capacity for each given scenario.

5.3.2.3 Spectrum cost considerations

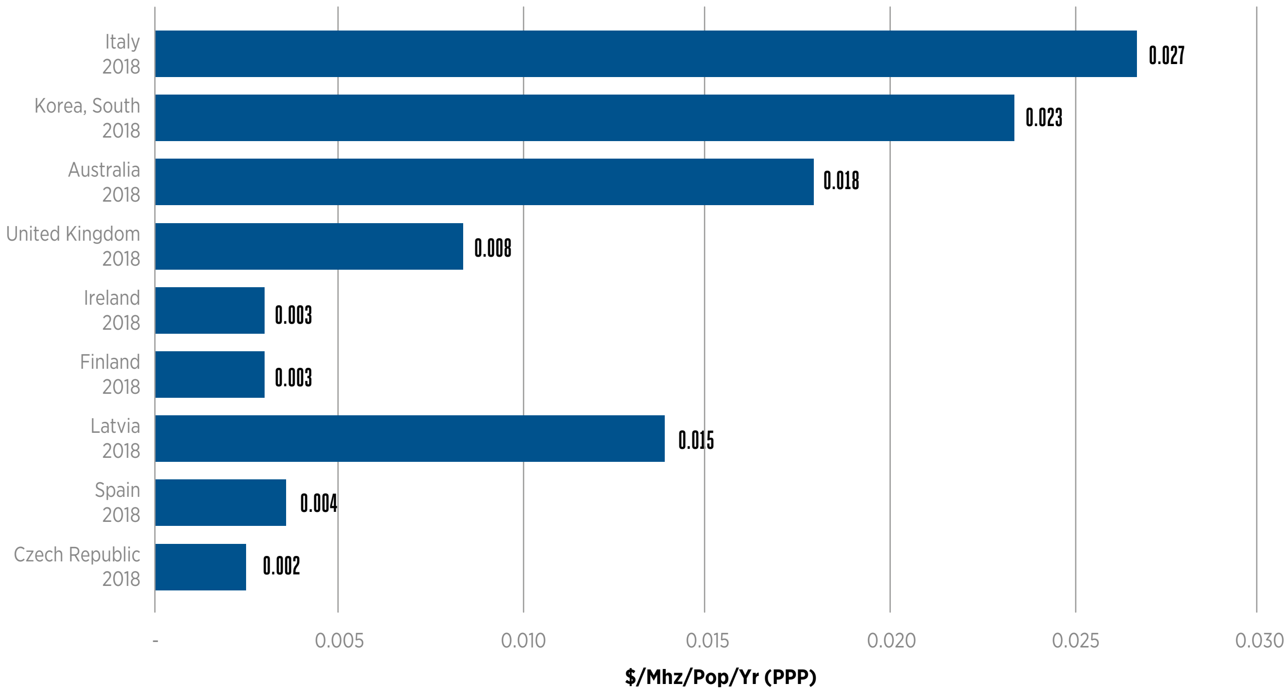
Spectrum is a major capex consideration for operators when deploying 5G

While acknowledging the implication of spectrum prices, this model does not incorporate spectrum costs in the modelling. Spectrum prices vary widely as there are many potential factors affecting them, such as spectrum allocation approaches; reserve prices; spectrum available at the market; 4G coverage; potential newcomers; and much more.

The race for spectrum will continue across high and low bands. Prices for 3.5 GHz used to be very low, but they have been increasing since last year, with the UK auction reaching very high levels. The 3.5GHz band is seen by many as the pioneer band for 5G, hence the increase in interest. As presented in Figure 5.3.2, its auction price varies significantly mainly due to national policy decisions such as the auction design selection.

FIGURE 5.3.2

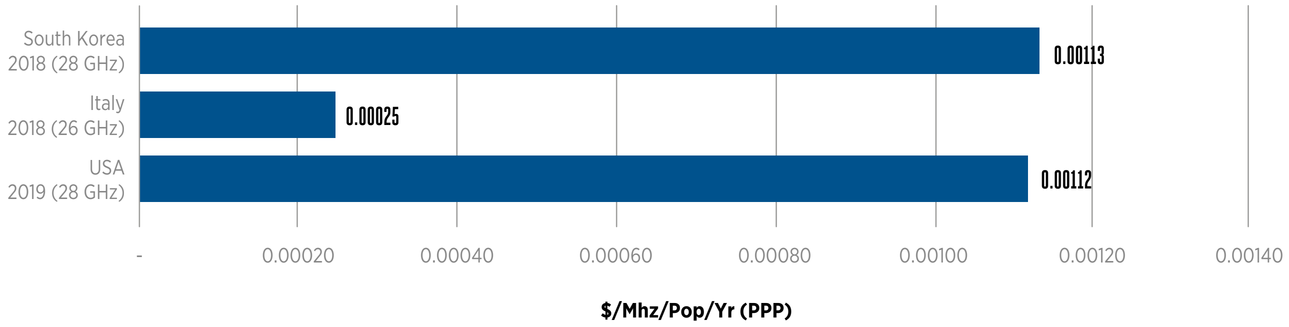
SUMMARY OF THE COST OF SPECTRUM FOR 3.5GHZ (SOURCE: GSMA INTELLIGENCE)



Prices for mmWave have been very low, but there is a risk of them getting higher with the recently completed mmWave auctions in South Korea, Italy or the US. For now, considering prices paid by operators through acquisition is a related indicator in considering spectrum prices for other countries. In the US, Verizon acquired XO Communications for $1.8 billion and Straight Path Communications for $3.1 billion; AT&T paid $207 million for Fiber Tower and spectrum in 39 GHz. Figure 5.3.3 highlights the range of prices paid so far for mmWave spectrum (values for US are provisional as at 1 January 2019).

FIGURE 5.3.3

SUMMARY OF THE COST OF SPECTRUM FOR MMWAVE (SOURCE: GSMA INTELLIGENCE)



5.3.3 OPEX

5.3.3.1 Virtualisation

Savings from virtualisation in the IT industry suggest that operators could achieve similar benefits

According to EMA IT management research, over 70% of organisations report that virtualisation has delivered “real, measurable cost savings.[90]” Virtualisation, especially with sophisticated management, allows significant operational expense savings. 5G networks will present an opportunity for operators to reproduce such benefits.

The model assumes a higher proportion of the network to be virtualised for operators adopting Options A and B. As the demands for the core and RAN stretch its capabilities, operators need to find ways to ensure efficiencies through advancements in technologies required to keep up. The model applies an estimated percentage reduction of average opex per site. This is taken from the GSMA's Network Economics work where the economic impact of various network transformation strategies is modelled.

90. https://www.vmware.com/files/pdf/vmware-solution-opex-reducing-opex-wp-en.pdf

5.3.3.2 Additional OPEX savings

Energy efficiency and backhaul relief will provide additional Opex savings

Recent work within the GSMA's Future Networks Programme has explored and identified significant potential cost savings from energy efficiency and backhaul relief that were incorporated in the model.

Energy efficiency savings can come from either alternative energy sources to take the network off the main power grid and network load optimisation to reduce the energy consumption. The GSMA has identified and estimated average saving of 10-30% per annum in total network opex. This is reused in the model.

Backhaul relief provides operators a means of reducing their opex and capex by minimising the need for incremental spending to expand capacity. This can be achieved by using innovative transport architecture with RAN to cope with the challenges and optimisation of the transport demand. As networks evolve through 4.5G to 5G with more complexity, network densification and intelligence at the edge, the need will be even greater to optimise transport network architecture within mobile RAN to resolve the challenges of backhaul/fronthaul demand and the corresponding increase in cost (Capex and Opex).

The GSMA has identified and estimated an average saving of 20-30% per annum in total network opex for archetypal operators from backhaul relief: this has been applied to the model.

5.4 Revenue Model – Assumptions

KEY TAKEAWAY

- **Incremental revenue growth in the core business will come from new consumer use cases (e.g. AR/VR), enterprise/IoT use cases (e.g. real time automation), and new broadband opportunities (e.g. FWA).**

5.4.1 Revenue mechanics

Incremental revenue growth in the core business will come from new consumer use cases, enterprise/IoT use cases, and new broadband opportunities

The model estimates the upside from new 5G use cases and prioritised (based on extensive research) value creation to capture revenue streams. The model assumes different revenue impacts (or incremental ARPU uplift) dependant on region and archetype, and also by scenario deployment. The focus of the model is on three revenue streams: new consumer use cases, enterprise/IoT use cases and new broadband markets (primarily FWA).

The model relies on these revenue assumptions to estimate:

a) the amount of incremental ARPU uplift for each of the three revenue streams.

b) the amount of revenue required to maintain a sustainable cost intensity.

For example, the model assumes a higher level of incremental ARPU for Enterprise and IoT in the enterprise-focused Option B compared to the capacity-focused Option C. Table 5.4.1 summarises the impact of the main 5G era value opportunities for a Major player, integrated products operator in a developed market.

TABLE 5.4.1

SUMMARY OF THE ASSUMPTIONS FOR THE BEST-CASE INCREMENTAL ARPU INPUTS FOR THE MODEL (5 YEARS POST 5G LAUNCH)

	Base case scenario	Option A (Rapid, full 5G deployment)	Option B (Enterprise focused 5G deployment)	Option C (Capacity optimisation 5G deployment)
		Growth assumptions used in model		
Total 'incremental' ARPU	100%	3.0x	1.9x	1.3x
New Consumer Use cases (esp. Cloud AR/VR)	7.7%	4.2x	2.8x	1.9x
Enterprise Use Cases	87.7%	2.9x	1.8x	1.2x
New Broadband Markets (esp. FWA)	4.6%	3.3x	2.3x	1.8x

5.4.2 New consumer use cases

Cloud AR/VR is the clearest, incremental 5G era consumer opportunity

Operators will continue to seek new consumer use cases, in the 5G era to add to their current portfolio of value added services. This is the direct Business-to-Consumer (B2C) opportunity for 5G and will shape how operators are able to complement and enrich their core mobile broadband proposition.

Amongst all the possible new consumer use cases, Cloud AR/VR is the clearest and, potentially, most lucrative opportunity for operators. Its conceptualisation, architecture and requirement make it reliant on a super-fast, low latency, mobile connectivity.

As such, the model uses Cloud AR/VR as the exemplified consumer use case to drive incremental ARPU in the fifth year post 5G launch. Huawei's *"5G Unlocks a world of opportunities: top ten 5G use cases"* report estimates the market size for Cloud AR/VR by 2025 to be $292 billion. The operator addressable market opportunity will reach more than $93 billion (30% of the total). This is about 8% of overall operator revenue in 2025, giving a potential ARPU increment of $1.60 for a major, integrated operator in a developed market.

5.4.3 Enterprise/IoT use cases

Real time automation is the clearest, incremental 5G era enterprise opportunity

As much of the incremental 5G opportunity will come from the enterprise segment, a clear understanding of the requirements and market opportunity is needed. This opportunity will be best addressed with rollout Options A or B – rapid or enterprise focused 5G deployments.

In *The guide to capturing the 5G industry digitalisation business potential*[91], Ericsson quantified the opportunities from nine application-based clusters, identifying a $204 billion to $619 billion addressable opportunity for operators by 2026. The upper threshold of $619 billion is equivalent to 53% of overall operator revenue in 2026, giving a potential ARPU increment of $10.70 for a major, integrated operator in a developed market.

5.4.4 New Broadband Markets

5G will open up the FWA opportunity

5G promises to unlock the FWA opportunity for operators, thanks to its ample capacity. This is a major development for operators, because 5G will provide competing broadband technology that can match or better some fixed broadband options.

SNS Telecom reports in *5G for FWA: 2017 – 2030 – Opportunities, Challenges, Strategies & Forecasts*[92] that FWA subscriptions will grow from about $1 billion in 2019 to $40 billion by 2025. This is about 3% of overall operator revenues in 2025, giving a potential ARPU increment of $0.70 for a major, integrated operator in a developed market.

With operators now working towards 5G FWA to provide high speed broadband to residential users, fixed wireless broadband will be a revenue growth opportunity.

91. https://www.ericsson.com/assets/local/networks/documents/report-bnew-18001324.pdf
92. http://www.snstelecom.com/5gfwa

5.5 Model Outputs & Results

KEY TAKEAWAYS

- **The model suggests that the Option C deployment model delivers a 5% revenue uplift with minimal change in the cost intensity.**
- **Unsurprisingly, there are significant increases in capex and opex for the more intensive deployment scenarios (A&B) across both developed and developing markets.**
- **Revenue modelling suggests that incremental revenues across both developed and developing markets will be insufficient in the more intensive deployment scenarios to outweigh the increase in costs.**
- **Option C will deliver the most efficient return on investment of the 5G scenarios assessed across both developed and developing markets.**

5.5.1 High level results

The model suggests that Option C is the optimal deployment model and delivers a 5% revenue uplift with minimal change in the cost intensity

The results presented in this section detail initial simulation from the deployment cost options and value creation models. They attempt to cover all eight operator archetypes, with assumed variations and sensitivities applied for each scenario.

Figure 5.5.1 displays the results for all eight operator archetypes based on the default assumptions. The models supplement this document and are able to be manipulated to suit the users profiling.

Based on the analysis, it is clear that the evolutionary approach will be the natural path for most operators, allowing them to minimise investments while the incremental revenue potential of 5G remains uncertain.

FIGURE 5.5.1

SUMMARY OF OUTPUTS FROM THE 5G BUSINESS CASE MODEL

Country Profile	Operator Archetypes		Measure	Rapid, Full-Scale Deployment	Enterprise Focused Deployment	Capacity Opimisation Deployment
Developed	1	Major Player, Integrated Products	Cost Intensity Change	29%	10%	-4%
			Revenue Uplift	147%	10%	5%
	2	Major Player, Mobile Only	Cost Intensity Change	28%	10%	-2%
			Revenue Uplift	145%	10%	5%
	3	Minor Player, Integrated Products	Cost Intensity Change	47%	19%	-1%
			Revenue Uplift	149%	11%	5%
	4	Minor Player, Mobile Only	Cost Intensity Change	42%	18%	1%
			Revenue Uplift	152%	10%	5%
Developing	5	Major Player, Integrated Products	Cost Intensity Change	35%	14%	-2%
			Revenue Uplift	135%	11%	5%
	6	Major Player, Mobile Only	Cost Intensity Change	29%	11%	-2%
			Revenue Uplift	131%	11%	5%
	7	Minor Player, Integrated Products	Cost Intensity Change	51%	19%	-7%
			Revenue Uplift	111%	11%	5%
	8	Minor Player, Mobile Only	Cost Intensity Change	43%	19%	0%
			Revenue Uplift	130%	11%	5%
				In this column, the percentage used is the increase in Revenue required in Year 5 (from Year 0) for the operator to maintain a sustainable cost intensity level.		

In the model, cost intensity change is defined as:

(Capex + Opex) / (Revenue in year 5) – (Capex + Opex) / (Revenue in year 0)

For Options B and C, revenue uplift is simply defined as the delta between year five revenue and year zero revenue for each operator archetype. For Option A, instead the model calculates the increased amount of revenue the operator is required to generate in order to maintain a sustainable cost intensity (in this simulation the default assumption is that the 'sustainable' cost intensity level is within a threshold of 0-2% of base [year zero] cost intensity).

5.5.2 Cost results

The deployment cost model outputs show the indexed costs estimates for all archetypes and scenarios

Cost results in the model sum total network capex and total network opex.

Where applicable, the cost lines have adjustable parameters which can be toggled to reflect the expectations of the user. The cost line assumptions in the simulations in these results can be found within the deployment cost model.

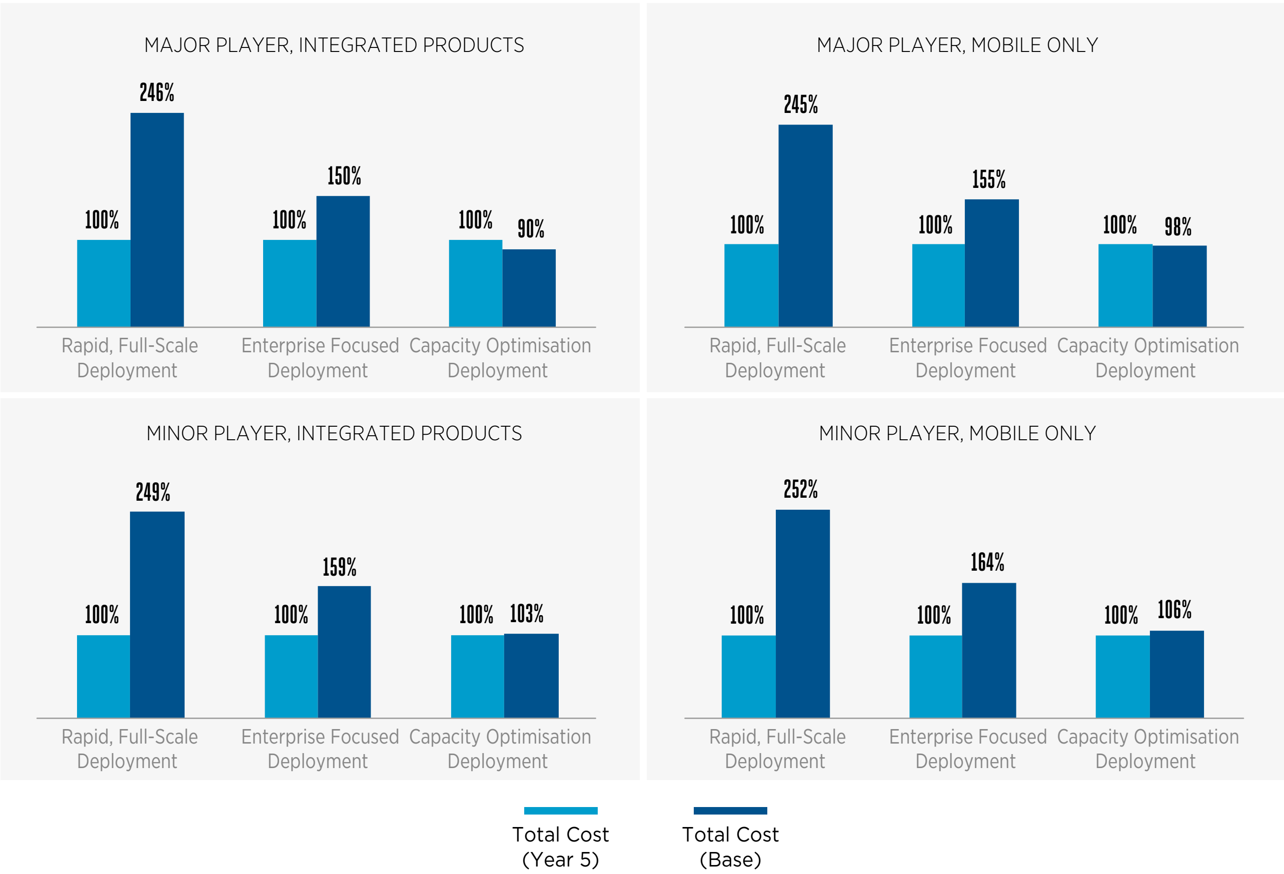
5.5.2.1 Cost results – Developed market

In the initial simulations for developed markets, the model estimates the total cost (CAPEX + OPEX) deltas for four operator archetypes in a hypothetical developed country, between baseline and end of year five of 5G rollout. The results are shown in Figure 5.5.2.

Across the board there are expected increases in costs for operators in developed markets, for both scenario Options A and B. Relatively, the largest increase is expected for mobile only players, largely due to the estimated increase required on fibre spend. Though still estimated to see cost lowered/flat in scenario Option C, 'Minor players' are expected to reap the benefits from network economics strategies at a slower rate than major players, which see a more significant cost saving at the end of year five.

FIGURE 5.5.2

COST PROJECTIONS FOR OPERATOR ARCHETYPES IN A DEVELOPED MARKET



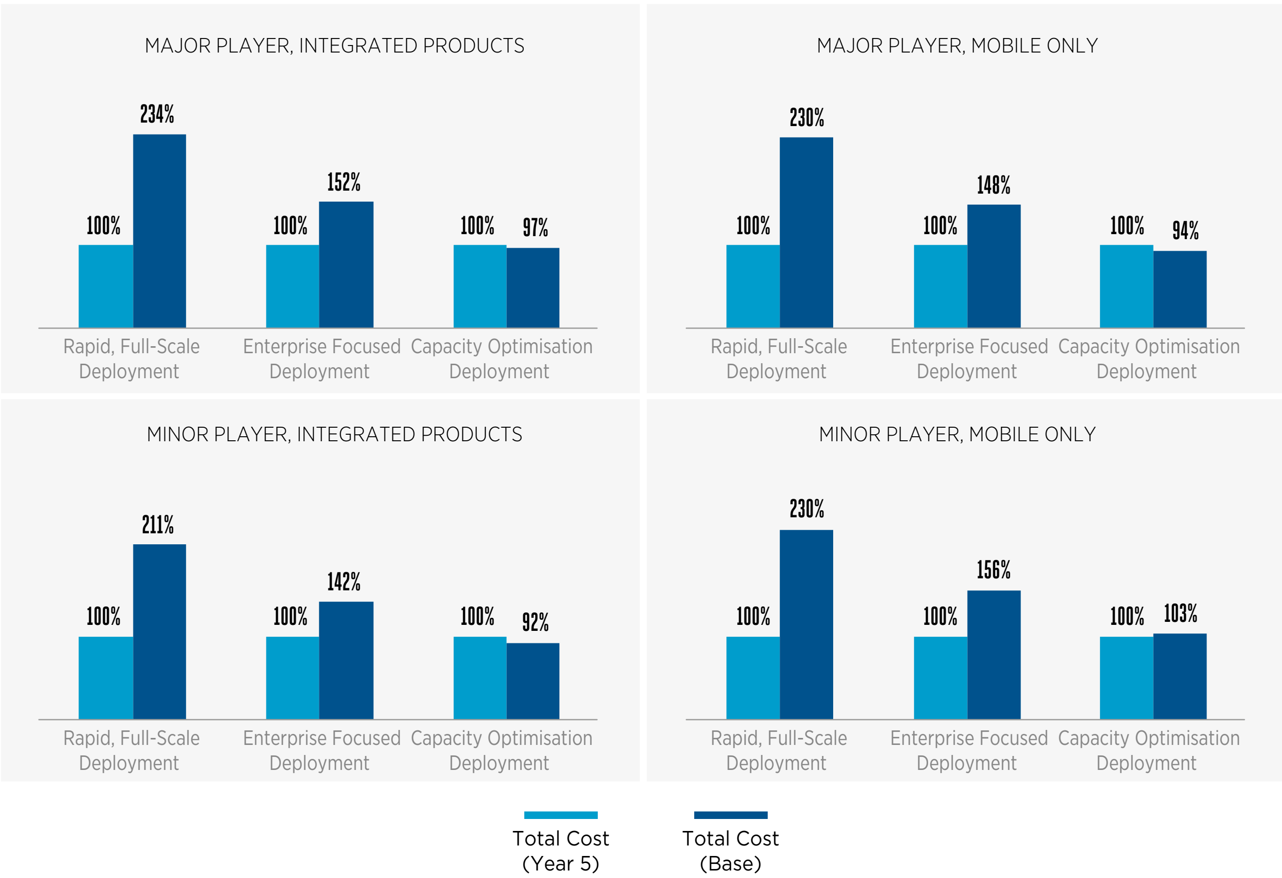
5.5.2.2 Cost results – Developing market

For first model simulations with 'developing' markets, the model estimates the total cost (CAPEX + OPEX) deltas for four operator archetypes in a hypothetical developing country, between baseline and end of year five of each 5G deployment scenario. The results are shown in Figure 5.5.3.

Similar to operators in developed markets, there are estimated to be significant jumps in capital expenditure for operators in developing markets, especially for Options A and B. The largest increase is expected for a 'Major Player, Integrated Products' which is estimated to have a 234% (indexed) increase in total cost at end of year five compared to base year. This is owing to an estimated annual capex increase (relative to existing annual capex levels) of 114% from rapid large-scale infrastructure investment. Though still estimated to see cost lowered/flat in Option C, operators in developing regions are expected to reap the benefits from network economics strategies at a slower rate than those in developed markets, which see a more significant OPEX cost saving at the end of year 5.

FIGURE 5.5.3

COST PROJECTIONS FOR OPERATOR ARCHETYPES IN A DEVELOPING MARKET



5.5.3 Revenue results

The deployment cost model outputs show the indexed revenue estimates for all archetypes and scenarios.

The changes are calculated using estimations of increases in service ARPU from specific 5G use cases as described in section 4 of this chapter

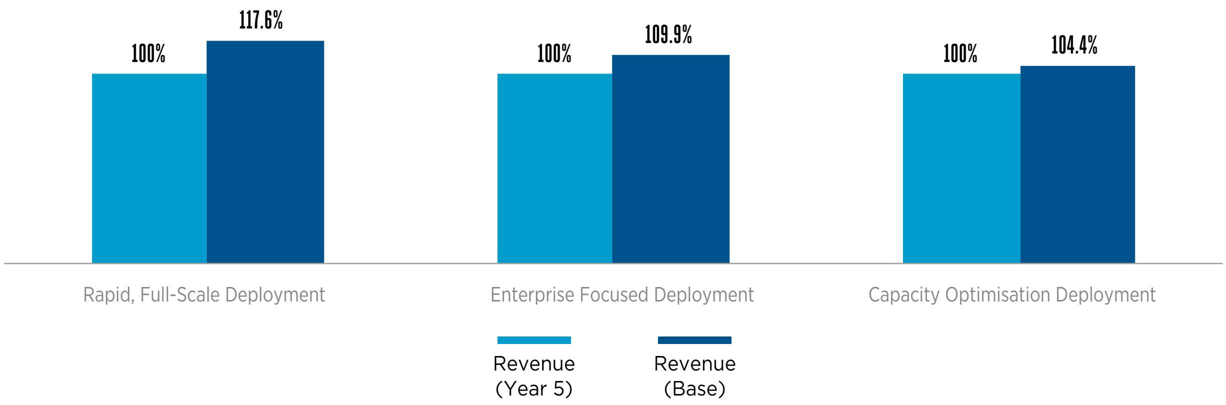
Within the model, the incremental service revenue ARPU estimations have changeable inputs which can be adjusted to reflect the expectations of the user. These initial simulations are based on default revenue assumptions which are also described in Section 5.4.

5.5.3.1 Revenue results – Developed market

For first model simulations with 'developed' markets, the model estimates the (average) indexed revenue deltas of four operator archetypes in a hypothetical developed country, between baseline and end of year five of each 5G deployment scenario. The results in figure 5.5.4 show the average revenue changes of four operator archetypes in the developed country profile, per scenario.

FIGURE 5.5.4

AVERAGE REVENUE PROJECTIONS OF OPERATOR ARCHETYPES IN A DEVELOPED MARKET

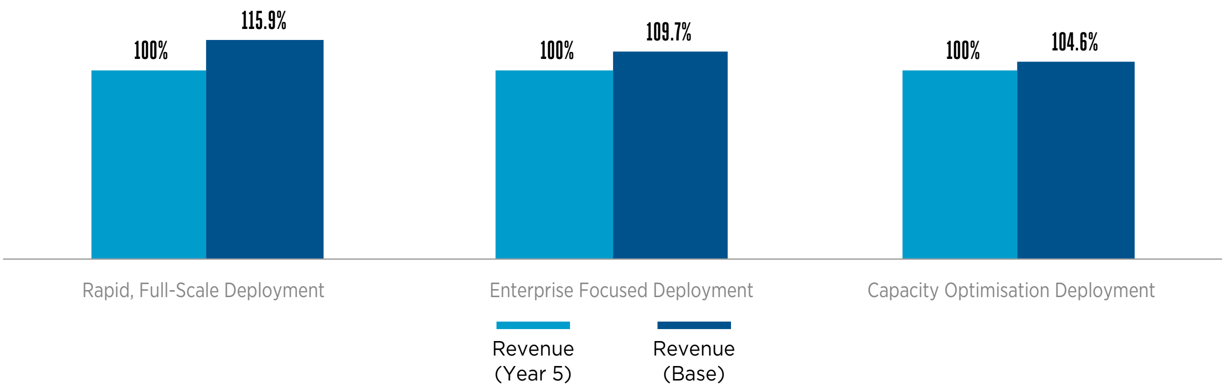


A key revenue assumption behind each scenario is the percentage of subscribers 'impacted' by 5G, i.e. the proportion of total subscribers/connections that operators will realise 5G revenues from. The default parameters used in these assumptions are as follows: A: 60%, B: 40% and C: 20%.

That strongest revenue uplift is estimated to be in a rapid full-scale 5G deployment, with a higher proportion of subscribers impacted but also due to a higher estimated contribution of revenues from both enterprise/IoT and consumer use cases.

FIGURE 5.5.5

AVERAGE REVENUE PROJECTIONS OF OPERATOR ARCHETYPES IN A DEVELOPED MARKET



5.5.3.2 Revenue results – Developing market

Considering the default assumptions, the outcome for operators in developing markets portray a similar result for those developed markets.

Out of the three major use cases expected to enhance revenues for 5G in developing regions, FWA sees a relatively stronger expected growth, with improved infrastructure investment (incl. fibre) and considering a stronger uptake of the service in more rural regions.

5.5.4 Cost intensity results

Following the modelling of both total costs and revenues it is important to provide context to the results in the form of a 'cost intensity' consideration.

Cost intensity = (CAPEX + OPEX) / Revenue

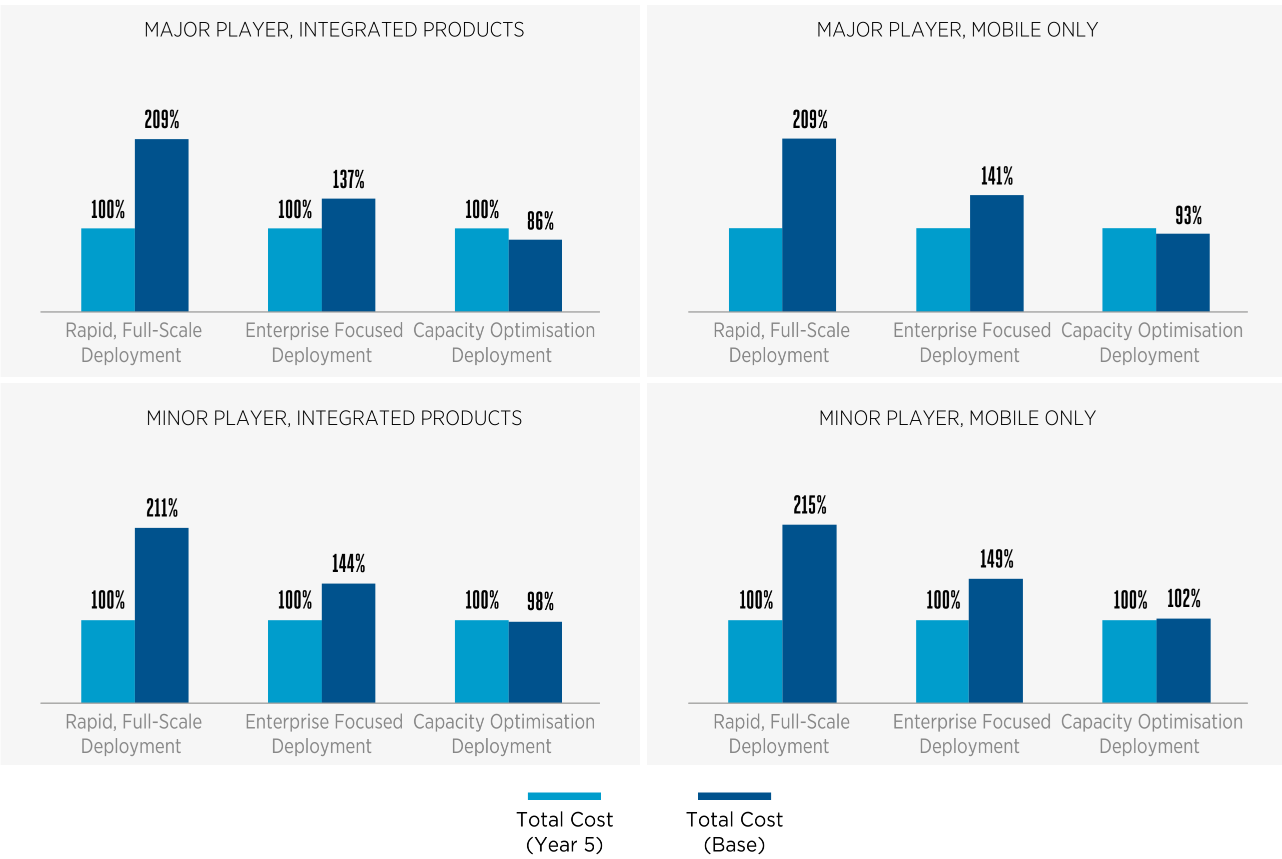
This is an important measure for operators as it gauges the economic sustainability of the network. For example, from the revenue results we understand there to be a strong uplift in Option B which may paint it as the desirable deployment scenario, but once costs are taken into account we see cost intensity percentages increase by over 2x. Thus to ensure a desired cost intensity percentage, the operator must in fact generate massive revenues. It is assumed that operators have an objective to maintain their cost intensity of minimal deviation from the percentage at year zero, throughout the 5G era.

5.5.4.1 Cost intensity results – Developed market

Cost intensity levels for developed market operators is estimated to increase significantly through Option A, owing to higher CAPEX and OPEX through the deployment period.

FIGURE 5.5.6

COST INTENSITY (INDEXED) PROJECTIONS OF OPERATOR ARCHETYPES IN A DEVELOPED MARKET



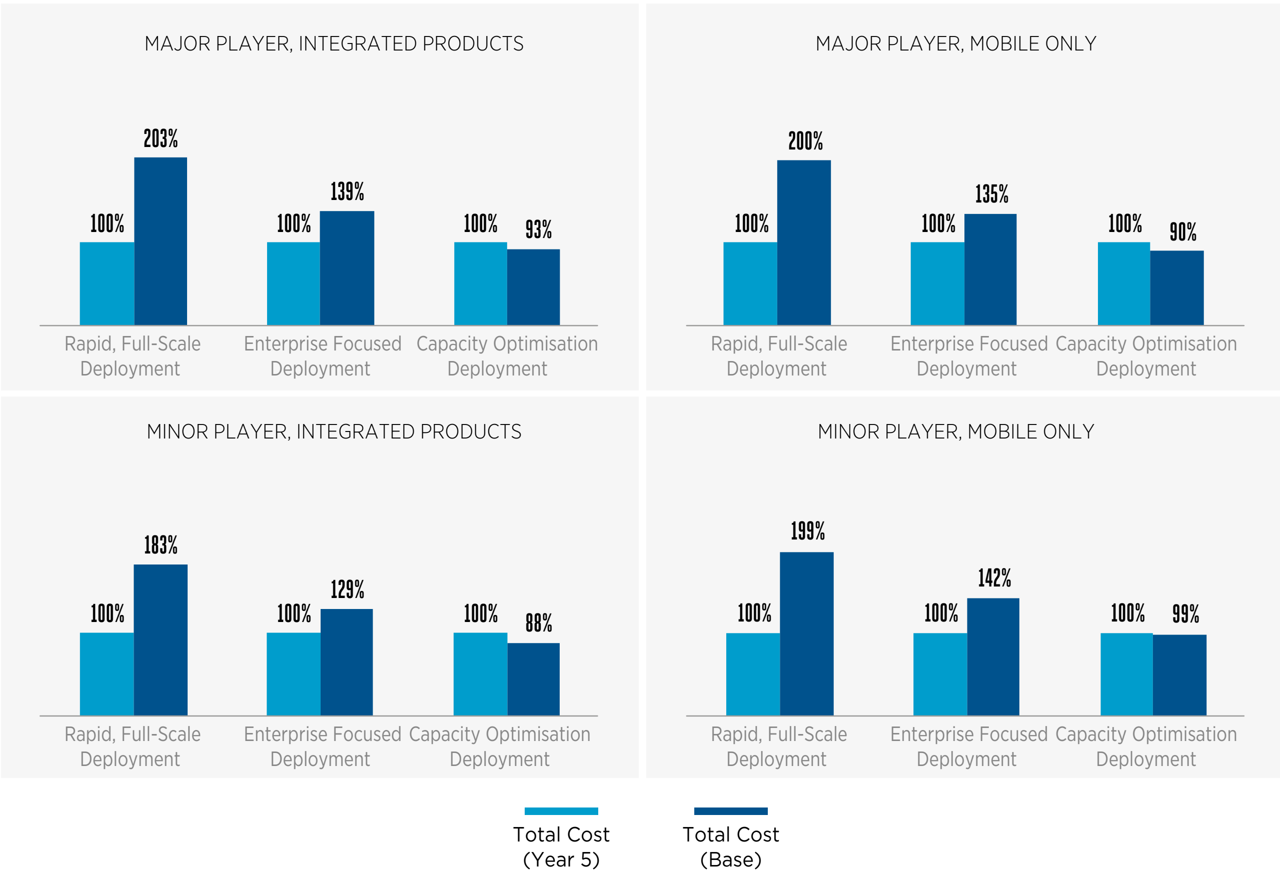
In scenario Option C, however, there is potential for operators to see a reduction in this measure, owing largely to the assumption that operators benefit well from network economic strategies such as infrastructure sharing and energy efficiencies. Operators in the region can realise strong savings in OPEX from these, for example the archetypical major player with integrated products, with cost intensity reduced to 86% of its baseline measure.

5.5.4.2 Cost intensity results – Developing market

Thought still high, the estimated growth of total cost intensities for operators in developing regions are not as pronounced, with the average level of change in Option A, for example, around 200%.

FIGURE 5.5.7

COST INTENSITY (INDEXED) PROJECTIONS OF OPERATOR ARCHETYPES IN A DEVELOPING MARKET



For scenario Option B, indexed cost intensities increase by an average of 135% across the four archetypes. Most operators correctly would consider this too large a spike in this measure, but considering the level of investment and the anticipated capex increase involved, this may not be a feasible deployment option for some.

Similar to developed markets, operators in developing countries are also able to realise cost intensity reduction following the deployment of 5G in a capacity optimisation-driven approach. The assumption here highlights a stronger saving from infrastructure sharing, particular for major players.

5.5.5 Deployment cost model simulation – example

The results for a major player with integrated products, in a developed country illustrates the business case for most 5G pioneer markets

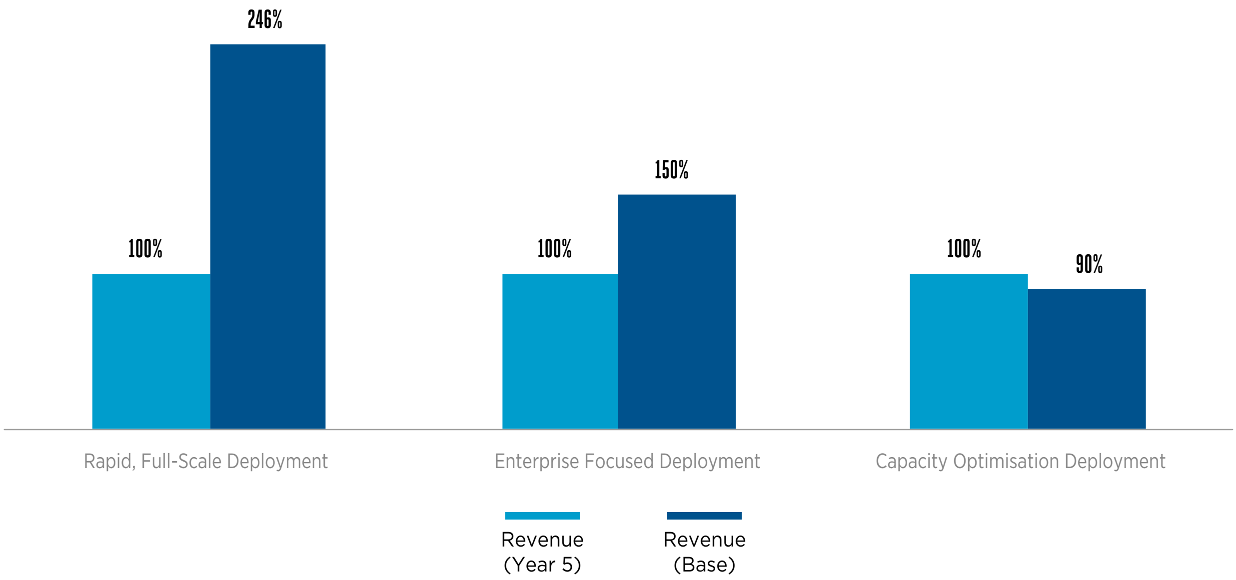
An initial simulation from the cost model is conducted for operator archetype: Major player, integrated products, in a developed country. The outputs range from Total Costs (OPEX+CAPEX); Cost Intensity (total cost/revenue); Revenue; and 'Time to Build', which estimates the amount of time it would take to deploy 5G given the operators annual capex envelope.

5.5.5.1 Total Cost (indexed)

The initial simulation for this archetype shows that the total cost (CAPEX+OPEX) relative to baseline (indexed) for deployment Option A increases nearly 2.5-times (see Figure 5.5.8). The main drivers of this are the anticipated increase in spend for cell site densification, upgrades to existing sites, and the amount of fibre required for this type of deployment.

FIGURE 5.5.8

COST RESULTS FOR A MAJOR, INTEGRATED OPERATOR IN A DEVELOPED MARKET



5.5.5.2 Cost Intensity (indexed)

The initial simulation for this archetype shows that cost intensity (capex + opex / revenue) relative to baseline (indexed) for deployment Option A almost doubles. Owing to huge costs associated with a new infrastructure, as well as increased operational costs from network complexity with a standalone core.

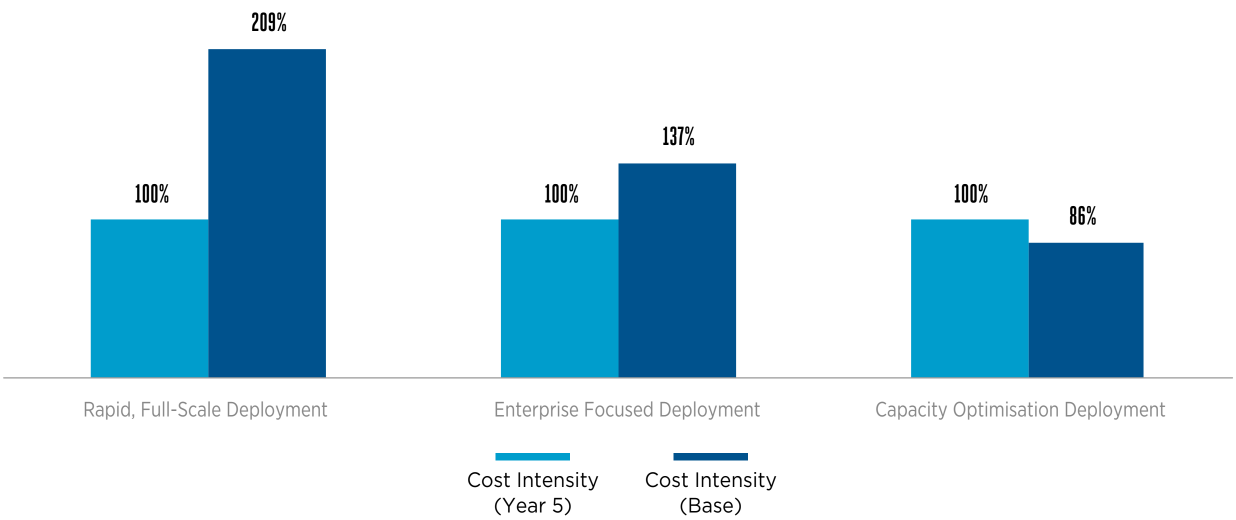
An alternative, and potentially viable, deployment option for operators with matching profiling is Option B rollout where cost intensity is estimated to be 1.3-times higher than that in the baseline year (see Figure 5.5.9).

Owing to a more refined, targeted deployment, CAPEX is not predicted to be as substantial as full standalone.

However, it is clear that if cost efficiency and pragmatism is at the forefront of operator's minds when considering various deployment options, choosing Option C is very likely to be most sensible. After extrapolating estimated network economic efficiencies, especially savings in OPEX, there is actually a potential to lower cost intensities. This is, however, also dependant on the additional revenue that can be generated from 5G.

FIGURE 5.5.9

COST INTENSITY RESULTS FOR A MAJOR, INTEGRATED OPERATOR IN A DEVELOPED MARKET



5.5.5.3 Revenue

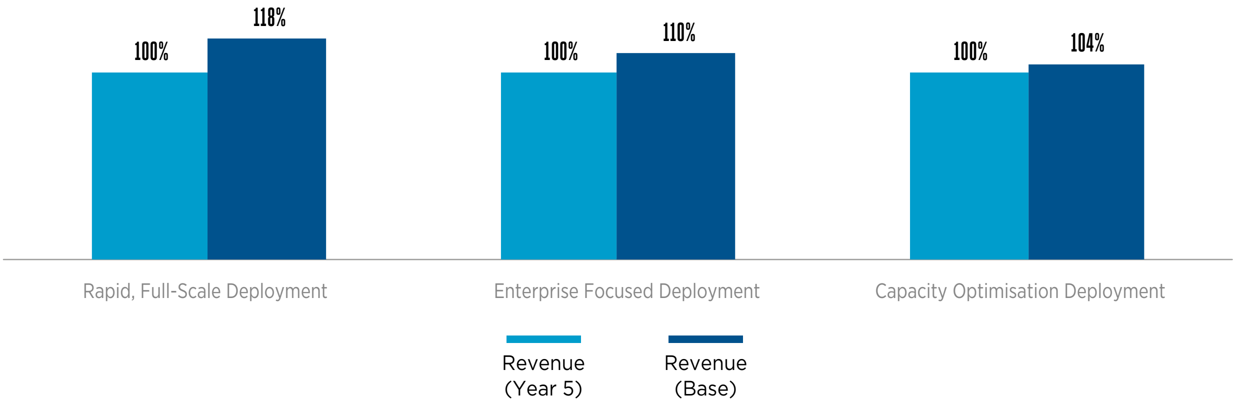
As described in section 5.4, estimates on incremental ARPU growth will come from three particular cases: New consumer use cases (Cloud AR/VR); Enterprise/IoT; New broadband markets (FWA), for each operator archetype and deployment scenario. Within the model, as with the cost lines, these inputs are flexible and can be altered to suit user expectations.

Though results for this archetype suggests Option A deployment generates the biggest increase in revenue from base year, what must be considered is that cost intensity increases vastly from substantial capex investments and increased opex. For this operator to keep its cost intensity at a sustainable level (minimal deviation from baseline cost intensity), it must realise revenues nearly 2-2.5 times higher than existing annual revenue (see Figure 5.5.10).

Option C suggests that revenue grows marginally, indicating a suitable return on investment for this deployment scenario. However, this is dependent on cost efficiencies being incorporated which result in lower opex spend and less economic strain.

FIGURE 5.5.10

REVENUE RESULTS FOR A MAJOR, INTEGRATED OPERATOR IN A DEVELOPED MARKET



5.5.5.4 Capex 'Burn Rate'

The definition of this result is effectively how many years it would take an operator to deploy 5G. It is calculated by:

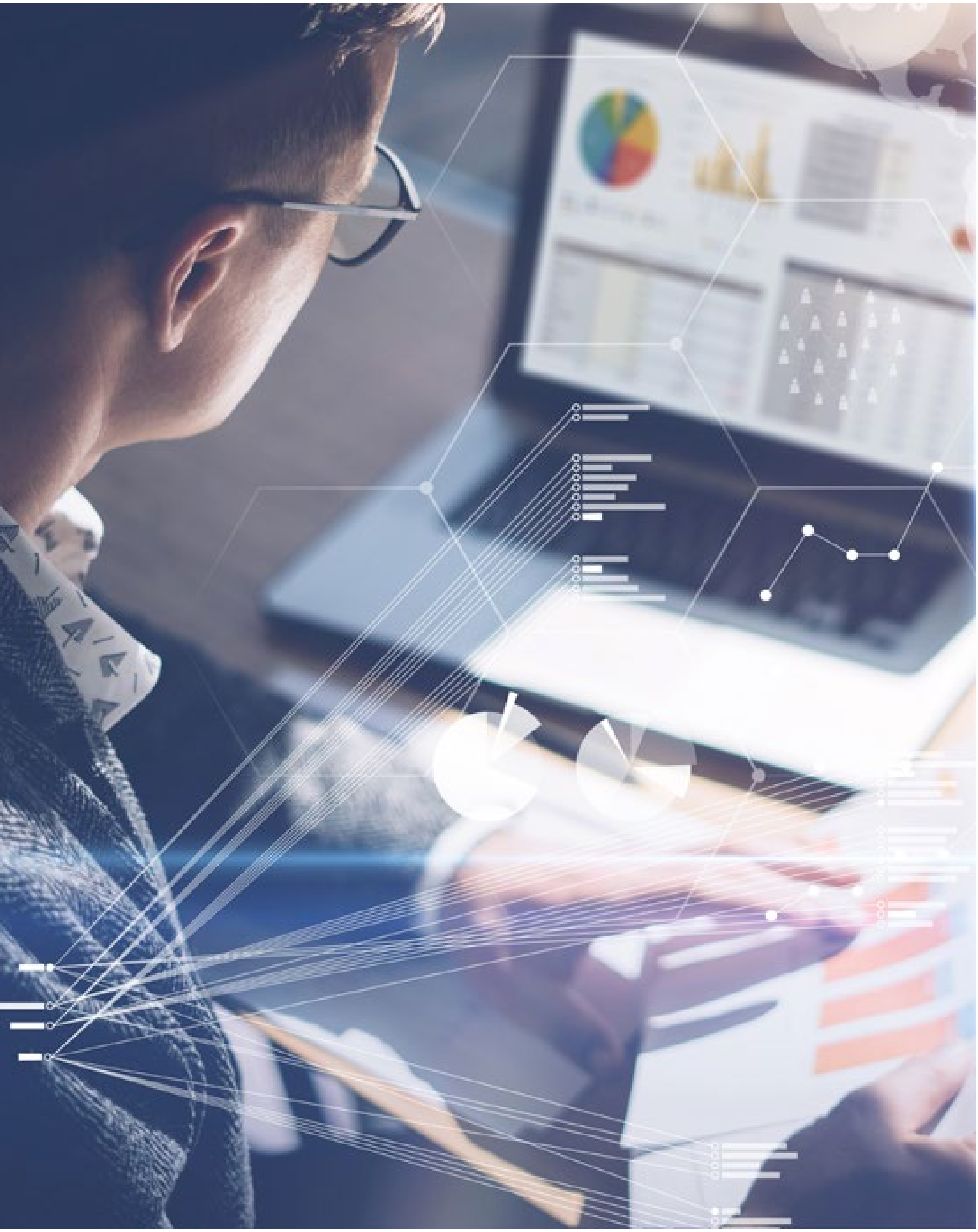
Cumulative capex required to deploy 5G (for each scenario), ($)/estimated annual capex envelope, ($)

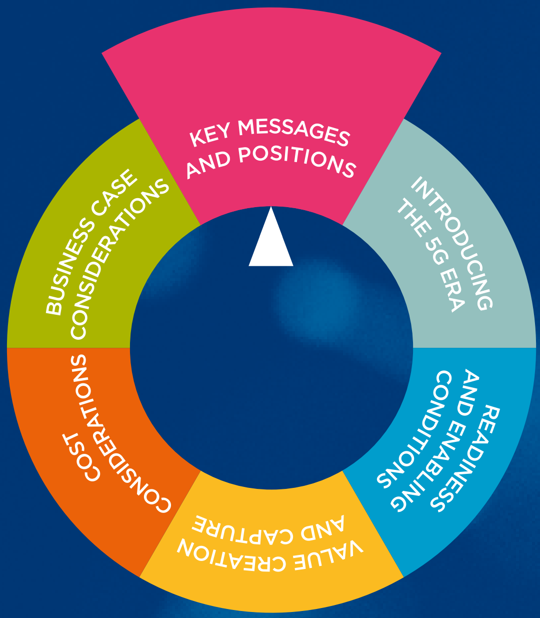
FIGURE 5.5.11

NO OF YEARS OF CAPEX REQUIRED FOR A MAJOR, INTEGRATED OPERATOR IN A DEVELOPED MARKET

	Metric	Rapid, Full-Scale Deployment	Enterprise Focused Deployment	Capacity Optimisation Deployment
5G Capex 'Burn Rate'	Years	6.3	2.9	0.7
Annual CAPEX Increase	%	125%	58%	14%

The table of results (see Figure 5.5.11), for this particular archetype, deploying based on Option A, would take up to six years longer than deploying based on Option C; with an annual capex increase of 125% compared to 14% for scenario Option C, which is a more expected level of investment and/or spend for operators categorised in this segment.





6 Key Messages and Positions for the Industry

Chapter 6 provides suggested industry-level messages and positions relating to the 5G era, providing operators with a set of considered messaging for different stakeholders. The goal is that if common messaging and terminology can flow through all members' communications, the industry will convey a clearer and more impactful narrative.

Operators can use this industry-level messaging to complement their own communication activities with governments, regulators, analysts, media and customers. This is with a view to facilitating a consistent industry voice.

GSMA members are encouraged to distribute this material to their marketers, communicators, speechwriters and spokespeople, and encourage them to use this content in external-facing materials as appropriate.

6.1 GSMA's Perspective

KEY TAKEAWAY

- **The GSMA leadership is clear about the significance of 5G and how it will benefit citizens, enterprises and society. At the same time, the related challenges are understood.**

6.1.1 GSMA Leadership's Views

"The arrival of 5G is very significant… with the arrival of 5G things which are now in the realm of science fiction will become reality."
Sunil Mittal, Chairman, GSMA 2017/18

"Mobile operators and our wider industry have a key role to play in promoting a safer and more inclusive digital world, while building the infrastructure and services that will carry us forward as we enter this new era of intelligent connectivity."
Stéphane Richard, Chairman, GSMA 2019/20

"5G is a giant step forward in the global race to connect and digitise economies and societies: it is an opportunity to create an agile, purpose-built network tailored to the different needs of citizens and the economy. But it is vital that all stakeholders work together to ensure that 5G is successfully brought to market."

"One of the biggest challenges for the 5G future is to ensure that there is a supportive regulatory environment – one that fuels investment and fosters innovation. A policy framework that reflects the changing digital landscape while minimising costs and barriers to network deployment will deliver the best outcomes for society and the economy is needed."

"The timely release of spectrum, flexibility to share networks under commercial agreements and facilitation of small cell deployments will encourage the infrastructure investments required in order to deliver the global benefits of the 5G Era."
Mats Granryd, Director General, GSMA

6.2 Industry-level Messaging

KEY TAKEAWAYS

- The GSMA encourages common messaging and terminology in members' communications to ensure that the industry conveys a clearer and more impactful narrative on 5G.
- Intelligent Connectivity will enable revolutionary new products and services to be developed, benefiting governments, businesses, consumers and society in general.
- Examples of new services will include:
  - Remote control of robots in real time increasing industrial productivity
  - Remote training and telepresence for increased efficiency and effectiveness
  - Smart agriculture – enhanced food production and efficient distribution
  - Connected care – real time, intelligent health and home monitoring
  - Proactive environment management with Predictive Modeling and Monitoring
  - Autonomous transportation – convenient, safe, independent travel
  - Cloud-based mobile gaming – immersive gaming anywhere, without a console

6.2.1 Generic 5G elevator pitch

The global benefits of the 5G Era: an industry-level elevator pitch for operators

The mobile industry's purpose is to intelligently connect everyone and everything to a better future: 5G is the next major step in delivering this purpose.

Building on and working together with 4G, 5G provides the ability to connect people and things better, faster and more efficiently in a 5G Era.

The faster mobile internet speeds, seamless connectivity, increased capacity and greater flexibility that 5G provides – together with Mobile IoT, big data analytics and artificial intelligence – will fundamentally improve the way we live and work in an age of Intelligent Connectivity.

As demand for seamless connectivity grows, especially in cities and industrial areas, 5G will facilitate the opportunity to create even more agile, purpose-built networks tailored to the different needs of citizens, enterprises and society.

5G will drive future innovation and economic growth: it will be an evolutionary step with a revolutionary impact, delivering greater societal benefit than any previous mobile generation and enabling new digital services and business models to thrive.

Intelligent Connectivity will sit at the heart of new smarter ecosystems that benefit everyone: society will use technology to tackle the world's biggest challenges; consumers will enjoy immersive, contextual experiences and enterprises will be able to embrace the Fourth Industrial Revolution.

4G will continue to deliver high-speed mobile broadband, supporting the numerous and increasing connectivity needs of citizens and the economy, and it will help to support 5G. 4G is also key to continuing the drive to connect even more of the world's unconnected people to mobile broadband for the first time.

With 4G networks already covering 81% of the global population across 208 countries – increasing to 86% by 2025 – and 5G networks set to cover nearly 40% of the global population by 2025 (source: GSMA Intelligence), the 5G Era is truly upon us.

Appropriate spectrum and regulatory conditions are needed in order to continue to encourage the required investments by the mobile industry and allow 5G Era benefits to be realised by all.

6.2.2 Messaging for enterprise customers

Operators have more to offer enterprises in the 5G era

The following section comprises additional messages oriented specifically towards the enterprise sector setting out the significant benefits that the 5G era can deliver to businesses.

Please also refer to the results of the enterprise research conducted as part of this work (see Section 3.4).

> In addition to new revenue opportunities, the business benefits of 5G include reduced operating costs, an increased return on capital employed and, ultimately, greater profitability.
>
> 5G is a giant step forward in the global drive to digitise economies and societies, acting as an innovation platform upon which new transformational digital services and business models will evolve and thrive.
>
> Smarter platforms facilitated by 5G, AI and machine learning, will use data collected from the IoT to enable improved decision-making and business efficiencies, resulting in the cost-effective delivery of new and improved products and services in an age of Intelligent Connectivity.
>
> This intelligently connected world will enable a new, unprecedented era of automation, facilitating enhanced services - from personalised healthcare and enhanced welfare, to smart cities and transport.
>
> Anything that needs to be connected will be connected. The IoT is scaling with more and more connected products and sensors providing essential data to improve device performance, with an anticipated 25 billion connections by 2025.
>
> 5G will provide the opportunity for individual enterprises' needs to be met by dynamically tailoring and configuring mobile networks to their particular requirements (Source: GSMAi Intelligence).
>
> Operators are trusted, proven and experienced enterprise partners with the capabilities, experience and licences to operate secure mobile networks based on global, interoperable standards, that deliver economies of scale and are future-proof.

6.2.3 Use case examples from a customer benefits perspective

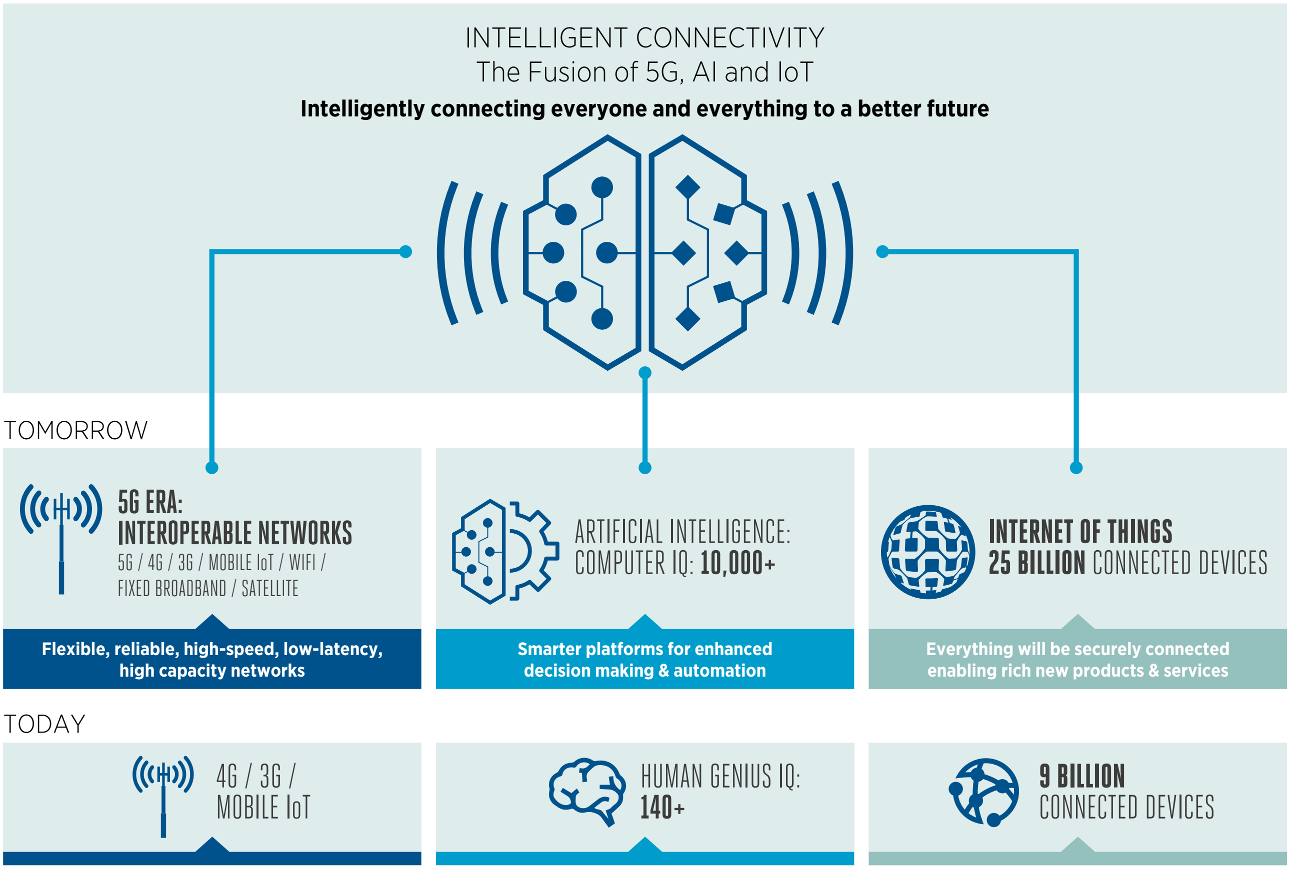
How operators can add even more value in a world of Intelligent Connectivity

5G mobile broadband will deliver download speeds of over 1Gbps and enable a consistently high-quality mobile broadband experience with reliable internet access at home, in the office and on the move. This enhanced, reliable and high-speed mobile broadband will facilitate so-called "hyperconnectivity", a world of always-available communication, entertainment and services.

5G, together with the IoT, facilitated by operators' LPWA networks, combined with AI and machine learning, will fundamentally alter the way we live and work in an age of Intelligent Connectivity, see Figure 6.2.1.

FIGURE 6.2.1

TOWARDS A WORLD OF INTELLIGENT CONNECTIVITY



6.2.3.1 Remote control of robots in real time increasing industrial productivity

High speed, low latency 5G mobile networks will enable a tactile internet delivering haptic experiences for new use cases. With tactile internet, users can actuate precise control, through instantaneous communications, to support touch-based interaction with visual feedback. Automation, robotics and telepresence are already growing in importance in industrial applications like smart factories and the remote operation of industrial machinery. Data from a multitude of new connected sensors will provide more valuable data to smart platforms to further enhance the industrial benefits.

The tactile internet, i.e. low latency combined with high availability and reliability, will take the possibilities still further, enabling the efficient manufacturing of highly customised products, and remote inspection, maintenance and repair of everything from industrial plant to aeroplanes, and, for example, remote mining in high-risk areas.

AI and machine learning-assisted intelligent platforms enhanced by 5G will enable better robotic coordination and collaboration processes thereby improving production performance to cost-effectively deliver higher quality products and services. Businesses will also be able to use 5G to control remotely located machinery used in industrial production based on input from sensors and cameras located on-site. If necessary, specialist machines will be able to print 3D objects on demand, enabling them to repair broken components. Over time, factories will become increasingly automated, enabling them to be controlled largely by staff in another location. This will mean more flexibility about where to locate production plants.

6.2.3.2 Remote training and telepresence for increased efficiency and effectiveness

High speed, low latency 5G mobile networks combined with VR and AR technologies will enable new opportunities in training and education with telepresence, for example by experiencing high-risk situations from the safety of a control room or office. 5G and the combination of new generations of headsets will enable AR/VR devices to be wireless and completely mobile.

Machinery and health and safety training will be conducted in AR, while factories' smart sensors will measure and control emissions.. Highly skilled workers will be able to practice tasks prior to performing them: for example, surgeons can rehearse heart surgery and civil engineers can test scenarios before applying the optimal changes at an oil refinery. Intelligent ecosystems will be able to apply predictive analysis with high-probability results.

6.2.3.3 Smart Agriculture – enhanced food production and efficient distribution

Mobile IoT is already enabling increased crop yields, crop quality and livestock management through enhanced monitoring of soil conditions, improved use of pesticides and fertilisers, animal welfare, and tracking of weather conditions. Facilitated by 5G, AI-assisted agriculture big data platforms will utilise multiple real time data feeds to help make more informed food production decisions.

For example, 5G era technologies can be used to help monitor and control the conditions inside greenhouses to optimise the growth of the crop. Mounted inside the greenhouse, connected sensors can transmit data to an application that gives the grower a clear and real-time overview of the temperature and humidity levels throughout the structure. The grower can then adjust conditions, for example, by applying heated air to the crop.

Intelligently connected transportation will increase the efficiency of distribution through optimal routing and monitoring of temperature control of food in transit. This more effective management of vehicle refrigeration will lead to crops and food being delivered in better condition with longer market and shelf lives.

Connected drones are already being used for crop spraying, land management and aerial surveillance: intelligent AI-assisted agricultural platforms with machine learning will further enable long-term improvements to farm production through better understanding of the agricultural process.

6.2.3.4 Connected Care – better and more affordable healthcare

The digital health solutions enabled by 5G and Intelligent Connectivity will support healthcare professionals in delivering higher quality, more consistent and efficient healthcare. They will assist governments and healthcare providers in increasing access or managing epidemics and empower individuals to manage their own health more proactively and effectively. Examples, according to PwC, are that digital health at scale could save €99 billion in healthcare costs in the EU, $14 billion in Brazil and $3.8 billion in Mexico (GSMA digital healthcare report 2016). The elderly and the chronically ill will benefit from mobile-enabled wearable and smart home devices which will provide everyday activity monitoring in addition to medication regime assistance and reassurance. “Always on” connected devices will enable relatives and carers to stay in touch for day-to-day contact, as well as emergency assistance to be provided.

Wearable wellness devices will monitor key biometrics indicators securely networked to remote health platforms for real-time analytics against personal medical profiles to assess current and future health. This will enable enhanced personal wellness management at scale, better access to health information and more effective professional treatment.

6.2.3.5 Proactive environment management with predictive modeling and monitoring

Predictive modelling enhanced by 5G will be used to reduce pollution in smart city scenarios by providing more data to enable accurate pollution forecasting models.

Real-time AI-assisted monitoring platforms will enable even more sophisticated big data models through the smarter analysis of weather, commuter information and town planning information.

5G will accelerate and enhance this predictive modelling ability, enabling it to be applied to more societal problems such as disease control, weather and natural disaster management in addition to day-to-day challenges such as city traffic optimisation. For example, in China, mobile is already being used to facilitate anti-flood and other waterway analysis, enabling monitoring and management of hydroelectricity, water transfer and environmental situations.

6.2.3.6 Autonomous Transportation – convenient, safe, independent travel

The rise of smart cars and intelligent transport systems facilitated by 5G will optimise traffic flows, further enhance travel safety and reduce journey times. Connected transportation will be augmented with "conditional automation" offering self-driving abilities under specific conditions.

On-board sensors will enable these automated connected vehicles to be responsive and intelligent enough to travel safely and efficiently. They will use data from multiple sources to adapt to changes in climate, traffic and other road users as necessary.

In the coming years customers will be able to summon intelligently connected, automated vehicles, controlled via their mobile device for pick up virtually anywhere, Uber and Volvo's partnership being but one example of development in this space.

Fleets of drones and road-based unmanned, autonomous, delivery vehicles will enable fast, low-cost, secure delivery directly to customers, with smart homes enabling enhanced, flexible delivery access options.

6.2.3.7 Cloud-based Mobile Gaming – immersive gaming anywhere, without a console

Fast, mobile, low latency access to powerful cloud-based gaming servers will enable gamers to enjoy the latest titles without the need to purchase expensive consoles and hardware: as an example, Oculus Quest is already being positioned as "No PC, No Worries, No Limits".

The gaming experience will be enhanced with more freedom of movement, player orientation and better interaction with the game and the real world: the Vive wireless gaming adapter is being promoted as "Untethered Virtual Reality".

Gaming will become more immersive thanks to AR and VR enabled by 5G; it will be more social, more realistic and more contextual and engaging. Machine learning remote gaming platforms will intelligently alter games by improving players' online experiences based on historical and real-time data.

6.3 GSMA 5G-era Policy Positions

KEY TAKEAWAYS

- The GSMA's Policy Group has developed policy considerations to support the sustainable rollout and commercialisation of 5G.
- Policymakers are urged to streamline the conditions for 5G deployment by setting a national mobile network deployment policy that simplifies planning procedures for small cells, grants operators access to public sites for antenna siting, and establishes uniform electromagnetic field (EMF) rules that are based on internationally agreed levels.
- Network flexibility to meet the varied connectivity requirements of 5G services and open internet principles are not mutually exclusive, and regulators should encourage the efficient use of network resources through features such as network slicing.
- Regulators that get as close as possible to assigning 100 MHz per operator in 5G mid-bands (e.g. 3.5 GHz) and 1 GHz per operator in millimetre wave bands (e.g., 26 GHz and 28 GHz) will best support robust 5G services.
- Licensed spectrum is essential to guarantee the necessary long-term heavy network investment needed for 5G and to deliver a high quality of service. Licences should be technology neutral and have a long duration with a predictable renewal process.
- The financial demands of 5G deployment on mobile operators will be significant, requiring a high level of investment with uncertain returns. To support their digital policy aspirations, governments should act to ease the cost burden faced by the mobile industry to roll out 5G networks.

6.3.1 Policy Actions to Support 5G Implementation

The GSMA's Policy Group has developed policy considerations to support the sustainable rollout and commercialisation of 5G

5G connectivity opens up the possibility of a world of revolutionary new products and services, with these new networks central to the realisation of an advanced digital economy and society. However, the barriers to network deployment are significant, including coverage requirements that distort the market. National governments and regulators must do their part by supporting operator investment and removing deployment roadblocks.

Accordingly, policymakers and regulators need to shift from the current policy focus of minimising prices for consumers towards a value maximisation vision. They should take supportive action in the following four areas to bring 5G to fruition in their market (see Figure 6.3.1): Network Densification; Network Virtualisation; Spectrum Allocation & Assignment to operators; and Regulatory Costs and Fees.

FIGURE 6.3.1

SUMMARY OF GSMA PUBLIC POLICY CONSIDERATIONS RELATING TO 5G

NETWORK DEPLOYMENT	NETWORK FLEXIBILITY	5G SPECTRUM CONSIDERATIONS	REGULATORY COSTS
STREAMLINE REGULATORY CONDITIONS to facilitate 5G network deployment	**PROVIDE REGULATORY FLEXIBILITY** for innovative propositions that use 5G	**RELEASE SUFFICIENT SPECTRUM FOR 5G** that is harmonised and affordable	**EASE FINANCIAL DEMANDS OF 5G** by bringing down regulatory costs and fees
Simple planning procedures and regulations	Technical and commercial flexibility for operators	Contiguous spectrum for each operator	Recognition of steep investment with uncertain returns
Access to public sites	Regulatory flexibility that allows dynamic network configuration	Reasonable terms and prices	Reduce mobile specific taxes and fees
EMF rules and compliance processes aligned with international guidance	Avoid prescriptive rules that limit innovation and investment	Exclusive licensing of spectrum bands	Modernise policy framework to create a better investment environment

6.3.1.1 Network Deployment

Mobile operators' ability to deliver high-speed, high-capacity 5G connectivity is dependent on the deployment of small cells, including more densely distributed antennas and the provision of backhaul to connect a far greater number of mobile base stations, particularly in cities. Policymakers are urged to streamline the conditions for 5G deployment by setting a national mobile network deployment policy that simplifies planning procedures for small cells, grants operators access to public sites for antenna siting, and establishes uniform electromagnetic field (EMF) rules that are based on internationally agreed levels.

6.3.1.2 Network Flexibility

One of the central capabilities of 5G is its ability to 'virtualise' the network, dynamically configuring network resources to increase efficiency and to deliver bespoke managed connectivity for innovative products and services. To realise the full economic potential of 5G at the earliest stages of its deployment, regulators should establish technical and commercial flexibility for mobile operators and for companies developing new services that will rely on the capabilities of 5G.

6.3.1.3 Spectrum Allocation & Assignment

5G networks require access to spectrum in low, medium and high radio frequencies and in larger contiguous blocks than previous mobile generations require. Regulators that get as close as possible to assigning 100MHz per operator in 5G mid-bands (e.g. 3.5GHz) and 1GHz per operator in millimetre wave bands (e.g., 26GHz and 28GHz) will best support robust 5G services.

Millimetre wave mobile bands will largely be agreed at WRC-19 where the GSMA recommends support for the 26GHz, 40GHz and 66GHz to 71GHz bands. The 28GHz band is not being considered at WRC-19 but will be used by 5G in several leading countries (e.g., Japan, South Korea and the US) and so should also be supported where possible.

On spectrum assignment, licensed spectrum is essential to guarantee the necessary long-term heavy network investment needed for 5G and to deliver a high quality of service. Licences should be technology neutral and have a long duration with a predictable renewal process. Policymakers are also encouraged to support voluntary spectrum pooling between operators to help drive faster services and maximise spectrum efficiency.

6.3.1.4 Regulatory Costs and Fees

The financial demands of 5G deployment on mobile operators will be significant, requiring a high level of investment with uncertain returns. To support their digital policy aspirations, governments should take action to ease the cost burden faced by the mobile industry to rollout 5G networks.

Steps should be taken in many areas, including increasing regulatory certainty, reducing or eliminating mobile-sector taxes and lowering administrative fees. It is especially vital that regulators avoid inflating 5G spectrum prices (e.g., through excessive reserve prices or annual fees) as this risks limiting 5G network investment and driving up the cost of services for users.

7 Appendix

The appendix covers the following five topics:

1. **5G NR spectrum bands**
2. **NB-IoT and LTE-M requirements**
3. **The BEMECS 5G Readiness framework**
4. **Lessons from IT virtualisation (co-authored by VMWare)**
5. **Network Slicing - Making it happen (by Kings College London)**

7.1 5G NR Spectrum Bands

TABLE 7.1.1

5G NEW RADIO SPECTRUM BANDS

Frequency range	Band	Name	Mode	Downlink (MHz)- Low	Downlink (MHz)- Middle	Downlink (MHz)- High	Bandwidth (MHz)	Uplink (MHz)-Low	Uplink (MHz)- Middle	Uplink (MHz)-High	Duplex spacing
Sub-1GHz	n71	600	FD	617	634.5	652	35	663	680.5	698	-46
Sub-1GHz	n12	700 a	FD	729	737.5	746	17	699	707.5	716	30
Sub-1GHz	n28	700 APT	FD	758	780.5	803	45	703	725.5	748	55
Sub-1GHz	n83	UL 700	SU				45	703	725.5	748	
Sub-1GHz	n20	800	FD	791	806	821	30	832	847	862	-41
Sub-1GHz	n82	UL 800	SU				30	832	847	862	
Sub-1GHz	n5	850	FD	869	881.5	894	25	824	836.5	849	45
Sub-1GHz	n8	900	FD	925	942.5	960	35	880	897.5	915	45
Sub-1GHz	n81	UL 900	SU				35	880	897.5	915	
1-6GHz	n51	TD 1500-	TD	1427	1429.5	1432	5				
1-6GHz	n76	DL 1500-	SD	1427	1429.5	1432	5				
1-6GHz	n50	TD 1500+	TD	1432	1474.5	1517	85				
1-6GHz	n75	DL 1500+	SD	1432	1474.5	1517	85				
1-6GHz	n74	L-band	FD	1475	1496.5	1518	43	1427	1448.5	1470	48
1-6GHz	n3	1800	FD	1805	1842.5	1880	75	1710	1747.5	1785	95
1-6GHz	n80	UL 1800	SU				75	1710	1747.5	1785	
1-6GHz	n86	UL 1800-	SU				70	1710	1745	1780	
1-6GHz	n39	TD 1900+	TD	1880	1900	1920	40				
1-6GHz	n2	1900 PCS	FD	1930	1960	1990	60	1850	1880	1910	80
1-6GHz	n25	1900+	FD	1930	1962.5	1995	65	1850	1882.5	1915	80
1-6GHz	n70	AWS-4	FD	1995	2007.5	2020	25 / 15	1695	1702.5	1710	300
1-6GHz	n34	TD 2000	TD	2010	2017.5	2025	15				
1-6GHz	n1	2100	FD	2110	2140	2170	60	1920	1950	1980	190
1-6GHz	n84	UL 2000	SU				60	1920	1950	1980	
1-6GHz	n66	AWS-3	FD	2110	2155	2200	90 / 70	1710	1745	1780	400
1-6GHz	n40	TD 2300	TD	2300	2350	2400	100				
1-6GHz	n41	TD 2500	TD	2496	2593	2690	194				
1-6GHz	n38	TD 2600	TD	2570	2595	2620	50				
1-6GHz	n7	2600	FD	2620	2655	2690	70	2500	2535	2570	120
1-6GHz	n77	TD 3700	TD	3300	3750	4200	900				
1-6GHz	n78	TD 3500	TD	3300	3550	3800	500				
1-6GHz	n79	TD 4500	TD	4400	4700	5000	600				
above 24GHz	n258	26 GHz	TD	24250	25875	27500	3250				
above 24GHz	257	28 GHz	TD	26500	28000	29500	3000				
above 24GHz	n261	28 GHz	TD	27500	27925	28350	850				
above 24GHz	n260	39 GHz	TD	37000	38500	40000	3000				

7.2 NB-IoT and LTE-M requirements

The NB-IoT and LTE-M technologies are in constant evolution as they are being refined to better support increasing market demand. Release 13 established the initial base of LTE-M and NB-IoT functionality for massive IoT. As indicated in the preliminary self-assessment in 3GPP, Release 15 will add the functionality to fulfil all the requirements of IMT-2020 with respect to the Massive IoT.

Release 14 and 15 address the aspects of mobility, throughput, power consumption and positioning. Another important addition is a RAT type for LTE-M (NB-IoT already has a unique RAT type from Release 13). One of the main purposes of such an identifier is the ability to distinguish LTE-M traffic from the traditional LTE traffic. This allows mobile operators to uniquely identify LTE-M and NB-IoT traffic, giving the opportunity to combine them in a single Network Slice and also have a variety of advantages, such as applying a dedicated charging model for Massive IoT. At this stage there are no expected major modifications or improvements planned for LTE-M and NB-IoT in 3GPP Release 16, where most of the effort will be on the ultra-reliable low latency communication (URLLC) aspects for fulfilling IMT-2020.

The table below provides a high level overview of the set of capabilities that have been defined in the different 3GPP releases. The GSMA Deployment Guides for NB-IoT[93] and LTE-M[94] provide details for all features and guidelines for their deployment.

TABLE 7.2.1

TECHNOLOGY SPECIFICATIONS FOR LTE-M AND NB-IOT

LTE-M		
3GPP Release 13 (Category M1)	**3GPP Release 14 (added Category M2)**	**3GPP Release 15**
FDD and TDD support	VoLTE support	LTE-M traffic identifier (RAT Type)
Power optimisation (PSM & eDRX)	Mobility enhancement in Connected Mode	BEST (Battery Efficiency Security for low Throughput)
Coverage Extension (CE Mode A and CE Mode B)	Higher data rate available	
Two power classes for the UE	Positioning by E-CID and OTDOA in addition to CellID	
Connected Mode Mobility	Multicast transmission/Group messaging	
Ability to support a voice call	Release Assistance Indication	
SMS support		
Service Capabilities Exposure Function (SCEF)		

93. https://www.gsma.com/iot/nb-iot-deployment-guide/
94. https://www.gsma.com/iot/lte-m-deployment-guide/

TABLE 7.2.1

TECHNOLOGY SPECIFICATIONS FOR LTE-M AND NB-IoT (cont.)

NB-IoT		
3GPP Release 13 (Category NB1)	**3GPP Release 14**	**3GPP Release 15**
FDD support only	Non-Anchor PRB Enhancements	Local RRM Policy Information storage
Support a range of communication options (IP over Control Plane, IP over User Plane, Non-IP over CP, Non-IP over UP)	Connected Mode Mobility added	BEST (Battery Efficiency Security for low Throughput)
Non-IP Data Delivery (NIDD)	Higher data rate available	TDD Support
Different deployment options (in-band, guard-band, standalone)	Positioning by E-CID and OTDOA in addition to CellID	
Power optimisation (PSM & eDRX)	Multicast transmission/Group messaging	
Coverage Extension (CE Mode 0, CE Mode 1 and CE Mode 2)	Release Assistance Indication	
Two power classes for the UE	Added a new lower power class	
Cell reselection only supported		
Singletone or Multitone Transmission		
Service Capabilities Exposure Function (SCEF)		

7.3 The BEMECS Framework

The GSMA has developed the BEMECS (Basic, Economic, Market, Enterprise, Consumer, Spectrum indicators) framework to provide an evaluation tool to assess the 5G market readiness of different countries.

The BEMECS framework tool covers 160+ countries and uses a traffic light system (Green, Amber, Red) to analyse each indicator for each market.

TABLE 7.3.1

THE BEMECS FRAMEWORK – THE FULL DETAILS

BEMECS 5G Readiness Framework			
5G Enablers	**Enabler List**	**Analysis**	**Data Source**
B - Basic Indicators	Region	These indicators provide the socio-political context that will shape the 5G era in each country. They are exogenous and independent of the telecoms industry	GSMA
	GSMA Region		GSMA
	Population		World Bank
	Population Density		World Bank
	Urbanisation		World Bank
E - Economic Indicators	GDP (Real)	These exogenous indicators provide the macroeconomic context that will shape the 5G era in each country	World Bank
	GDP Growth Rate - Real (2018 - 2023)		IMF
	GDP Growth Rate - PPP (2018 - 2023)		IMF
	GDP (real)/Capita		World Bank
	GDP (Constant)/ Capita (2010 - 2017)		World Bank

TABLE 7.3.1

THE BEMECS FRAMEWORK – THE FULL DETAILS cont.

BEMECS 5G Readiness Framework			
5G Enablers	**Enabler List**	**Analysis**	**Data Source**
M - Market Indicators (both mobile & fixed)	Total Subscribers	These indicators reflect the market status ahead of the 5G era in each country	GSMAi
	No of operators (>95% of market)	Given recent trends towards consolidation, 3-player markets are considered optimal for 5G readiness: competition is healthy enough to encourage 5G deployment but not too much to cause deflationary hyper-competition	GSMAi
	Mobile Connections Penetration	>100% suggests a mature market where customers are keen for the next new thing. <70% is indicative of a challenged operating environment with a sizeable pent up demand for basic connection	GSMAi
	Unique Subscribers Penetration	This indicator clarifies whether the general penetration levels is as a result of multi-SIM ownership. >80% suggests a mature market while <50% is indicative of a suggests that there is a sizeable unconnected population	GSMAi
	Average ARPU (Q2 2017 - Q2 2018)	Operators eventually deployed 2G/3G/4G in all markets regardless of ARPU. Same will happen for 5G. However, ARPU of <$10 are unlikely to correlate with a market that can absorb the higher cost of networks and devices in the early 5G era	GSMAi
	ARPU Growth (2018 - 2025)	ARPU is projected to fall for most markets. However a <-5% forecasted decline over the early 5G era suggests that operators need to be doing more to stabilise their business	GSMAi
	Mobile Services Revenue Growth / GDP growth (2018 - 2023)	>100% is indicative of a healthy operating environment and a positive future outlook that is attractive to operators for 5G commercialisation. <0% is indicative of a challenged operating environment where operators are struggling to grow	GSMAi
	Average Download Speed (Mbps)	>40Mbps suggests 5G is next logical step. <10Mbps suggests market can still provide a lot of value with 4G	Ookla
	4G penetration	>70% suggests a market that has attained 4G maturity and ready for the next leap in technology. <40% means the market is not optimal for NSA 5G and may have to wait for 5G SA availability	GSMAi
	Smartphone penetration	>70% suggests widespread consumer readiness for a next generation device. <40% indicates that there is more work to do to increase adoption of high-end/high-tech devices	GSMAi
	Fixed broadband penetration	Markets with >20% fixed broadband penetration are already used to high-speed internet services (and extensive availability of Wi-Fi) for consumer and enterprise customers. These markets should be readier to welcome 5G	ITU
	Fibre (FTTH) penetration	While high capacity microwave links are emerging, fibre will remain key as backhaul for 5G base stations. >20% FTTH suggests a healthy fibre capillarity that can support low cost 5G rollout. <5% suggests that there is little fibre backhaul for 5G	ITU
	Internet backbone penetration	>100% (compared to the USA) suggests there is enough international internet backbone to support a thriving domestic ICT sector. <50% suggests that the market needs more international connectivity options	ITU
	Electricity availability per population	The 5G era will support the digital transformation of all sectors of the economy. >90% suggests that energy/electricity availability is not a constraint to this. <60% suggests an economy where the energy needs of consumers and enterprises are yet to be fully met	SE4ALL

TABLE 7.3.1

THE BEMECS FRAMEWORK – THE FULL DETAILS cont.

BEMECS 5G Readiness Framework			
5G Enablers	**Enabler List**	**Analysis**	**Data Source**
E - Enterprise Indicators	Current Status: IoT connections / Population	>15% suggests a market that is already actively exploiting the opportunity presented by IoT. <5% suggests that the market has yet to tap its IoT potential	GSMAi
	Innovation Potential: Population with Tertiary education	>50% suggests that there is a sufficient pipeline of intellectual creativity to develop new 5G-enabled solutions that are applicable to the local market. <20% suggests that a critical mass of young people are not being properly equipped to create new 5G-enabled services.	UN
	Innovation Potential: registered websites/1000 people	>172 (Median + 1 Standard Deviation for all countries) suggests an ecosystem that is prolific and diversified in creating an internet-based frontend for local services. <11 (Median for all countries) suggests that more needs to be done to provide an internet frontend for local services.	ZookNIC
	Innovation Potential: apps developed/1000 people	>3.7 (Median + 1 Standard Deviation for all countries) suggests an ecosystem that is prolific and diversified in creating an app-based frontend for local services. <0.4 (Median for all countries) suggests that more needs to be done to provide an app frontend for local services.	AppFigures
	Barriers to innovation: Ease of doing business	Operators need an innovation and investment friendly regulatory environment to fully explore 5G era business opportunities. >70% suggests a market with fewer obstacles to innovation. <40% suggests that policymakers should be doing a lot more to encourage investment and innovation	World Bank
	Barriers to innovation: apps in national language	>70% suggests that Enterprises have a vibrant ecosystem of locally-relevant internet/app resources. <30% suggests that more needs to be done to localise and use digital technology in enterprise environments	AppFigures/ Ethnologue
	Enterprise Example: E-Government availability	Government is often the biggest 'enterprise' vertical and >70% availability of e-Government services is an indication that the market has gone far to use digital technology for enterprise applications. <30% suggests that more needs to be done to use digital technology in enterprise environments	UN
C - Consumer Indicators	Affordability: ARPU/ GDP per capita (monthly analysis)	<3% suggests that most customers can, in general, afford to pay for premium 5G services. >6% is indicative of a market where mobile telecom's share of the consumer wallet has little room for growth.	GSMAi
	Affordability: Internet Device ASP / GDP per capita	<3% suggests that most customers can afford the cheapest internet device, either by paying for it out rightly or via some of subsidy or financing scheme. >6% is indicative of a market where the cheapest internet device is still seen as an unaffordable luxury.	Tarifica
	Ability: Literacy rates	>80% suggests most consumers can, with minimal effort, embrace new 5G-enabled services and enterprises can be assured of adoption of new 5G-enabled services. <50% is indicative of a market that has yet to reach tipping point on literacy and where many customers are mostly comfortable with basic voice and video services only.	UN
	Usability: Household computer penetration	Several 5G era use cases (e.g. Cloud AR/VR) will require new hardware/gadgets. Markets with >70% household computer penetration are indicative of a readiness to acquire the next entertainment or productivity-enhancing gadget. <30% suggests there are affordability challenges to buying new gadgets.	ITU
	Consumer example: mass market Fixed Wireless Access (FWA) opportunity	A "mostly Blue Ocean opportunity" for 5G FWA exists where there is high household computer penetration but low Fixed Broadband (FBB) penetration. In "mostly Red Ocean" markets, 5G FWA will compete aggressively with existing FBB. Other markets are "Deserts" for 5G FWA. However, every market will have 'oasis' of FWA opportunities for affluent residential areas or business districts	GSMA
	Consumer example: mobile social media accounts (% of pop)	Social media has been a flagship consumer use case in the 4G era. >60% suggests that this service has reached maturity levels and customers are ready for new 5G era flagship use cases. <30% suggests that not enough consumers can afford, or are eager to embrace new use cases	We Are Social

TABLE 7.3.1

THE BEMECS FRAMEWORK – THE FULL DETAILS cont.

BEMECS 5G Readiness Framework			
5G Enablers	**Enabler List**	**Analysis**	**Data Source**
S - Spectrum Indicators	<1GHz availability	>161MHz (Median + 1 Standard Deviation for all countries) are markets where operators have substantial spectrum in the recognised sub 1GHz 5G NR bands. 0 means operators do not have any spectrum in the recognised sub 1GHz 5G NR bands	GSMAi
	1 - 6 GHz for 5G availability	>300 MHz (assume 3 operators with 100MHz blocks each) are markets where operators have substantial spectrum in the recognised 1 - 6 GHz 5G NR bands. 0 means operators do not have any spectrum in the recognised 1 - 6 GHz 5G NR bands	GSMAi
	>6GHz for 5G availability	Markets where operators have substantial spectrum in the recognised >6GHz 5G NR bands are ready for 5G on mmWave spectrum.	GSMAi

7.4 Lessons from IT virtualisation

Evolving mobile operator networks to network clouds

Co-authored by VMWare

7.4.1 Best Practices for telcos learned from the IT Datacentre virtualisation market

The process of virtualisation for mobile operators will bring the architecture of the software-defined data centre into the telecom network domain, delivering a common infrastructure platform for IT and network operations. Experts concur that there are two important benefits to virtualisation: cost and agility. When combined, there is immense potential to realise value for mobile operators, particularly with the imminent arrival of 5G. Operators have a window of opportunity to transform their networks to distributed network clouds, and in turn play a keystone role in the next generation of cloud evolution

The competitive landscape is changing on multiple fronts for mobile operators, with new services and new players battling for subscribers with different 'just-in-time' or on-demand business models. This requires operators to embrace non-traditional areas, such as digital, and to work in faster, more agile ways. This business imperative is analogous to the digital transformation that the IT data centre has gone through over the past two decades, culminating in "datacentre clouds", where business agility depended on IT agility.

Cloudification (including Virtualisation and Software Definition of Network Assets and Services) helps organisations shift IT resources from mundane tasks to more strategic projects that create value for the business. VMware, a key player in the virtualisation space, believes that well-executed virtualisation can reduce capex by up to 60%, with business infrastructure virtualisation solutions also enabling organisations to significantly reduce IT opex. For example, in a research study with 30 customers in a variety of industries, VMware found that the operational impact of virtualisation on IT operations resulted in:

- **94% of respondents realised operational savings** with virtual infrastructure for both one-time and day-to-day tasks.
- one-time tasks of provisioning servers, decommissioning servers and migrating servers from one data centre to another each took at least **75% less** time with virtualisation.
- performing the specific day-to-day tasks of hardware maintenance, rolling back from unsuccessful patches and rolling back from unsuccessful configuration changes each took **at least 75% less time with virtualisation.**

By simplifying and automating ordinary IT activities, virtualisation solutions can dramatically reduce routine management and maintenance tasks and their associated labour hours, saving organisations energy that can be focused on new business efforts and enabling companies to improve productivity and service availability, while reducing operating costs.

Another lesson that can be gleaned from the transformation of the IT sector is that the performance and robustness that comes with virtualising IT workloads and applications is significant. Similar to the early experiences with some operators as they deploy network functions virtualisation (NFV), the early days of the IT data centre market were met with trepidation about whether or not applications could run as good or better in a virtualised environment as they did on dedicated hardware. The industry quickly realised how robust the technology was and today the vast majority of all IT applications and workloads are virtualised. Mobile operators are likely to follow a similar path where initial deployments start off with some scepticism, but once cost savings are realised, the pace of VNF (Virtual Network Functions) onboarding accelerates, technical barriers (such as performance and latency) are progressively overcome and confidence grows with each subsequent deployment.

When looking at the business justification for virtualisation of network functions and transforming carrier networks into cloud-like infrastructure, operators need to consider the holistic benefits beyond just the reduction in hardware and software costs. Across multiple industries, the TCO of virtualisation has far reaching benefits including:

- Reducing costs by consolidating idle resources and redeploying those resources on new projects.
- Increasing efficiencies in IT operations. This benefit is just as transferrable to network operations.
- Improving time to implementation of new services, leading to faster 'time-to-revenue'.
- Reducing cost of launching and operating new services through remote, software defined delivery and management. No need for truck rolls and install/decommissioning of expensive hardware
- Increasing disaster recovery capabilities, including decreasing recovery time on existing non-high availability services.
- Building cost-effective and consistent development and test environments.
- Reducing costs in troubleshooting, technical support training and maintenance.
- Consistency in management and security through the ability to apply a common set of configuration rules across large distributed environments.
- Leveraging hyperscale public cloud environments where needed.

Over the past two decades, tech innovation has reshaped our expectations and transformed almost every industry, from banking to media, healthcare to retail, manufacturing to transportation that has depended heavily on the underlying technology infrastructure. Telecommunications is no different. As these other industries have witnessed, virtualisation is the foundational principle leading to cloud like agility and efficiency.

5G essentially marks the "cloudification" of the telecom industry, which requires a new mindset and culture. As mobile operators start to deploy 5G, NFV is an essential technology to compete and differentiate, **creating new value** for their customers: new products, new services, new revenue streams. As the IT data centre market did before, mobile operators will need to embrace the first rule of the cloud, which is to consistently automate everything and use industry standard platforms where possible for infrastructure. It also means embracing core tenets of modern software development like Agile/continuous delivery, which allows teams to compress and accelerate their innovation cycles. Equally important are business model transitions from existing services to a new service model encompassing concepts like marketplaces, SaaS services, shared revenue, shared cost and multi-tenancy. These are the essential principles that define a cloud-centric culture and where operators can benefit from learning from their IT predecessors.

7.4.2 Technical Advantages: A production-proven NFV platform is essential for 5G success

With automation, scalability, and an extensible platform for creating and delivering new services, mobile operators can begin to match the agility of cloud service providers and reap the cost benefits that they have come to realise in their IT operations. Key advantages are listed below:

7.4.2.1 Accelerated network performance and scale

Facing rapidly increasing data traffic and demand for enhanced user experiences, Mobile Operators are renewing their focus on architecting the network for optimum application throughput, response times, scale, and service continuity. NFV enables Control and User Plane Separation (CUPS) – this is quickly becoming fundamental to the 5G toolbox, enabling extensible network deployment, operation, and independent scaling between control plane and user plane functions, while not affecting the functionality of the existing nodes.

With the extensibility to deploy user plane (UP) nodes closer to the RAN, a CUPS- based NFV deployment facilitates reduced latency and increased throughput for applications without increasing the number of control plane (CP) nodes. This also allows for the independent evolution of the CP and UP functions, including their placement and scaling.

This approach also aligns well with other evolving techniques such as MEC, where the UP nodes become the data plane for MEC servers, and Network Slicing, where Mobile Operators can dynamically create a network slice to form a complete, autonomous and fully operational network customised to cater to diverse customer needs.

7.4.2.2 Intent based assurance

Deploying new services on-demand, with real-time scaling, monitoring, and proactive avoidance, has now become imperative. Mobile operators can leverage NFV capabilities to achieve assured application performance based on business and operational intent, increased capacity utilisation without resource contention, 360-degree visibility with real-time insights, root cause analysis and remediation, and reduced operational costs through real-time predictive analytics, contextual troubleshooting, and closed loop automation.

7.4.2.3 Carrier-grade networking and security is key

Mobile operators are increasingly seeking networking and security platforms that provide consistent connectivity, QoS, integrated security, and inherent automation to deliver applications and services, when and where needed. Well-executed NFV implementations can facilitate this fundamental shift in networking capabilities by offering complete multi- tenant service separation, consolidated network functions in NSX including NAT and load balancing, simplified administration of application QoS profiles, enhanced network resiliency and distributed stateful re-walling, and cross-cloud and native PaaS support.

7.4.2.4 Unified virtualised environment across IT & network operations

With Mobile operators looking for increased flexibility and efficiencies in bringing new services to market, the ability to programmatically deploy services anywhere from the data centre to cloud, to branch, and the edge, and across different technologies, including VMs and containers, is becoming key. With NFV, operators can deploy both VM and container workloads on a VIM with a single network fabric allowing them to seamlessly deploy hybrid workloads where some components run in containers and others in VMs.

7.4.2.5 Extensible platform

Phased delivery of NFV functionality not only returns a better business case but also ensures mobile operators can minimise the need for new operational skills and processes, providing a more manageable on-ramp to NFV- based service deployment. A virtualised cloud environment for the carrier network also has the advantage of being able to leverage the hyperscale “public” cloud environments (from the likes of Amazon, Microsoft, Google) where needed. As an example, seamless movement (through a process that VMware refers to as “vMotion”) of a network function or addition of new capacity from a public cloud could be a valuable asset to improve the resiliency and capacity management of carrier networks.

7.4.2.6 Simplify network operations

NFV promises to give operators unprecedented agility and flexibility in deploying and operating their networks. Software defined architectures that are the foundation of NFV enable remote deployment, manageability and ongoing operations. Uniformity across compute, storage, and network environments allow for a reduced set of operating principles and configuration complexity.

7.4.3 A Multi-Service Multi-Tenant Platform Returning ROI for NFV

The evolution from static, appliance-based network elements to an agile, virtualised telco cloud environment enables mobile operators to drive down costs while establishing a common platform for new service innovation and revenue expansion. This secure NFV environment can be shared across lines of businesses and multiple tenants, allowing for convergence of telco network, IT, and B2B services into a multi-cloud architecture.

Complete tenant resource isolation can be achieved using policy-based allocation of isolated compute, storage, and networking resources mapped to individual tenants of the cloud(s), providing complete tenant and VNF isolation. Provider and tenant-based roles and service policies further help establish delegated access, and availability and performance boundaries across the cloud(s).

This multi-services platform approach allows mobile operators, tenants, and customers to share a common pool of resources, creating a portfolio of network, managed hosting, and cloud services on demand, driven by orchestration techniques similar to those managing workloads in cloud data centres.

Service agility is further enhanced through standard and pre-defined tenant services that can be deployed on-demand in response to changing customer and network requirements. Tenant-specific portals and northbound APIs enable several operational intelligence capabilities including monitoring, issue isolation and remediation, automation workflows, and capacity planning and forecasting.

7.5 Network Slicing - Making It Happen

Insights from the first global end-to-end implementation at KCL

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7.5.1 Executive Summary

- Network slices were introduced as a concept in order to effectively support the diverse requirements of 5G applications.
- Network slices provide a functional construct to achieve two orthogonal objectives: (i) isolation between traffic which may interfere with each other; and (ii) a network design which best supports the mix of applications that are running within the slice.
- Native support for isolation can provide strong security guarantees, which makes it attractive to new client groups, such as enterprise customers. However, cost factors and limited granularity of slicing at UE or radio network may lead to (partial) sharing.
- The paradigm of partial sharing creates the key tensions which must be managed in any implementation of network slicing. First, in the shared parts of the infrastructure, there is a tension between separation by reserving resources and the gains that can be achieved by statistical multiplexing. Second, the difficulty of virtualising and sharing radio resources imposes restrictions on the number of slices. This leads to questions about where the network slice "ends" (i.e., whether the slice reserves resources and provides guarantees all the way up to the UE, or just in the core network, or the core and parts of the access network), and whether slices will be shared amongst customers who may have similar requirements.

7.5.2 Recommendations

The major takeaways for the telco industry are as follows:

1. **Embrace the heterogeneity of tenants:** If network slices become successful, they will disappear from public view and act as an enabler for different applications that will excite more interest. However, the engineering that will go into making this happen can be the "make or break" factor for widening the range of industry verticals as customers of 5G telecommunications offerings. This requires mobile operators to play at both ends of the economic spectrum, catering both to high end consumers who require high levels of differentiation and to consumers who require low cost slices, requiring operators to operate well-tuned and optimised networks at high levels of efficiency to derive revenue through volume.
2. **Optimise granularity of network slices:** While a higher granularity in network slices allow for more differentiation and can enable more innovative business models, it also increases the costs of provisioning a slice. The level of granularity is, hence, a critical decision. Current (Release 15) standards specify that at any given time, a single UE may be associated with up to eight distinct network slices. This places a hard constraint on the number of end-to-end network slices that can be pushed all the way to a client device. Negotiating this tension between greater isolation through completely separate network slices, and lower costs of sharing slices will be a key component in the economics and business models of network slicing.

3. **Understand that network slicing can serve different ends:** Associated with the previous point, network slicing can serve at least three different functions, each with different deployment constraints and different economic driving forces: (i) as a container to provide a degree of isolation to customers; (ii) as a way of providing a "tailored" network, suitable for a particular kind of application (e.g., a connected cars network slice for automotive applications); and (iii) as a way of specifying a desired set of quality of service (QoS) parameters commonly demanded by common applications. The degree of sharing increases from (i) to (iii), and costs decrease correspondingly.
4. **Establish interoperability and inter-operator co-operation:** Network slices of global players (e.g., UPS or FedEx managing a fleet of vehicles) require the orchestration of different kinds of resources from different parts of their network. Such orchestration may span different countries and different operators. Thus, realising the collective benefit of network slicing will require operators to come together and ensure interoperability of major network slices. Learning from the success and adoption of the SIM, a common interface for creating and managing network slices needs to be simple, and universally supported. slices allow a much richer interface for tenants to express their requirements, so is not an easy matter for network slices to achieve an equivalent level of global support and common levels of functionality. For this to happen, all operators will need to work together and standardise a common set of supported functionalities, and a common language or protocol for negotiating requirements between themselves and the industry verticals.
5. **Ensure intra-operability or consistency of operation:** Especially in large operators with equipment and implementations from multiple vendors, it is important to ensure the different parts of the operators' network infrastructure (potentially running different network stacks), provide a consistent definition or behaviour of network slicing, so that the end customers can be provided with a guaranteed behaviour.
6. **Automate the management of network slices:** Scale will hit, and it will hit hard. Despite progress in various MANO options, including some outstanding work by ETSI, we still have a way to go here, in automating the management of network slices. The only way to address the scalability will be through automating the instantiation of the network slices within a single domain or across multiple domains. This automated process will bring in a need to define negotiation protocols for cross-domain slices and also verification processes to ensure output of the automated instantiation performs as planned. For the full benefits of network slicing to be realised, the creation of network slices should be simplified as much as possible, and operators should enable on-the-fly and responsive increasing or decreasing of a slice's resource requirements.
7. **Slice templates with predefined and optional fields:** Having standardised slice templates could bring down the cost and time to deploy of network slices significantly, guarantee interoperability, and enable automation of slice management on global scale. While slice templates should have largely predefined fields with fixed size to achieve the above, ability to set default values in these fields and additional optional fields will allow network operators to draw a clear differentiation in the service they offer.

8. **Prepare for new business models and new ways of working:** Network slicing creates new roles for mobile operators as infrastructure providers and will draw in new industry verticals who will act as tenants that rent this infrastructure. Multi-tenancy and sharing of infrastructure in a transparent manner will create significant new revenue streams for operators, but will also require fundamental operational changes to realise these benefits. We expect that at least in the initial days, major companies with a worldwide presence will be able to ensure their bespoke slice requirements by striking deals with all major operators in the markets they wish to operate in. In other circumstances, mobile operators may need to come together to cooperatively provide a type of network slice that is seen to have a high demand, but has not been standardised yet (e.g., through the allocation of a Slice/Service Type or SST value). We may also see the creation of specialised aggregators, who help create a standardised network slice for a particular industry requirement, and provide the interoperability at the service level for an industry, by working with different operators. Such aggregators would be akin to special-purpose MVNOs, providing a bespoke kind of network at a lower price or higher efficiency or quality (for instance, a network slice that is tuned for massive IoT).

9. **Prepare for a fundamental change the relationship between mobile operators and end customers:** For the first time, enterprises in industry verticals will be able to create native and specialised networks that allow them to reach customers directly on top of mobile operators' infrastructure. The implications of this change are several: exchange of customer information between verticals and mobile operators need to comply with privacy laws in different jurisdictions; operators will need to consider that users may, in some cases, not be locked in as they are now, and this will need to be factored into the economic models of operation and pricing structures; and business operations will need to change to accommodate the potential B2B (or B2B2C) models of operation.

10. **New regulation will be required to identify how and to what extent users' data can be mined:** With reaching out to the customers, verticals will also have some degree of access to customers' data. While some sectors (e.g., content providers, online advertising industry) have had significant revenue by mining their users' data in the past, regulations have not allowed other sectors such privilege. New regulations will be needed in how users' data can be used by different verticals.

7.5.3 A technical background

The Next Generation Mobile Network Alliance (NGMN) defines network slicing as a concept for running multiple logical networks as independent business operations on a common physical infrastructure [1]. 3GPP Release 15 incorporates the notion of network slicing, and defines it as "A logical network that provides specific network capabilities and network characteristics." As one of the core functional enhancements introduced in 5G, it is expected that network slices will be a critical and indispensable component of cellular networks in the near future.

Network slices were introduced as a concept in order to cleanly support the diverse requirements of 5G applications: For example, a massive number of data flows for machine-type communications that each require inexpensive transport of a small number of bits impose a fundamentally different set of requirements on the mobile network from a single data flow supporting remote surgery, which requires low latency, low error rates and support for much higher bandwidth. It is envisioned that in 5G, such diverse applications may run in parallel networks that are logically separated from one another, whilst sharing the same physical infrastructure, i.e., in two different network slices.

Network slices provide a functional construct to achieve two orthogonal objectives: (i) isolation between traffic which may interfere with each other; and (ii) a network design which best supports the mix of applications that are running within the slice. Native support for isolation can be used to provide strong security guarantees, which makes it attractive to new groups, such as enterprise customers. Because each slice can be tailored to support a particular application or mix of applications, network slices can also be used to provide strong quality of service guarantees (based on isolation from other network slices). As a corollary, this can also lead to differentiated services in different network slices (a matter for policy debate).

Network slicing is achieved by using NFV techniques. Virtualisation allows multiple logical network functions to co-exist on the same physical hardware infrastructure without interfering with each other. The performance guarantees required by the applications are supported by reserving appropriate resources and chaining together virtualised network functions to create a network slice that delivers end-to-end functionality between the network endpoints being connected. Whereas partially shared infrastructure, which is composed of generic hardware resources such as Network Function Virtualization Infrastructure (NFVI) resources, work well in certain parts of the network, it is harder to virtualise or slice other hardware resources, and may require dedicated hardware for network elements in the RAN.

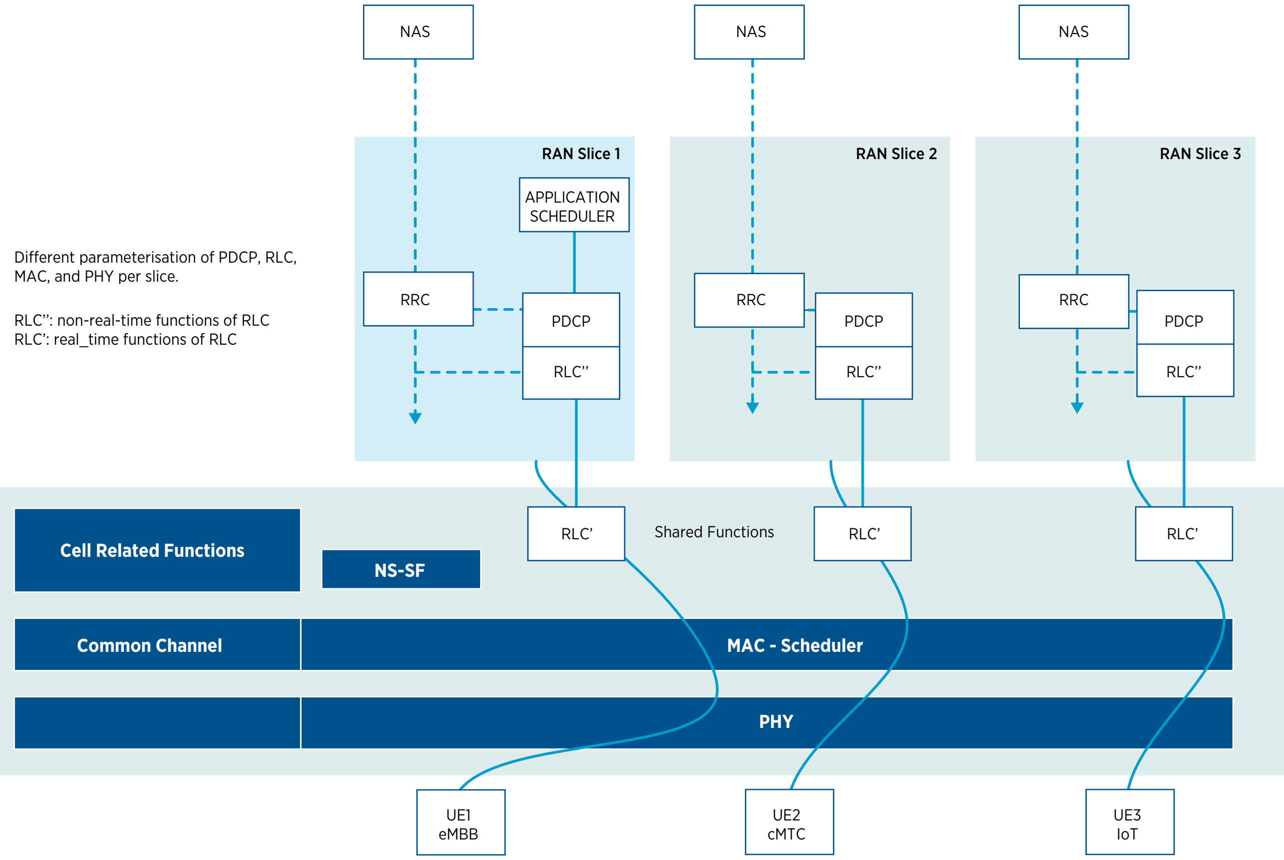
This paradigm of partial sharing creates several tensions which must be managed in any implementation of network slicing. First, in the shared parts of the infrastructure, there is a tension between separation by reserving resources and the gains that can be achieved by statistical multiplexing: If traffic from different slices are using the same network resources, it can lead to contention and congestion, resulting in delays, dropped packets, etc. To achieve true isolation, network resources need to be reserved in advance. However, reservations greatly decrease the statistical multiplexing gains that can be derived from the network. Second, the difficulty of virtualising and sharing radio resources imposes restrictions on the number of slices. This leads to questions about where the network slice ends, and whether slices will be shared amongst customers who may have similar requirements (For example, to support connected cars on 5G, will/should there be a separate slice for Ford cars and a separate slice for BMW cars, etc., or will there be a single network slice for cars from all manufacturers).

Generally, three solution groups are discussed with varying levels of common functionality in 3GPP standards [2]: Group A is characterised by a common Radio Access Network (RAN) and completely dedicated Core Network (CN) slices, i.e., independent subscription, session, and mobility management for each network slice handling the UE. Group B also assumes a common RAN, where identity, subscription, and mobility management are common across all network slices, while other functions such as session management reside in individual network slices. Group C assumes a completely shared RAN and a common CN control plane, while CN user planes belong to dedicated slices.

7.5.3.1 Example of shared and slice-specific functionality

FIGURE 7.5.1

EXAMPLE OF THREE SLICES SHARING COMMON SPECTRUM (TAKEN FROM [7])



As described in *Mannweiler et al.* [7], when spectrum is shared amongst mobile virtual network and service operators, the RAN is a typical example of a shared network functionality, part of which is controlled by a single authority and part is shared. Figure 7.6.1 illustrates the case of a common spectrum shared by three network slices, each with own RAN and CN part. The layer 2 Control-plane is split into cell related functions which are common to all slices, and session or user specific radio resource control (RRC). Depending on the underlying service, RRC can configure and tailor the User-plane protocol stack. For instance, Slice 1 has an application scheduler, not present in the other two slices.

7.5.4 Use cases and benefits of network slicing

Network slices and the softwarisation of the network in 5G enable a clear separation between functionality and infrastructure. This leads to a new paradigm of Network Infrastructure as a Service (NIaaS), and a role for traditional mobile network operators as infrastructure providers (InP), on top of which different industry verticals can create and tailor networks that suit their particular mix of application-level requirements. Each user of an infrastructure slice is termed as a tenant. The key attraction of network slices from an InP point of view, is that it enables multi-tenancy, i.e., multiple independent clients who are oblivious to each other but are sharing the same set of physical network resources. This enables huge cost benefits for InPs, and we expect this to be the key economic incentive for today's mobile network operators to deploy network slicing. The new guarantees provided by network slices also make it attractive from the perspective of the tenants. Furthermore, tenants only pay for the amount of network resources they use. Thus, network slices create a win-win situation for both the infrastructure provider and the verticals that run on top of the network. Below, we list the key aspects that unlock value.

7.5.4.1 Security (Isolation and privacy)

Network slices enable infrastructure providers to make two key security guarantees to their tenants: (i) isolation, i.e., one tenant cannot interfere with another tenant's traffic; and (ii) privacy: i.e., one tenant cannot infer another tenant's traffic details.

With isolation, the infrastructure provider guarantees that an action in a network slice belonging to one tenant will not in any way affect other tenants. Interference includes malicious attacks as well as inadvertent errors. Thus, for instance, if there is an attack on a slice operated by one tenant, for instance a rapid increase in network traffic due to a denial of service attack, other tenants are protected from the effects of that attack. Isolation between slices enables 5G to become a platform for applications such as finance and health care to use the public 5G networks. For instance, highly lucrative financial applications such as dark pool trading and algorithmic trading rely on extremely low latency connections. While advances in 5G lead to low latency, such applications will also require that their flows are not affected by background traffic which can suddenly increase the experienced latency at inconvenient times. Similarly, a surgeon operating remotely over a 5G network will require not only low latency, but also an extremely low error rate. Interference from other traffic can lead to tragic consequences and, therefore, isolation through network slicing will be critical to adoption of 5G by such applications. Note that these requirements are distinct from merely expressing a QoS preference. Typically, QoS guarantees are treated as "soft" whereas a violation of QoS in the examples cited here could have severe financial or human effects.

Isolation between network slices leads naturally to the second security element: privacy of each network slice. Each tenant is guaranteed that other tenants are not able to infer characteristics of the network traffic within its slice. This guarantee that other tenants cannot infer the network characteristics of a network slice allows sensitive applications to make use of 5G network infrastructure. For example, enterprise networks spanning multiple locations can run over 5G rather than having to create separate and parallel connectivity infrastructure. Because network slices are constructed using softwarised and virtualised network functions, they are expected to have lower running costs than leased private lines. This creates lower CAPEX and OPEX for the InP, which can pass on the savings to the tenants. Additionally, the softwarisation also leads to flexible allocation of resources, allowing tenants to rapidly change their demands on the 5G network depending on their business needs.

7.5.4.2 Improved QoS and traffic management

As noted above, there is a distinction between network slicing and QoS. However, the isolation guarantees offered by slicing also becomes an enabling factor for improved QoS management: a tenant can more easily manage its traffic and ensure better QoS for itself since other tenants cannot interfere with it. Although 5G provides also provides for 5QI [2] as a mechanism for specifying QoS requirements, 5QI values are standardised and interpreted in well-known and well-specified ways. The flexibility of network slicing creates a parallel and much more flexible mechanism for tenants to express bespoke QoS requirements. For common kinds of network slices, such requirements can be expressed in terms of a template, which will then be instantiated by the infrastructure provider [3].

7.5.4.3 Creating tailored services

Given spectrum is one of the most valuable assets of any mobile operator, dividing frequency bands to different use cases and industries does not offer the best use of spectrum. As not all use cases have the same pattern of use, network slicing, with slice isolation, provides an opportunity for services to physically co-reside on the same frequency bands but remain logically isolated and secure.

7.5.4.4 Autonomy in network management

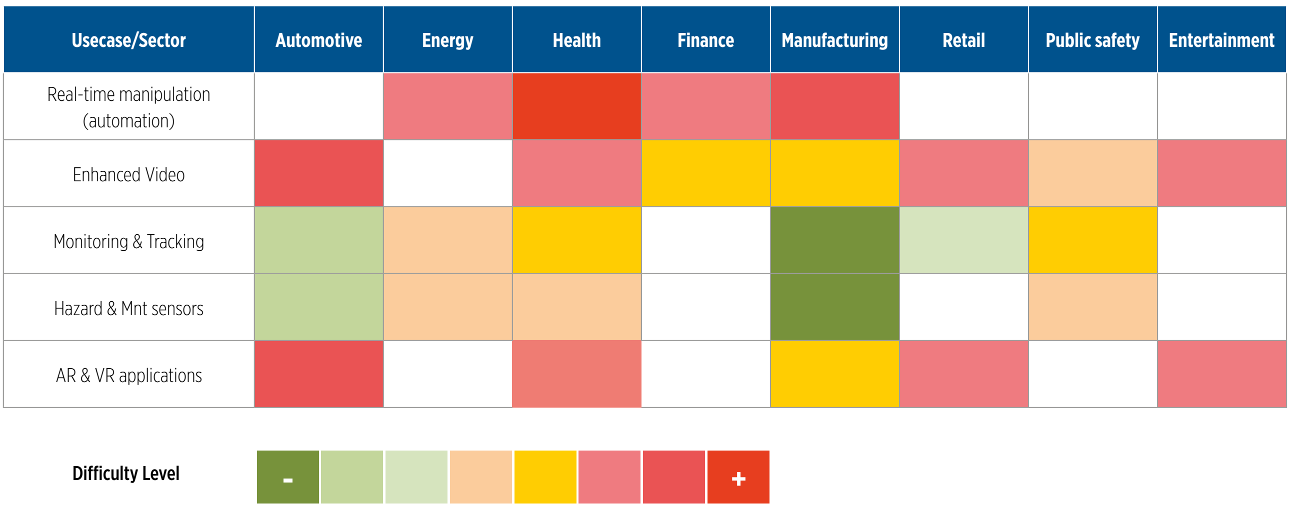
Because of isolation, neither the infrastructure provider nor the other tenants are affected by the actions of a tenant in a given network slice. Thus, tenants can be given much more flexibility in managing the logical networks encapsulated as a network slice. This allows all sorts of novel applications not possible before, ranging from implementation of custom ways of differentiating across services, which may not be possible in the public 5G network (e.g., due to network neutrality guidelines) to rigorous and tailored rules for managing different kinds of traffic that fit a particular tenant's needs (e.g., attaching a dedicated bearer for a particular kind of flow, or having flows without a bearer at the logical level).

7.5.4.5 Vertical support and revenue

Network slicing as one of the main distinguishing features of 5G compared to the previous generation in terms of how mobile operators serve their business users, makes it also the major defining factor of revenue models. It is however important to understand, deployment difficulty both in terms of performance requirement of a certain use case, as well as the level of required support from network, varies for different use cases. At the same time, the challenges of deploying use cases and the relevance of different use cases to vertical sectors, also greatly vary. This diversity is captured in Figure 7.5.2, below. Taking a few examples from Figure 7.5.2, e.g. real-time manipulation is an extremely challenging use case since it requires high reliability and low latency simultaneously. However, deploying real-time manipulation in a vertical such as healthcare is even more challenging given the precision required for the operations, or in manufacturing sector in which there is a high degree of dynamic. While use cases such as hazard and maintenance sensors are less challenging to deploy, there is yet a higher challenge for deployment in public safety sector given the higher requirements on security and resilience.

FIGURE 7.5.2

DIFFICULTY OF ADDRESSING DIFFERENT VERTICAL SECTORS AND USE CASES WITHIN THOSE SECTORS



It is also evident that a single vertical sector might be in-need of multiple use cases with different connectivity requirements and level of deployment difficulty. One of the examples of a vertical market is the automotive industry and the path to connected autonomous driving. While the use of URLLC for assisted and autonomous driving functionalities will be exploited, there are also opportunities for providing on-the-move entertainment services, with different connectivity requirements that can potentially be delivered through different slice(s).

7.5.5 The challenges and deployment constraints

The challenges for achieving network slicing have to do with business pressures and realities on the ground that may make it difficult to achieve an implementation that makes the network slice seamless and transparent to its end users. To see what the challenges are, it may help to consider some properties that would make for a successful network slice. In the best case scenario, the network slice will become an ICT commodity, just like today's compute clouds. It will be:

a) **As easy to deploy network slices as a virtual machine on today's cloud providers:** Today's 4G networks are complicated and complex beasts, requiring highly trained network engineers. 5G network slice functionality will be exposed (potentially via intermediaries; see Section 7.6.2) to verticals, whose core business practice does not include telecommunications. If a slice takes more than a few minutes to deploy, it already becomes too complex and complicated for non-experts, especially small and medium players who may drive much of the operators' revenue by sheer numbers. Note that network slices are much more complicated than today's cloud virtual machines, since slices require not only the allocation of virtualised compute resources, but also radio resources, as well as co-ordinated orchestration and management of these resources, chaining them together appropriately for end-to-end functionality.

b) **Easy to change the size and configuration of a slice on the fly, and at short notice:** New applications and verticals for 5G networks will have two key incentives for adoption - new functionality that enables their businesses to use 5G, and cost reductions. Businesses will see immediate savings in CAPEX by using a virtualised network infrastructure that can be shared with other tenants without compromising security. In the long-run however, cost reductions through OPEX savings are likely to dominate as the main driver for continued usage of network slices. To enable this, it is key that network slices can be changed on the fly - for instance, the amount of bandwidth reserved, or the latency, or number of devices connected may change based on business needs that are hard to anticipate when the slice is being setup. To enable wide adoption, it is imperative that operators should allow applications to start using network slices at the lowest price point that makes sense for the tenants, and then expand or decrease their usage on the fly to suit business needs.

c) **Granularity of radio resources and RAN slicing:** Given providing isolation between radio resources would also bring issues such as wireless interference, slicing RAN is clearly constrained. While in regular operation of the mobile network, RAN resources are dynamically allocated to users, when it comes to the end-to-end network slicing, how dynamic and granular those could be linked to a slice at core network is a challenge. Various models for association between radio resource management and network slicing are studied including auctioning [5].

d) **Revenue associated to verticals:** Not all vertical sectors and all associated use cases come with the same revenue pattern. While some might ask for very strict requirements to the targeted network slice, their revenue potential might be insignificant. Market research have shown diverse levels of difficulty in addressing different verticals and use cases, not directly relevant to the difficulty of deployment (seen in Figure 7.6.2).

7.5.5.1 Example from KCL's participation in the 5G testbed and trials

During 2017-18, King's College London together with University of Surrey and University of Bristol debuted the world's first 5G end-to-end network, which involved a number of cutting edge applications ranging from intelligent cameras and real-time social media collection across the city of London to innovative 5G performances with artists in distributed locations. Together with partners, we have developed a feasibility study to examine what network slicing across multiple operator domains can achieve. In this study, the low-latency application is control of a drone, which is launched both from a local operators' core network and a remote operator's core network. In the latter case, a low-latency network slice is stretched from local operator's core network to the remote operators' core network, where the application server runs (further information is available in [6]). The study has successfully demonstrated the potentials of network slicing in delivering low-latency applications globally, and over multiple operators' networks, relying however on the interoperability of the participating operators' slices. While this proof-of-concept has successfully demonstrated the feasibility of stitching network slices across two operator domains, it has also indicated that manual configuration of a cross-operator slice is a timely process requiring significant coordination.

7.5.5.2 Interoperability (consistent network slices across operators)

As mentioned above, network slices require the orchestration of different kinds of resources from different parts of the network. For instance, as mentioned above, in the 5G network slice demo at King's College London, a drone at KCL was remotely controlled from the USA, requiring an ultra-reliable low latency slice which spanned a local operator in the USA and a local operator in the UK. Although the demo was intended to stretch and showcase the capabilities of 5G network slicing, such multi-operator network slices will not be uncommon in the near future. Consider, for example, a network slice being used by FedEx or UPS to monitor and manage a fleet of vehicles across different countries of the EU. This slice would have to span different operators in different countries, providing seamless connectivity over a heterogeneous set of radio devices, potentially operating at different frequencies. The IoT and machine type communications in general will rely on a geographically distributed set of connected devices.

Today, managing such devices and services is straightforward, requiring only a Subscriber Identity Module (SIM). Global interconnectivity and roaming is managed behind the scenes by the mobile operators. However, this interface is also restrictive, providing only a small set of well-known service levels. Network slicing will allow much finer differentiation of services, allowing different applications to fully utilise the power of 5G. However, for this expectation to be fulfilled, there needs to be a common interface that allows the tenants to express their needs to different infrastructure providers, and negotiate the service levels needed.

Learning from the success and adoption of the SIM, such a common interface for creating and managing network slices needs to be simple, and universally supported. However, network slices allow a much richer interface for tenants to express their requirements, so is not an easy matter for network slices to achieve an equivalent level of global support and common levels of functionality. For this to happen, all operators will need to work together and standardise a common set of supported functionalities, and a common language or protocol for negotiating requirements.

Support for standardised network slicing is already underway. Through the so-called Service/Slice type or SST values, release 15 of the 3GPP architecture specification [2] specifies standardised sets of network functions for common use cases such as enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (URLLC) and massive IoT (MIoT). Standardised network slices can span multiple operators, with functions potentially federated across geographies. However, these few standardised templates for network slices are unlikely to satisfy the exact network requirements imposed by many major industries and verticals (e.g., for a particular kind of robotic surgery, or a particular kind of functionality expected by an autonomous car), and support for such specific requirements will only be satisfied with bespoke network slices. This poses problems: consider, for instance, a car manufacturer which relies on a bespoke kind of network slice for a special-purpose connected car application, created after extensive discussions with a major mobile operator in Germany. If this car were to cross the German borders and a similar arrangement has not been reached with operators on one or more countries in mainland Europe, the connected car application may well not work as intended, with potentially disastrous consequences for road safety.

We expect that at least in the initial days, major companies with a worldwide presence will be able to ensure their bespoke slice requirements by striking deals with all major operators in the markets they wish to operate in. In other circumstances, mobile operators may need to come together to cooperatively provide a type of network slice that is seen to have a high demand, but has no standardised SST value (yet). We may also see the creation of specialised aggregators, who help create a standardised network slice for a particular industry requirement, and provide the interoperability at the service level for an industry, by working with different operators. Such aggregators would be akin to special-purpose MVNOs, providing a bespoke kind of network at a lower price or higher efficiency or quality (for instance, a network slice that is tuned for massive IoT).

7.5.5.3 Intra-operability (consistent network slices within an operator)

A different concern from the above, and one that operators themselves are likely to bear the burden of, is ensuring uniform behaviour of a network slice within a single operator's network. This arises because of legacy radio hardware and software stacks. Because of cost issues, most operators will likely evolve their infrastructure to 5G on top of existing investments, both in software and hardware. They may even have equipment and software from multiple vendors, with different network stacks in a messy but coherent co-existence. Deploying network slices will require exposing abstractions on top of this infrastructure and may lead to bugs or inadvertent behavioural differences in different parts of the network. This will be an important challenge in the early days of network slicing deployment.

A further challenge arises because of the heterogeneity in 5G radio. Cost concerns may lead to only certain kinds of radio being deployed in certain locations, which then may place restrictions on the universal availability of bespoke network slices.

7.5.5.4 Slice per service or slice per customer?

As indicated above, one major concern for the viability of network slicing is the limitations in the granularity of slicing radio resources. A further limitation is that, at the UE level, current 3GPP specifications (i.e., Release 15), allow a maximum of eight slices that the UE can associate with.

Given these real limitations, we expect to see two distinct models for network slicing deployment. The first model will associate a network slice with a unique consumer. For instance, a car manufacturer may obtain a network slice from a major mobile operator to deliver a "connected car" feature for their entire car fleet. The second model is driven more by cost efficiency: mobile operators may define a network slice for a particular kind of service (e.g., mobile broadband, or fixed wireless access). All customers requiring that service will then share a network slice.

The difference between these two models is a trade-off between security and cost: The first model enables better isolation, but because of the inherent limitations of network slicing especially at the radio access network, will involve a much higher price point than the second model. We expect that the majority of network slice consumers will end up sharing a particular kind of network slice (e.g., for enhanced mobile broadband (eMBB), or massive IoT (MIoT)). In other words, the value realised by the customers of a shared slice is simply in the bespoke kind of network that the slice represents, which may provide better support for that application (e.g., an MIoT slice may support much higher levels of control plane or signalling traffic).

Among the benefits of network slicing mentioned above, shared slices involve giving up the isolation advantage and likely will not allow autonomy in network slice management. However, within each slice, it is possible to provide differentiated services and improved QoS. Network slices, whether shared across customers or not, also provide a distinct advantage to mobile network operators by separating different traffic types. This will allow better service, billing and network management, and the simplification of operator networks that can result from principled application of network slicing principles can itself justify the introduction of network slices.

7.5.5.5 Cost vs performance - hard vs soft network slices

Infrastructure providers and tenants alike will have a choice between so-called "hard" network slices, wherein resources are reserved a priori, and "soft" network slices, where the same network resources are multiplexed among different slices. Certain application and traffic types such as ultra-reliable and low latency communications (URLLC) may have no option but to require hard network slicing. Other applications may be able to benefit from the cost savings that can be achieved by soft slicing and overbooking of network resources among competing customers who will likely not require those resources all at the same time. As above, aggregators may come in as tenants of infrastructure providers (today's mobile network operators) and provide a lower cost service by apportioning the slice to their customers.

7.5.6 Vision for network slicing: a laundry list of work items

A number of technical, economic and business factors will influence the final shape of network slicing as it starts to be embraced around the world. Our vision of the work required within the telecommunications industry for network slicing involves three principal components: enabling automated network slice setup; resolving issues created by limitations in granularity; and defining network slicing with a view to the future, and negotiating visibility to end consumers when network slices reach all the way to the UE.

7.5.6.1 Automation in setup of network slices

We foresee the automation of establishment and maintenance of network slices to be a critical factor in enabling scale and wide adoption. While an essential part of defining a network slice is identification of requirements and ensuring network slices can be tailored to the requirements of the service, it is also important that the slices can be setup quickly and with low cost. One of the most prominent solution to achieve this is the definition of a network slice template that could be adopted by operators globally. A template, as seen in Figure 7.5.3, including properties of the slice, i.e. slice parameter-i, with the fixed size for different entries, could be filled either by the network operators, translating their users' or vertical customers' requirements. Having fixed and standard size slice-parameter-i will also allow multiple operators to establish cross-operator slices, when needed, rapidly and through an automated process. While the standard template will allow quick and low-cost setup of network slice, leaving the actual values of slice parameter-i to be selected by operators will allow differentiation in the design and value proposition for different operators globally. Additionally, having an optional field to accommodate extra features of the network slice could offer greater degree of differentiation between operators and how they offer services to their vertical customers.

FIGURE 7.5.3

SLICE TEMPLATE TO BE USED FOR SETUP OF A SLICE AND CAN BE EXCHANGED FOR NEGOTIATION BETWEEN TWO OPERATORS IN ESTABLISHMENT OF A CROSS-OPERATOR SLICE

Slice type (k-0 bits)	Slice parameter-1 (k-1 bits)	Slice parameter-2 (k-2 bits)	...	Slice parameter-n (k-n bits)	Optional fields (extra features)

To support the cross-operator instantiation of a network slice through automated process, the negotiation procedure should also be designed and have a standard form. For example, whether a three-way handshake is sufficient for such negotiation or further cycle of handshake is required. An additional consideration is whether telco operators will be willing to negotiate the establishment of a cross-operator slice using the same slice parameters as they have used to setup the initial slice. However, in a nutshell, we foresee the negotiation for cross-operator setup of network slices through exchanging the slice template as seen in Figure 7.5.3.

The automated instantiation of the network slices also requires an additional step in the setup of a slice, which is verification. Verification will allow the network operators to ensure what has been planned and instantiated has in fact been setup and deliver the expected performance. Such verification might also be needed during the maintenance of the network slice to reassure the performance of a given slice remains as provisioned. There is a strong body of work in the field of verification that can be used in developing this stage of the automated slice setup and maintenance process.

7.5.6.2 Defining network slices with a view to the future

We also foresee the granularity and number of network slices to be far beyond having three typical slice of eMBB, mMTC and URLLC, with slice types defined with three bits, as currently standardised by 3GPP [2]. In fact, it is extremely important to define the format of the slicing template in a way that network slicing can be scalable in the foreseeable future and does not face limitations in either the number of different slices that could be defined (this is k-0 in Figure 7.5.3; e.g. in [2], k-0 is 3), or number of different parameters that define and differentiate a slice (this is n in Figure 7.5.3). The community has similar experience with the IPv4 header that has later been addressed through more scalable definition of the IPv6 header, for example. As mentioned earlier, since slicing is one of the main business drivers for 5G, such differentiation should also be offered to the network users', i.e. vertical customers. Hence, the number of slices and the differentiation between them will be of much higher diversity. For example, an automotive manufacturer should be able to request their own slice with the extra features of their choice. Defining a flexible view of network slicing that takes into account both the need for standardisation as well as the need for differentiation will be important.

7.5.6.3 Negotiating visibility of the end consumer between operators and verticals

While we see a high level of personalised and customised network slices as an essential part of future 5G networks, it should be noted that from an operator perspective, creating an "end-to-end" network slice that reaches all the way to the UE and providing control of this network slice to an interested third party vertical can create a more direct connection between verticals and consumers. This potential removal of the current direct relationship between mobile operators and end consumers can have profound effects, which will need further examination:

- End consumers will potentially be no longer tied to individual mobile operators, and this loss of lock-in may need to be factored into prices and operating models.
- It may, in some cases, be technically more challenging to implement certain functionalities (such as roaming and handoff), without a full knowledge of the end consumer, and their identity and patterns of behaviour.
- Given privacy laws in certain jurisdictions (e.g., GDPR in the EU), legal aspects of handling customer information of the tenant verticals without a direct relationship with the consumers themselves needs to be looked into carefully.
- While the regulation, on how users' data can be used, have been very strict in some sectors, mining users' data has been a significant source of revenue in other sectors. This differentiation between regulatory aspect will remain the same, but there will also be a possibility of a greater level of differentiation.

In the converse case, where the network slice does not reach all the way to the UE, or is shared between multiple customers, verticals will need some information about the consumer they are interacting with, and this information will be held by the operators. Transferring this information across in a safe and legal way to the verticals will need looking into.

7.5.7 Conclusion

Network slicing will be a key factor in realising the economic benefits promised by 5G. In this document, we identified several use cases and benefits, ranging from improved security through better isolation, improved QoS through virtualised networks tailor-made for particular application requirements, better support for industry verticals and autonomy in network management. However, we also identified several challenges to realising these benefits, chief among which are interoperability of network slices and clarification of the extent of a network slice ("Where does the slice end"). We identified a vision for addressing these challenges, through automation of network slice setup, creation of a flexible and well-understood set of templates for different kinds of network slices, and negotiating visibility to the end consumer. It is our view with this, the potential of network slicing will become a reality without a shadow of doubt.

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