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Australian Communications and Media Authority

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Evidence that informs

5G and mobile network developments—Emerging issues

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Executive summary

Four years after the initial deployment of 4G networks in Australia, the mobile sector is turning its attention to the specification and development of the next generation of mobile broadband services: 5G or fifth generation mobile.

Australia has benefited from progressive investments and upgrades in mobile network capabilities and service deployments. Successive generations of mobile technologies have been deployed in Australia approximately every ten years. 5G represents the next expected evolution in mobile technologies, with the first commercial deployments in Australia expected from 2020.

There are two defining requirements for 5G that separate it from previous developments. They are its near-zero latency and data rates of 1–10 Gbps.[1]

These two features support an 'anytime, anywhere, anyone and anything' capability of 5G, which is expected to play a role in supporting a wider deployment of the Internet of Things (IoT) in Australia.[2]

This paper uses the 5G characteristics identified in the GSM Association (GSMA) Intelligence's Understanding 5G: perspectives on future technological advancements in mobile to assess consumer and industry demand, technology developments enabling 5G and potential use cases. These technology characteristics are outlined below.

Specific requirements for 5G (source: GSMA Intelligence)

> Data rates 1–10 Gbps connection to end point in the field
> Near zero latency: 1 millisecond end-to-end round trip
> 1,000 times more bandwidth per unit area
> 10 to 100 times more connected devices
> Perception of 99.999 per cent availability and 100 per cent coverage
> 90 per cent reduction in network energy usage
> Up to 10-year battery life for low power, machine-type devices.

The ACMA's current focus in this area, as outlined in its Corporate plan, is directed towards facilitating access to public resources such as spectrum and telephone numbers, as Australians move to adopt 4G and 5G technologies and make increased use of mobile broadband, machine-to-machine communications and the IoT.[3]

[1] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 6.
[2] ACMA, *The Internet of things and the ACMA's areas of focus—Emerging issues in media and communications*, Occasional paper, November 2015, page 9.
[3] ACMA, *Corporate plan 2015-19*, July 2015, page 5.

Enabling the next phase of mobile network development is likely to require the regulator's attention in a number of areas, including:

> facilitation of access to mobile services by allocating resources necessary to allow wireless networks to develop
> supporting the international harmonisation of spectrum arrangements to provide economies of scale for manufacturers and provide flow through benefits to Australian consumers arising from lower device costs.

This report examines:

> the ongoing development of mobile networks in Australia
> expected consumer and business drivers of demand for the next generation of mobile services
> the technological developments that will underpin 5G network deployments
> use cases that will require 5G in order to be deployed.

The paper also reflects on aspects of existing regulatory arrangements that enable or potentially inhibit the further development and deployment of the next generation of mobile services in Australia.

Feedback—tell us what you think

In this report, the Australian Communications and Media Authority (the ACMA) is looking at the potential routes to 5G network deployment, and asking whether there are any major impediments to the development of 5G networks in Australia. In particular:

1. Are there any additional demand drivers supporting 5G network deployment in Australia not identified in this paper?
2. Are there any additional significant enablers or major inhibitors to 5G network deployment in Australia that are not identified in this paper?
3. Are there additional regulatory issues around 5G network deployment, relevant to the ACMA's responsibilities, which are not discussed in this paper?

How to provide feedback

> **By email**—please email research.analysis@acma.gov.au.
> **Online**—use our new beta online consultation facility to provide comments and answers to the questions above.

Introduction

Mobile networks, as well as the services and applications they support, have facilitated substantial economic and social benefits for the Australian community. Mobile-based services, including online banking, location services, news and entertainment and social networks are supporting the everyday lives and activities of Australians. They also provide a range of benefits for Australian businesses by improving productivity, supporting flexibility and innovation, generating time savings and enhancing customer reach and experience.

A recent ACMA-commissioned study found that mobile broadband increased Australia's economic growth rate by 0.28 per cent each year from 2007 to 2013. This equates to an economic contribution of $33.8 billion by mobile broadband over this period, primarily through productivity improvements.[4]

There is recognition across the international community that communications networks support not only increases in productivity and efficiency, but also play an increasingly key role in driving innovation and social benefit. In Europe, the 5G Infrastructure Public Private Partnership (5G PPP) estimates that five per cent of European GDP, with an annual value of around 660 billion Euro, is generated by the information and communications technology (ICT) sector, including mobile broadband.[5]

The mobile industry, globally and in Australia, has begun to turn its attention to the next stage of development in mobile networks: 5G.

While the capabilities of 5G are still being defined, it is expected to support a massive increase in connections, lowered latency and much faster speeds. These characteristics are forecast to support the next stage in the convergence of communications—the IoT.

In this paper, the ACMA is looking at the demand for, and technological enablers of, the deployment of 5G networks. The paper will also reflect on the existing regulatory arrangements that may be useful in facilitating the next stage of mobile network development.

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Our research program—research**acma**—underpins the ACMA's work and decisions as an evidence-informed regulator. It contributes to the ACMA's strategic policy development, regulatory reviews and investigations, and helps staff better understand the agency's role in fulfilling its strategic intent to make media and communications work for all Australians.

[4] Research report prepared for the ACMA by the Centre for International Economics, The economic impacts of mobile broadband on the Australian economy from 2006 to 2013, April 2014, page 2.
[5] 5G PPP, 5G Vision: The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services, February 2015, page 5.

research**acma** has five broad areas of interest:

> market developments
> media content and culture
> social and economic participation
> citizen and consumer safeguards
> regulatory best practice and development.

This research contributes to the ACMA's market developments and regulatory best practice and development research themes.

This paper continues the ACMA's focus on emerging issues in media and communications. Past papers in the emerging issues series include:

> Mobile apps (May 2013)
> Near-field communications (May 2013)
> Cloud computing (June 2013)
> Privacy and digital data protection (June 2013)
> Six emerging trends in media & communications (November 2014)
> The Internet of things and the ACMA's areas of focus—Emerging issues in media and communications. (November 2015).

(R)evolution towards 5G

Since the 1981 introduction of 1G mobile networks in Australia, consumers and industry have readily adopted each evolution of mobile communication and data services and mobile networks, and the services they support are a firmly embedded part of the Australian economy and society.

Evolution of mobile networks

The first 1G mobile networks were deployed in the early 1980s and were optimised for mobile voice communication services. Since that time, a new mobile generation has been deployed around every 10 years.

> The first 2G system supporting improved mobile voice and a short message service (SMS) was deployed in 1991.

> In 2001 the first 3G system was introduced, supporting mobile voice, SMS and for the first time, email and internet use on mobile devices.

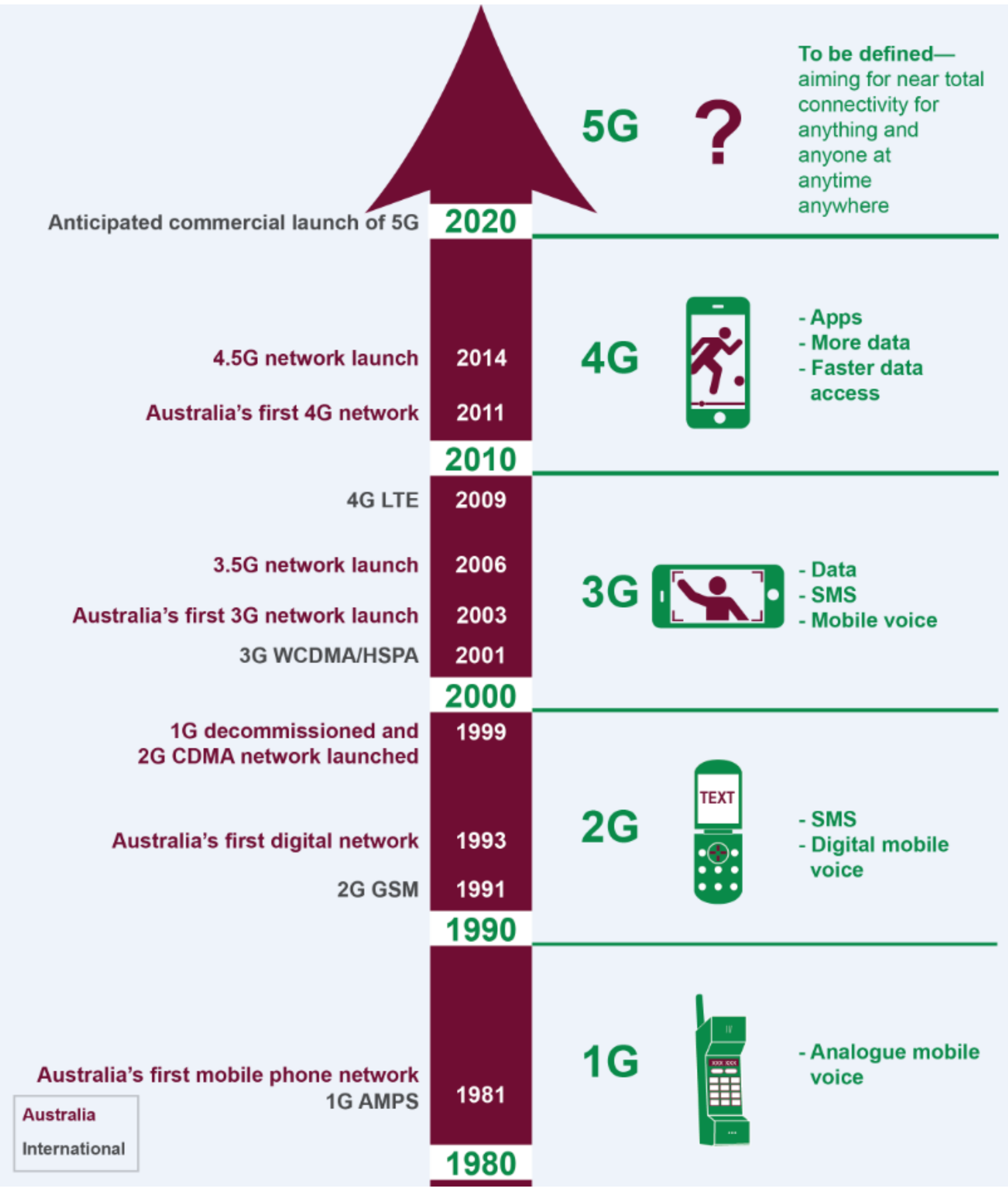
> The first 4G (Long Term Evolution (LTE)) system appeared in 2009, representing a step change in increased capacity and speed for data, supporting mobile video and an explosion of online apps and content for mobile users.

Research and planning is currently underway to define 5G systems, with industry bodies planning for commercialisation in 2020. There have been a range of 5G-related announcements by Australian mobile operators in 2015, including the commitment towards the deployment of a commercial 5G mobile network by 2020.[6]

Figure 2 illustrates this technology evolution, including milestones for deployment of mobile networks in Australia.

[6] Telstra have announced a commitment to deploy commercial 5G networks by 2020. Alex Kidman, Telstra and Optus outline their speedy futures, PCMag, 2 March 2015.

Figure 1: Mobile networks evolution



Source: ACMA

Each of Australia's three mobile carriers is continuing with further enhancements to its existing mobile networks. All three mobile carriers rolled out LTE-A carrier aggregation technology in 2014. Carrier aggregation allows network operators to combine spectrum in disparate radio-frequency bands to increase bandwidth and user data rates. Telstra has also announced that it has commenced foundation work on 5G with an anticipated commercial network launch around 2020.[7]

[7] Graeme Philipson, MWC – Telstra outlines path to 5G, ITWire, 2 March, 2015.

Towards 5G

Industry organisations, governments, consumer groups and standards bodies around the world are working to clarify and define the key characteristics of 5G.

Seven key characteristics of 5G

Key characteristics of a 5G network are expected to include lower latencies, faster network data rates and support for a massive increase in network connections.

The two requirements that could be classified as revolutionary and generation-defining for 5G are the near-zero latency and data rates of 1–10 Gbps.[8]

The specific requirements for 5G identified by GSMA Intelligence provide a useful framework for assessing consumer and industry demand for 5G services and potential use cases, as well as the technological developments needed to support construction of a 5G network.

The seven key characteristics that will be required of a network for it to be classified as a 5G network are:

> **Data rates**—data rates of 1–10 Gbps, which is a step change for mobile networks and is expected to facilitate a high quality and a more seamless user experiences. By comparison, 4G networks in Australia provide advertised data rates of between 2–100 Mbps.[9]

> **Ultra low latency**—reduce latency to a one millisecond end-to-end round trip delay. This is also a step change for mobile networks. By comparison, 4G networks can theoretically achieve a minimum latency of 10 m/s.[10]

> **Bandwidth**—provide 1000 times more bandwidth per unit area than available on existing mobile networks. This will support faster data rates and increase network capacity to support data intensive applications in both the uplink and downlink.

> **Connections**—support the growth of between 10 to 100 times more connected devices than is now supported by existing networks. This is also theoretically possible on evolving 4G networks and mass connectivity is identified as a key enabler for the IoT.

> **Always on**—be available everywhere (100 per cent coverage) at all times (99.999 per cent of the time). This requirement is also theoretically achievable using evolving 4G technologies. It is necessary for high mobility applications and coverage indoors and outdoors as well as high reliability requirements for services where network outage could have catastrophic consequences.

> **Energy usage**—reduce network energy usage by 90 per cent.

> **Battery life**—facilitate up to 10 years battery life for low power, machine-type devices. Both the energy usage and battery life requirements are theoretically achievable using evolving 4G technologies and are aimed at ensuring future networks are cost effective for network operators.

GSMA Intelligence notes that the majority of these requirements can theoretically be delivered by existing 4G technologies, reflecting the evolutionary nature of 5G

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[8] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 6.

[9] Australian mobile network operator websites.

[10] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 13.

development. While this paper will use the 1–10 Gbps characteristic, it is noted that the ITU's official roadmap states 5G could achieve speeds of up to 20 Mbps.

Supporting IoT developments and context-aware services

The 'anytime, anywhere, anyone and anything' capability of 5G is expected to support the forecast increase in device connections as part of the widespread rollout of IoT in Australia.[11]

Services delivered over 5G networks will not necessarily require every key characteristic associated with 5G networks. For example, there will be services that require ultra-low latency with limited mobility needs, such as remote surgery, while other services such as M2M may require high mobility but are not latency sensitive. It may not be technologically possible to deliver all 5G characteristics for the same service at the same time (utilising practical bandwidth resources). This suggests that 5G networks may instead deliver a suite of characteristics of which a subset will be required for a specific situation or service, rather than a blanket set of service guarantees.

Some analysts envision that 5G will further enable context-aware services that provide relevant information in the right form depending on the context, rather than a user actively searching for that information. That is, the network or service will deliver relevant information according to the situational requirements, without the user actively participating in the process.[12]

[11] The ACMA has published a paper on the development of the Internet of Things. ACMA, *The Internet of Things and the ACMA's areas of focus, Emerging issues in media and communications, Occasional paper*, November 2015.

[12] 4G Americas, 4G Americas' recommendations on 5G requirements and solutions, October 2014, page 11.

Demand for mobile services

While technology capability enhancements such as 5G may be possible, commercial decisions about where and when to deploy new technologies are informed by estimates of possible market demand and network utilisation.

Industry and consumer demand for, and use of services on mobile networks are key drivers for increases in mobile traffic. The volume of data downloaded by Australians is one measure of network utilisation. In the three months to June 2015, Australians downloaded over 71 PB of data via mobile handsets. This represents an 85 per cent increase since the three months to June 2014.[13]

Projections of total mobile data traffic vary, but all forecast strong growth. The Analysys Mason base case mobile network infrastructure forecast produced for the ACMA in 2014, which is broadly in line with forecasts produced by other analysts including Cisco, suggests that each year's incremental growth will be larger than the previous years.[14] Total mobile data traffic is forecast to increase from 7.7 PB per month in 2011 to 137.9 PB per month in 2020.[15]

Table 1 outlines selected demand drivers for mobile services and the improvements that 5G networks will offer. This chapter explores these factors as drivers for increased network traffic and an input into commercial decisions for network investment.

Table 1: Demand drivers for improved mobile networks

1. Consumer drivers
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. Business drivers
Increased productivity
Enhanced/new services

Consumer demand drivers

Increases in device connections, data-based services and the number of mobile-only consumers all provide evidence of changes in demand for mobile services. At the same time, social trends—such as increased fixed-mobile substitution—can further

[13] ABS, 8153.0 Internet Activity, Australia, June 2015.

[14] Analysys Mason, Updated final report for the Australian Communications and Media Authority, Mobile Network Infrastructure Forecasts, June 2015.

[15] Analysys Mason, Mobile network infrastructure forecasting model (Excel), June 2015.

encourage consumer demand. These elements inform planning for network upgrades and investment by telecommunications companies.[16]

Increasing number of mobile devices

The growth in smartphone and tablets in Australia is a major driver of mobile data traffic growth.[17] Seventy-four per cent of Australians were estimated to be using a smartphone as at May 2014 compared to 64 per cent a year earlier.[18] Smartphone penetration has been forecast to increase to 91 per cent in 2017.[19]

An Analysys Mason base case forecast produced for the ACMA in 2014 suggests that between 2012 and 2025, handset subscriptions in Australia will rise from 21.3 million to 28.0 million representing 103 per cent penetration—with voice-only subscriptions declining from 5.1 million in 2012 to 50,000 by 2018.[20]

Increasing use of data-based services

A combination of the increasing supply and take-up of data-based services is contributing to the increase in data traffic.

One example of data-based services is the use of mobile applications. Seventy-five per cent of Australians with a mobile phone capable of 3G or 4G services had downloaded an app in the six months to May 2014.[21]

Another example is consumers using over-the-top (OTT) services. One example of the transfer to OTT services is the adoption of IP-based OTT communications services at the expense of SMS volumes.[22] It has been estimated that OTT instant messaging (IM) services carried more than twice the volume of messages than SMS in 2014, compared to a ratio of 1:1 in 2012.[23]

New services that will further increase data traffic is the introduction of Voice over LTE (VoLTE), which delivers voice over data streams, by network service providers. VoLTE is expected to provide higher quality voice than current digital voice services and enhanced services, including rich communication offerings.

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[16] Analysys Mason, Updated final report for the Australian Communications and Media Authority, *Mobile Network Infrastructure Forecasts*, June 2015, page 6.

[17] Research report prepared for the ACMA by the Centre for International Economics, *The economic impacts of mobile broadband on the Australian economy from 2006 to 2013*, April 2014, page 13.

[18] ACMA consumer survey cited in ACMA, Communications Report 2013-14, November 2014, page 20.

[19] Research report prepared for the ACMA by the Centre for International Economics, *The economic impacts of mobile broadband on the Australian economy from 2006 to 2013*, April 2014, page 13.

[20] Analysys Mason, Updated final report for the Australian Communications and Media Authority, *Mobile Network Infrastructure Forecasts*, June 2015, page 27.

[21] ACMA, Communications report 2013–14 series, *Report 1—Australians' digital lives*, March 2015, page 18.

[22] ACMA, *Six emerging trends in media and communications*, November 2014, page 7.

[23] Deloitte, *Technology, Media & Telecommunications Predictions 2014*, 2014, page 36.

From the perspective of a network owners and operators, VoLTE also offers cost and spectrum efficiencies.[24] The deployment of VoLTE removes the need for a separate voice network, reducing operational costs and allowing spectrum to be refarmed for other uses. One analyst has estimated that combining the voice and data network, mobile network operators can achieve 30 to 40 per cent more efficient use of spectrum.[25]

Mobile network service providers are exploring delivering voice services over data streams through the deployment of VoLTE. It has been rolled out in some markets such as Singapore, and is being tested in others. Telstra and Vodafone have announced plans to launch VoLTE in 2015.[26]

Consumer expectations of next generation communications and entertainment experience

Consumer interest in mobile services and applications such as games and video also encourages improvements in the capabilities of mobile networks. These services require high speeds, and (to a much lesser extent) low latency. Substantial take-up and usage of these services increases demand for a mobile network that can support these requirements for a large population of users. Cisco forecasts that video will make up 72 per cent of global mobile data traffic by 2019, compared to 55 per cent at the end of 2014.[27]

Globally 4G customers are reported to use double the amount of data than non-4G customers, and sometimes three times as much. The use of video streaming by 4G users is often cited as a reason for this difference.[28]

The percentage of users viewing video content via mobile devices, though relatively low, is increasing, particularly in younger age segments. One survey found that sixteen per cent of respondents aged 14–17 viewed television programs and films via their mobile in 2015, compared to seven per cent a year earlier.[29]

The popularity of consuming video over mobile devices has encouraged the testing of LTE-Broadcast (LTE-B) technology. LTE-B is a wireless standard that allows the broadcast of one video stream to multiple consumers with appropriate 4G devices at the same time. LTE-B is still at trial stage internationally. The technology has been commercially deployed in South Korea, where the operator has claimed substantially improved congestion levels on the mobile network.[30] In Australia, Telstra conducted a live trial in January 2015 and announced plans to establish permanent LTE-B channels at large venues and major events, such as sport events.[31]

Increasing expectations of reliability for mobile-only users

One trend of consumer demand is fixed-mobile substitution. As the take-up of mobile devices has increased, so has the number of mobile-only consumers. Twelve per cent

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[24] Ovum, *Future Strategies for VoLTE Deployment*, February 2013, page 2.

[25] Roger Entner, Recon Analytics, quoted in Brian Nichols, What is VoLTE and Why Does it Matter for Verizon, AT&T, and T-Mobile Investors?, The Motley Fool, 1 December 2014.

[26] Alex Kidman, Telstra and Optus outline their speedy futures, PCMag, 2 March 2015.

[27] Cisco, Visual Networking Index: Global Mobile Data Traffic Forecast Update 2014-2019 White Paper

[28] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 5.

[29] Accenture, Digital video and the connected consumer, April 2015, page 3.

[30] SNS Research, *The LTE, LTE-Advanced & 5G Ecosystem: 2015-2020*, 2015, page 77.

[31] Telstra media release, Telstra to conduct world's first stadium trail of LTE- B technology, 31 January 2015.

of adult Australians are now exclusively mobile, that is, they do not have a fixed-line phone or broadband connection. The 18–24 (16 per cent) and 25–34 (22 per cent) age groups were more likely to be exclusively mobile.[32]

Growth in the number of exclusively mobile Australians is likely to encourage consumer demand for always on mobile services, as the mobile network will be their primary connection to the internet and provider of voice call capability.

Business demand drivers

Business demand—through the use of mobile services to improve productivity and enhance existing activities—also increases mobile traffic and informs commercial decisions around the timing and type of network improvements deployed.

Mobility as an enabler of increased business productivity

Many industries have identified mobility as a tool for increasing productivity. At a basic level, the ability of employees to work from any location on any device is a key enabler for increasing productivity.[33] Other benefits of mobility for enterprises include improvements in field operations and decreased IT costs.[34] ACMA qualitative research with small and medium enterprises (SMEs) found that the use of smart devices could improve processes, such as being able to invoice 'on-the-go'. Paperwork and job updates can be completed on the mobile in real-time as opposed to in the office.[35]

Industry demand for the benefits of mobile broadband was further assessed in recent ACMA research which identified advantages of mobile broadband for business, including:

> reduced costs
> saved time for employees with access to mobile broadband
> increased sales
> improved quality of services
> access to new markets
> access to new suppliers.[36]

Existing services enhanced by access to mobile data storage

The potential to enhance existing services can drive demand for mobile network improvements. One example is cloud services. In Australia, 19 per cent of businesses had a paid cloud computing service as at June 2014.[37] The use of cloud-based services has several identified benefits for business including:

> the ability to access services from multiple devices
> enabling pay-as-you go access to services
> continuous update of software

[32] ACMA, *Australians get mobile*, June 2015.
[33] Deloitte, Gov on the Go Boosting public sector productivity by going mobile, page 2.
[34] KPMG, 2014 Cloud Survey report, 2015.
[35] ACMA, *SMEs and digital communication technologies*, September 2014, pages 18 and 26.
[36] ACMA-commissioned research, the Centre for International Economics, *The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013*, April 2014, page 2–4.
[37] ABS, 8129.0 – Business Use of Information Technology, 2013-14, 16 July 2015.

> outsourcing of security.[38]

Cloud services can be a further driver for improved mobile data services, as they can allow access to data, software and services anywhere and anytime. One analyst group found that 42 per cent of respondents cited a mobile workforce as a driver for investment in the cloud.[39] Cloud-based services that are used to store and transmit very large data files, or data that require a low latency response time, will encourage further improvements in mobile networks. For example, cloud-based electronic health records would permit the download of high resolution medical images and video to any device.[40]

Invitation to comment:

1. Are there any additional demand drivers supporting 5G network deployment in Australia not identified in this paper?

[38] Department of Communications, Cloud computing, 2015.

[39] KPMG, Elevating business in the cloud, 2014.

[40] 4G Americas, 4G Americas' recommendations on 5G requirements and solutions, October 2014, page 8.

Technological enablers for 5G

Demand drivers, and their impact on mobile traffic and congestion, can be responded to in several ways by mobile network owners. A network operator has three options to increase network capacity and ease any congestion:

> **technology**—use more spectrum-efficient technologies
> **topology**—deploy appropriate (denser) network infrastructure and topologies
> **spectrum**—acquire additional spectrum.[41]

The choice of an option or options will depend on what solution is the most commercially attractive, taking into account the capital or operating expenditure required, the time and effort to acquire and plan for more sites on the network, the investment needed to acquire more spectrum and the availability of new spectrum. Other factors, such as technological advancements, state and local planning and installation processes will also influence commercial decisions on the timing and type of network investment made.[42]

Since 5G characteristics are still under development, the optimal network configurations and specific spectrum arrangements required for 5G are yet to be defined. It is unclear what the specific mix of options will be at present, although it is expected that 5G will exploit emerging technologies, such as Massive Multiple Input Multiple Output (Massive MIMO) and beamforming techniques that enable spectrum to be used more efficiently and make use of higher frequency bands with wider bandwidths a viable option.[43]

This chapter explores the technological developments enabling the rollout of 5G networks within these three identified options to deliver additional network capacity.

Technology developments and spectrum efficiency

Massive MIMO and beamforming are key technologies for 5G

Techniques to improve spectrum efficiency enhance the capacity and speed of mobile networks without using additional spectrum. Such efficiency techniques continue to evolve and some key ones to support the rollout of 5G are Massive MIMO and beamforming. In combination, these two developments enable access to additional spectrum that was previously unattractive for use by mobile services.

MIMO involves the simultaneous use of multiple antennas to increase spectrum efficiency and cell capacity. MIMO can either support multiple parallel data streams with many users or maintain high data throughput to a single user, and is one technique to improve data throughput for users at the cell edge. While 4G standards include MIMO, 5G systems are expected to extend the MIMO concept to Massive MIMO by increasing the number of antennas in use at the base station. This will enable a larger number of users to be served simultaneously in the same time-frequency block or provide higher data throughput to a smaller set of users.[44] A

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[41] The options to address mobile broadband network capacity are discussed in detail in ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015, pages 28–37.

[42] Analysys Mason, Mobile infrastructure forecast model, June 2015, pages 6–7.

[43] ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015, page 29.

[44] 4G Americas, 4G Americas' recommendations on 5G requirements and solutions, October 2014, page 20.

number of vendors have commenced tests on Massive MIMO, including ZTE, Ericsson and Samsung.

Alongside Massive MIMO, many industry bodies and researchers are also investigating the potential benefits of beamforming. In beamforming technology, transmission beams are formed and targeted towards the end-user. 3D beamforming achieves this in both the vertical and horizontal planes, rather than having a base station that continuously sends out signals over a large area.

In considering mobile broadband applications, end-user equipment is ideally compact enough to be handheld, as with 4G mobile phones and related devices. In an example beamforming application, the end-user equipment is serviced by the optimal beam from the base station, chosen from a selection of many, with beam switching and tracking in order to maintain the optimal connection as the user moves in time and space.[45] The utilisation of beamforming enables the network to potentially overcome the high signal and path loss experienced at millimetre-wave range of the spectrum.

Together, Massive MIMO and beamforming help to mitigate the signal and path loss typically experienced in higher frequency bands. This facilitates access to millimetre-wave frequencies that were previously considered unsuitable for many mobile applications. The availability of greater amounts of spectrum in the millimetre-wave frequency range also enables access to channels with larger bandwidths (in the order of 100s of MHz) and therefore higher data rates can be provided to end-user equipment, thus enabling key characteristics of 5G systems.

Exact bandwidth and data rate capability at certain frequencies have not been defined as yet. However, there have been a number of demonstrations, with some examples listed in Table 2.

Table 2: Examples of 5G demonstrations at millimetre wave frequencies

Demonstrator	Peak data rate	Frequency	Bandwidth
Nokia	10 Gbps	73 GHz	1 GHz
Ericsson	5.8 Gbps	15 GHz	400 MHz
Samsung	7.5 Gbps 1.2 Gbps (in moving vehicle at 60 MPH speeds)	28 GHz	800 MHz

Source: Auri Aittokallio, Telecoms.com, Nokia claims 10 Gbps demo realistically shows future 5G capabilities, 9 April 2015 and Stephen Shankland, CNet, Mobile industry dips its toes in 5G waters for next-gen networks, 4 March 2015.

45 SK Telecom, 5G White Paper; SK Telecom's View on 5G Vision, Architecture, Technology and Spectrum, 20 October 2014, page 27.

More work needs to be done to fully understand the propagation characteristics of millimetre wave frequencies and how to manage potential radio interference issues.[46] The expense and logistical challenges of installing multiple antennas and beams at each cell is identified as one potential barrier to deployment.[47]

Network infrastructure and topology

The second option to improve the capacity and speed of mobile networks is to extend or alter the topology of the network to accommodate new infrastructure. When there is insufficient spectrum and demand is high, additional infrastructure is needed to reduce or spread the number of users per cell, or to improve the capacity of each cell.[48] There are several possible developments in network topology that may be needed to fully embrace/enable 5G, including adding base stations and more scalable and intelligent network architecture.

5G requirements for additional base stations

5G networks are expected to be significantly denser than current networks through the placement of additional base stations, particularly in urban environments. Network densification will be necessary to support increased traffic and connections, as well as achieve low latency and high throughput and to deal with the significantly shorter paths of millimetre wave frequencies. Both network densification and the degree of flexibility and intelligence required of 5G networks may result in some changes to the way in which networks are deployed and operated.

In particular, ultra-low latency services will require content to be served from a physical position very close to the user, which is likely to pose challenges for existing network roaming models and increase the need for operator interconnect points to potentially every base station.[49] To address these challenges and the expense associated with increasing network density, industry groups are exploring the potential for different network deployment models.[50] These may involve shared deployments, integration of third party deployments and in the most extreme case the deployment of a single neutral host network.[51]

Flexible, scalable and intelligent network architecture

Network investment to support 5G will likely need to go beyond the deployment of additional base stations. 5G networks are expected to be more flexible, scalable and contextually aware than current mobile networks.

It is unlikely that a network architecture that would achieve all of the stated 5G characteristics at all times could be cost-effectively developed and deployed.[52] Instead 5G network architecture is expected to be capable of operating across different

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[46] SNS Research, *The LTE, LTE-Advanced and 5G Ecosystem: 2015-2020; Infrastructure, Devices, Operator Services, Verticals, Strategies and Forecasts*, February 2015, page 101.

[47] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 12.

[48] ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015, page 32.

[49] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 12.

[50] NGMN Alliance, NGMN 5G White Paper, February 2015, page 43.

[51] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 13; Jeremy Green, Ovum, The Roadmap to 5G Mobile Networks, page 4.

[52] NGMN Alliance, NGMN 5G White Paper, February 2015, page 36.

spectrum frequencies and to flexibly adapt to rapidly changing resource demands and fast traffic variations in both the uplink and downlink.

For example, 5G networks are likely to be designed to be able to scale well to cater for high-data-rate and low latency services, as well as machine-to-machine (M2M) connections that require much lower bandwidths to send small amounts of data infrequently.[53] Similarly, support for mobility is likely to be provided only to those devices that require it with network capacity able to scale up rapidly to support use cases requiring high mobility and/or throughput on demand, such as lifeline (also known as sanctity of life) communications in a disaster or emergency situation.

To enable this degree of flexibility, industry groups are exploring the concept of organising network capacity in slices or modules. 5G networks would be built to recognise the different requirements of particular use cases including coverage, mobility, reliability, latency, security and throughput, and to meet these needs in a programmable and switchable manner according to priority and need.[54]

Emerging technologies such as Self-Organising Networks (SON), Network Function Virtualisation (NFV) and Software Defined Networking (SDN), are expected to play a key role in supporting this type of flexible and agile network operation.[55] SON refers to the ability of mobile networks to self-configure and optimise.

NFV allows network functions, such as firewalls, to be implemented by a program instead of a physical piece of hardware, separating network infrastructure from the services that it provides. SDN enables dynamic reconfiguration of network architecture to adjust for changes to load and demand.[56] In an SDN, for example, network functions can be rapidly relocated to continuously support reliable lifeline communications in a disaster situation where some network assets such as base stations may have been damaged.

Similarly, network capacity could be dynamically re-assigned to serve customer demand in peak times or for specific occasions. For example, there may be a greater demand for upload capacity during a concert or sporting event as consumers share video of the event. An SDN could dynamically adjust uplink and downlink video bit rates to meet changing demand. The network would need to employ intelligent traffic management processes, responding to real-time data about the number of users in a service area, the quality of user experience and requirements for mobility among other factors. In rapidly re-configuring capacity, networks would also need to automatically manage potential interference issues.[57]

The emergence of more flexible network architecture was foreshadowed in the May 2015 report to the Australian Government of the review of Australia's spectrum management framework undertaken by the Department of Communications and the Arts in conjunction with the ACMA (Spectrum Review). Recommendations in this report included support for automatic interference management.

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[53] 4G Americas, 4G Americas' recommendations on 5G requirements and solutions, October 2014, page 13.
[54] NGMN Alliance, NGMN 5G White Paper, February 2015, page 36.
[55] 5G PPP, 5G Vision: The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services, February 2015, page 4.
[56] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 14.
[57] NGMN Alliance, NGMN 5G White Paper, February 2015, page 43.

Spectrum

A third option to increase network capacity is to acquire more spectrum. The use and availability of different parts of the radiofrequency spectrum will influence the pathway to 5G, as will related technological developments that influence the mobile networks' use of spectrum.

The ACMA is responsible for the management and allocation of radiofrequency spectrum, including spectrum for mobile broadband. The ACMA paper, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity* ('Beyond 2020'), outlines the three aspects of the ACMA's role in the supply of spectrum for mobile broadband services:

1. Ensuring spectrum management arrangements for bands expected to be used by mobile broadband services are made under suitable conditions including sufficient licence tenure and technology flexibility.
2. Optimisation of arrangements for spectrum already available for mobile broadband services.
3. Re-farming (as appropriate) additional spectrum for potential use by mobile broadband services.[58]

The future spectrum needs of mobile broadband has most recently been considered by the ACMA through its latest update to the Five-year spectrum outlook and its consultation paper on the ACMA's mobile broadband strategy, Beyond 2020*.* Both papers note that the ACMA will continue its work in this area, including monitoring international developments and through the ACMA's existing work in international forums, including the World Radiocommunication Conference held in November 2015 and the work leading up to the next conference in 2019.[59]

5G expected to use a wide range of frequency bands

The ability to use a range of frequency bands and access technologies to deliver the particular requirements of a specific use case or service, will be a key characteristic of 5G networks.[60] This is likely to require the use of frequency bands other than those currently dedicated to mobile broadband use, and the flexible use of unlicensed spectrum or sharing of underutilised spectrum to provide extra capacity when required.

5G networks are expected to require a wide range of frequencies both below and above 6 GHz, although the exact frequencies are yet to be identified. A number of industry groups, academics and governments around the world have begun to explore the possibility of using higher frequencies for mobile broadband communications.

The ACMA and Australian industry representatives recently attended the International Telecommunication Union (ITU) Radiocommunication Sector 2015 World Radiocommunication Conference (WRC–15). The WRC–15 made a number of decisions that will influence how the issue of additional spectrum for mobile broadband will be considered around the world, and in Australia.

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[58] ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015, pages 33–34.

[59] ACMA, *Beyond 2020—A spectrum management strategy to address the growth in mobile broadband capacity*, September 2015 and ACMA, *Five-year spectrum outlook 2015–19:* The ACMA's spectrum demand analysis and strategic direction for the next five years, August 2015, page 38.

[60] Huawei, 5G: A Technology Vision, January 2014, page 6.

Under WRC–15 Agenda item 1.1 additional spectrum allocations for mobile services on a primary basis and additional identifications for International Mobile Telecommunications (IMT) were made in a number of bands. The main outcome of this agenda item was the significant international harmonisation of the frequency ranges 1 427–1 518 MHz and 3 400– 3 600 MHz for IMT.

In addition, a new Agenda item was approved for WRC–19 to study the possibility of additional identifications for IMT in specific bands between 24.25 and 86 GHz.[61] These frequency bands if identified will be an important consideration for international harmonisation and provide a focus for the development of 5G technologies. The US Federal Communications Commission proposed new rules in October 2015 for wireless broadband in wireless frequencies above 24 GHz. The rules included a proposal to authorise mobile operations in the 28 GHz band and the 39 GHz band.[62]

Spectrum at higher and lower frequencies have different characteristics and limitations for mobile communications. Frequencies in the millimetre-wave range being investigated for 5G offer much greater bandwidth than lower frequencies, and this permits the provision of wider channels and faster data rates as envisioned for 5G networks. However, the propagation characteristics of spectrum in this range mean that transmissions are subject to higher propagation losses. For this reason, 5G networks are likely to use current mobile bands, including spectrum below 1 GHz, to provide wide area coverage and in-building penetration, on top of higher frequency bands not previously used for mobile broadband.[63] 5G technology is therefore expected to harness the benefits of both lower and higher frequencies to support its characteristics.

Other 5G technological enablers

Other technological enablers of 5G relate to more than one of the three options for improving network capacity. These enablers include devices and technological developments to support and protect privacy and ensure reliability.

Developments in devices

Device-to-device (D2D) communication arrangements exist in upgrades to 4G networks, but are expected to be an integral part of the 5G network architecture solution. In direct D2D communication, devices under the control of the network operator are able to share connectivity and exchange data and content, making them both terminals and part of a configurable network infrastructure.[64]

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[61] WRC-19 Agenda item 1.13, the ITU-R is invited to conduct sharing and compatibility studies, taking into account the protection of services to which the band is allocated on a primary basis, for the frequency bands:

– 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and

– 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis.

[62] Federal Communications Commission, Notice of Proposed Rulemaking, FCC 15-138, 22 October 2015.

[63] Analysys Mason Quarterly, 5G will require new as well as established spectrum bands, but the availability of new bands is not confirmed, October-December 2014, page 2.

[64] METIS, Deliverable D6.6: Final report on the METIS 5G system concept and technology roadmap, April 2015, page 5.

D2D communications may be embedded in the 5G network architecture to support:

- ultra-low latency services[65]
- extension of coverage through the use of devices as relays[66]
- assistance with network capacity and energy consumption by playing a role in backhaul and confining traffic to the local area instead of drawing on network resources over a larger area.[67]

Security and reliability

Ensuring adequate security and reliability at network and device levels is expected to be crucial for many 5G supported services. Services such as e-health will require networks to be capable of safe-guarding transmitted sensitive personal information. Always-on reliability and defence against potential cyber security attacks will also be critical for applications such as remote surgery, public safety life-line communications and driverless cars. This will require further development in network architecture and technology.

There is tension between ensuring security and reliability at acceptable levels and supporting flexibility in network management and encouraging the development of new business models. Technical hurdles remain in structuring 5G networks to deliver both security and flexibility to network operators.

Invitation to comment:

2. Are there any additional significant enablers or major inhibitors to 5G network deployment in Australia that are not identified in this paper?

[65] SNS Research, *The LTE, LTE-Advanced and 5G Ecosystem: 2015-2020; Infrastructure, Devices, Operator Services, Verticals, Strategies and Forecasts*, February 2015, page 110.
[66] 4G Americas, 4G Americas' recommendations on 5G requirements and solutions, October 2014, page 25.
[67] METIS, Deliverable D6.6: Final report on the METIS 5G system concept and technology roadmap, April 2015, page 5.

Six 5G use cases

When consumer and business demand for mobile services drive increases in mobile data traffic, network owners respond by deploying one or a combination of network improvements, such as more efficient use of spectrum, depending on what option(s) is(are) more commercially attractive. The enhanced mobile network can then support enhanced services.

Industry analysts, vendors and international mobile organisations have developed a range of detailed examples of how 5G technology could be used which illustrate specific advantages— 'use cases'—based on the projected characteristics of 5G networks. Demand drivers for mobile services and the technological enablers of 5G networks are the building blocks for the identification of 5G use cases.

This chapter provides a brief overview of six use cases that outline the developments made possible by proposed 5G network characteristics. Each use case includes mention of individual demand drivers that relate to that example. A table at the start of each use case indicates which of the three consumer and two business demand drivers discussed earlier are relevant to that particular use case. The six cases are not an exhaustive list. It is expected that 5G will have the flexibility to adapt and accommodate a wide diversity of use cases, many as yet unidentified.

Use case 1: The Internet of Things (IoT)

Table 3: Drivers relevant to the IoT use case

1. **Consumer drivers**
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. **Business drivers**
Increased productivity
Enhanced/new services

Note: IoT specific drivers highlighted in blue.

The IoT can be understood as the aggregation of many M2M connections. It is not limited to communications, but includes big data analysis, cloud computing and sensors and actuators that in combination can efficiently run autonomous machines and intelligent systems.[68]

As the ACMA has noted previously, the IoT will allow an increasing number and diversity of things to be connected and support a range of rich and meaningful

[68] OECD, *Committee on Digital Economy Policy, Digital Economy Outlook, Chapter 5 Emerging Issues; The Internet of Things*, page 4.

information and data to be sent and received (and analysed), generating increased productivity as well as introducing enhanced and new services.[69]

The ITU defines the IoT as a global infrastructure for the information society, enabling advanced service by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.[70] The definition of the IoT is expected to evolve as the IoT becomes increasingly sophisticated and embedded into everyday lives.

Research analyst group IDC estimates that the worldwide IoT market will increase 133 per cent to $3.04 trillion in 2020, while the number of IoT connected units will reach approximately 30 billion.[71] Examples of current IoT services include freight tracking and logistics management using radio-frequency identification (RFID), monitoring and automation of lighting and energy in buildings, smart grids and meters in the energy industry, smart agriculture applications to track livestock and crop state, and smart wearables. Emerging applications include smart home services to let people control home appliances remotely or automate housework via communications with home devices and smart city infrastructure in response to massive urbanisation.

The IoT at a large scale requires a number of characteristics that can be provided by 5G:

> **Device connectivity:** serving a huge increase in the number of devices connected to wireless networks. If the number of IoT connected units reaches the predicted 30 billion,[72] for example, they are likely to significantly exceed the number of traditional mobile network connections such as smartphones, tablets and computers.[73]

> **Energy efficiency:** The massive increase in connected devices making up a fully formed IoT is likely to require better energy efficiencies than currently possible, with some mobile broadband devices required to be on all the time while others will turn on intermittently. These energy efficiency needs could be supported by two 5G characteristics: support for up to 10-year battery life for low power machine-type devices and 90 per cent reduction in network energy usage.

> **Always on**: some potential IoT services will require ultra-reliability and availability, such as healthcare and automotive functions, where an outage in service availability could have life-threatening effects.

The highly scalable and contextual proposed nature of 5G networks could support the diversity of IoT applications with differing requirements for pricing, mobility, latency, network reliability and resilience.[74]

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[69] ACMA, *The Internet of Things and the ACMA's areas of focus*, page 1.

[70] ITU-T, Recommendation ITU-T Y.2060 "Overview of the Internet of Things", June 2012, page 1.

[71] David Swan, Telcos get cracking on Internet of Things, TechnologySpectator, 26 March 2015.

[72] David Swan, Telcos get cracking on Internet of Things, TechnologySpectator, 26 March 2015.

[73] SNS Research, *The LTE, LTE-Advanced and 5G Ecosystem: 2015-2020; Infrastructure, Devices, Operator Services, Verticals, Strategies and Forecasts*, February 2015, page 99.

[74] 4G Americas, 4G Americas' recommendations on 5G requirements and solutions, October 2014, page 6.

Use case 2: Rich communication services

Table 4: Drivers relevant to the rich communication services use case

1. Consumer drivers
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. Business drivers
Increased productivity
Enhanced/new services

Note: Rich communications services specific demand drivers highlighted in blue.

Rich communications services refers to the next generation of communications designed to meet the needs and expectations of consumers who are increasingly turning to OTT services and online video both at work and for entertainment. Consumer and, to some extent, industry demand for enhancements in this category of services will require improvements to mobile networks. These services range from personalised and interactive entertainment services through to support for the virtual office. Examples include:

> Optimised media delivery services that meet the different usage patterns for content consumption in different contexts[75] such as provision of real-time ultra-high-definition content streaming for watching concerts and sporting events from multiple angles. This includes the challenging task of delivering these services in ultra-dense user environments such as popular sporting events.

> Transference and delivery of ultra-high resolution images such as 4K-UHD (four times the resolution of Full-HD) and 8K-UHD (16 times the resolution), expanding to 3D imaging and hologram services over time.[76]

> Delivery of cloud gaming and video streaming on smartphones and tablets everywhere, including in high mobility environments such as trains, cars and planes.

> Enhancements to working across locations that are enabled by the capacity to share ultra-high resolution images and video in real-time. While existing 4G technology is currently capable of supporting both multi-person video calling and the high bandwidth data networks needed to draw on data stored in the cloud[77], rich communications services will support higher resolution images and be available in high mobility environments, facilitating knowledge sharing and collaboration anywhere and at any time.

5G characteristics that will enable rich communications services include:

> **Bandwidth and data rates:** needed to support both uplink and download of video rich services over wireless networks.

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[75] Ericsson, 5G: What is it for?, October 2014, page 9.

[76] SK Telecom, 5G White Paper; SK Telecom's View on 5G Vision, Architecture, Technology and Spectrum, 20 October 2014, page 33.

[77] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 10.

> **Ultra-low latency:** for enhanced user experiences potentially including the delivery of 3D images and holograms.
> **Always on connectivity**: to support services in high mobility environments such as cars, planes and high speed trains.

5G networks are expected to offer the data rates and capacity needed to support both uplink and download of video rich services over wireless networks.

Use case 3: Augmented reality and the tactile internet

Table 5: Drivers relevant to the augmented reality and tactile internet services use case

1. Consumer drivers
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. Business drivers
Increased productivity
Enhanced/new services

Note: Augmented reality and tactile internet specific demand drivers highlighted in blue.

Augmented reality and the tactile internet are developments which are expected to support potential new and enhanced services across industry sectors including health and automotive, as well as the next steps in immersive gaming and entertainment services.

Augmented reality refers to the integration of digital information with a video stream or user's environment in real time. It is expected to have applications in gaming and entertainment, but could also have practical applications in industry. For example, there are many potential applications of augmented reality in the mining industry. Improvements in network capability could support a remote operator of heavy machinery to access richer contextual information in real-time such as terrain information, impending weather, vehicle-related data, approaching vehicles and hazards and the layout of property boundaries and utility lines.[78]

The tactile internet refers to a system where humans will wirelessly interact with and control real and virtual objects, in such a way that the user interacting with the environment does not perceive any difference between local and remote content. This will typically involve a tactile (involving the sense of touch) control signal and audio and/or visual feedback.[79] For example, a user could wear an exoskeleton connected wirelessly that would enable physical therapy sessions without being in the same

[78] SK Telecom, 5G White Paper; SK Telecom's View on 5G Vision, Architecture, Technology and Spectrum, 20 October 2014, page 35.
[79] Next generation mobile networks (NGMN) Alliance, 5G White Paper, 17 February 2015, page 16.

location as the physiotherapist.[80] Other potential applications include remote surgery, remote driving and flying of unmanned vehicles, and remote augmented reality.[81]

5G characteristics that will facilitate augmented reality and the tactile internet include:

> **Bandwidth, ultra-low latency and data rates:** both augmented reality and the tactile internet require very high bandwidth, ultra-low latency and gigabit-speeds for instantaneous transfer of substantial data volumes over reliable connections.[82] The full realisation of the potential of augmented reality and tactile internet in this respect is beyond the capability of current 4G networks to deliver.

> **Always on connectivity**: to send data and video feeds and push contextual information to users in real-time.[83] Services such as remote surgery and driving will also require ultra-high reliability.

Independent of 5G capabilities, there are other technological developments required before the potential use of augmented reality and the tactile internet could become a reality, such as further developments in motion sensors and heads up display.[84]

Use case 4: Vertical industries use cases

Table 6: Drivers relevant to the vertical industry sectors use case

1. Consumer drivers
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. Business drivers
Increased productivity
Enhanced/new services

Note: Vertical industry sectors specific demand drivers highlighted in blue.

The vertical industries use case recognises the potential for mobile network developments to improve productivity and introduce new or enhanced services across a number of specific industry sectors. Examples of value creation for vertical industry sectors in mobile network developments include:

> **Healthcare**. There are several elements of consumer health that could be improved through the implementation of connected trackers and monitors. Example applications include:

   > Remote access to medical care. Individuals in remote areas may have very limited access to medical specialists. Providing the ability for medical specialists to perform surgery remotely could bring significant benefits.

[80] Gerhard P. Feltweis, Tech. Univ. Dresden, The Tactile Internet: Applications and Challenges, March 2014.
[81] METIS, Deliverable D1.5: Updated scenarios, requirements and KPIs for 5G mobile and wireless system with recommendations for future investigations, April 2015, page 47.
[82] Nokia, 5G uses cases and requirements, page 5.
[83] Ericsson, 5G systems; Enabling Industry and Society Transformation, January 2015, page 10.
[84] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 9.

- Monitoring. Health monitors for the unwell could allow patients to recover in the home.[85]

- **Automotive**. Motor vehicles are increasingly connected to their environments. Automotive demands for improved mobile data networks include:
  - Infotainment. Real-time information provided through connected devices including augmented reality dashboards.
  - Traffic. monitors on cars and transport links will provide a more detailed understanding of traffic flows, and may enable real-time changes to traffic (such as traffic lights, changing direction of lanes) to improve traffic flows immediately and long-term.[86]
  - Reducing accidents. If all cars have monitors tracking location, speed, and other environmental factors, the number of accidents may be reduced.[87]

While some of these applications are already supported by current 4G LTE networks, such as videoconference healthcare consultations and performance monitors on car parts, 5G networks are expected to help make these types of services more widely available.

5G characteristics that will support the vertical industries use case, include:

- **Bandwidth and device connections:** to support high data volumes and service an increase in the number of devices connected to wireless networks, such as health monitors, consumer devices, traffic monitors and sensors.
- **Ultra-low latency:** for applications such as remote surgery and driverless cars.
- **Always on connectivity:** with ultra-high reliability requirements for remote surgery and patient care and monitoring, as well as driverless cars and traffic monitoring. 100 per cent geographical coverage is also required to support an intelligent traffic monitoring and management system and driverless cars, and to ensure new remote healthcare services are available across metropolitan, regional and remote locations.

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[85] Ofcom, Promoting investment and innovation in the Internet of Things Summary of responses and next steps, 27 January 2015, page 9.

[86] SNS Research, *The LTE, LTE-Advanced & 5G Ecosystem: 2015-2020*, February 2015, page 80.

[87] Ofcom, Promoting investment and innovation in the Internet of Things Summary of responses and next steps, 27 January 2015, page 9.

Use case 5: Ultra-reliable and lifeline communications

Table 7: Drivers relevant to the ultra-reliable and lifeline communications use case

1. Consumer drivers
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. Business drivers
Increased productivity
Enhanced/new services

Note: Ultra-reliable and lifeline communications specific demand drivers highlighted in blue.

The ultra-reliable and lifeline communications use case refers to the next generation of public safety and disaster management communications services. In the future, disaster and safety communications are expected to evolve from largely voice and text based systems into an enhanced service that uses big-data driven real-time intelligence, more precise location information and real-time video.[88] This type of communications system could boost the capability of public safety organisations to coordinate operations and respond quickly and safely to locate and recover victims affected by natural disasters and other events.

5G characteristics that could support the ultra-reliable and lifeline communications use case include:

> **Bandwidth and ultra-low latency:** ultra-low latency and high bandwidth to support heavy traffic including both uplink and downlink video, to serve the need of both personnel on the ground and control centres for real-time intelligence and data.

> **Always on connectivity:** including very high reliability and support for high mobility in challenging physical environments and conditions.

It is expected that these requirements would be natively supported by 5G infrastructure configured to support ultra-high reliability and scalability to respond to sudden demands for increased network capacity.[89]

[88] SK Telecom, 5G White Paper; SK Telecom's View on 5G Vision, Architecture, Technology and Spectrum, 20 October 2014, page 42.
[89] 5G PPP, 5G Vision: The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services, February 2015, page 6.

Use case 6: Mobile broadband access everywhere

Table 8: Demand drivers relevant to the mobile broadband access everywhere use case

1. Consumer drivers
Increasing mobile connections and data usage
Next generation communications and entertainment
Reliability expectations
2. Business drivers
Increased productivity
Enhanced/new services

Note: Mobile broadband access everywhere specific demand drivers highlighted in blue.

The mobile broadband access everywhere use case aims to support connectivity in all locations and situations with the user experiencing no change in perceived quality of service. This includes high mobility situations where a user may be remotely working and interacting from a high speed train, vehicle or plane. Other examples include continuity of user experience both indoors and outdoors and in dense, high-traffic situations such as in concerts, sports stadiums or crowded public transport interchanges.

Mobile broadband access everywhere is also a requirement for productivity-enhancing use cases such as increasingly sophisticated smart grid and smart metering solutions in the energy, water and gas utilities sectors.[90] At the same time, the growth in the number of exclusively mobile customers suggests that some consumers will be increasingly relying only on the mobile network for communications and internet access, and so expect to have reliable access to that service.

The 5G characteristic underpinning the mobile broadband access everywhere use case is:

> **Always on connectivity:** available everywhere (100 per cent coverage) and at all times (99.999 per cent of the time).

While theoretically, mobile broadband access everywhere could be achieved using current network technologies, this has not been economically viable for network operators. Therefore 5G is expected to be capable of deployment under very low cost conditions, using ultra-low cost network infrastructures, ultra-low cost devices and ultra-low cost operation and maintenance.[91] To achieve this, some industry groups have noted that 5G may support varying data rates in different geographical areas. One estimate is that 5G will provide minimum data rates of several 100Mbps for users in urban and suburban areas, and rates of several 10Mbps everywhere else, including sparsely-populated rural areas in both developed and developing countries.[92]

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[90] GSMA Intelligence, Understanding 5G: perspectives on future technological advancements in mobile, December 2014, page 10.
[91] METIS, Deliverable D1.5: Updated scenarios, requirements and KPIs for 5G mobile and wireless system with recommendations for future investigations, April 2015, page 25.
[92] Ericsson, 5G systems; Enabling Industry and Society Transformation, January 2015, page 10.

5G developments and existing regulatory arrangements

The pathway to 5G remains uncertain, as spectrum requirements, device standards, network structure and capabilities are still being defined. However, the existing research and commentary on developments in mobile networks reveals important themes—such as scalability, flexibility and contextual awareness—that are likely to interact with existing regulatory arrangements.

Considering aspects of existing regulatory arrangements that enable or remove inhibitors to the further development and deployment of the next generation of mobile services in Australia can be usefully structured by the five key components of an internet-enabled economy. These are:

- infrastructure
- devices
- services/apps
- digital information/digital content
- users interacting with each of these elements.

This chapter considers existing regulatory arrangements that may further enable the development of mobile networks in each of the five key components.

Infrastructure

In terms of the ACMA's existing regulatory remit, actions by the regulator to support the ongoing development of mobile networks, including 5G, are likely to focus on:

- the allocation of public resources necessary to allow wireless network infrastructure to develop
- support for the international harmonisation of spectrum arrangements to provide economies of scale for manufacturers and provide flow through benefits to Australian consumers arising from cheaper device costs.

Supporting flexible network design requirements

5G networks are expected to support a range of services that will often have differing requirements in terms of quality of service, network structures and communications paths. This means that the structure and capabilities of 5G networks are likely to change according to context and incorporate a wide range of technologies and devices based on need.

Regulation around mobile networks administered by the ACMA is currently based on defined network and service environments. The anticipated network design requirements for 5G may require adjustment to facilitate consumer and business benefits, depending on how 5G networks evolve. The ACMA is monitoring these developments to assess their impacts on likely future spectrum demand.

Higher frequency bands and new spectrum requirements

No specific frequencies have been identified for 5G as yet by industry proponents, although it is likely to operate in both high (millimetre wave) frequency bands (for dense urban environments) and lower frequency bands (for example, below 6 GHz).

The ACMA issues technology flexible licences. This means that although technical arrangements may be optimised for specific applications (such as mobile broadband), the choice of technology to deploy is purely a commercial decision for licensees. It is likely that bands currently used for 2G, 3G and 4G in Australia will be identified internationally by standards bodies, regional organisations and individual countries for future 5G use. This would enable operators, in a process known as ‘refarming’, to transition their spectrum to the highest value use if and when required. Operators would then be able to deploy 5G services in these bands regardless of whether additional spectrum is identified or not. As an example, in Australia, spectrum initially used for 2G either has been or is currently being refarmed for 3G and 4G purposes.

The predicted growth in IoT devices and data traffic, as well as the contextual use of spectrum depending on network and service requirements, will increase demand for capacity, and therefore potentially spectrum, and flexible spectrum allocation to allow for different use cases, particularly if that spectrum is also allocated for other uses.

The ACMA and regulators internationally are responding to these challenges. The 2015 Spectrum Review undertaken by the Department of Communications and the Arts in conjunction with the ACMA makes recommendations to improve the flexibility of the spectrum policy and management framework that will further assist in the development of mobile networks. The ACMA has also recently released its mobile broadband strategy consultation paper, Beyond 2020, that is in part designed to address the forthcoming challenges presented by 5G and other developments in terms of spectrum allocation and management. As another measure, the ACMA is proposing changes to spectrum class licensing arrangements in the 900 MHz, 2.4 GHz band and 5.8 GHz spectrum bands to support a variety of IoT applications such as data telemetry, machine data and monitoring and sensor networks.[93]

Regulators internationally are also responding to these challenges. Some communications regulators have begun to look into the feasibility of licensed shared access to spectrum, while research on the technologies needed to enable sharing is also underway. In April 2015, the FCC announced innovative new arrangements in the 3.5GHz band, which will see implementation of a three-tier shared-use framework involving Incumbents, Priority Access and General Authorised Access. These arrangements will enable access to 150 MHz band suitable for wireless broadband services, while still protecting the incumbent military radar systems from interference.[94]

In its final report, the EU project for Mobile and wireless communications enablers for the twenty-twenty society (METIS) advocated the development of a spectrum toolbox to allow 5G systems to operate under different regulatory frameworks and spectrum sharing scenarios. The toolbox would contain tools to enable operation in both high and low frequencies using small and large bandwidths, facilitate different sharing scenarios and adopt different rules for different services, all in a time-sensitive environment where shifting spectrum demands are flexibly accommodated as service demands on 5G mobile networks change.

Devices

The ACMA’s involvement in the international harmonisation of spectrum arrangements influences the device standards development which enables the availability of affordable handsets.

[93] ACMA, Easier access to spectrum for the Internet of Things, December 2015.

[94] Federal Communications Commission Breaking down barriers to innovation in the 3.5GHz band, 21 April 2015.

International harmonisation of spectrum arrangements

Part of the ACMA's role is to participate in the harmonisation of international spectrum arrangements. This will be an important influence on the availability and cost of 5G devices in Australia.

Most recently, the ACMA actively engaged in the issue of identification of spectrum for International Mobile Telecommunications (IMT) in preparation for the identification of future agenda items at WRC–15. The ACMA were heavily involved in the development of the Asia–Pacific regional position through contributions to the Asia–Pacific Telecommunity Conference Preparatory Group for WRC–15. The successful result was the creation of a future Agenda item on this issue.[95]

The impact of the ACMA's role can also be seen in the ACMA's work on achieving regional agreement on an efficient and usable band plan for the 700 MHz band. By collaborating and harmonising with Australia's Asia–Pacific neighbours, the ACMA ensured the Australian market could benefit from global economies of scale and have a greater choice of mobile handsets in the 700 MHz band. These benefits are also achieved in other bands used for mobile broadband (and other services) by Australia supporting and adopting internationally harmonised arrangements.

Device-to-device (D2D) communications and altered traffic paths

D2D communications, an integral part of potential 5G network structures, will enable communications to bypass elements in a centralised network design. Traffic in this context is directly communicated between devices via a direct link using cellular resources rather than a base station, and so bypassing core network elements.[96]

Different traffic paths offer potential opportunities in terms of improved quality of service, to allow routing of traffic to mitigate areas of network congestion.

D2D communications may also require some assessment of how D2D traffic flows are accommodated within the regulatory framework, so that important regulatory requirements such as the emergency call service and interception requirements that rely on location information often gleaned from mobile base station traffic, can continue to be supported in a D2D communications environment.

Services/applications

5G networks are expected to support enhanced services and applications and will be a particularly important support for the development of the IoT. Many existing regulatory arrangements that come within the ACMA's remit, including its role in telephone numbering administration and managing internet security via the Australian Internet Security Initiative (AISI), will interact with the development of enhanced services enabled by 5G networks, including the IoT.

Enabling the IoT applications

The ability of 5G networks to support a massive increase in device connections is expected to be a support for the IoT. Devices and services within the IoT will serve a range of services including monitoring, sensing, and delivering updates for a wide variety of purposes. As noted earlier, changes proposed by the ACMA to the spectrum class licensing arrangements that authorise particular device applications are intended

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[95] Letter to the Editor from ACMA CEO Chris Chapman, *Communications Day*, 13 November 2015, pages 9–10.

[96] SNS Research, *The LTE, LTE-Advanced and 5G Ecosystem: 2015-2020; Infrastructure, Devices, Operator Services, Verticals, Strategies and Forecasts*, February 2015, pages 110–11.

to facilitate easier access to IoT applications. In addition, exploiting the maximum potential of the IoT will require industry and consumers to trust network security and the processes in place to ensure secure storage, transport and use of data.

Content

5G networks will enable enhanced services including the provision of content in a variety of contexts. Existing regulatory arrangements managed by the ACMA will interact with the provision of content services over 5G networks.

5G networks likely to enable context aware content

Context-awareness is a key theme in commentary on 5G networks and services. The 5G network has been described as content displayed as it is needed or relevant rather than the user actively seeking such material. The provision of relevant information when it is needed without action by the user has the potential to offer benefits.

The shift to context-awareness has been described as reconfiguring relationships between the service and the user. For example, in a 5G context the emphasis of healthcare approaches could shift more towards wellness. In this scenario, the network is continually providing relevant support for wellness, such as dietary, blood pressure, and exercise monitors in combination with other services. This permits greater emphasis on proactive support of wellness that has the potential to prevent the use of more extensive healthcare services in the future.[97]

Context-aware networks could deliver more informative, efficient, immediate and targeted emergency services warnings, which may contribute to an enhanced protection of the public provided by emergency services.

The protection and treatment of an individual's personal data, in terms of security and privacy, may be challenged by the automatic generation of content.

The ACMA identified digital information management, which states that 'the treatment of data by media and communications network operators, service providers, and other rights holders should respect user preferences, relevant privacy legislation and applicable community standards',[98] as an enduring concept for media and communications regulation.

In the envisaged context-aware network, information or content is generated automatically rather than by request. This arrangement potentially risks the unauthorised or inappropriate sharing of content or information and challenges the concept of digital information management.

The risk of personal or sensitive information being shared without authorisation exists for any online user. A context-aware network elevates this risk in two ways:

- it potentially holds more information about a user than current networks
- it displays relevant information as a push rather than pull service.

While there are general privacy obligations that apply to the disclosure of personal information, there remains communications-specific obligations administered by the ACMA that relate to disclosure of the content of communications.

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[97] Travis Johnson, CEO, Mnet Mobile, Mumbrella 360 conference presentation, 'Technology – What's Now and Next?', 2015.

[98] ACMA, *Enduring concepts: Communications and media in Australia*, November 2011, page 7.

To the extent existing privacy and security protections are not regarded by consumers as adequate in this environment, it may act as a barrier to consumer confidence in using context-aware services on 5G networks and regulatory certainty will become more important.

User experience

The goal of 5G networks to provide a seamless user experience will require network operators to match the performance characteristics of fixed networks in terms of speed, quality, reliability and security.[99] Some analysts have also noted that the requirement to build out fibre closer to the customer to support high frequency mobile networks will also contribute to the breaking down of the distinction between fixed and mobile networks, as mobile networks incorporate fixed network elements.[100]

The changing use of mobile services, as well as its increasing similarity to fixed services, has a two-fold effect:

> existing technology-specific regulatory arrangements, such as the standard telephone service and number portability, may ultimately prove in the future to be a barrier to full exploitation of the benefits from developments in mobile networks

> consumers have access to an increasing range of OTT services and mobile networks that can partially or totally fulfil fixed-line service functions.

Regulatory attention has traditionally focused on fixed-line telephone services, such as the standard telephone service and universal service obligation. The ability of the individual to access multiple communications access and service pathways suggests that in the future there may be ways to achieve the universal service objective other than a regulated service.[101]

Invitation to comment:

3. Are there additional regulatory issues around 5G network deployment, relevant to the ACMA's responsibilities, which are not discussed in this paper?

[99] Huawei, 5G: A Technology Vision, January 2014, page 3.

[100] Mark Newman, Ovum, *5G is not mobile*, 23 October 2014, page 3.

[101] ACMA, *Six emerging trends in media and communications*, November 2014, page 14.

Conclusion

5G represents the next stage of development for mobile networks. Due to be deployed in Australia from around 2020, the specific pathway to achieve projected 5G characteristics—such as the ability to support a massive increase in connections, speeds of 1–10 Gbps, and greatly reduced latency—is under development. It is likely to involve a combination of higher frequency bands and technological developments, including Massive MIMO and beamforming.

5G use cases display the potential benefits of this next stage of mobile network development. One use case is the IoT, for which 5G will provide support for, particularly in enabling an increase in device connections with an anywhere and anytime capability.

There is significant development activity underway internationally to prepare for 5G technologies.

For its part, the ACMA is already working to identify ways that 5G technologies can be facilitated in Australia, including through its day-to-day spectrum management activities, its recently released mobile broadband strategy, Beyond 2020, the Spectrum Review undertaken jointly with the Department of Communications and the Arts, and work in national, regional and international fora, including the World Radiocomunication Conference held in November 2015.

The ACMA will continue to monitor developments in the deployment and use of mobile networks, and consider ways that new technologies and services can be facilitated under existing regulatory arrangements. In particular, the ACMA is interested in views from stakeholders on the following questions:

1. Are there any additional demand drivers supporting 5G network deployment in Australia not identified in this paper?
2. Are there any additional significant enablers or major inhibitors to 5G network deployment in Australia that are not identified in this paper?
3. Are there additional regulatory issues around 5G network deployment, relevant to the ACMA's responsibilities, which are not discussed in this paper?

The ACMA appreciates responses and feedback on the questions it has raised throughout this paper, which will assist it to refine its monitoring capabilities in this area and identify important enablers for 5G network deployment in Australia.

Glossary

Name	Definition
1G	First generation mobile technology. Mobile telecommunications services that use analogue techniques to provide voice communications.
2G	Second generation mobile technology. Mobile telecommunications services that use digital techniques, providing voice communications and a relatively low transmission rate for data.
3G	Third generation mobile technology. Broadband mobile telecommunications services supporting both voice channels, and IP-based video and data services.
4G	Fourth generation mobile technology. Enhanced broadband mobile telecommunications services supporting voice, video and data services over an all IP network.
5G	Fifth generation mobile technology. There is currently no agreed definition or standard for 5G technology.
Advanced Mobile Phone Service (AMPS)	The first generation mobile analogue system.
Augmented reality	An enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device or interface.
Bandwidth	A measurement of how much data can flow through a specific connection at one time. Bandwidth also refers to a range of frequencies used to transmit a signal.
Beamforming	A processing technique used for signal transmission or reception.
Carrier Aggregation	A technology that allows mobile network operators to use spectrum in disparate radio-frequency bands as a single transmissions channel. Carrier aggregation is part of the LTE-A specification.
Code-Division Multiple Access (CDMA)	2G and 3G digital mobile telephony system.
Cloud computing	Internet-based computing where data and applications are hosted online, stored on remote servers and available to clients on demand through broadband internet-enabled devices.
Device-to-device communications (D2D)	Each terminal is able to communicate directly with other terminals bypassing the core network in order to either share their radio access connection, or to exchange information.

Name	Definition
Fixed Mobile Convergence (FMC)	The merging of the previously distinct fixed and mobile platforms.
Fixed Mobile Substitution (FMS)	The displacement of fixed voice (and sometimes data) services by mobile voice (and sometimes data) services.
Global System for Mobile communications (GSM)	2G mobile digital technology.
High Speed Packet Access Plus (HSPA+)	A technical standard for mobile networks that enhances WCDMA based 3G networks. It provides data rates of up to 168 Mbps (downlink) and 22 Mbps (uplink).
Internet of Things (IoT)	Encompasses the increasing number of 'things' (whether domestic appliances, monitoring equipment, or a great range of other objects) that communicate over the internet with little or no human involvement.
Latency	The amount of time a data packet takes to travel through a network, measured from when a query or request is sent into the network from a device to when the response or required data arrives back at that device.
Licensed Shared Access (LSA)	Enables non-commercial entities to share their spectrum with wireless carriers while retaining control over it.
Long Term Evolution (LTE)	A suite of radio and core network specifications for the enhancement of mobile networks beyond 3G capabilities. It is associated with 4G system builds providing higher data rates, higher quality of service and better resource utilisation.
Long Term Evolution – Advanced (LTE-Advanced)	Involves enhancements to LTE including improvements to carrier aggregation, small cell performance and interference management techniques, resulting in the ability to provide higher peak data rates, theoretically over 1 Gbps.
Long Term Evolution – Broadcast (LTE-B)	A wireless standard that allows the broadcast of a video stream over a mobile network to multiple consumers with appropriate 4G devices at the same time.
Massive Multiple Input, Multiple Output (Massive MIMO)	Refers to the idea of equipping wireless transceivers with a very large number of antennas to increase the spectral efficiency of a wireless link.
Millimetre wave spectrum	Spectrum in the frequency range from 30 to 300 GHz. Frequencies in this range have wavelengths between 1 and 10mm. Due to their higher bandwidth over traditional cellular bands, millimetre wave bands can provide significantly wide channel sizes and higher speeds.
Machine-to-machine communications (M2M)	Automatic communications between devices without the need for any human interaction.

Name	Definition
Network Function Virtualisation (NFV)	Allows network functions to be implemented by a program instead of a physical piece of hardware, separating network infrastructure from the services that it provides.
Over-the-top-services (OTT services)	Online delivery of video direct to the consumer without the network access provider being involved in the control or distribution of the content itself.
Quality of Service (QoS)	A set of standards and mechanisms to ensure high-quality performance for applications.
Radio Access Network (RAN)	A part of a mobile telecommunications network. The RAN connects the device to the core network.
Radio-frequency identification (RFID)	Small devices consisting of a chip and an antenna that act as a unique identifier for an object. Uses include tracking of goods and access management.
Software Defined Networking (SDN)	Enables dynamic reconfiguration of network architecture to adjust for changes to load and demand.
Tactile internet	Refers to a system where humans will wirelessly interact with and control real and virtual objects, in such a way that the user interacting with the environment does not perceive any difference between local and remote content.
Time Division Duplex (TDD)	Duplex communication links that separates uplink and downlink traffic through the allocation of different time slots within the same frequency band.
Voice over LTE (VoLTE)	Voice services are delivered over data streams by mobile network providers.
Wideband Code Division Multiple Access (WCDMA)	3G mobile technology.

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