A symbiotic ecosystem: Google's contribution to the telecoms sector

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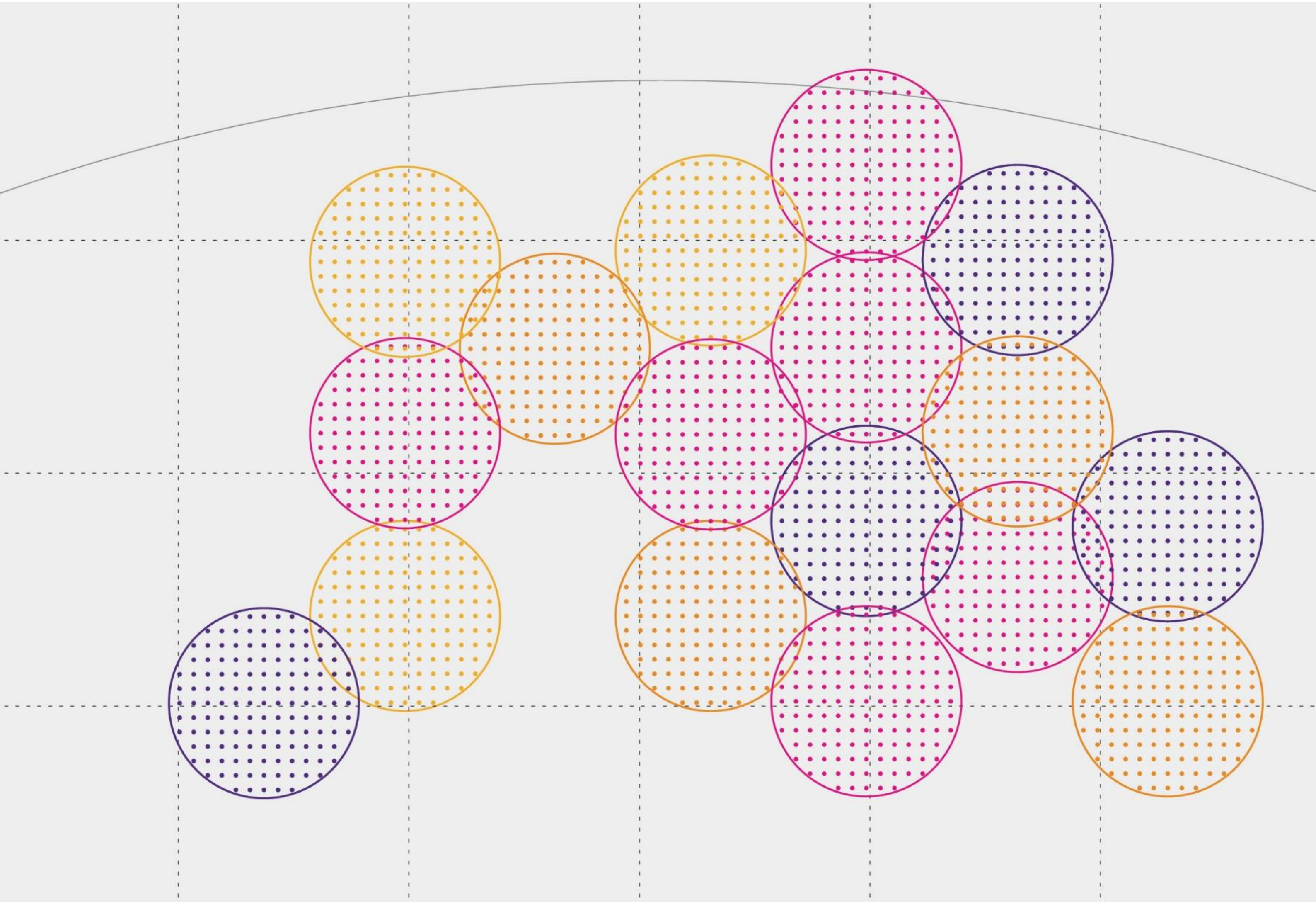

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About Plum

We are a leading independent consulting firm, focused on the telecommunications, media, technology, and adjacent sectors. We apply extensive industry knowledge, consulting experience, and rigorous analysis to address challenges and opportunities across regulatory, radio spectrum, economic, commercial and technology domains.

About this study

This study explores the mutually beneficial relationships that exist between participants in the telecommunications sector, including Google. It explores the sector and how it is evolving, and looks at the contribution of end user services, network infrastructure investments and various partnerships to the sector.

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Glossary

Term	Definition
4k	4k resolution refers to a horizontal display resolution of approximately 4,000 pixels, with four times the pixel count of full HD. Higher display resolutions typically require higher bandwidth to deliver.
8k	8k resolution refers to a horizontal display resolution of approximately 8,000 pixels, with four times the pixel count of 4k. Higher display resolutions typically require higher bandwidth to deliver.
4G	The fourth generation of mobile communications technology, allowing wireless Internet access at a higher speed than the previous generation.
5G	The fifth generation of mobile communications technology, allowing wireless Internet access at a higher speed than the previous generation (among other benefits).
6G	The sixth generation of mobile communications technology, currently in development.
AI	Artificial Intelligence.
APAC	Asia-Pacific.
API	Application Programming Interface. An interface that enables two different software applications to interact.
AR	Augmented Reality. A technology which layers virtual elements over the real world.
ARPU	Average Revenue Per Unit.
BSS	Business Support Systems. The systems used by a CSP to manage its customer-facing business operations.
Cache	A local copy of information, such as online content.
CAGR	Compound annual growth rate.
CAPEX	Capital Expenditure. The money an organisation spends to buy or maintain physical assets, such as network infrastructure.
CDN	Content delivery network. A geographically distributed collection of servers that speeds up delivery of content by bringing it closer to end-users.
Cloud	Computing resources, including processing and storage, that are accessed via the Internet.
CPE	Customer-Premises Equipment. Equipment located at the end-user premises which is used to deliver communications services.
CSP	Communications Service Provider. An organisation that provides connectivity services for accessing the Internet. May provide fixed broadband, mobile data or both.
Data packet	A small unit of data, packaged for transmission over a network. Typically, packets are small segments of a larger piece of data (such as an image), which are reconstituted by the receiving device.
DSL	Digital Subscriber Line. A networking technology that enables Internet access over telephone lines.
Edge	Edge Computing. Cloud-based processing power and data storage located at the edge of a network, meaning data can be processed closer to end-users.
FTTC	Fibre to the Cabinet. Broadband architecture in which optical fibre is deployed to a cabinet near to customers' premises, generally using copper wires for the last leg.
FTTP	Fibre to the Premises. Broadband architecture in which optical fibre is deployed all the way to a customer's premises.
FTTX	Fibre to the *x*. Refers to the deployment of optical fibre in broadband networks.

Term	Definition
HD	High Definition. Refers to video of higher resolution and quality than standard-definition. Higher display resolutions typically require higher bandwidth to be delivered.
Hyperscale cloud provider	A business that provides cloud computing, storage and networking at scale. Such businesses are often also online service providers (OSPs).
IoT	Internet of Things. A network of connected physical objects which can exchange data with other devices and systems. Objects can include sensors, household appliances or industrial machines.
IP	Internet Protocol. A protocol for transmitting and routing data across networks.
IXP	Internet Exchange Point. A physical location at which organisations can interconnect and exchange Internet traffic.
Latency	The time lag between a data packet being sent and its arrival.
LTE	Long Term Evolution. A mobile communications standard, commonly used in conjunction with 4G.
M2M	Machine-to-machine communication. Automated communication and data transfer between two or more connected devices.
MEC	Multi-access Edge Computing (MEC) places data processing and storage capabilities closer to the client – typically, at or close to the edge of an access network. This means that data can be processed closer to the end user.
MNO	Mobile Network Operator.
MVNO	Mobile Virtual Network Operator. A wireless communications provider that relies on an MNO for the delivery of its connectivity services.
OPEX	Operating Expenditure. An ongoing cost for running an organisation. Includes staff costs, electricity and marketing.
OS	Operating System. A program that manages and operates a computing device's hardware and provides a platform for running other software applications.
OSS	Operations Support Systems. Systems used by a network operator to manage communications networks.
OSP	Online service provider. An entity which supplies an online service or application.
PoP	Point of Presence. A network interface point between two organisations. PoPs are often located at IXPs.
RAN	Radio Access Network.
RCS	Rich Communications Services (RCS) protocol. The objective of RCS is to replace SMS with an interoperable messaging service with an enhanced feature set.
R&D	Research & Development.
Router	An Internet switch that receives data packets and (hopefully) sends them on to the right place.
SDN	Software-defined Networking. SDN uses software to communicate with and manage the network hardware to direct traffic on the network.
SD-WAN	Software-defined Wide Area Network. A WAN that uses software to manage and control the network.
Server	Hardware that stores and transmits online content.
SMS	Short Message Service. A system that enables mobile users to send and receive text messages.
Value chain	The full range of businesses and activities required to deliver a product or service to consumers.
VoIP	Voice over Internet Protocol. The transmission of voice over an Internet connection.

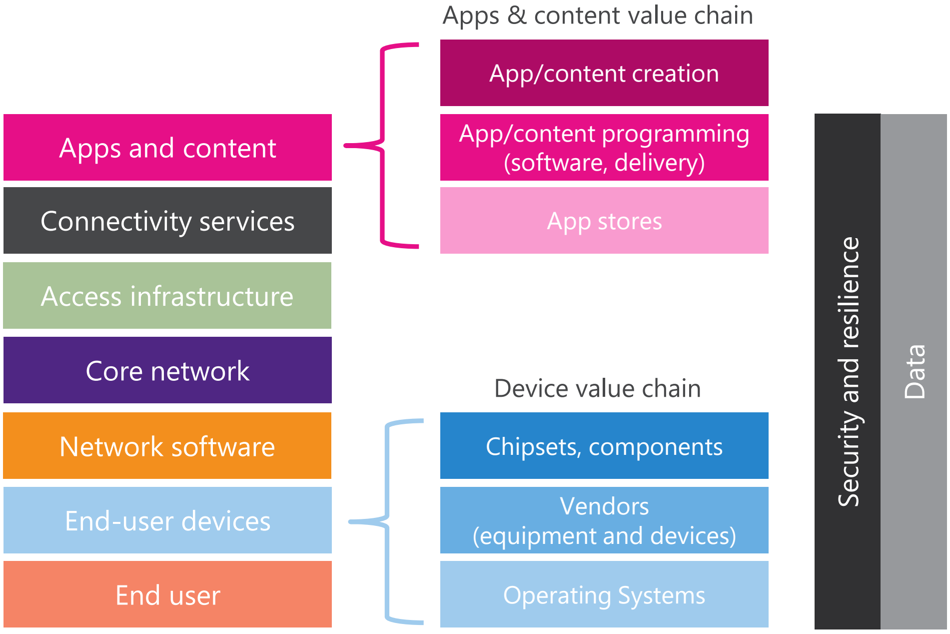
Term	Definition
VR	Virtual Reality. A technology enabling a simulation of a real or imaginary world.
WAN	Wide Area Network. A telecommunications network that extends over a large geographic area
XaaS	"Anything As A Service". A general concept referring to services which leverage cloud computing for delivery, instead of relying on-site software and hardware.

Executive Summary

Today, many consumers and businesses across the world can use their connected devices to access a vast array of digital content and services at the touch of a button. The delivery of these services is enabled by a complex ecosystem with global scale, much of which is not always visible to everyday users. This is illustrated in Figure 1 below.

While the figure below presents this as a linear model, in practice there are numerous interdependencies and relationships across different parts of the ecosystem, and many participants are active in multiple parts of the ecosystem. Meanwhile, the security and resilience of services and networks is a key consideration across the wider sector and data is used throughout the ecosystem to manage, refine and optimise service delivery.

Figure 1: Illustration of the wider telecoms sector



Major sector players typically have differing but complementary roles.

- **Communications Service Providers (CSPs)** operate access infrastructure and provide connectivity services to end users, and are making inroads into content provision and other value-added services.
- **Equipment vendors** specialise in end-user devices as well as network apparatus, and in some cases are offering connected services for a number of industrial applications.
- **Online service providers (OSPs)** typically focus on the provision of applications and content to consumers and businesses, but in many cases they have also invested heavily in data centres and international connectivity to support the delivery of those services.

While sector players tend to focus on different layers within the sector, the boundaries between these different layers are becoming more blurred. Partnerships between players across different layers of the sector are becoming increasingly common, and are helping to drive value and improve efficiency across the wider sector. Partnerships are also playing a key role in the delivery of the next wave of consumer and industrial applications, where successful service delivery often relies on combinations of connectivity, computing power, software and hardware.

Symbiotic relationships across the telecoms sector

We have identified various mutually beneficial relationships that exist between telecoms sector players. These are relationships that exist between two or more sector players and help to deliver benefits for all players involved. In some cases, the relationships will also deliver benefits to the telecoms sector as a whole and/or to the wider economy.

We have grouped the identified relationships into three broad categories (Figure 2). Note that these include both *indirect* symbiosis (for example, complementarities that exist between connectivity services, devices and online services) and *direct* symbiosis (for example, when sector players enter a partnership to deliver a particular service).

Figure 2: Symbiotic relationships between telecoms sector players discussed in this report

Category	Area for symbiosis	Description
Driving demand for connectivity and services	**Complementary devices and services (the virtuous circle)**	Online services, devices and connectivity services are complementary goods and exist in a virtuous circle, encouraging demand for each other. Consumers upgrade to higher speed connections and larger data bundles because they are making heavier use of online services.
	Commercial partnerships for next generation bundles	Partnerships across the sector are delivering compelling service bundles to consumers and enterprises, fuelling demand for connectivity.
	Enabling new products and revenue streams	Partnerships across the sector are enabling new communications use cases and revenue streams across a variety of consumer and industrial applications.
Enabling efficiencies for market players	**Enabling efficient network deployment**	Symbiosis between network operators and OSPs in planning network deployments can lead to significant cost efficiencies in capital expenditure as well as enhanced consumer quality of experience.
	Enabling efficient network operations	Symbiotic partnerships between telecoms sector players can help to manage and operate networks more efficiently, reducing operating costs and network downtime, as well as generating environmental benefits.
	Enabling efficient business processes	Symbiotic partnerships between telecoms sector players can generate business efficiencies, helping to lower operating costs and increase customer satisfaction.
Investment in networks	**Avoided costs**	Investments in network infrastructure by players across the sector are bringing content and services closer to end-users, reducing costs that would otherwise be incurred.
	Enhanced user quality of experience	Investments in infrastructure and technology across the telecoms sector is helping to reduce online services' bandwidth requirements and improve users' quality of experience, enhancing demand for connectivity and digital content.

Note: relationships in **bold** are those where we have attempted to quantify the benefit.

The value of symbiotic relationships

We attempt to estimate the future benefits that could accrue from the types of symbiosis highlighted in Figure 2, with a focus on the Asia-Pacific region. The benefits are computed for CSPs as they are central to the telecom value chain. Our estimates take the form of incremental annual free cashflow from the year 2026. We describe below the possible market scenarios that form the basis for our estimation of potential benefits from deeper symbiosis. The two scenarios are:

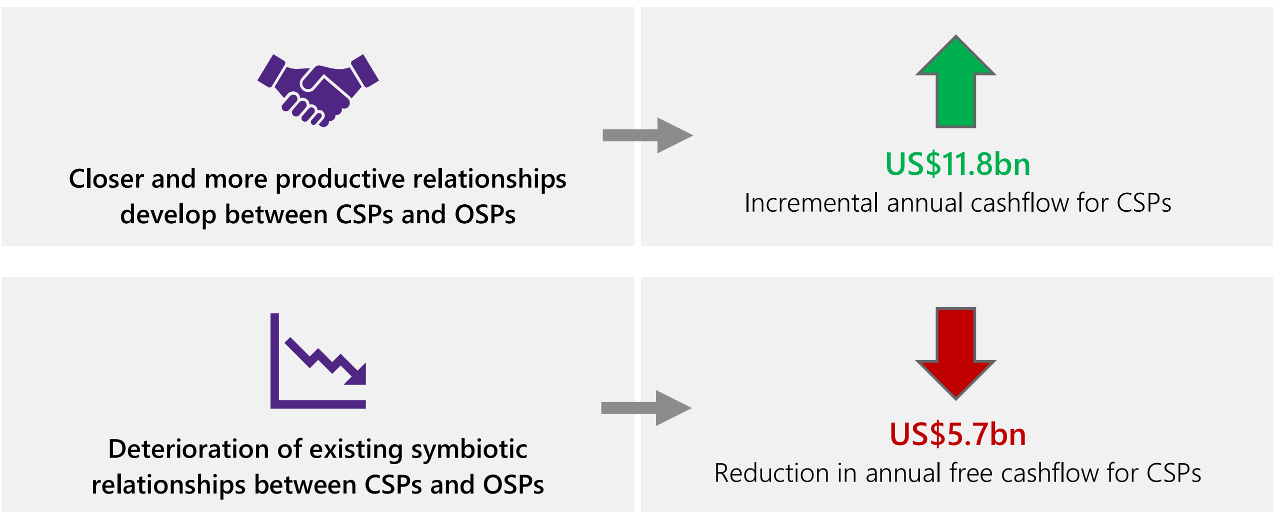
1. The base case, in which existing symbiotic relationships are not deepened any further. There is no major improvement in content and services for local use, reducing incentives for end-users to switch to higher-end connectivity packages. There is also a gradual decline in OSPs' annual investment in network infrastructure as the regulatory environment becomes more challenging for such investment.
2. A scenario where a closer and more productive relationship is forged between CSPs and OSPs. OSPs continue to invest in network infrastructure. Operators and OSPs continue to partner to offer new service bundles (which may include new connectivity use cases which rely on operator and OSP collaboration) and to enhance operational efficiency.

It should be noted that even in the base case, many of the benefits of symbiosis will already being enjoyed. For example, OSPs' existing portfolios of apps and content will already be driving usage and consumption of high-end plans, while extant infrastructure (including caches and points of presence) in the region is already helping to reduce costs that would otherwise be incurred by network operators. The benefits computed for the second scenario therefore represent potential incremental benefits of additional and deeper partnerships.

Plum estimates that, in the scenario where CSPs develop closer and more productive relationships with OSPs, there could be **US$11.8bn** incremental cashflow per annum in the APAC region from 2026 onward. This comprises benefits from partnering to offer compelling content and service bundles, from enabling additional network and operational efficiencies, and from new infrastructure investment.

The analysis presented thus far has assumed that all of the existing benefits of symbiosis remain in place. However, there is the possibility that the existing symbiotic relationships deteriorate. One example of how this could happen could be the introduction of network traffic charges, which would deter infrastructure investment and hinder the virtuous circle of demand. Plum estimates that a deterioration of the existing symbiotic relationship could result in a potential *reduction* in free cashflow of up to **US$5.7bn** per annum from 2026.

Figure 3: Total incremental cashflow by area for symbiosis



Figures reflect estimated changes to CSP cashflow in the APAC region to 2026.

Wider economic impact

Our quantitative analysis focuses on the benefits that can accrue to telecoms sector actors. However, it is worth noting that the symbiotic ecosystem is also delivering wider benefits to national economies, societies and the environment.

- **Macroeconomic benefits.** Greater adoption and use of connectivity services, driven by the desire to access and use online content and applications, has been identified as an important driver of economic growth. The adoption of online communications and digital services by businesses is also helping to drive productivity. We also expect that novel industrial applications of edge computing in key industry verticals (such as manufacturing, logistics and healthcare) will further enhance productivity gains. In most cases, edge computing solutions are delivered using the cloud services of OSPs, and unlocking their full potential will require an investment-friendly regulatory environment.

- **Societal benefits.** Digital inclusion remains a key policy goal in many jurisdictions – even those with comparatively high levels of Internet use. Compelling applications and content can offer strong incentives for non-users to get online and develop digital skills. In turn this can help local communications ecosystems attain ‘critical mass’ of consumers and local content producers. Increasing connectivity and digital skills will also enhance social inclusion and increase the reach and effectiveness of e-government initiatives.

- **Environmental benefits.** The use of digital services can play a vital role in climate change mitigation. For example, services are being used for remote working, smart buildings, and to enhance industrial efficiency. According to the GSMA, the ratio of energy saved through use of digital services to the energy consumed in using digital services is 10:1.[1] In addition, the telecoms and digital sectors have themselves become more energy efficient over time through leveraging of AI and data analytics. This has resulted in a reduction of these sectors’ global carbon footprint over the past decade, even as data traffic and service usage has increased.

The future of the symbiotic ecosystem

To date, the symbiotic ecosystem has delivered a range of benefits for consumers, businesses and the wider economy. The ecosystem has supported and facilitated significant growth in the number of connected users worldwide. At the same time, the capability, quality, variety of online services available to consumers and businesses has dramatically increased. These developments have been supported by an ecosystem that facilitates growth and innovation.

New and emerging applications suggest that symbiotic relationships across the telecoms sector are likely to become more important than ever. For example, edge computing solutions, typically delivered by partnerships between telecoms sector players with distinct specialisms, have the potential to transform key industry verticals. Delivering the next wave of consumer applications is also likely to be reliant on combining connectivity, computing power and AI.

There is also the challenge of connecting the billions of people that remain without Internet access – a challenge that is not just about deployment of infrastructure, but about affordable devices and compelling online applications and content. According to the GSMA, around 85% of Internet non-users live within the footprint of a broadband network. Symbiosis between telecoms sector players here will be key in offering compelling reasons to get online, in providing affordable devices, and in serving rural populations with novel technologies.

[1] GSMA (2019). The enablement effect. https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf

Enabling the potential of the symbiotic ecosystem

In summary:

- Online services are delivered by a complex ecosystem which operates at a global scale. Numerous players are active in this ecosystem, typically focusing on certain segments of the telecoms value chain. These players work together to ensure consumers and businesses can get the most out of online services.

- Indirect and direct symbiosis between players operating in different layers of the telecoms sector is helping to increase service demand, to drive value and to improve efficiency. Direct partnerships between telecoms sector players are also becoming increasingly common, and are helping to grow the entire sector.

- The symbiotic ecosystem has substantial potential for growth. Plum estimates that there could be US$11.8bn incremental cashflow in APAC region by 2026 if CSPs and OSPs develop closer and more productive relationships. Such partnerships can also help generate wider macroeconomic, societal and environmental benefits.

- Partnerships will be instrumental in delivering the next wave of connected applications, including virtual and augmented reality, connected device management and analytics, and novel cloud-based services ("anything as a service"). These emerging applications will help drive future economic growth, but in many cases a partnerships between sector players will be needed to realise their full potential, which will rely on low latency connectivity, high service reliability and computing power.

Below we outline ways in which telecoms sector stakeholders might encourage the further development of the symbiotic ecosystem.

- **Businesses** operating in the sector should take a holistic view of the ecosystem's development and be open to the opportunities presented by partnerships. Businesses that are not open to this prospect risk being left behind in the delivery of the next wave of connected services. They may also miss out on opportunities to drive operational efficiencies and reduce costs.

- **Policymakers** should recognise the importance of partnerships in delivering the next wave of connected services for consumers and enterprises. These services will drive growth of the digital economy, which will enhance productivity and economic growth. Policymakers can encourage the symbiotic ecosystem by facilitating infrastructure deployment, Internet take-up and digital skills.

- **Regulators** should aim to facilitate complementary relationships between telecoms sector players. This could be achieved by streamlining regulation of infrastructure deployment, enabling market entry and allowing partnerships between telecoms sector players operating in different segments of the sector. New regulatory interventions should be subject to regulatory impact assessments, which should take into account the impact on the wider ecosystem.

Both policymakers and regulators should be aware of potential adverse consequences of moving away from open Internet norms, which have enabled significant innovation and growth in the sector. For example, restrictions on the free flow of data run the risk of deterring creation and consumption of digital apps and content – potentially turning the virtuous circle of demand into a vicious circle. Such restrictions may also serve to deter the infrastructure investment needed to deliver the next wave of digitisation and economic growth. Policymakers and regulators should recognise a range of capabilities will be needed to deliver the connected applications of the future, and avoid treating any particular element of the sector with particular favour.

1 Unpacking the telecoms sector

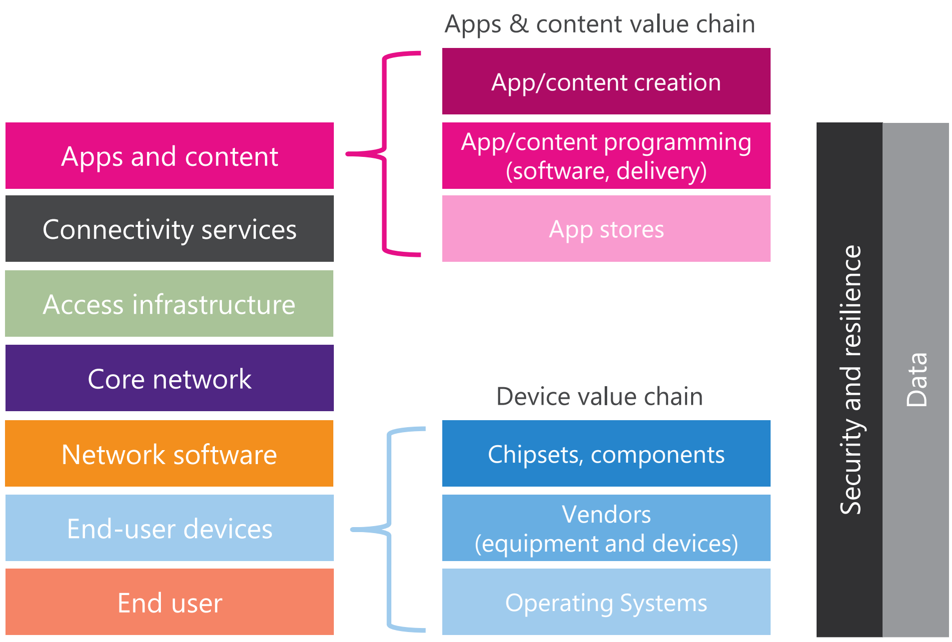
Today, many consumers can use their mobiles and connected devices to access digital content from across the world almost instantly. Businesses are making use of connected applications and cloud services to improve collaboration and productivity. The application of large-scale machine-to-machine (M2M) communications, the Internet of Things and automation (dubbed the Fourth Industrial Revolution) promises to drive the next wave of economic growth.

Underpinning all these developments is a complex ecosystem which operates at a global scale. Whilst this can be characterised as a value chain, in practice there are numerous interdependencies and relationships across different parts of the ecosystem, and many telecoms sector participants are active in multiple areas. Further, end-user interactions are not limited to one component of the value chain, and there are arguments that end-users of services are not the endpoint of the chain.

The telecoms sector can be described in various ways and to different levels of complexity. A simple approach might consist of three layers – applications, networks, and end-user devices. Whilst straightforward, this approach obscures some key detail and nuance in each of the layers – for example, it groups together local access networks and international backbone infrastructure. However, these two areas are quite distinct, both in terms of the active players and the challenges they face. Further, dividing the value chain into three layers does not allow a comprehensive assessment the linkages between different parts of the system.

Figure 1.1 sets out a view of the telecoms sector, which includes additional segments in order to highlight key areas involved in service delivery. For this study, the focus is on applications ('apps') and content through to end-user devices. There are other categories which are more distantly related to the sector that have not been represented and fall outside the scope of this study (including, for example, media and content production, or recycling of old devices). It is worth noting that this stack does not represent a linear chain; as described above, there are multiple linkages between different elements of the stack.

Figure 1.1: Illustration of the wider telecom sector



Note that the security and resilience of services and networks is a key consideration across all segments of the telecoms sector. Similarly, data is used across the sector to manage, refine and optimise services. It is also worth considering how applications, which are reliant on the entire network infrastructure, are linked to end users in terms of usage but software infrastructures in terms of functionality.

Figure 1.2 describes the telecoms sector segments and the different categories (or elements) that sit within these. For example, the connectivity service segment comprises data, voice and messaging services delivered to end-users (including both consumers and enterprises) while access infrastructure includes fixed and radio access networks as well as passive infrastructure.

Figure 1.2: Elements of the wider telecoms sector

Sector segment →	Apps & content	Connectivity services	Access infrastructure	Core & Interconnection	Network software	End-user devices	End user
Elements →	• Apps/content creation • Apps/content delivery • Online comms • App stores • Consumer cloud • AI/Analytics	• Data • Voice (inc. VoIP) • Messaging (SMS, MMS, RCS)	• Fixed access network (fibre, cable, DSL) • Radio access network (spectrum) • Passive infrastructure (towers and ducts)	• Physical core infrastructure • Data centres • National backbone • International backbone (International gateway, subsea, satellite) • Backhaul	• Core infrastructure software • BSS/OSS • VRAN • Edge computing • AI/Analytics	• Chipsets and components • Equipment and devices (e.g., mobile and IoT devices, CPE units) • Operating systems	• Individuals • Businesses and other organisations (e.g. NGOs) • States
CSPs	◔	●	●	◑	◔	◔	-
Equipment vendors	◔	◔	○	◑	◕	●	-
OSPs	●	◔	◔	◕	◔	◕	-

Key: ○ limited to no presence in segment, ● very strong presence in segment (key business focus).

The presence and level of involvement of operators, equipment vendors and OSPs is highlighted for each segment of the telecom sector. The various groups of players have differing but complementary specialisms:

- **Communications Service Providers (CSPs)** have a strong presence in providing access infrastructure and connectivity services to end users, and are making inroads into content provision and other value-added services.
- **Equipment vendors** specialise in end-user devices as well as network apparatus, and in some cases are offering connected services for a number of industrial applications.
- **Online service providers (OSPs)** typically focus on the provision of applications and content to consumers and businesses, but in many cases they have also invested heavily in data centres and international connectivity to support the delivery of those services.

Figure 1.3 places Google's current services and products within the telecom sector segments. Whilst the list of Google products is not exhaustive, it illustrates that Google is a key provider of apps and content. It is also a key player in the development and provision of network software and the core and interconnection segments, which support both the quality of experience for end users and the operations of CSPs and network operators.

Figure 1.3: Google's services in the wider telecoms sector

Sector segment	Apps & content	Connectivity service	Network software	Core & Interconnection	Access infrastructure	End-user devices	End user
Google – for individuals*	• YouTube services • Google Play services • Chrome browser • Productivity apps (e.g., Gmail, Sheets) • Google Voice, Messages, Meet • Google One (storage)	• Google Jibe (RCS standard) • Google Duo (video calling) • Google Fi (MVNO, USA) • Google Fibre (USA) • Google Voice	• Google Anthos • 5G edge cloud - GMEC • BSS/OSS stack • Google Cloud • Smart analytics	• Data centres • International and metro backbones (e.g., subsea cables) • Content Delivery Network Platforms • Google Global Cache	• Google Fibre	• Android OS • Devices including Chromebook, Google Assistant, Wear OS, Pixel, Pixel Book Go, Nest Wi-Fi router	• Individual Google user
Google – for businesses*	• Ad services (e.g., AdSense, Ad Manager) • Data Studio, Analytics • Google Workplace & other business productivity apps (e.g., Business Messages, Business Profile) • Chrome enterprise (software) • Google One (storage) • Contact Centre AI (customer service)					As above, and: • Chrome enterprise (hardware) • Pixel for Business	• Business Google user

Note: * Selected Google services (list not exhaustive).

The following sections discuss the individual segments and categories identified within the wider telecoms sector in greater detail.

1.1 Apps & content

The first segment is dedicated to the applications ('apps') and hosted content that end users access and interact with via their devices.

This segment can be described as having its own value chain, as shown in Figure 1.1. This includes developing and maintaining apps (including the supporting software), developing content that is delivered to the end user through apps and web browsers, and app stores where end users can access and purchase apps for their devices. This segment also includes provision of online communications services such as WhatsApp or FaceTime, and supporting services such as consumer cloud (data storage services) and data analytics. These individual categories within this segment are discussed in more detail below.

While the focus here is more narrowly on the app and content ecosystem, it is worth noting that apps and connectivity support the wider digitisation of the economy and the broader Internet ecosystem, including activities such as e-commerce, social networking, gaming and advertising. A.T. Kearney estimated that as of 2020, the global Internet economy was worth nearly $6.7tn,[2] or around 8% of global GDP.[3]

While these figures are large, they are also likely to underestimate the benefits of the Internet ecosystem. GDP figures do not include the benefits consumers receive from a service, over and above what they pay (the ‘consumer surplus’). As many online services are offered at zero price, the consumer surplus is likely to be large: according to one estimate, Facebook’s platform generates a median consumer surplus of about $500 per person per year.[4]

Apps and content add value to the telecoms ecosystem by providing a key driver for consumers and businesses to take up connectivity services. A greater number of connected users ultimately benefits the entire sector. Partnerships between OSPs and CSPs are enabling online services to be bundled with connectivity services (refer to Section 1.2), to the benefit of both parties and consumers.

1.1.1 Applications & content services

Application software (apps) covers the set of instructions (programs, procedures and rules) associated with a computer system. More specifically, within a device, application software operates above the operating system software and is designed for the use of end users. Depending on the type of app and the nature of the end-user device, apps may be pre-installed or downloaded by the end user through an app store or web browser (further discussed in Section 1.1.3).

The app and content ecosystem is vibrant, and is host to a wide range of actors including software developers, content creators, distributors, and advertisers. A variety of business models are employed, including paid-for applications, subscription services, advertising-supported applications, ‘freemium’ services and freeware or shareware. In many cases, applications and services are available to users at no cost. Apps may be available free-of-charge or the end user may be charged for the services – on a subscription basis, for one-time access, or on a premium basis for access to additional features. There are also apps that are designed specifically for different end users, such as specific enterprise applications, which may be paid for in bulk or commissioned specifically.

A broad range of applications

There is a broad range of apps with various uses, which include the following (a non-exhaustive list).

- Software designed to meet the specific needs of individuals and households on a large panel of services, such as entertainment and streaming platforms (Spotify, Netflix, YouTube, Sky Go, Xbox Cloud Gaming), home automation software (Home Assistant, PiDome), e-commerce and marketplaces (Amazon, Alibaba, Trouva), industry and sale platforms (Uber, AirBnB), and payment and fintech (Paypal, M-Pesa).

- Software designed to enable online interactions, such as online communication services (discussed in detail in Section 1.1.2), social media services (Facebook, Instagram, Viber, Twitter), and location-based services (Google Maps, Citymapper).

- Software designed to meet specific needs of business and industry use. such as improving processes, creating products and delivering services. This may include Enterprise Resource Planning (ERP), Customer Resource Management (CRM), finance management, supply chain (Sage CRM), online

[2] GSMA (2022). The Internet Value Chain. https://www.gsma.com/publicpolicy/resources/Internet-value-chain
[3] GDP percentage computed using World Bank data for the global economy in 2020.
[4] Erik Brynjolfsson and Akinash Collis (2019). How Should We Measure the Digital Economy? HBR. https://hbr.org/2019/11/how-should-we-measure-the-digital-economy

advertising services (Google ads, Airpush), software and applications to support IoT (AWS, Google Cloud, Microsoft Azure) and predictive maintenance and asset tracking (Upkeep).

- Software designed to run and manage the other applications on the device (or infrastructure), such as storage, archive, back up applications, cloud-based services (including VirtualBox, Solarwinds backup) and distribution platforms for app software (app stores, which are discussed in Section 1.1.3).

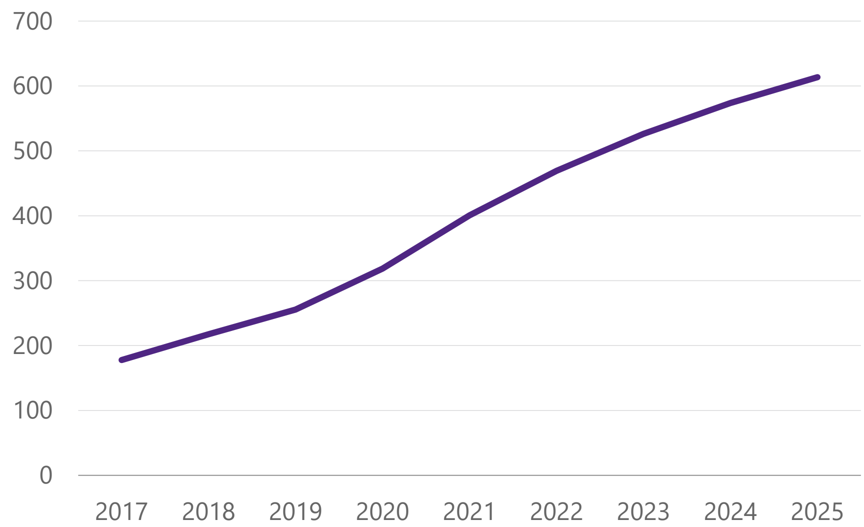
The first and second items in the list above include apps that are specifically designed to deliver content services to end users. For example, video and audio streaming platforms such as YouTube, Netflix and Spotify or content aggregators such as Apple News that distributes and personalises publisher content to readers. These apps, like many others broadly discussed above, help the users to quickly access desired content on-demand.

Media content (such as downloaded videos and music) is not included in the telecoms sector for the purposes of this report, but it is clear that the boundaries between the telecommunications industry and content creation is blurred, with telecom firms entering the content production business (for example, the Comcast's acquisition of NBCUniversal) and production companies making increased use of interactivity enabled by telecoms (with Netflix's interactive programming, and the rise of 'Games as a Service' from several developers).

A growing industry

The growth of the application industry is unprecedented, with revenues more than doubling in size over a four-year period, as shown below.

Figure 1.4: Total revenue of mobile applications by year, in billions of USD[5]



The greatest share of revenue comes from games, although as a proportion of the total this is predicted to fall over time, as revenue from social networking and other entertainment increases. However, this large industry is characterised by a number of very large applications, with a long tail of smaller revenues. Out of a total of 21 million applications available, 233 generated revenues of more than $100 million in 2021[6]. The most profitable

[5] Source: Statista. Available at https://www.statista.com/forecasts/1262892/mobile-app-revenue-worldwide-by-segment
[6] Source: State of Mobile 2022 report, Data.ai (formerly App Annie)

apps are overwhelmingly mobile games, which represent 75% of apps whose annual revenues are greater than $100 million.

It should be noted that this data includes only mobile apps; it does not consider the sales of software for more traditional computers. While this is now a relatively smaller market, it remains profitable for many developers, and indeed there may be instances where increased mobile applications engagement increases interest in desktop applications.

1.1.2 Online communications services

Online communications services are a distinct group of apps that allow end users to communicate over IP networks. The rise in digital platforms and social networks has been accompanied by both an increase in demand for broadband Internet – particularly mobile broadband – and a decrease in the use of SMS, MMS and traditional voice.[7]

A key driver of the take-up of online communications apps is that most allow free-of-charge use, provided the user has Internet access.[8] This differs significantly from traditional telecoms services, where users select post-paid contract packages that provide allowances for data, voice and messaging or have pre-pay packages where they are charged according to usage (per minute or per message). Some online communication apps also offer additional personalisation or functionality such as group chats, file sharing, and video calling that traditional telecommunication services did not offer.

The growth in consumer usage of online communications apps has clearly benefitted consumers, allowing more intense usage of communications services and offering additional features. In some markets, this has had a negative impact on revenues from traditional voice and messaging services. However, it has contributed to strong growth in demand for data services and it appears that overall revenues for telecoms operators are stable or growing.[9]

Social media and other digital platform providers have a strong presence in the online communications segment. Meta and its products (such as WhatsApp, Facebook Messenger, Instagram and Facebook) offer several of the most popular interpersonal communications and social media platforms. However, the online communications segment remains competitive and innovative, and firms have continued to develop their offerings: for example, videoconferencing platform Zoom emerged as a leading platform during the Covid-19 pandemic, outstripping growth and, in some cases, displacing traditional business-focused online communications services such as Microsoft Teams, Cisco WebEx and Google Meet.[10] There have also been several high profile acquisitions in the sector, such as Meta's (then Facebook's) acquisition of WhatsApp, Viber by Japanese e-commerce and tech conglomerate Rakuten, and LinkedIn and Skype by Microsoft.

Traditional and online communication services can, however, be viewed as both substitutes and as complementary services in how they are used by consumers, despite differences in the functionality they can offer. For example, research indicates that users tend to opt for voice calls to communicate with close friends and relatives, whereas other relationships tended to be maintained via WhatsApp or other social networks.[11]

[7] PPMi (2021). Analysing EU consumer perceptions and behaviour on digital platforms for communication, analysis report prepared for the Body of Regulators for Electronic Communications (BEREC), BoR (21) 89. https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/9965-analysing-eu-consumer-perceptions-and-behaviour-on-digital-platforms-for-communication-analysis-report

[8] PPMi for BEREC. (2021).

[9] Analysis of 30 major CSPs showed that the operators' combined revenue grew by a CAGR of 2.5% between 2018 and 2020. TM Forum (May 2021). Global trends in telco OpEx. Available at: https://inform.tmforum.org/insights/2021/05/global-trends-in-telco-opex/

[10] Vox, 4 December 2020, The pandemic was great for Zoom. What happens when there's a vaccine? Available at: https://www.vox.com/recode/21726260/zoom-microsoft-teams-video-conferencing-post-pandemic-coronavirus

[11] Fernández-Ardèvol and Rosales (2018), Older people, smartphones and WhatsApp. Smartphone Cultures, 55-68.

The tendency to use traditional or online communications tends to be driven by additional factors such as whether the communication is cross-border (where it is often cheaper to use online services) and urgency of communications (due to formality, preference for voice). Another key factor is the access to the relevant technology to both participants in a communication link; there is a greater chance of traditional voice being used when contacting older relatives, for example.

A key development in the communications space is the implementation of the Rich Communications Services (RCS) protocol. The objective of RCS is to replace SMS with an interoperable messaging service with an enhanced feature set, including group chat, read receipts, and the ability to share high resolution images. In 2016, the GSMA announced a partnership between the GSMA, Google and a set of global operators to enable RCS services on Android devices.[12]

1.1.3 App stores

Application stores are digital distribution platforms (or digital marketplaces) that allow end users to download software apps. App stores are most commonly associated with mobile and tablet devices, where apps are used by end users to directly access goods, services and content from the app provider. App stores often come pre-installed on end-user devices, as with Apple’s App Store for mobile and tablet devices using the iOS operating system.

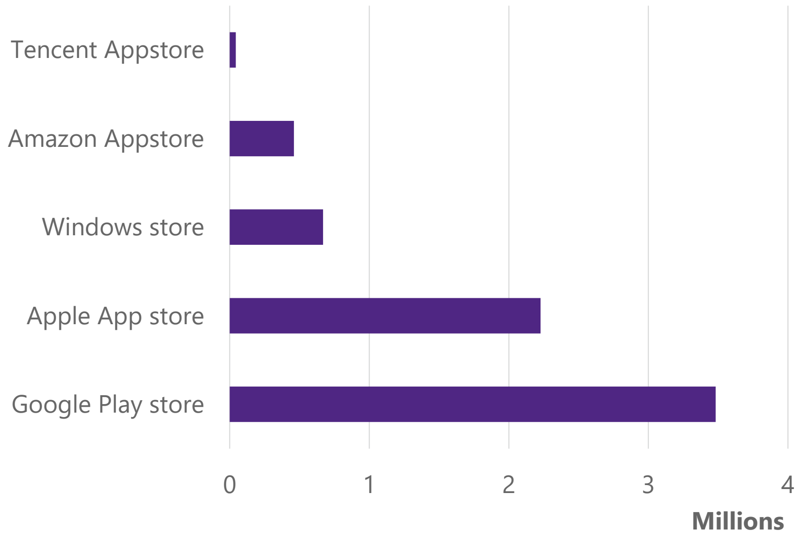
This differs from the context of desktop and laptop computers, where end users have historically tended to access online services through web browsers, and to use software applications that are either pre-installed or installed from physical media. However, this distinction is blurring: for example, Google Chromebook users can use the Google Play Store (app store) to install Android apps onto their laptop device, while Microsoft’s Store provides applications for devices running on the Windows operating system.

While app stores may be designed to run on a specific operating system or device type, there are also independent cross-platform app stores – for example, Steam is a video game store and client for desktop users on multiple operating systems, while Opera Mobile store is compatible with difference devices on various mobile OS platforms.

App stores provide a curated environment where end users can access apps that are compatible with their device and allow a consistent and secure experience. Most app store operators will test software apps before they become available to ensure users and continue to monitor app releases to ensure apps meet certain standards (such as compliance, quality control and security). This is challenging, given the number of applications that have been made available on the largest app stores, as shown below.

[12] GSMA (2016). Global Operators, Google and the GSMA Align Behind Adoption of Rich Communications Services. https://www.gsma.com/newsroom/press-release/global-operators-google-and-the-gsma-align-behind-adoption-of-rcs/

Figure 1.5: Number of apps available on selected app stores as at Q1 2021[13]



It is worth noting that while some app stores are tied to certain hardware (such as Apple's App store only being available on iOS and MacOS devices), there are moves to allowing competing app stores (such as Amazon's offering being available on Android devices) and app stores that are available on multiple platforms.

1.1.4 Consumer cloud and analytics

Consumer cloud services and data analytics services include both data storage services used by app and content providers, and those used by individual consumers and enterprise users.

App and content providers use data storage services to support their web and mobile applications. Services such as Google Cloud Datastore are suitable for large-scale, structured data and allow providers to sort and query different types of data in order to collect real-time inventory and product details, develop user profiles and deliver customised services based on the user's preferences and past activities, and conduct certain transactions.[14]

The cloud storage and database requirements of app and content providers will depend on the nature of the application and data. For example, Google's Firestore is a cloud-native NoSQL program suitable for mobile, web and IoT application that offers real-time and offline sync whereas Cloud Storage may be more suitable for applications that need to storage large immutable content, such as images or movies.[15] At the far end of the scale, Amazon S3 Glacier is designed for very large-scale data storage but with extremely slow access, used for non-critical backups or archives.

Data analytics services are often integrated with cloud databases. For example, Google Analytics for Firebase offers "free, unlimited reporting on up to 500 distinct events."[16] The services provide users with insights on app

[13] Source: Statista. https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/
[14] Further information on Google Cloud Datastore outline via: https://cloud.google.com/datastore/docs/concepts/overview
[15] Further details on Google Cloud databases is available online: https://cloud.google.com/products/databases
[16] Refer to: https://firebase.google.com/products/analytics?gclid=CjwKCAiAo4OQBhBBEiwA5KWu_2klJBKiuLjgUCH2Ybcpg1kZBgGuduK_r9f4IQHbAuCF10FefxkMBoCyo8QAvD_BwE&gclsrc=aw.ds

usage through to acquisition and in-app purchases. By offering this in conjunction with off-site databases, large and efficient computing power can be used to query the databases and run the analytics.

1.2 Connectivity services

Connectivity services refer to the connectivity products and supporting services delivered to end users. For mobile connectivity, this is often defined in terms of allowances for data, voice and messaging, although there is an increasing reliance on service quality in marketing materials. For fixed connectivity, the service is more often defined in terms of quality of the connection, such as expected network speeds.

This segment also includes important activities to support and manage the customer relationship, such as customer service, technical support and billing. In addition, it includes sales and marketing activities.

The nature of the service provided will further differ depending on the end user.

- **Consumers (personal users)** – Mobile packages tend to be defined by allowances for data, voice and SMS messaging services for a set monthly fee (post-paid contracts). They can also be specified in terms of cost per unit of usage for these services (prepaid contracts). While there are examples of service quality being part of the offering (most notably with some operators charging extra for 5G services), in general consumer connectivity services are sold on a 'best available' basis.

  Fixed (wired) and fixed-wireless connectivity subscribers tend to be households (as opposed to individuals). Such connections are typically sold based on the connection bandwidth, but may also include monthly data caps. Since the quality of connection is better known, artificial limits may be placed on lines so that a variety of speeds can be sold.

  In some developed markets, there has been increasing fixed-mobile convergence at both network and retail levels. Converged offers to customers can take several forms, including a single package that includes both fixed and mobile services (a service bundle). Fixed-mobile packages are often also bundled with pay TV packages or subscriptions to video-on-demand services.

  In some cases, converged offers may be part of service continuity agreement – this may, for example, provide customers with a back-up 4G connection in case of service disruption on the fixed connection.

- **Enterprise (business users)** – Businesses will often require a higher service quality and reliability than consumers. Enterprise-level connectivity services frequently offer higher reliability than consumer-grade connections. In some cases, this may backed up by service level agreements (SLA), which may offer users compensation if the connection fails. Some businesses will take leased line services which offer a guaranteed bandwidth.

  While such connectivity services may be suitable for most enterprises and SMEs, some will have additional connectivity requirements that are better served with a private cellular network. These are networks that use owned, shared or unlicensed wireless spectrum and LTE and 5G equipment, base stations or small cells to connect edge devices. Typical use cases for private LTE/5G networks include manufacturing facilities, ports, airports, mining operations and utilities.[17] Such a network may be installed and operated by the enterprise itself, by mobile operators, or by neutral hosts.

For consumers, the data allowance has become an increasingly important component of mobile packages. In some advanced telecoms markets such as Taiwan and South Korea, this has been reflected by large or unlimited data allowances (which are sometimes differentiated by connection speed) being the key feature of mobile tariff

[17] Refer to https://www.ericsson.com/en/dedicated-networks?gclid=EAIaIQobChMIr4yX4_-G9gIViK3tCh1Plgl7EAAYAiAAEgJ1qPD_BwE&gclsrc=aw.ds

and unlimited allowances for voice and messaging. In some markets operators now offer unlimited data for specific social media or entertainment apps (such as Facebook or YouTube) with a specified allowance for other data usage (general browsing and use of other apps), voice and messaging services. These special allowances are sometimes backed by financial contributions from the affected apps.

In the case of mobile, the connectivity service provider may be the mobile network operator (MNO) which owns and operates the underlying network upon which services are provided, or by MVNOs reliant on a host MNO to deliver services to end users. Similarly, fixed connectivity services may be provided end users by those that own and operate the underlying fixed infrastructure or may be provided by operators reliant on access to other infrastructure. Given the usual monopoly structure of the fixed infrastructure market, it is common for wholesale access to the network to be mandated and wholesale prices to be regulated, leading to multiple retail operators using the same network and offering the same connectivity services.

1.3 Access infrastructure

Access infrastructure or access networks are telecommunications networks operating at local or national scale that connect end-users (subscribers) to other telecoms networks. These physical networks are used to provide the connectivity services described above.

They can include:

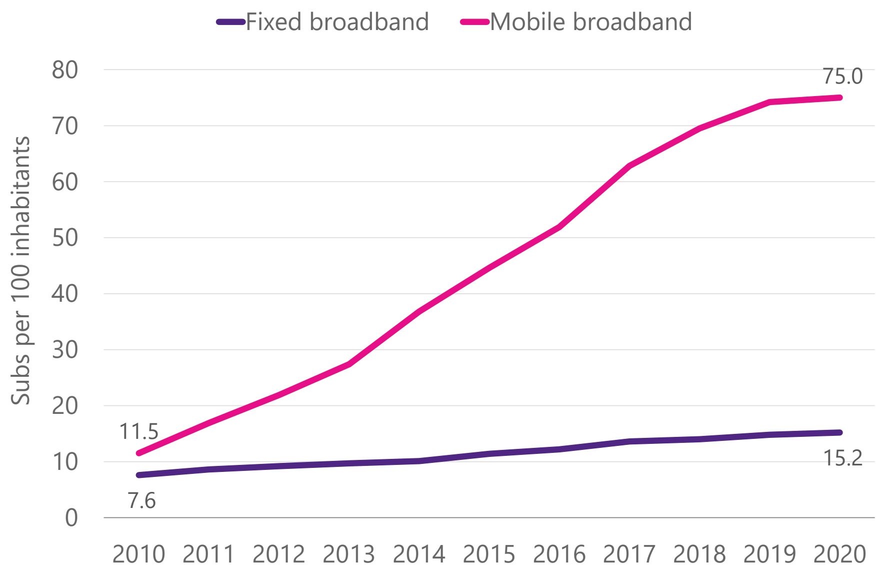
- **Fixed access networks**. These networks that provide connectivity to end users through wireline technologies such as full fibre to the premise (FTTP), fibre to the cabinet (FTTC), or cable. The deployment of these fixed technologies differs due to market development and presence of legacy networks (for example, a fixed telephone network). Fixed networks may also use fixed wireless capability where the physical medium is replaced by a wireless link between a premises and a base station.

  The economics of fixed network deployment rely on a cost-effective network build and sufficient revenue per household to provide a return on investment, which can be challenging in less densely-populated areas. In some countries, fixed networks are not widely deployed, and connectivity services are primarily supplied over mobile access networks.

- **Mobile access networks.** These networks use radio spectrum to provide service to devices that may either be static (but not fixed) or in motion. The key part of a mobile access network is the RAN (Radio Access Network). Similar to fixed access, RAN capabilities and performance will depend on the technology standard used, the radio frequencies deployed and the amount of radio infrastructure deployed. For example, LTE/4G and 5G technologies provide lower latency, higher throughput and faster download speeds than 2G and 3G technologies. Whilst most mobile connectivity is via public cellular networks, there are an increasing number of private LTE and private 5G networks. Such networks tend to be local (geographically defined) wireless networks that are deployed for enterprises and industrial users.

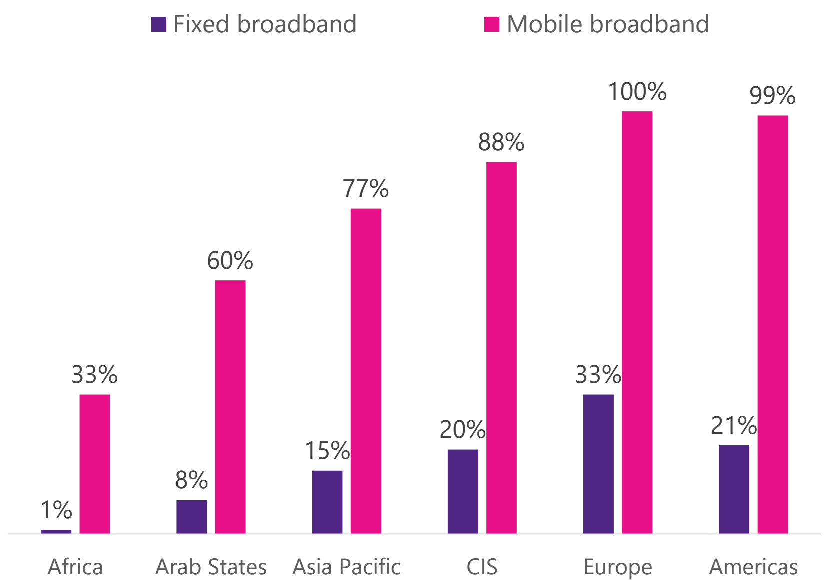
The mix between fixed and mobile networks is changing over time, and varies by region. Many countries are seeing increased greater reliance on wireless technology – both mobile and fixed wireless – to meet demand. Overall, the adoption of mobile broadband has grown significantly more rapidly than fixed broadband. Figure 1.6 below demonstrates this globally.

Figure 1.6: Global broadband adoption trends[18]



Although mobile is the dominant technology globally, the mix between fixed and mobile connections varies by region. In Europe and the Americas, fixed broadband adoption is relatively widespread compared to the rest of the world, although mobile penetration is close to or exceeding 100%. In developing regions, particularly in Africa, most connections are mobile since there has historically been less investment in fixed broadband infrastructure, and mobile services are more affordable.

Figure 1.7: Broadband penetration per 100 inhabitants by region, 2020[19]



The advancement of mobile technology, particularly with 5G, means any gaps in capability between fixed fibre and mobile connectivity services are being narrowed: the applications and services used on mobile connections are broadly similar to those carried over fixed-line connections. Although it is expected that file sharing will be

[18] ITU (2020). Measuring digital development: Facts and figures. Available at https://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx
[19] ITU (2020). Measuring digital development: Facts and figures.

less common on mobile devices, and social networking used more, the biggest application in terms of data usage and bandwidth requirement will be video streaming.

For both mobile and fixed networks, the access infrastructure can be split between:

- **Active infrastructure**, which is the electronics and technology used to carry transmissions or send data, such as antennae and laser receivers; and
- **Passive infrastructure**, such as towers and ducts, is the physical network infrastructure that supports access networks. Passive infrastructure may be shared between multiple operators and there are various examples of sharing arrangements. For example, passive infrastructure may be operated by a neutral operator who provides access (as is the case with Malaysia's DNB) to others or, as a regulatory intervention to ensure competitive retail markets, operators may be required to provide others with access to their own infrastructure.

Access infrastructure has historically been deployed and operated by CSPs, in particular incumbent operators, although a number of countries have encouraged infrastructure competition and in these countries there is an increasing rate of network build by other operators. In Asia, several conglomerates have successfully launched themselves as mobile network operators, leveraging their positions in technology and media markets. A notable example is the Rakuten Group in Japan, which initially entered the Japanese market as an MVNO in 2014 and is now deploying RAN infrastructure since launching as a full MNO in 2018.[20] Rakuten has since become a disruptive player, offering low-cost plans and integrating advanced digital technologies to support its network rollout.

Hyperscale cloud providers such as Microsoft Azure and Google Cloud are increasingly working with infrastructure operators to optimise deployment. For example, Google's Network Planner tool is a web browser application that allows providers to plan and optimise their radio network deployments.[21] This service integrates Google traffic and geospatial data and allows users to run advanced propagation models in the Google Cloud. This service also supports the Spectrum Access System (SAS) developed by Google and its ecosystem partners (Nokia, Ericsson, Airspan, Cambium and others) which, in turn, supports the USA's dynamic spectrum sharing system, CBRS.[22]

1.4 Interconnection

Networks tend to interconnect with one another in the core segment. This allows efficiency to be achieved by optimising the number of inter-network links. Network interconnection might take place in a network operator's premises or a neutral interconnection point. In future, there might be growth in interconnection toward the edge of networks for specific services.

'Backhaul' commonly refers to parts of networks which provide bitstream conveyance of traffic from access nodes to major points of aggregation, meshing, and switching (for example, in the UK market, Openreach's EAD products). For example, with FTTP access networks, traffic must be conveyed from users' premises to major Internet peering hubs at data centres with colocation facilities. Backhauling typically traverses a number of network elements including metropolitan fibre rings, regional and national trunks, and international trunks (using a variety of physical technologies, including microwave point to point, satellite links, long distance overland fibre trunks, and submarine fibre trunks).

[20] Analysys Mason, 23 March 2020, All eyes are on Rakuten Mobile's MNO launch, but it remains to be seen if its model will be successful. Available at: https://www.analysysmason.com/research/content/articles/rakuten-mobile-launch-rdmm0-rdrp0/
[21] https://www.google.com/get/spectrumdatabase/network/
[22] https://www.google.com/get/spectrumdatabase/partners/

1.4.1 IP Peering

Interconnection traditionally referred to the connection between telecom network operators' core networks. However, this picture has become more complex over time as the provision of applications and content from data centres has grown. This has led to a huge increase in interconnection between traditional telecoms network operators and OSPs (and directly between OSPs), and other non-traditional network operators such as enterprises and government agencies. This interconnection is often, in reality, IP peering.

IP peering describes the process where network operators come together at a physical point of presence to interconnect traffic destined for the interconnected parties' networks or their downstream customers. IP peering is typically offered at major datacentre hubs, with colocation facilities. Economically, IP peering is almost always transacted without payment which helps make the Internet resilient and reliable for users and operators. To ensure reachability across the whole Internet, both telecoms operators and content and application providers will also purchase IP transit services from an upstream provider who will provide such global reachability.

The remainder of this section discusses other categories relevant to the core and interconnection infrastructure segment.

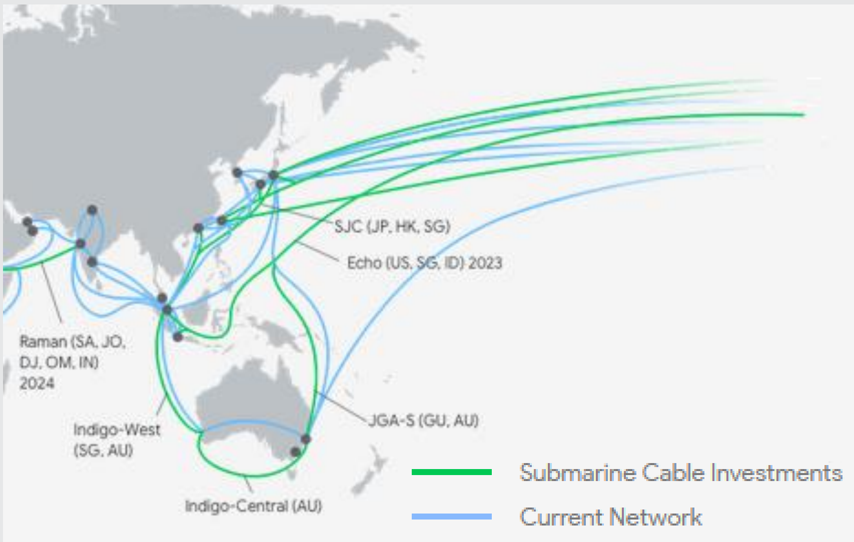
1.4.2 International backbone

International backbone is the principal data route between large, interconnected networks and primarily consists of terrestrial fibre and subsea cables that provide international data transfer. Historically, international backbone was provided by specialist telecom providers with some co-investment from large national CSPs. In recent years, however, OSPs have increasingly invested in international backbone: Google, Meta and Microsoft have been the largest investors in subsea cables.[23] These investments have tended to be co-investments with other digital players, international connectivity providers and local CSPs (refer to Figure 1.8 for examples). Between 2013 and 2017, the international bandwidth of OSPs grew by 80% per annum, representing almost half of the international bandwidth consumed in 2017.[24]

[23] Wired, 18 November 2018, 'Google and Facebook are gobbling up the Internet's subsea cables'. Available at: https://www.wired.co.uk/article/subsea-cables-google-facebook
[24] Delta Partners (2019). From telcos to tech-cos. Available at: https://deltapartnersgroup.com/2019/03/05/from-telcos-to-tech-cos/

Figure 1.8: Google's investment in subsea cable infrastructure

As of 2019, Google is directly involved in supporting the global subsea cable network. Google's network in the APAC region is shown below.



Selected examples of Google's international backbone projects and partners are listed below.[25]

- **INDIGO cable system** consists of two distinct cable projects – Indigo West (4,600km) which connects Singapore to Perth via Jakarta, and Indigo Central (4,600km) which connects Perth to Sydney.[26] The consortium partners include Google, AARNet, Indosat Ooredoo, Singtel, SubPartners and Telstra. The system supplier is Alcatel Submarine Networks (ASN).

- **Japan-Guam-Australia South (JGA-S)** cable system launched in 2019 and includes the JGA South and JGA North systems, which operate as separate cable systems, and interconnect at a cable landing station in Piti, Guam.[27] JGA South is a consortium cable with Google, AARNet and RTI as partners whereas JSA North is a private cable with RTI as the sole operator and investor.

- **The South-East Asia Japan Cable System (SJC)** is owned by a consortium including China Mobile, China Telecom, SingTel, Telin, Google and others. has landing stations in Japan, China, Hong Kong, the Philippines, Brunei, Thailand and Singapore.

- **FASTER** is a trans-pacific cable system[28] with landing points in Japan, Taiwan and the US that is co-owned by Google, KDDI, Global Transit (Time dotCom) and various local CSPs, including Singtel, China Telecom, China Mobile and KKDI. The service launched in 2016 and stretches 11,629km.

- **Echo** is a forthcoming Pacific subsea cable which will link California to Singapore, with plans to also land in Indonesia. It is expected to be ready for service in 2023.[29]

- **Curie**, the first fully Google-owned international subsea cable runs from Los Angeles, California down the Pacific coast to Valparaíso, about 120km northwest of Chile's capital, Santiago. Its total length is 10,000 km. Google announced that its second self-owned international subsea cable, OSPs have invested in international bandwidth to support delivery of their services (such as data centre content distribution and cloud computing). It is expected that OSPs will continue to invest in international backbone to increase international capacity and support increased data demand. For OSPs, being able to manage international backbone infrastructure also ensures a high level of security and resilience where networks link to key data centres.

1.4.3 Data centres

Data centres are physical facilities that house:[30]

- **Network infrastructure**, to connect servers, data centre services and storage as well as to provide connectivity to external networks and end-users.
- **Storage infrastructure**, which is the storage systems and server hardware that is essential for data storage and management.
- **Computing resources**, which are the applications used to provide processing, memory and local storage within the data centre.

There are multiple variants of data centres that provide a range of services including colocation, peering, hosting, provision of cloud services, and specific services for enterprises, among others. The growth of edge computing means that the role of data centres is evolving over time.

There are many data centre providers around the world of varying sizes. Some are facilities that enterprises have developed to manage their own services and data, while others have been conceived to provide cloud services at a very large scale. Hyperscale cloud providers such as AWS and Microsoft Azure have invested heavily in data centre provision to support cloud services. Data from the Synergy Research Group reported that AWS, Microsoft and Google accounted for more than half of the world's largest data centres (approximately 600 data centres) in the third quarter of 2020.[31]

In the APAC region, the hyperscale data centre market is expected to grow at CAGR 4.6% from 2020 to 2026.[32] AWS, Microsoft, Google and Meta were reported to be the largest investors in data centres in Southeast Asia in 2020/21, followed by Apple, Alibaba and Tencent.[33] This trend has been observed globally, and has been partly attributed to increased demand for digital services and a shift to remote working, supported by cloud facilities, during the Covid-19 pandemic. As of 2020, overall data centre investment reached US$37 billion and more than 100 new hyperscale data centres being built.[34] As of 2021, Google operates 23 data centres in nine countries.[35]

[25] Venturebeat, 2019, How Google is building its huge subsea cable infrastructure. Available at: https://venturebeat.com/2019/04/24/how-google-is-building-its-huge-subsea-cable-infrastructure/
[26] Submarine Cable Networks, January 2022, INDIGO. Available at: https://www.submarinenetworks.com/systems/asia-australia/indigo
[27] Submarine Cable Networks, January 2022, JGA. Available at: https://www.submarinenetworks.com/en/systems/asia-australia/jga
[28] Submarine Cable Networks, January 2022, FASTER. Available at: https://www.submarinenetworks.com/systems/trans-pacific/faster
[29] https://cloud.google.com/blog/products/infrastructure/introducing-the-echo-subsea-cable
[30] Cisco (2022). What Is a Data Center? Available at: https://www.cisco.com/c/en_uk/solutions/data-center-virtualization/what-is-a-data-center.html
[31] As reported by: CRN, 27 January 2021, AWS, Google, Microsoft are taking over the data centre market. Available at: https://www.crn.com/news/data-center/aws-google-microsoft-are-taking-over-the-data-center
[32] PR Newswire, 16 August 2021, Asia-Pacific (APAC) Hyperscale Data Center Size by Investment to Reach USD 39.24 Billion by 2026 – Arizton. Available at: https://www.prnewswire.com/news-releases/asia-pacific-apac-hyperscale-data-center-size-by-investment-to-reach-usd-39-24-billion-by-2026--arizton-301355939.html
[33] Channel Asia, 4 June 2021, Hyperscale cloud providers ramp up data centre investment. Available at: https://www.channelasia.tech/article/688888/hyperscale-cloud-providers-ramp-up-data-centre-investment/
[34] DCD, 27 January 2021, Microsoft, Amazon, and Google operate half the world's 600 hyperscale data centers. Available at: https://www.datacenterdynamics.com/en/news/microsoft-amazon-and-google-operate-half-the-worlds-600-hyperscale-data-centers/
[35] https://www.google.co.uk/about/datacenters/locations/

The importance of data centres and colocation continues to grow as the take-up of cloud-based services and storage increases. For security and resilience, and to permit business continuity, data will often be stored across multiple data centres. It should also be noted that due to the size and requirements of data centres, geographic location is key, and a number of data centres globally are being set up in northern regions where computers require less artificial cooling.

1.4.4 Caching and Content Delivery Networks

A cache is a store of static digital content embedded within a network – typically close to end users. Caches can exist at various levels of the network: within access networks, within content provider networks or at content provider Points of Presence. If a user requests a certain item of content, and that content is held on the cache, it can be served within the network, rather than relying on content to be conveyed from source servers (which are typically much further away).

Caching helps to reduce the amount of traffic sent on peering and transit links, reducing costs for CSPs. The amount of traffic which can be served this way depends on the consumption patterns of network users. Google's caches (Google Global Cache) can typically serve between 70-90% of Google traffic from the local cache.[36] Caching also has the benefit of improving the end user's quality of experience, offering reduced latency in the provision of requested content. Caching is well established in the industry and continues to grow in importance with drivers such as 5G technology – which rely upon edge clusters for provision of some low latency services.

A Content Delivery Network (CDN) is a network of geographically distributed servers which help cache content at the network edge. The role of CDNs try to place their content as close to the end-user as technically and commercially possible. CDNs often have servers in many data centres around the globe, which makes it easier to interconnect with CSPs close to end-users. Smaller online service providers typically make use of independent CDNs such as Akamai, while larger providers operate their own CDNs.[37] Cisco predicted that CDNs will carry 72 percent of total Internet traffic by 2022.[38]

1.4.5 Points of presence (PoPs)

A point of presence (PoP) is a physical location at which two or more entities may interconnect their networks to allow handover of traffic, and are especially important in backhaul trunking, IP peering, and IP transit. CSPs, content delivery networks (CDNs) and major OSPs will all generally operate multiple points of presence. For example, Akamai, a large CDN, has points of presence in over 135 countries.

A CDN or OSP PoP will generally contain caching servers, bringing content closer to end users, with corresponding advantages to latency and the end user experience. However, such PoPs can act as a handover point for exchanging traffic – for example, almost all traffic to and from Google is offloaded onto Google's network at Google's Edge PoPs. A key issue for OSPs is the choice of location for PoPs to achieve best efficiency in terms of access and content distribution.

[36] https://support.google.com/interconnect/answer/9058809?hl=en
[37] For example, Netflix initially relied on independent CDNs, but today operates its own CDN, 'Open Connect'
[38] Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

1.5 Network software

The network software segment refers to software that is used to manage and maintain the network, as well as software applications that are used to support the provision of telecoms services to end-users.

This segment has traditionally been served by specialist software providers or software developed in-house by the telecom network operators. In recent years, however, developments in telecommunications network architectures have facilitated the entry of OSPs and hyperscale cloud providers as Software Defined Networking (SDN), Network Function Virtualisation (NFV) and edge computing become more prevalent. These concepts are increasingly becoming a part of the network design and are embedded in the 3GPP and ETSI standards. As the trend toward open networking continues the use of software solutions in networks is expected to increase.

As networks continue to evolve towards increased use of open standards and software driven implementations, networks are progressively being developed with interfaces (including APIs) and modules (software containers) to enable development of rich ecosystems, supporting many distinct commercial players. The software-defined core networking industry is well established and has been in place for around ten years. As network solution vendors have progressively moved and matured their products as cloud-native, cloud-based core networks have become prevalent, with network operators looking towards their suppliers to provide solutions as managed services.

1.5.1 Core and infrastructure software

The use of software techniques in core networks has been developing for some time. Newer generations of network technology are making increased use of the flexibility, scalability and cost advantages of core networks operating on cloud native machines through virtualisation of core network functions.

The goal for many network operators is to run as much as possible of their core network on standardised software and hardware. This is already happening with LTE advanced packet core and 5G core networks and is expected to evolve to support of 5G Standalone core capability.

Moving the core into software delivers benefits through being able to innovate services faster and more effectively, it removes constraining telecoms hardware dependencies, and it allows for much improved service monitoring and quality management. The Open Networking Foundation (ONF) is a consortium dedicated to fostering innovation in software-defined programmable networks, with members including network operators, OSPs and vendors.[39]

1.5.2 Edge technologies

Edge computing generally refers to a cloud-based IT service environment located at the edge of a network. It is often a distributed, open IT architecture depending on decentralised processing power. The proximity of edge computing can have significant benefits both in terms of speed (latency and bandwidth) and overall network efficiency. Edge computing is an enabler of many mobile computing and Internet of Things (IoT) technologies, where processing power is unable to be incorporated into the devices themselves.

Multi-access Edge Computing (MEC) is a technology aiming to satisfy the requirements of high-bandwidth and low-latency applications which operate at the edge of the network. MEC is based on the convergence of IT and telecommunications networking. Key benefits are reduced network congestion and improved performance for

[39] Refer to: https://opennetworking.org

low-latency applications. MEC also includes workloads running on customer premise equipment and other points of presence at the customer site.

Providers of edge computing are likely to be multiple combinations of MNOs and system vendors, together with cloud operators such as Google or AWS. Edge potentially enables many new use-cases such as IoT, V2X, AR and VR, or remote medicine, which require high performance network capabilities.

1.5.3 Consumer experience and service

Other software applications focus on improving customer experience. These can include aspects of OSS/BSS but more specifically includes the use of AI analytics to provide real-time, data-driven insights that allow network providers to make more timely decisions and better anticipate users' needs, such as targeted marketing campaigns and offering more personalised products, thereby improving services and reducing churn.[40] For example, Google Cloud's BigQuery platform provides a scalable data analytics solution for telecommunications companies to store, process, and analyse data in real time, and build personalisation models on top of this data.[41]

Many cloud-based operators also offer a suite of services that can support customer service. The introduction of cloud-based AI to provide chatbot or call centre support can help lower costs, improve efficiency (i.e., by resolving or sorting queries prior to involving a human operator) and increase customer satisfaction. [42] For example, Google Cloud Contact Centre AI employs a virtual assistant and use of voice recognition and analytics to identify and categorise the customer's (spoken) request and field this to the appropriate in-person agent. It can then provide initial information and coach agents through the customer-agent call. In some cases, these services may be repackaged or integrated with the CSPs' own services. For example, Telefonica's Aura virtual digital assistant platform[43] runs on Microsoft's cloud and AI services. Aura, which is available on different connected devices and platforms, allows customers to manage their products and services with Telefonica (e.g., video-calling, TV channel control) and access real-time support through voice interaction.

1.6 End-user devices

The end-user device segment describes the hardware used to connect to the Internet and other communications services. This segment can be depicted as a sub-value chain, as the categories and component parts are more distinctly layered than in other segments of the wider telecoms sector.

Over the past 20 years, the penetration and usage of connected devices has increased significantly across the globe. In the APAC region, around 60% of the population have a mobile phone, and around two-thirds of these are smartphones.[44] However, 'connected devices' is a broader category than smartphones and tablets. There is rapid growth in consumer and industrial IoT devices – including connected household items, vehicles and industrial sensors. The GSMA estimate that there are 1.8bn active IoT connections in the APAC region, and predict this will grow to over 3bn by 2025.[45]

The presence of different ecosystem players (established equipment and device vendors, entrant device providers and OSPs) varies significantly by the type of device: Apple and Samsung are prominent in the

[40] AWS (2021). Customer experience, reimagined. Available at: https://apps.kaonadn.net/5146287135522816/index.html#section=customer_exp
[41] Google, 2021, Press Releases. Available at: https://cloud.google.com/press-releases/2020/0305/google-cloud-telco-strategy
[42] Google Cloud, 2021, Contact Centre AI. Available at: https://cloud.google.com/solutions/contact-center/
[43] Microsoft, 11 June 2019, Spanish telco builds digital assistant based on natural language bot, engages customers on new level. Available at: https://customers.microsoft.com/en-us/story/726906-telefonica-media-telco-cognitive-services-azure
[44] GSMA (2021). The Mobile Economy: Asia Pacific 2021. https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/08/GSMA_ME_APAC_2021_Web_Singles.pdf
[45] *Id.*

smartphone space, Dell and HP are prominent manufacturers of personal computers, while Cisco specialises in networked products.

This section presents a simplified overview of the device ecosystem. The actual picture is more complex, with an expansive ecosystem that includes device sellers, refurbishers, support services, and disposal and recycling services.

1.6.1 Chipsets and device components

End-user devices (and infrastructure equipment) are composed of discrete device components. These components can be classified as:

- **Electronics**, which are technologies (dealing with electrons) capable of electrical emission, flow and control. These include transistor, sensors, integrated circuits that are used to build electronic systems such as laptops, IoT devices, Wi-Fi and customer-premise equipment (CPE) systems, and smartphones.

- **Photonics**, which are technologies (dealing with photons) capable of generating, detecting or manipulating light over the whole spectrum. These technologies involve use of lasers, optics, fibre-optics and electro-optical devices in a large range of technologies, including communications and IT.

The device components using these technologies include electronic circuits, smartphone processors, display technologies (such as LED and laser), power sources such as batteries, resistors, diodes, transistors, antennas, transmitters, receivers, sensors (detecting motion, proximity, velocity, temperature, pressure, light, vibration), positioning modules and imaging sensors.

These discrete device components tend to be provided by specialist manufacturers and sold to equipment and device manufacturers. For example, Taiwan Semiconductor Manufacturing Co (TSMC) is one of the largest semiconductor companies and held 54% of global market share by end-2021.[46] TSMC and Samsung (the second largest semiconductor company, with 17% global share) are the only companies capable of producing the 5-nanometre chips that go into Apple's iPhone. Many end-user device manufacturers (such as Apple) rely on these providers to supply internal components for their devices.

1.6.2 Equipment and devices

Equipment and devices are the pieces of electronic equipment used by the end user to utilise apps and content. This includes device components (Section 1.6.1) and the operating system (Section 1.6.3). It is also supported by applications software and the services offered by these applications.

This segment includes mobile phones, smartphones, tablets and laptops, Wi-Fi routers and other CPE systems, Internet of Things (IoT) devices and smart personal objects (wearables, home personal assistants, thermostats), industrial IoT objects (robots, heavy machinery), transportation (vehicle telematics, connected vehicle, fleet management), individual radar and camera devices (fixed or mobile) for surveillance and detection, Ultra High Definition screens, drones (personal, industrial, mission critical), and satellite dishes.

There is a wide range of equipment and device providers, with different providers specialising in particular devices and technologies. These include consumer electronics companies and OSPs in addition to providers of

[46] https://www.visualcapitalist.com/top-10-semiconductor-companies-by-market-share/

enterprise solutions and hardware. For example, Netgear specialises in routers and other networking equipment for home and business use, while Samsung and Apple have strong positions in the global smartphone market.[47]

Connected devices and sensors are also being deployed in industrial contexts, such as in manufacturing centres and warehouses, as part of the ongoing automation of industry (dubbed Industry 4.0). In this context, connected devices can help make industries more efficient, reduce maintenance downtime, extend equipment life, reduce waste and improve agility. Ericsson has predicted that by 2030 there will be 4.7 billion wireless modules across smart manufacturing floors.[48] The use of connected devices in the industrial context is often coupled with the deployment of a private LTE/5G network to reduce latency and enhance security. Key players in the Industry 4.0 space include Nokia and Ericsson.

1.6.3 Operating systems

An operating system (OS) is a software programme that manages hardware, software and storage resources, and provides a common software platform for all other applications used on a device. The most common operating systems are Google's Android OS, Apple iOS and Apple macOS, Linux, and Microsoft Windows.[49]

Operating systems run on different hardware and in some cases are designed to be tightly coupled to the hardware. For example, Apple's iOS is primarily designed for iPhones and iPad tablets whereas its macOS is used on its Mac desktop and laptop computers. Microsoft Windows and Apple iOS and macOS are proprietary to companies, whereas Linux is a family of open source and freely available systems.

Google's Android OS was originally based on the Linux kernel.[50] The core Android platform is available for anyone to use and develop, via the Android Open Source Project (AOSP).[51] Like other operating systems, this provides user interfaces and architecture, security programs, and allows users to offer consistent experiences across different Android-powered devices for users and app developers. Android is used by Google and other companies to run Android compatible mobile smartphones and tablets, and this has led to Android OS being primarily considered an alternative to Apple's iOS; Android OS has been adopted by Samsung, OnePlus, Xiaomi amongst others.[52]

[47] Counterpoint, 29 November 2021, Global Smartphone Quarterly Market Data (Q4 2018 – Q3 2021). Available at: https://www.counterpointresearch.com/global-smartphone-share/

[48] Refer to: https://www.ericsson.com/en/industries/manufacturing?gclid=EAIaIQobChMI9fmluf2I9gIVCOrtCh094wprEAAYASAAEgJ6uPD_BwE&gclsrc=aw.ds

[49] Chron, 9 April, 2019, Five Common Operating Systems. Available at: https://smallbusiness.chron.com/five-common-operating-systems-28217.html

[50] The kernel is a computer program at the core of a computers operating system. The kernel generally has complete control over everything in the system, and connects the application software to the hardware of a computer and/or device (e.g., CPU, memory, device functions).

[51] Android Open Source Project. Available at: https://source.android.com/

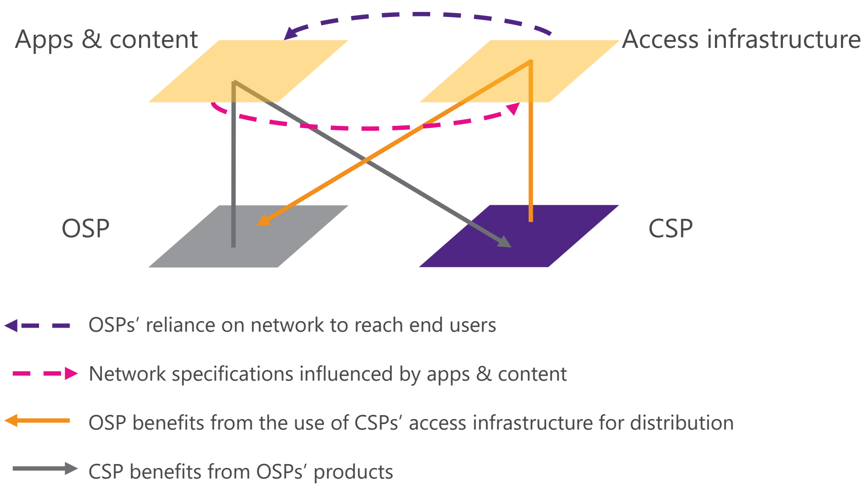
[52] MUO, 2 December 2021, Is Android Really Open-Source? And Does It Even Matter? Available at: https://www.makeuseof.com/tag/android-really-open-source-matter/

2 Symbiotic relationships in the telecoms sector

The different segments of the telecoms sector described in Section 1 are connected in a web of different linkages. For example, apps and content are delivered to end users through connectivity services, which are provided over access infrastructure and core networks. Users then consume these apps and content on their devices. Providers of apps and content therefore rely on network and devices in order to reach end users. However, linkages based on this reliance are only part of the story. End users' requirements and demand for online services and content determine what types of apps and content will be consumed, which, in turn, dictate the specifications of connectivity services, network and devices.

Figure 2.1 shows some of the linkages discussed above between apps and content and access infrastructure – different segments of the telecoms sector – and the underlying relationships between app and content providers and CSPs.

Figure 2.1: Example of linkages and symbiotic relationships in the telecoms sector



Underlying this web of linkages are the relationships between the actors who provide or procure products and services encompassed by the respective segments. In the example above, app and content providers benefit from the commercial activities of CSPs and device manufacturers. It is through the CSPs' engagement of network vendors to build their network and the device manufacturers' supply of end-user devices that app and content providers can supply their services to end-users.

The flow of benefits in this relationship is not unidirectional. End-users purchase their connectivity service from CSPs in order to consume online services and content provided by app and content providers. Without access to content and applications, consumers would demand less from their connectivity services, or may choose to stop buying such services altogether.

This means end users' willingness to pay for connectivity services sold by CSPs as well as their willingness to pay for devices will increase with the availability and accessibility of relevant apps and content. In this way, app and content providers also benefit CSPs and device manufacturers. The delivery of Internet-based content and services can thus be characterised not as a two-sided market, but rather as a multi-sided market, including end-users, CSPs, intermediaries, device manufacturers and OSPs.[53]

[53] Plum (2011). The Open Internet – A Platform for Growth. Available at: https://plumconsulting.co.uk/wpdm-package/plum-oct11-the-open-Internet-a-platform-for-growth-pdf/?wpdmdl=1471

In this section, we explain how the symbiotic relationships between different players manifest across different segments of the telecoms sector. We focus particularly on how the value of other key players within the sector can be enhanced through their relationships with OSPs. The areas for symbiosis discussed in this section are shown in Figure 2.2 below.

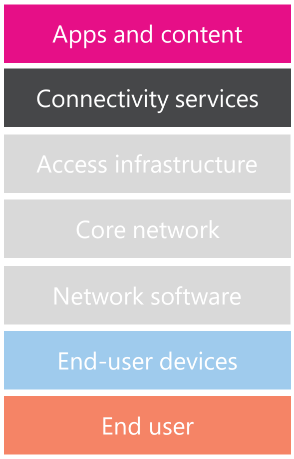
Figure 2.2: Symbiotic relationships discussed in this section

Category	Area for symbiosis	Description
Driving demand for connectivity and services	Complementary devices and services (the virtuous cycle)	Online services, devices and connectivity services are complementary goods and exist in a virtuous cycle, encouraging demand for each other.
	Commercial partnerships for next generation bundles	Partnerships across the sector are delivering compelling service bundles to consumers and enterprises, fuelling demand for connectivity.
	Enabling new products and revenue streams	Partnerships across the sector are enabling new communications use cases and revenue streams across a variety of consumer and industrial applications.
Enabling efficiencies	Enabling efficient network deployment	Symbiosis between network operators and hyperscale cloud providers in planning network deployments can lead to significant cost efficiencies and enhanced consumer quality of experience.
	Enabling efficient network operations	Symbiotic partnerships between sector players can help to manage and operate networks more efficiently, reducing operating costs and creating environmental benefits.
	Enabling efficient business processes	Symbiotic partnerships between sector players can generate business efficiencies, helping to lower operating costs and increase customer satisfaction.
Investment in networks	Avoided costs	Investments in network infrastructure are bringing content and services closer to end-users, reducing costs that would otherwise be incurred.
	Enhanced user quality of experience	Investments in infrastructure and technology across the sector are helping to reduce online services' bandwidth requirements and improve users' quality of experience, enhancing demand for connectivity and digital content.

2.1 Driving consumer demand for connectivity and digital services

This section considers various ways in which demand for connectivity, digital services and connected devices can be strengthened through the symbiotic relationships between OSPs, CSPs and device manufacturers.

Figure 2.3: Telecoms sector segments considered in this section



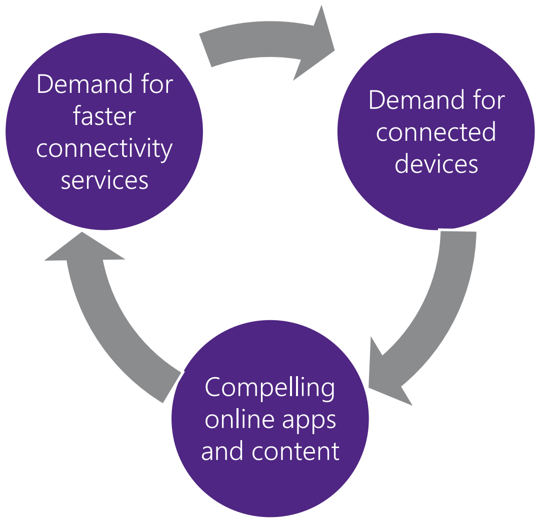
2.1.1 Complementary services and the virtuous cycle of demand

Connected devices ("end-user devices" in Figure 2.3), connectivity services and online services ("apps and content") are complementary goods – products which are bought and used together. Devices and connectivity services are prerequisites for accessing online content and services, such as social networks or video-on-demand services.

In turn, compelling online services encourage users to upgrade and upscale their device and connectivity service. For instance, they may choose to upgrade their mobile data package to one with a larger data allowance to allow them to spend more time watching online video. Similarly, consumers may upgrade their smartphones to allow access to the latest apps and games.

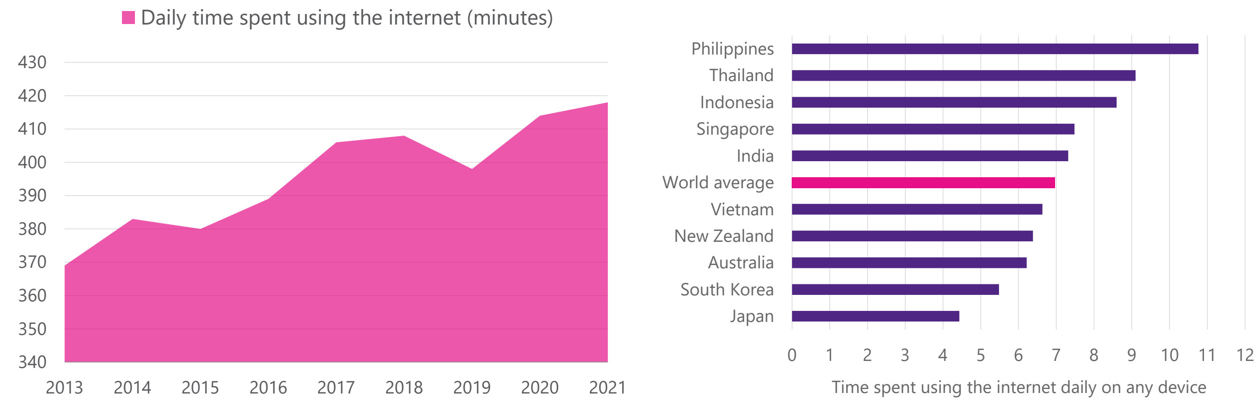
This relationship can be characterised as a 'virtuous cycle' (Figure 2.4). Increased consumer demand for online services helps boost demand for connectivity and devices. In turn, high quality Internet service and a capable device facilitate the consumption of online services.

Figure 2.4: The virtuous circle of devices, connectivity services and online services



Consumers across the globe are spending ever-increasing amounts of time online (Figure 2.5). More and more of this time is spent using online services such as video, social networks and gaming. According to GWI, on average, over one third of time spent online is now spent on social networks.[54] This suggests connectivity and digital services are becoming increasingly embedded in consumers' lives.

Figure 2.5: Time spent using the Internet, global average and selected countries

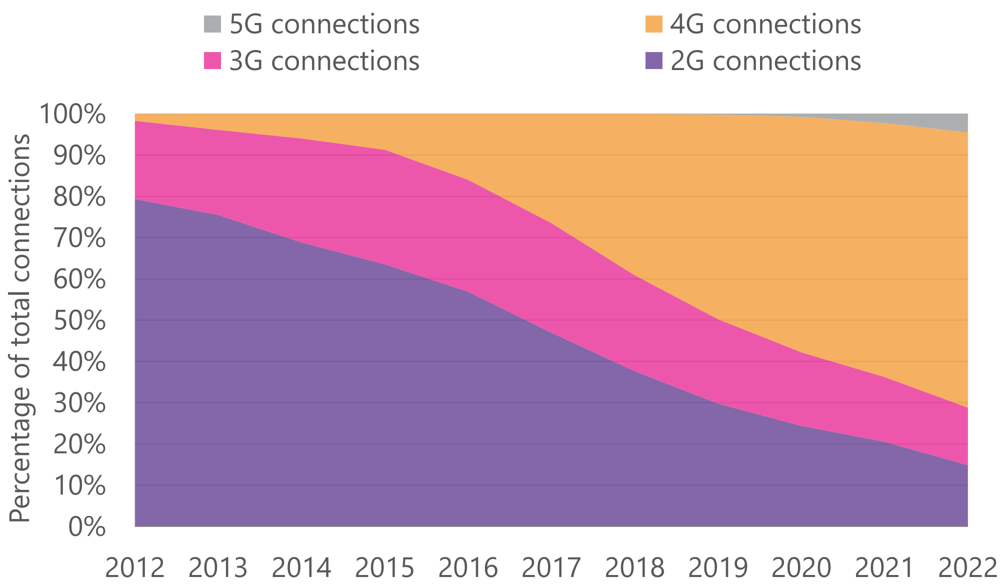


Source: Datareportal. Digital 2022 Global Overview Report

Consumers want connectivity services and devices which enable them to make the most of online services. They may elect to choose a mobile broadband package with a higher data cap, or a fixed broadband connection which is uncapped and/or offers a higher speed. Consumers' appetite for faster connectivity is evidenced by the rapid transition to 4G, which offers higher speeds and greater reliability than 3G (Figure 2.6).

[54] Datareportal (2022). Digital 2022 Global Overview Report. Available at: https://datareportal.com/reports/digital-2022-global-overview-report

Figure 2.6: Mobile connections by technology, APAC region



Source: GSMA Intelligence. Figures reflect APAC region excluding PRC.

Crucially, consumers also appear willing to pay more for enhanced access to online services. Research from the CCIA indicated that 69% of consumers would upgrade their service if it resulted in a better YouTube experience.[55] Another survey[56] showed that 25% of UK's respondents would be willing to pay more for an increased broadband speed, 23% in France and Germany and 21% in the USA. Evidence from Thailand further suggests that use of over-the-top video streaming services increases consumers' willingness to pay for fibre broadband.[57]

More intense use of online services goes hand-in-hand with demand for enhanced connectivity. The ITU has reported that demand for online services results in both new subscribers for broadband services and existing subscribers upgrading their subscriptions for greater speed and bandwidth.[58] As a result, it characterised the relationship between OSPs and CSPs as a "symbiotic relationship" rather than a "zero-sum game":

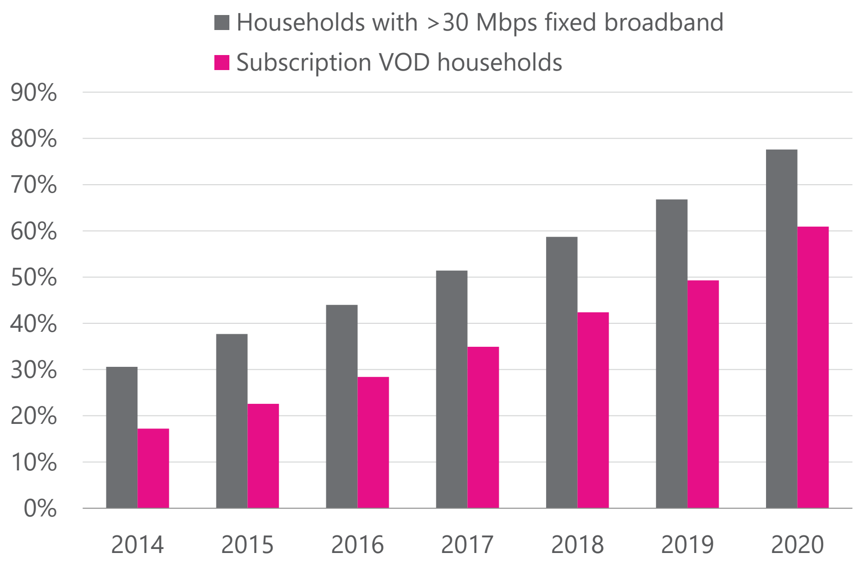
> **"OTTs provide the content that drives demand for telecommunication operator services. It is not a "zero-sum game" but rather a symbiotic relationship"**

Ofcom, the UK's communications regulator, has found that the main drivers of residential demand for higher speeds have been an increase in the use of video-on-demand and gaming, and the simultaneous use in a home of multiple devices.[59] Figure 2.7 illustrates how, in the UK, take-up of superfast (>30 Mbps) residential broadband services has grown in parallel with take-up of subscription video on demand services. It is also worth

[55] ICM Research (2013). Broadband Consumption Study, France and Germany.
[56] Survey by Oliver Wyman (2020). Available at: https://www.consultancy.uk/news/26189/quarter-of-consumers-willing-to-pay-more-for-faster-broadband
[57] Sudtasan, T. and Mitomo, H., (2017). Willingness-to-pay for FTTH for secured and stable usage of OTT media streaming services. 28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017, International Telecommunications Society (ITS), Calgary. Available at: https://www.econstor.eu/bitstream/10419/169500/1/Sudtasan-Mitomo.pdf
[58] ITU (2020). Economic impact of OTTs on national telecommunication/ICT markets. https://www.itu.int/dms_pub/itu-d/oth/07/23/D07230000030001PDFE.pdf
[59] Ofcom (2020). Promoting competition and investment in fibre networks: Wholesale Fixed Telecoms Market Review 2021-26. Volume 2: Market assessment, 8 January 2020

noting that operators often specifically use HD or 4K video streaming as a prompt to encourage customers to upgrade to higher speed packages.[60]

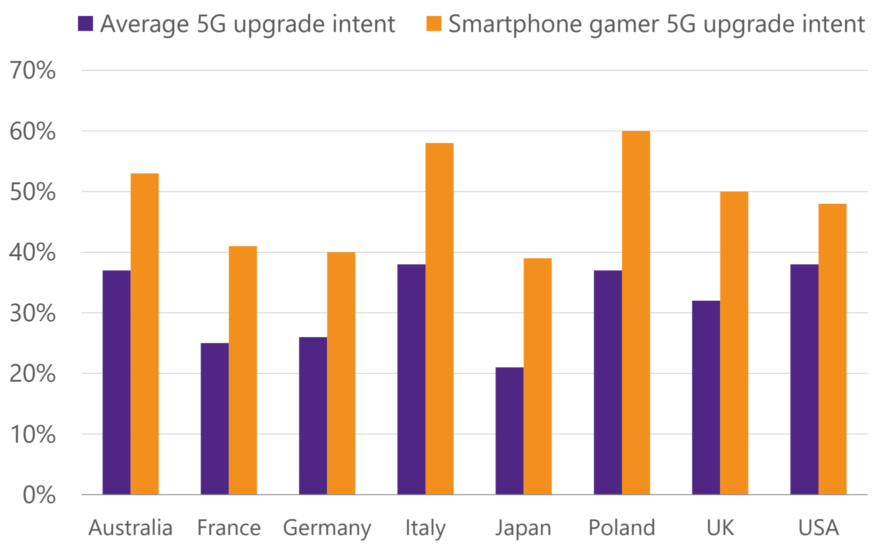
Figure 2.7: Take-up of superfast broadband and subscription video-on-demand services in the UK



Source: Ofcom. Subscription video on demand (SVOD) households refers to households with at least one SVOD subscription.

One specific example of consumers' appetite (and willingness to pay) for premium connectivity services is the launch of 'gamer' services in many markets.[61] Such services, which may be offered over fixed or mobile connections, promise increased reliability and lower latency, often at a premium price point. Figure 2.8 illustrates how smartphone gamers show a higher intent to upgrade to 5G services.

Figure 2.8: 5G upgrade intent among average users and smartphone gamers



Source: GSMA Intelligence[62]

[60] For example, Maxis (Malaysia) https://www.maxis.com.my/en/broadband/ and Optus (Australia) https://www.optus.com.au/broadband-nbn/home-broadband/plans/shop

[61] Gaming is a key driver of demand in many markets, in particular Japan and South Korea. Gamers typically demand fast connectivity with low latency to ensure good quality of experience. Refer to: https://www.ericsson.com/en/reports-and-papers/mobility-report/articles/mobile-cloud-gaming

[62] GSMA Intelligence (2020). Global Mobile Trends 2021: Navigating Covid-19 and beyond.

In future, a new and emerging set of user applications, including AR/VR services, high resolution livestreaming, and cloud gaming, is likely to further enhance users' willingness to pay a premium for enhanced connectivity services. These novel applications are discussed in greater detail in Section 4.1.

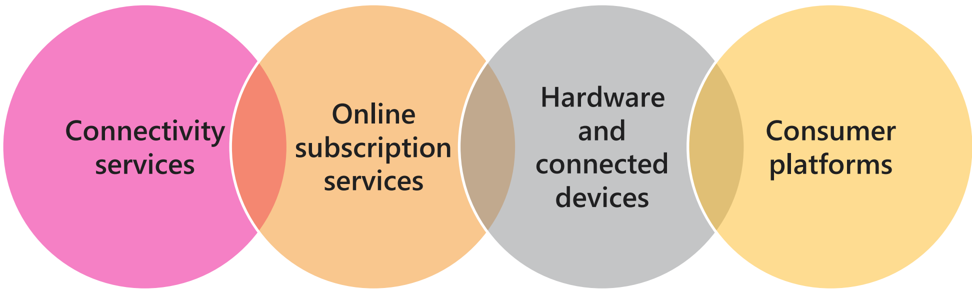
Conclusion

Online services, devices and connectivity services are complementary goods and form a symbiotic relationship. Consumers have been upgrading to higher speed connections, larger data bundles and more capable devices because they are making heavier use of online services. This trend is likely to continue with the emergence of new digital applications like AR/VR and cloud gaming.

2.1.2 Direct partnerships – building 'next generation' bundles

The previous section described the symbiotic relationship that exists between devices, connectivity services and online services. This is characterised as an 'indirect' symbiosis: it would exist absent any action by sector players. However, there is also a growing trend towards direct partnerships between sector players to offer 'next generation' service bundles.

Figure 2.9: Potential components of a 'next generation' bundle



Bundling is not a new phenomenon in telecoms markets: many customers around the world take triple play (typically landline, broadband and TV) or quad play (landline, broadband, TV and mobile) bundles. Bundling is attractive to consumers as it lowers the administrative overhead of managing subscriptions, and bundled services are typically offered at a lower price than if each service was purchased individually.

However, telecoms operators are now increasingly offering bundles or services which include access to online services or platforms. These may include subscription VOD or audio streaming services such as YouTube Premium (Figure 2.10). Other services offered may include personal cloud storage, gaming services or access to applications.

Figure 2.10: YouTube Premium

YouTube Premium is a paid membership that allows an ad-free enhanced experience across many of Google's video and music services, like YouTube, YouTube Music, YouTube Gaming and YouTube Kids. Amongst the offered features is the ability to view content offline or in the background (so consumers can use the app as a music player).

Many CSPs in Asia have partnered with Google to offer mobile plans with timely free access to the YouTube Premium service. For example, in South Korea, LG U+ offers a YouTube Premium branded mobile pack that includes unlimited data, and unlimited access to YouTube Premium services.[63]

In Japan, SoftBank offers a 6-month free access to YouTube Premium services for all subscribers to its "Merihari Unlimited plan" while its competitor KDDI hosts the same offer for customers who subscribe to eligible plans directly from their mobile smartphone.

'Next-generation' service bundles may also offer connected 'smart home' devices. These are devices such as security cameras, smart thermostats or voice-activated assistants, which can be offered as an optional 'add on' to consumers (Figure 2.11). Service bundles may also include intelligent television set-top boxes, which can be powered by platforms which offer consumers a unified experience across different devices. This provides operators with an opportunity to develop their content offerings, and is likely to be especially important in markets where smart TVs are not common.

Figure 2.11: Google and TRUE collaboration

Thailand's leading cable TV provider and the country's largest Internet service provider TRUE has partnered with Google to be the first and exclusive distributor of the Google Nest Mini smart speaker in the country.

The device which understands commands and speaks in the Thai language features 360-degree surround sound speakers and three microphones, with Voice Match Technology and a touch control sensor. It is compatible with other True products such as the "Inno Hybrid Plus box", "True ID TV" and includes personal assistance from Mari via Thai verbal commands.

The Thai operator has also launched a promotion[64] offering a free Google Nest Mini to customers who apply for its 1Gbps fibre Internet service as well as other discounts for other customers.

This approach to bundling is not necessarily restricted to the consumer market. Enterprise-grade connectivity services are now being bundled with online business productivity services such as cloud storage, email, videoconferencing and business applications (Figure 2.12). They may also help and facilitate businesses to build

[63] U+ website, accessed April 2022. https://www.uplus.co.kr/ent/fiveg/Retrieve5GPremPackDetailInfo.hpi?prodCd=LPZ0002645
[64] Ryt9, March 20, 2020. True Group partners with Google to turn your home into a Smart Home With "Google Nest Mini" the first and only smart speaker. https://www.ryt9.com/en/prg/238736

an online presence.[65] Such packages are typically aimed at SMEs, helping them to digitalise and reducing administrative overhead.

Figure 2.12: Google Workspace for enterprise customers

In Japan, CSPs including NTT, KDDI and Softbank are collaborating with Google to offer enterprise customers a wide range of solutions to improve productivity and make it easier for employees to work together[66].

For instance, NTT Docomo[67] provides its customers with the Google Workspace solution, a cloud-based product that integrates all the functions required for business such as email, calendars, drives and documents availability in real time from any device, anytime and anywhere. The Google Workspace is provided in combination with mobile lines and smart devices and with a variety of optional services that can be used with Google solutions such as an installation and utilisation support.

There are a variety of benefits to 'next generation' bundles. A more tailored approach gives consumers a variety of options, allowing them to obtain more of the services they want. For connectivity providers, next generation bundles can increase the attractiveness of their product offering and reduce customer churn.[68] And online service providers benefit from reaching a larger userbase and from the cross-promotion of their services.

As the adoption of online services grows, so too will the importance of next-generation bundles. It is likely that there will be an increasing variety of bundles on offer, to better fit users' preferences and requirements. The importance of partnerships across the wider sector is therefore likely to increase over time.

Conclusion

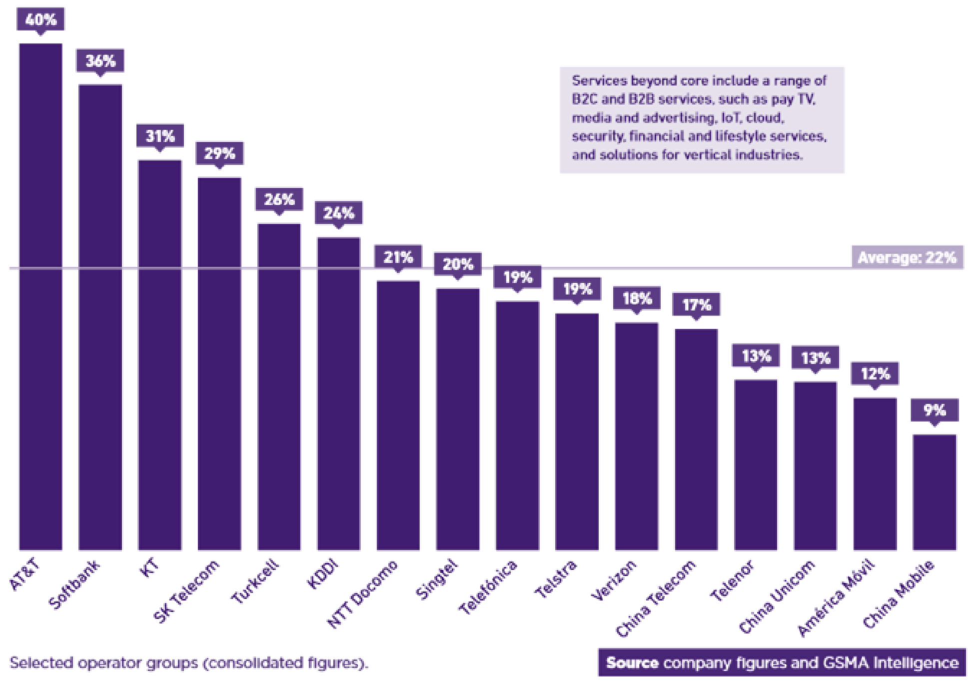
Partnerships across the wider telecoms sector are delivering 'next generation' bundles to consumers and enterprises, offering compelling mixes of connectivity services, content and digital services.

2.1.3 Enabling new revenue streams

Research from the GSMA indicates that many CSPs are diversifying their revenue, with revenue from services beyond core services now accounting for 22% of major operators' revenue (Figure 2.13). In this context, services beyond core include a range of services beyond connectivity, such as pay TV, advertising, IoT, cloud storage and computing applications, financial and lifestyle services, and connected solutions for vertical industries.

[65] PR Newswire, 8 Nov 2021. "Indosat Ooredoo and Google Launch Strategic Partnership to Accelerate Digitalization Across SMBs and Enterprises in Indonesia". Available at: https://www.prnewswire.com/news-releases/indosat-ooredoo-and-google-launch-strategic-partnership-to-accelerate-digitalization-across-smbs-and-enterprises-in-indonesia-301418343.html
[66] Docomo Business. https://blog.google/products/google-cloud/how-google-cloud-transforming-japanese-businesses/
[67] https://www.nttdocomo.co.jp/biz/service/googleworkspace/
[68] According to one survey, 51% of operator respondents said collaboration with OSPs had helped with customer retention. See: https://telecoms.com/228392/ott-partnerships-boost-customer-retention-says-survey/

Figure 2.13: Revenue beyond core services as a % of total revenues (2019)



Source: GSMA, Global Mobile Trends 2021.

In many cases, these services are delivered in partnership with other sector players. Section 2.1.2 discussed and presented examples of partnerships in relation to online content services, connected devices and online consumer and SME applications. In this section we focus on multi-access edge computing and private networks as potential revenue drivers.

As discussed in Section 1.5.2, multi-access edge computing (MEC) places data processing and storage capabilities closer to the client – typically, at or close to the edge of an access network. This means that data can be processed closer to the end user without having to travel deeper into the network. The key benefits to this approach are low latency, high bandwidth, and the opportunity to use trusted local computing and storage.[69]

There are two broad categories of MEC: public MEC and private MEC. Public MEC embeds processing and storage capabilities at the edge of a public network, with services that are typically available to any customer. Private MEC runs over a private network (refer to Section 1.2) with edge computing infrastructure and access network installed on the customer premises (e.g. a manufacturing facility). Customers may also combine both public and private MEC (hybrid MEC) to meet their requirements.

The potential use cases for MEC are myriad. Figure 2.14 sets out some example use cases of both public and private MEC.

[69] Ericsson (2020). Edge computing and 5G. Available at: https://www.ericsson.com/4a2d13/assets/local/edge-computing/doc/edge-computing-5g-report-2020.pdf

Figure 2.14: Selected applications of Multi-access Edge Computing

Context	Potential applications
Airports	• Driverless airport fleets • Detection of COVID-19 patients • Real-time analytics enabling quicker airplane turnaround
Ports	• Real-time processing of manifests • Predictive maintenance • Autonomous Guided Vehicle control
Healthcare	• Low-latency telepresence • Local processing of sensitive data • Access to 3D imaging and scan data
Manufacturing	• Autonomous Guided Vehicle control • Enhanced industrial robots • Augmented reality, allowing engineers to intervene remotely
Entertainment	• Low-latency mobile cloud gaming • AR/VR experiences at sports venues • Personalised instant replays
Smart cities	• Real-time sensor-driven automation • Safety monitoring • Climate control

Sources: AWS, Vodafone, Ericsson, RCR Wireless

MEC solutions are frequently delivered by partnerships of CSPs, equipment vendors and/or hyperscale cloud providers. For example, Singaporean operator Singtel has launched a public MEC solution based on Microsoft's Azure Stack.[70] In the US, Verizon has brokered partnerships with Cisco, IBM, AWS and Microsoft,[71] while Australian operator Telstra is offering a 5G-enabled MEC solution for enterprises in collaboration with Microsoft and Ericsson.[72] In South Korea, operator LG U+ has partnered with Google to offer 5G MEC solutions (Figure 2.15).

[70] SingTel news release, 03 Feb 2022. Available at: https://www.singtel.com/about-us/media-centre/news-releases/singtel-first-to-launch-public-mec-solution-with-microsoft-in-asia

[71] Lennighan, M. 20 October 2020. "Verizon taps up Nokia for private 5G push". Available at: https://telecoms.com/507011/verizon-taps-up-nokia-for-private-5g-push/

[72] Telstra media release, 06 October 2021. Available at: https://www.telstra.com.au/aboutus/media/media-releases/telstra-5G-enabled-edge-compute-solution-2021

Figure 2.15: Development of Multi-access Edge Computing in South Korea

South Korea's CSPs are developing Multi-access Edge Computing (MEC) through partnerships with cloud solutions providers. This technology is used to move the computing of traffic and data storage from a centralized cloud to the edge of the network and closer to the customer's devices. The data collection and processing closer to the customer reduces latency and brings real-time performance to high-bandwidth use cases such as augmented reality and video analytics.

An example of such partnerships includes the collaboration between mobile carrier LG U+ and Google[73]. MEC is built on the operator's 5G network while Google Cloud solutions are used to provide advanced services such as artificial intelligence and machine learning. Both companies are working on upgrading the technology and establishing an ecosystem for it.

The benefits of MEC for the mobile operator include a reduction in cloud data storage and transport costs, conservation of network bandwidth and reduced network congestion as well as opportunity for new services and new revenue streams.

An IoT use case for MEC is a connected car constantly sensing driving patterns, road conditions and other vehicle movements to provide safety guidance to the driver. Most of the predictive and prescriptive insights need to be provided with very low latency. That means sensor data needs to be collected, processed, and analysed at the edge of the network, in order to provide timely insights to the driver[74].

The variety of potential use cases means that MEC presents a significant opportunity for telecoms sector players. The GSMA reported that, as of 2020, 80% of mobile operators in the APAC region were offering private network solutions. GlobalData forecasts that service revenues across five categories of edge services will grow from $2.5bn in 2021 to $5.5bn by 2025, a 5-year CAGR of 17%.[75] This does not include incremental revenues associated with new low-latency use cases, which will further increase this total.

Conclusion

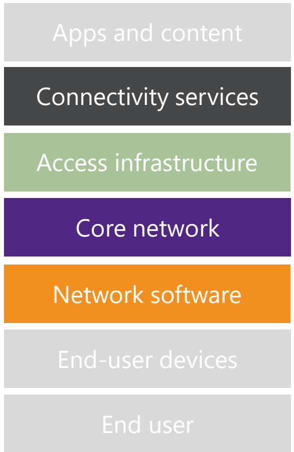
Partnerships across the telecoms sector are enabling new communications use cases and revenue streams, across a variety of consumer and industrial applications.

[73] Eun-Jee, P., 20 September 2020. "LG U+ partners with Google to develop MEC technology". Available at: https://koreajoongangdaily.joins.com/2020/09/20/business/tech/LG-U-mobile-edge-computing/20200920175100467.html
[74] Juniper Networks. What is multi-access edge computing? Available at: https://www.juniper.net/us/en/research-topics/what-is-multi-access-edge-computing.html
[75] GlobalData Technology, 12 November 2021. "Telco edge forecasts imply encouraging opportunity for monetization". Availabe at: https://www.verdict.co.uk/telco-edge-computing-monetization/

2.2 Enabling efficiencies

This section considers how symbiotic relationships between telecoms sector players are helping these players reduce costs and improve the efficiency of their business or network. For example, combining hyperscale cloud providers' strengths in AI and machine learning techniques with CSPs' network data and management experience can generate substantial efficiency gains. In this section we explore several examples of this.

Figure 2.16: Telecoms sector segments considered in this section



2.2.1 Optimising network deployment

The GSMA estimates that CSPs in the APAC region will collectively spend $219bn on network deployment over the next five years.[76] Partnerships can help to ensure that this investment is spent in a way that maximises its value, both to operators and to consumers. In particular, the combination of operators' data about where, when, and how subscribers use their devices with AI and machine learning capabilities can generate valuable insights about how best to deploy networks.

Network planning tools, such as Google's Network Planner, can help operators visualise network usage patterns, coverage and signal strength, and to identify where network overloads might arise. This can help to optimally position new infrastructure and make upgrades in order to reduce costs and deliver a better quality of experience to consumers.

AI-powered planning tools also allow agile planning processes, with iterative processes to constantly refine the models' accuracy, and the ability to model multiple scenarios. Such tools are constantly improving: for example, a recent study examined the use of 'deep learning' (a machine learning technique using neural networks) for image analysis in order to improve indoor coverage for fixed wireless access networks.[77]

The potential benefits of AI-powered planning are likely to depend on the environment and market. However, available estimates suggest that the cost reductions could be significant. For example, McKinsey has estimated that the use of novel network technologies could lead to a 40% reduction in mobile operators' capital expenditures.[78] A case study of a mobile operator planning a 5G rollout found that using AI-based planning tools resulted in a 37% accuracy improvement in capacity prioritization, a 72% reduction in capacity

[76] GSMA (2021). The Mobile Economy Asia Pacific 2021. Available at: https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/08/GSMA_ME_APAC_2021_Web_Singles.pdf
[77] Chu, Yi, A., Hamed Grace, D. et al. (2021). Deep Learning Assisted Fixed Wireless Access Network Coverage Planning. IEEE Access. ISSN 2169-3536
[78] McKinsey (2017). Reinvention through digital. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/digital%20mckinsey%20insights%20number%201/digital%20mckinsey%20insights_issue%201.ashx

degradation, and a 76% reduction in unnecessary capex and opex.[79] There are also likely to be benefits to users' quality of experience, which may lead to higher usage and lower customer churn.

Conclusion

Symbiosis between network operators and hyperscale cloud providers in planning network deployments can lead to significant cost efficiencies and enhanced consumer quality of experience.

2.2.2 Enabling network efficiencies

The application of novel technologies and synergies across the telecoms sector can also generate efficiencies in the operation of telecoms networks. Similar to their application in network deployment, these approaches rely on the combination of AI and machine learning techniques, computing power and large quantities of network data.

There are many ways AI and machine learning techniques can be deployed to improve the efficiency of network operations.

- **Network virtualisation.** The disaggregation of software and hardware and implementation of network functions in software can reduce the cost of managing a network and dependence on proprietary network hardware. This technology can make it straightforward to reconfigure network capacity, and also pave the way for further automation of the network (as below). Network operators typically interact directly with equipment vendors (such as Ericsson or Nokia) and hyperscale cloud providers to implement virtualised, software-defined networks, or equipment vendors may adopt hyperscale cloud provider-developed technologies themselves.[80]

- **Network self-driving and self-healing.** The use of AI enables the intelligent automation of networks, allowing them to operate and self-correct. One example of this is 'loop-back' detection, where an intelligent network can automatically detect and isolate faulty network switches.[81]

- **Fault detection and prediction/predictive maintenance.** AI can be used to monitor network equipment and traffic and predict where failures might occur. One example of this is the Anomaly Detection Service, launched by Nokia and Vodafone and powered by Google Cloud (Figure 2.17). AI's ability to rapidly analyse data also assists in root cause analysis, quickly identifying which network element is most likely to be related to an observed network problem.

- **Traffic management.** AI can be used to dynamically predict bandwidth requirements and to adjust capacity and traffic routing accordingly. This allows network operators to balance the loads on their network, distributing traffic in order to improve network coverage and user quality of experience. For example, Ericsson has indicated that the application of AI to optimising 5G traffic can improve 5G coverage by up to 25%.[82]

- **Energy efficiency.** AI can predict traffic patterns and autonomously turn off carriers that are predicted to be idle, without impacting network quality. According to the GSMA, a partnership between Turkcell and P.I. Works to deploy AI-based network optimisation resulted in a 3.6% reduction of the power

[79] EY (2020). How telco operators are optimizing their capex by applying AI. https://www.ey.com/en_gl/tmt/how-telco-operators-are-optimizing-their-capex-by-applying-ai
[80] Analysys Mason (2017).
[81] Refer to https://eu.dlink.com/uk/en/resource-centre/blog/ai-s-role-in-network-management
[82] Refer to https://www.ericsson.com/en/ai

consumption of the operator's radio network.[83] Ericsson has indicated that its AI-powered energy management solution can yield a 15% reduction in energy-related OPEX.[84] A reduction in energy consumption also generates reductions in network-driven CO_2 emissions.

- **Network Security.** AI contributes to strengthen network security by detecting anomalies in the behaviour of the system (compared to predefined normal use) and by recognizing characteristics of an attack.

Figure 2.17: Anomaly Detection Service

Nokia and Vodafone partnered to launch a jointly developed machine learning product, running on Google Cloud, to quickly detect and remedy network anomalies. The Anomaly Detection Service is being rolled out across Vodafone's European network.

This service quickly detects and troubleshoots network irregularities, such as site congestion or high latency. Vodafone expects that around 80 percent of all its anomalous mobile network issues and capacity demands will be automatically detected and addressed using Anomaly Detection Service.

The deployment of the Anomaly Detection Service on Google Cloud allows secure management and analytics of the data. The network data are streamed to Vodafone's data analytics platform, enabling Vodafone's network engineers to make decisions on boosting capacity and remedying anomalies.

The potential benefits of AI-powered network management will depend on the size and design of an operators' network, and on the market in question. However, McKinsey has estimated that such technologies would enable network operators to reduce network operating expenses by 30-40%.[85] A 2015 report by Bell Labs and Arthur D. Little estimates that adopting virtualisation and software-defined networks could lead to an operating cost reduction of 27% per fixed line and 25% per mobile SIM.[86]

Conclusion

Symbiotic partnerships between vendors, hyperscale cloud providers and CSPs can generate significant improvements in network operating efficiencies, as well as environmental benefits.

2.2.3 Enabling business efficiencies

Symbiotic partnerships which straddle the sector can also help to drive operational efficiencies, reducing business operating costs and improving customer satisfaction. The combination of CSPs' data and customer relationships with hyperscale cloud providers' AI and machine learning and analytics experience can identify ways to streamline business processes and improve customer management.

[83] GSMA Future Networks Case Studies. Available at: https://www.gsma.com/futurenetworks/wiki/case-study-ai-use-cases-in-service-assurance/
[84] Refer to https://www.ericsson.com/en/managed-services/energy-infrastructure-operations
[85] McKinsey (2017). Reinvention through digital. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/digital%20mckinsey%20insights%20number%201/digital%20mckinsey%20insights_issue%201.ashx
[86] ADLittle and Bell Labs (2015). Reshaping the future with NFV and SDN. The impact of new technologies on carriers and their networks. Available at: https://www.adlittle.com/sites/default/files/viewpoints/ADL_BellLabs_2015_Reshapingthefuture.pdf

There are several ways this can be achieved:

- **Managing datasets**. By partnering with cloud providers, CSPs can create a secure data store in the cloud, using machine learning tools to help clean and manage the data. Cloud-based dashboards and frontends allow that data to be analysed and visualised in a consistent way.

- **Real-time analytics.** Cloud-powered analytical tools can be used to analyse large datasets at or near real-time to generate timely business insights (for example, detecting fraud during a transaction to minimise losses).[87] Connectivity service providers can use AI to analyse customer behaviour and data from earlier interactions to predict what consumers need before they reach out for support.[88]

- **Improved marketing.** Cloud computing and real-time analytics can be leveraged to deliver real-time product recommendations and personalised offers to customers, facilitating upselling and cross-promotion by Internet service providers. For example, Vodafone uses Google's BigQuery, a cloud-based data warehousing solution, to deliver personalised product messaging to its customers.[89] Analytics can also be used to identify customers who are likely to churn, and to develop personalised offers to help retain them.

- **Enhanced customer relationships**. AI-powered conversational virtual customer assistants, such as Vodafone's "TOBi"[90] or Singtel's "Shirley" powered by Google Cloud, can both reduce operating costs and improve customer satisfaction. In 2019 Vodafone UK reported that its virtual customer assistant was handling 900,000 queries per month, with more than half resolved without the need for further escalation.[91] Such agents can also assist human operators, and are becoming increasingly sophisticated (Figure 2.18).

- **Robotics process automation (RPA).** RPA allows repetitive business processes (such as order fulfilment, workforce management or data entry) to be automated. For example, SingTel uses 'robo-colleagues' to carry out simple and repetitive tasks, such as a digital field assistant to help resolve technical issues encountered on site.[92]

[87] For example, https://cloud.google.com/solutions/smart-analytics
[88] Ericsson Consumer & IndustryLab (2018). The zero-touch customer experience. Available at: https://www.ericsson.com/en/reports-and-papers/consumerlab/reports/the-zero-touch-customer-experience
[89] Wright, A., 08 July 2021. "3 ways Google Cloud is helping telecoms unleash the potential of 5G". Available at: https://sada.com/insights/blog/3-ways-google-cloud-is-helping-telecoms-unleash-the-potential-of-5g/
[90] Refer to: https://www.vodafone.co.uk/help-and-information/introducing-tobi
[91] Blagden, N., 15 December 2019. "Artificial brains and predictive care: Vodafone's digital journey". Availabe at: https://newscentre.vodafone.co.uk/viewpoint/artificial-brains-and-predictive-care-vodafones-digital-journey/
[92] IMDA Singapore, Company Case Studies. Available at: https://www.imda.gov.sg/-/media/Imda/Files/SG-Digital/Annex-B---No-Embargo-Company-Case-Studies.pdf

Figure 2.18: Enhancing customer support

In January 2021, Australian CSP Optus concluded a three-year strategic partnership with Google to improve its customer support using Google Cloud's Contact Center AI (CCAI) solution. This solution includes:

- **Dialoglow CX,** which allows quick creation of 24/7 operating advanced virtual agents that can switch between topics, handle supplemental questions, and operate across multiple channels to minimize live agent interventions.
- **The Agent Assist** solution, which delivers continuous support to human agents during their calls and chats by identifying intent and providing real-time, step-by-step assistance.
- **The CCAI Insights** solution, which relies on natural language processing to identify call drivers and sentiment.

Tapping into enhanced natural language recognition technologies, coupled with faster processing and real-time access to customer insights and product information, Optus helps customers quickly find the answers to their questions while enabling agents to better assist with customer requests.

The technology will help empower shorter call times, quicker resolutions, and improved outcomes for customer satisfaction, and it will allow the operator to achieve those goals more quickly. Whether through voice call or chat, customers will not need to go through menu prompts or option trees; they simply say or type their request, and the natural-language recognition feature finds the best way to assist them.

The machine learning (ML) model that powers the solution learns from millions of anonymized historical support logs about the type of questions customers ask and how they phrase their questions. It is constantly learning and evolving as new offers change or expand. Additionally, Optus has launched a "Call Translate" service, which uses Google Cloud technology to translate calls between different language speakers in real time across over the Optus Mobile network.

The scale of the benefits from such partnerships will depend on a variety of factors, such as the efficiency of existing processes and the size of the customer base. Nevertheless, the available estimates indicate the benefits could be sizeable. For example, IBM has estimated that RPA can reduce back-office operations in sales and customer service by 50%.[93] Telstra has indicated that around 30% of inbound calls to a contact centre could be resolved by AI, and that AI assistance can help call centre workers be more productive.[94]

Conclusion

Symbiotic partnerships between telecoms sector players can generate significant business efficiencies, helping to lower operating costs and increase customer satisfaction.

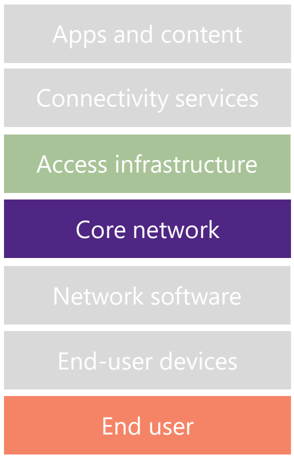
[93] Williams, P., 18 October 2021. "8 Ways RPA Is Helping Transform the Telecom Industry". Available at: https://www.ibm.com/cloud/blog/8-ways-rpa-is-helping-transform-the-telecom-industry

[94] Crawshaw, J. (2018). AI in Telecom Operations: Opportunities & Obstacles. Heavy Reading Reports. Available at: https://www.guavus.com/wp-content/uploads/2018/10/AI-in-Telecom-Operations_Opportunities_Obstacles.pdf

2.3 Complementary investment in networks

Investments made by telecoms sector players in network infrastructure can benefit the sector as a whole. In this section we focus on two specific benefits of complementary investment in networks: the avoidance of infrastructure duplication and the benefits of enhanced quality of connectivity.

Figure 2.19: Telecoms sector segments considered in this section



2.3.1 Avoided costs

The way that online content is delivered has shifted dramatically since the early days of the Internet. Historically, content would often be hosted by a single server, which might be located a long way from many users. Local CSPs would be obliged to either build out infrastructure to reach the content, or to arrange transit and/or interconnection with other networks.

Over time, there has been an ongoing trend to locate copies of Internet content closer to end-users. There are several advantages of this. First, it helps reduce the latency experienced by the end-user in accessing that content. Second, it reduces the chance that data packets will be lost on their journey to the end-user (which might happen if certain nodes on that journey happen to experience congestion). Third, it helps to reduce the need for international bandwidth, reducing transit and backhaul connectivity costs.[95]

Many OSPs make use of Content Delivery Networks (CDNs) to host and distribute content. OSPs have also invested significantly in network infrastructure in order to bring their content and services closer to end-users. Analysys Mason estimated that online service providers invested US$75bn in infrastructure per annum over the period 2014-17, while a 2020 study found that Google has spent over US$2bn in deploying and operating its network infrastructure in APAC since 2010, deploying Points of Presence in 15 cities across the region.[96] In addition, OSPs and hyperscale cloud providers continue to purchase and lease bandwidth capacity on both submarine cables and terrestrial links at a large scale. For example, around two thirds of international capacity used by Google across APAC is leased capacity.[97]

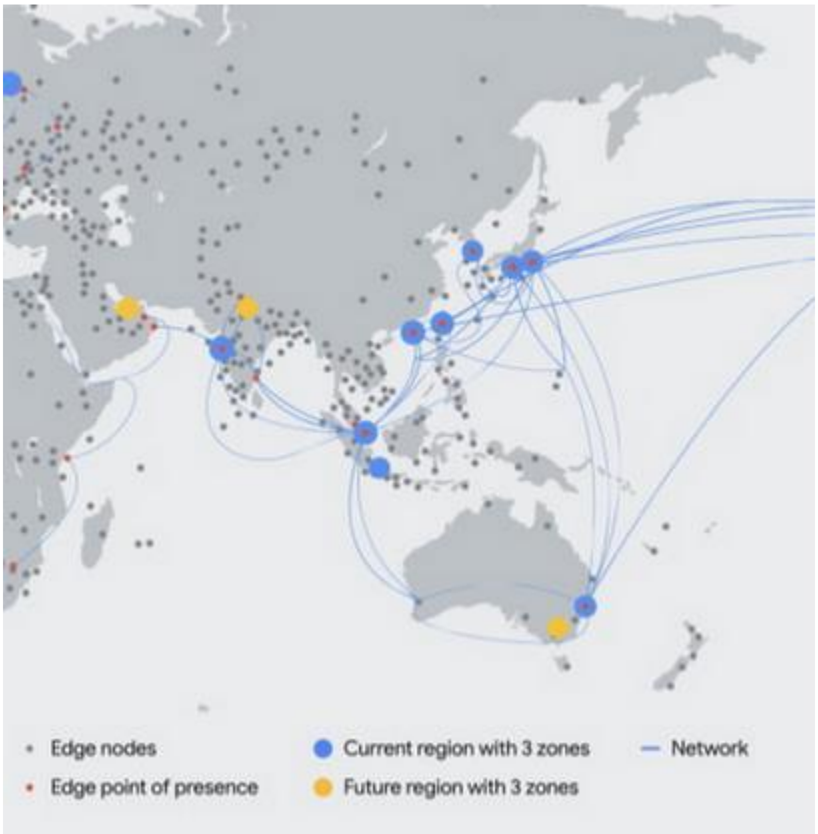
There are collaborative initiatives exist between operators and Internet companies aimed at co-investment in network infrastructure. For example, Amazon and Telefónica Perú launched the initiative Internet para Todos (Internet for Everyone) in collaboration with Facebook, Corporación Andina de Fomento (CAF) and International

[95] Ofcom (2016). Connected Nations 2016.
[96] Analysys Mason (2020). Economic Impact of Google's APAC network infrastructure.
[97] *Id.*

Development Bank (IDB) to bring Internet connectivity to rural areas.[98] Many submarine cables are also owned and operated by consortia of CSPs and OSPs.

This investment in infrastructure has generally brought content much closer to end-users. For example, Figure 2.20 illustrates Google's network in the APAC region. Edge Points of Presence (PoPs) represent points at which Google's network interconnects with other networks and Google's data centres. Edge nodes represent locations where Google's cache servers have been deployed inside network operators' and CSPs' networks.

Figure 2.20: Google's Cloud Network in the APAC region



Source: Google.[99]

These investments help support a good quality of experience for the services' end-users, increasing user satisfaction to the benefit of both the connectivity service provider and the OSP (see Section 2.3.2). But they also help to reduce costs for network operators and CSPs. There are various mechanisms for this:

- Avoidance of transit charges. In the absence of these network investments, CSPs would have to pay transit providers to interconnect with more distant networks and carry the requested traffic.
- Reduced need for international backhaul. In some cases the CSP may also need to build or lease international backhaul capacity in order to reach a transit provider or appropriate interconnection point.[100]

[98] ITU-D Study Groups (2020). Economic impact of OTTs on national telecommunication/ICT markets. Available at: https://www.itu.int/dms_pub/itu-d/oth/07/23/D07230000030001PDFE.pdf
[99] Refer to: https://cloud.google.com/blog/products/networking/understanding-google-cloud-network-edge-points
[100] Netflix (2021). A cooperative approach to content delivery: A Netflix briefing paper. https://openconnect.netflix.com/Open-Connect-Briefing-Paper.pdf

- Reduction in core network costs. CSPs may host multiple cache servers in their network. This enables content to be served to users from a local server, reducing the traffic that needs to be carried across the CSP's core network.

Conclusion

OSPs and hyperscale cloud providers are investing or leasing network infrastructure in order to bring content and services closer to end-users, reducing costs that would otherwise be incurred by network operators.

2.3.2 Enhanced user quality of experience

Investment in network infrastructure across the telecoms sector is helping to enhance consumers' quality of experience. For example, investments in technology upgrades to local access networks can enhance the speed and reliability of these networks, enhancing consumers' ability to use online services. This is discussed in Section 2.1.1 in regard to the virtuous circle of demand.

As discussed in Section 2.3.1, OSPs and hyperscale cloud providers are also investing in building or leasing network infrastructure in order to bring their content and services closer to end-users. This helps to improve users' quality of experience for three main reasons:

- Reducing the distance data packets must travel reduces the latency experienced by users of digital services; and
- Reducing the number of networks and network switches data packets must traverse reduces the chance that they will be lost (for example, in traversing a congested network).
- Hosting content within or close to the network makes network optimisation and traffic management more straightforward for network operators.[101]

Improved quality of service resulting from such investments benefits both OSPs and CSPs, as well as supporting the wider economy. For example, Analysys Mason estimates that Google's investments in submarine cables in the APAC region contributed to a 12–49% reduction in end-user latency across APAC economies, and that around 98% of regional Google traffic was served by Google's edge infrastructure.[102]

Consumers tend to elide both the quality of their connection and the quality of the online service; improvements in the quality of one will tend to benefit both the OSP and CSP involved.[103] Poor quality of experience is one of the key drivers of customer churn for CSPs[104,105] It also affects consumers' level of engagement with online services: research from Google has found that 53% of mobile website visitors will leave if a webpage doesn't load within three seconds.[106] Other research has also identified a strong correlation

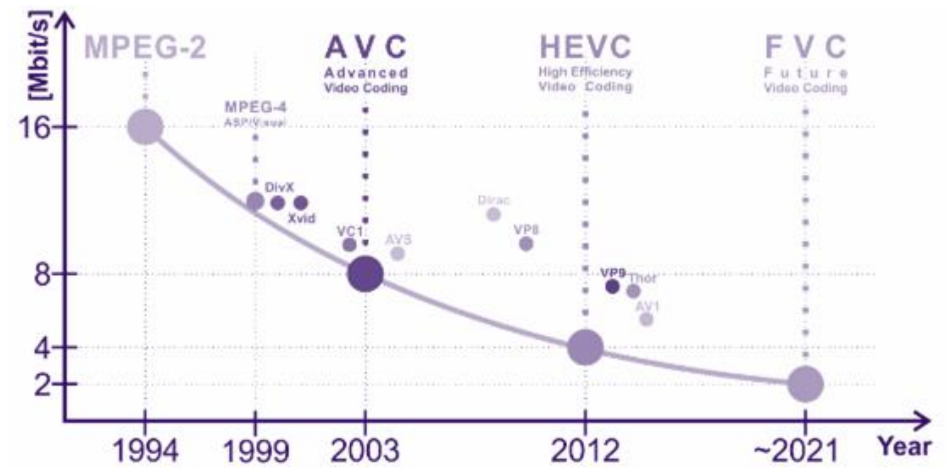
[101] GSMA, América Móvil and VIAVI Solutions – Creating Business Value through Content Delivery and Analytics, 17 December 2019.
[102] Analysys Mason (2020).
[103] Arslan, A., Floris, A., and Atzori, L. (2017). OTT-ISP Joint Service Management: A Customer Lifetime Value Based Approach. https://www.researchgate.net/profile/Arslan-Ahmad-7/publication/316974268_OTT-ISP_joint_service_management_A_Customer_Lifetime_Value_based_approach/links/59dd42f40f7e9b53c1971f55/OTT-ISP-joint-service-management-A-Customer-Lifetime-Value-based-approach.pdf
[104] Ahmad A, Floris A, Atzori L (2016) QoE-centric service delivery: A collaborative approach among OTTs and ISPs. Comput Netw 110:168–179
[105] https://www.opensignal.com/2021/09/15/the-quality-of-mobile-network-experience-helps-explain-churn-in-brazil
[106] Marketing Dive, 12 September 2016. Google: 53% of mobile users abandon sites that take over 3 seconds to load. Available at: https://www.marketingdive.com/news/google-53-of-mobile-users-abandon-sites-that-take-over-3-seconds-to-load/426070/

between webpage load time and bounce rate (the percentage of people who land on a page and immediately leave).[107]

In fact, online service providers have long been aware of the relationship between quality of experience and user engagement. For example, a 2012 study found that users start to abandon an online video if it takes more than two seconds to start playing, and that they are less likely to revisit a site if they experienced failure.[108] Akamai has found that 76% of survey respondents stated that they would abandon a video streaming service if rebuffering occurred several times.[109]

These considerations have prompted online service providers to make investments in building or leasing network infrastructure. They have also provided incentives for online service providers to make their services lean in order to improve quality of experience. One example of this is in the adoption of increasingly sophisticated video compression, which has, over time, substantially reduced the bitrate required for the same quality of video stream (Figure 2.21).

Figure 2.21: Estimated bitrate for 1080p HD video over time



Source: Karwowski, D., Grajek, T., Klimaszewski, K., Stankiewicz, O., Stankowski, J., & Wegner, K. (2016). 20 Years of Progress in Video Compression - from MPEG-1 to MPEG-H HEVC. General View on the Path of Video Coding Development. IP&C.

These trends are continuing with the implementation of the AV1 codec, an open format for video encoding developed by a consortium consisting of device manufacturers, video content providers and software firms.[110] Netflix has reported that, with AV1, Netflix users can now stream 25 hours of content for 4GB of data, more than double the amount they could stream in 2015.[111] Other new developments include Dynamic Resolution Encoding for live content (which can result in bandwidth savings for the same Quality of Experience[112]) and new, more computationally-efficient systems for transcoding video for different devices.[113]

[107] For example, refer to https://www.pingdom.com/blog/page-load-time-really-affect-bounce-rate/
[108] Krishnan, S. and Sitaraman, R. (2012). Video Stream Quality Impacts Viewer Behavior: Inferring Causality Using Quasi-Experimental Designs. https://www.akamai.com/site/en/documents/research-paper/video-stream-quality-impacts-viewer-behavior-inferring-causality-using-quasi-experimental-designs-technical-publication.pdf
[109] https://www.akamai.com/site/pt/documents/white-paper/measuring-video-quality-and-performance-best-practices.pdf
[110] Refer to: https://aomedia.org/av1/
[111] Netflix (2021). A cooperative approach to content delivery: A Netflix briefing paper. https://openconnect.netflix.com/Open-Connect-Briefing-Paper.pdf
[112] Ducloux. X., Gendron, P., and Fautier, T. (2022). Improving streaming quality and bitrate efficiency with dynamic resolution selection. Available at: https://dl.acm.org/doi/pdf/10.1145/3510450.3517304
[113] For discussion of this and related issues, refer to: https://blog.youtube/inside-youtube/new-era-video-infrastructure/

Conclusion

Investments in infrastructure and technology across the sector is helping to reduce bandwidth requirements and to improve users' quality of experience, enhancing consumers' demand for connectivity and consumption of online services.

3 Estimating the potential benefits of symbiosis in APAC

In this section, we estimate the benefits that could accrue in Asia Pacific from the types of symbiosis discussed in Section 2. The benefits are computed for CSPs as they are central to the sector. The estimates take the form of incremental free cashflow in the year 2026, given that cashflow is tangible and an important consideration for CSPs' commercial decisions. The year 2026 is chosen as it is near enough to the present for any projection to still be robust. At the same time, it is far enough for meaningful impacts of changes to market conditions to be observable.

Figure 3.1 below is a modified Figure 2.2. Figure 3.1 shows the areas of symbiosis elaborated in Sections 2.1 to 2.3 that will be quantified in this section. The areas for symbiosis in which benefits to CSPs are estimated are highlighted in pink.

Figure 3.1: Types of symbiosis for benefit estimation

Category	Area for symbiosis	Description
Driving demand for connectivity and services	Complementary devices and services (the virtuous cycle)	Online services, devices and connectivity services are complementary goods and exist in a virtuous cycle, encouraging demand for each other.
	Commercial partnerships for next generation bundles	Partnerships across the sector are delivering compelling service bundles to consumers and enterprises, fuelling demand for connectivity.
	Enabling new products and revenue streams	Partnerships across the sector are enabling new communications use cases and revenue streams across a variety of consumer and industrial applications.
Enabling efficiencies	Enabling efficient network deployment	Symbiosis between network operators and hyperscale cloud providers in planning network deployments can lead to significant cost efficiencies and enhanced consumer quality of experience.
	Enabling efficient network operations	Symbiotic partnerships between sector players can help to manage and operate networks more efficiently, reducing operating costs and creating environmental benefits.
	Enabling efficient business processes	Symbiotic partnerships between sector players can generate business efficiencies, helping to lower operating costs and increase customer satisfaction.
Investment in networks	Avoided costs	Investments in network infrastructure are bringing content and services closer to end-users, reducing costs that would otherwise be incurred.
	Enhanced user quality of experience	Investments in infrastructure and technology across the sector is helping to reduce online services' bandwidth requirements and improve users' quality of experience, enhancing demand for connectivity and digital content.

3.1 Key scenarios for benefit estimation

We describe below the possible market scenarios that form the basis for our estimation of potential benefits from symbiosis. The two scenarios are:

1. the base case; and
2. a scenario where a closer and more productive relationship is forged between CSPs, OSPs and hyperscale cloud providers.

It should be noted that even in the base case, a lot of the benefits of symbiosis will already be realised. For example, online companies and network vendors will still collaborate on technology development, which would make network operation and business processes more efficient for CSPs. OSPs' existing portfolios of apps and content will already be driving usage and consumption of high-end plans, while extant infrastructure (including caches and points of presence) in the region is already helping to reduce transit costs that would otherwise be incurred. The benefits computed for the second scenario therefore represent potential incremental benefits of deeper symbiosis.

3.1.1 Base case

In the base case, existing symbiotic relationships are not deepened any further. There is no major improvement in content and services for local use, reducing incentives for end-users to switch to higher-end connectivity packages. There is also a gradual decline in OSPs' annual investment in network infrastructure

Only a handful of new operators in the region deploy caches of service provider content to enhance the user experience for their subscribers. Consequently, there is not a good business case for online companies, such as Google, to continue to invest heavily in the region, and future investment tapers off. The market in this base case is thus characterised as follows:

- There is no major improvement in content and services for local users.
- There is no strong incentive for users to switch to a higher end package in the medium term, and the split between high- and low-end packages remains the same.
- Operators offer limited content bundles to limit the growth of streaming service consumption.
- There is more limited adoption of hyperscale cloud providers' network-enhancing solutions, such as Google Network Planner.
- There is also a gradual decline in annual investment in transport and content delivery networks by Google because there are fewer incentives to continue expanding its subsea cable network, Edge POPs or caches to serve the markets.

In summary, in this scenario there is very little deepening of the present interactions between sector players between 2021 and 2026.

3.1.2 Closer and more productive relationship

In this alternative scenario, CSPs in the region work closely with OSPs and hyperscale cloud providers to take advantage of the opportunities in the different areas for symbiosis. They embrace the revenue opportunities that a closer collaboration, such as a direct partnership with OSPs, would bring. CSPs also make full use of third-party AI-based network solutions to help them further improve operational and investment efficiencies to save on costs. The consequences of such developments would be:

- OSPs and hyperscale cloud providers will be encouraged by the bright business outlook to increase their presence in the countries.
  - This would happen through installation of new Edge POPs, CDNs and new international connectivity bandwidth, enabling their services to be brough closer to the end users and promoting a better user experience.
  - There is greater provision of content and services relevant to local users.
  - There will also be better local support for services provided by OSPs.

  The result would be a greater take-up of higher-end broadband packages, as content and applications become more attractive. There would additionally be an increase in the adoption of service bundles which now offer more relevant content and services.
- CSPs readily adopt OSPs' and hyperscale cloud providers' network roll-out, operating and maintenance solutions, as well as their business process solutions. This means that network virtualisation, network self-healing and predictive maintenance solutions, real-time analytics, and customer relationship management solutions offered by hyperscale cloud providers are widely deployed.

3.2 Methodology for benefit estimation

To estimate the cashflow in 2026, Plum developed forecasts of key financial and performance indices for the next 5 years using reported historical figures between 2017 and 2021. Forecasts produced for the markets by external intelligence services, such as the GSMA Intelligence, are also used to inform our own projections.

Plum defines the Asia Pacific region for our analysis as countries and territories in Northeast Asia, Southeast Asia, South Asia, and Oceania, excluding China and North Korea and very small islands in the Pacific. This represents a total of 28 countries and territories.

Raw data was not available for all operators across all countries and territories. Therefore, countries and territories are divided into four groups based on relevant market and demographic characteristics. This is done to enable infilling of data gaps. The characteristics used for grouping are:

- income per capita,
- fibre broadband penetration,
- unique mobile subscriber count and
- ARPU (as a measure of the willingness to pay).

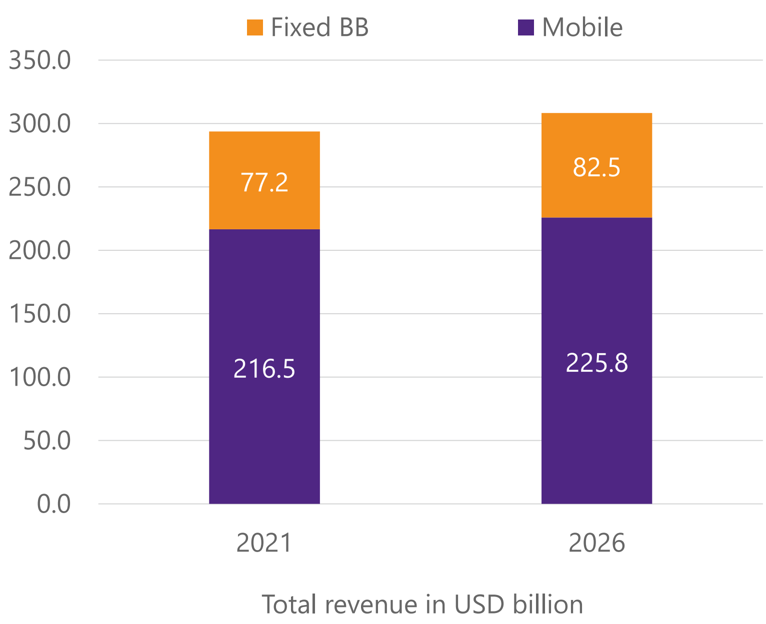
Figure 3.2 shows the four groups and their member countries and territories.

Figure 3.2: Asia Pacific country and territory groups for analysis

Group 1	Group 2	Group 3	Group 4
• Australia • Hong Kong • Japan • South Korea • Macao • New Zealand • Singapore • Taiwan	• Malaysia • Mongolia • Thailand • Vietnam	• Indonesia • Philippines • Sri Lanka	• Afghanistan • Bangladesh • Bhutan • Cambodia • Fiji • India • Laos • Myanmar • Nepal • Pakistan • Papua New Guinea • Solomon Islands • Timor-Leste

Figure 3.3 compares the estimated total revenue for mobile and fixed broadband in 2021 with the base case total revenue forecast in 2026 for Asia Pacific.

Figure 3.3: Base case total revenue for mobile and fixed broadband in 2021 and 2026



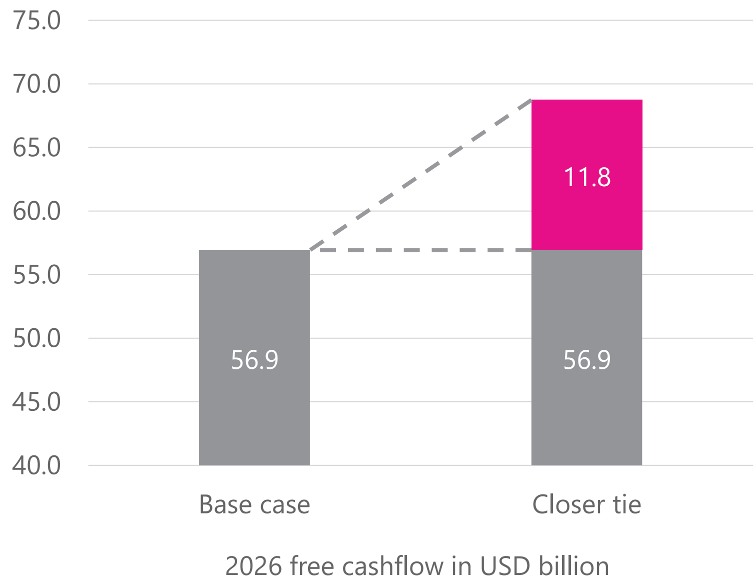
Some growth in total revenue is still expected as 4G penetration is still rising in many countries. Additionally, many developing countries in Asia Pacific have yet to deploy 5G or have only done so very recently, and there is room for growth. Fixed broadband subscriptions are still growing strongly as fibre is rolled out to previously unserved areas.

In Section 3.3, we present estimates of benefits in different areas for symbiosis, based on the forecasts of financial figures and KPIs for the base case and the alternative scenario with a deepening of the symbiotic relationship.

3.3 Results of benefit estimation

Plum estimates that there could be $11.8 billion incremental cashflow in the scenario where CSPs develop a deeper symbiotic relationship with OSPs and hyperscale cloud providers. This is a result of the effects on the revenue uplift and network cost efficiencies. This rise would be an increase of over 20% in free cashflow from the base case. Figure 3.4 below compares the base case cashflow and the cashflow under a deeper relationship, where the pink layer is the incremental free cashflow.

Figure 3.4: Base case and closer tie scenario free cashflow comparison



In Sections 3.3.1 to 3.3.3, we look at the contributions to this total incremental cashflow from the different areas of symbiosis.

3.3.1 Value estimate of demand-based benefits

In the event of a deeper relationship between CSPs and OSPs, the additional investment to improve user experience of apps and content as well as the quality and relevance of such apps and content would compel more subscribers to switch to a higher-end package. Connectivity service bundles that include popular content services, such as YouTube Premium, will generate additional revenue for CSPs. Such bundles, when offered with the right incentives, including discounts or other benefits to the subscription, would also make customers more loyal, reducing customer churn.

Figure 3.5 shows the assumptions that Plum used in estimating the incremental free cashflow from the above effects. Pre-paid and post-paid ARPU are used as proxies for the tariffs for high- and low-end mobile connectivity packages, as they reflect the consumption behaviours of different group of customers quite well. Post-paid packages would offer a better value for money for people whose usage exceeds a certain threshold. For fixed broadband, high-end packages are packages with a download speed in excess of 100 Mbps, and low-end packages are ones that offer a download speed of up to 100 Mbps.

Figure 3.5: Parameters (2026) for estimating incremental cashflow from demand-based benefits in 2026

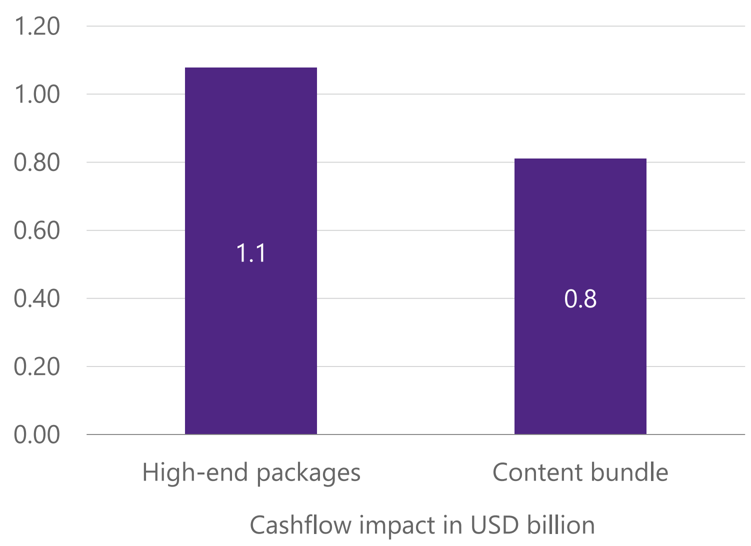
Parameter (2026)	Mobile		Fixed broadband	
	base case	closer tie	base case	closer tie
Price differential - high-end vs low-end (USD)	4.4	4.4	11.6	11.6
Percentage of high-end subscribers	19%	25%	30%	40%
Total subscriber (million))	3259	3259	214	214
Price of bundle (USD)	3.0	3.0	6.9	6.9
Percentage of subscribers with a bundle	20%	40%	20%	40%
Commission to operators	10%	10%	10%	10%
Base blended ARPU (USD)	4.9	4.9	32.7	32.7
Churn reduction through bundle	31%	35%	31%	35%
Percentage of subscribers to which churn rate reduction applies	20%	40%	20%	40%
Base monthly churn rate	2.9%	2.9%	1.7%	1.7%

Source: Plum research and analysis. Estimate of the percentage of high-end subscribers based on research by S&P. Estimates of percentage of subscribers with a bundle, commission to operators, and churn reduction based on Plum analysis of Analysys Mason research.

There are two sources of incremental cashflow. The first is increased revenue as more customers move to high-end packages and more service bundles are purchased, giving CSPs a higher blended ARPU in the 'deeper symbiosis' scenario, and an increased revenue stream from bundle commissions. The second is the reduction in churn, which saves operators on new customer acquisition cost. We conservatively estimate this using revenue churn reduction based on ARPU, which has historically been much lower than customer acquisition cost.[114]

The incremental cashflows in 2026 from the migration to high-end packages and from the effects of a higher take-up of bundles are shown in Figure 3.6.

Figure 3.6: Incremental cashflows in 2026 from high-end packages and content bundle



[114] Singtel reported in 2018 that its customer acquisition cost per postpaid subscriber for the year was at least twice as high as postpaid ARPU.

3.3.2 Value estimate of efficiency gains

A deeper symbiosis between CSPs and hyperscale cloud providers is expected to lead to more cloud solutions, described in Section 2.2, being adopted on a greater number of operators' networks. These solutions would, in turn, improve the efficiencies in network roll-out, network operations and other business processes. In addition, tools such as Google's CCAI would also help to identify and resolve any customer service issues quickly. The result would be a greater level of customer retention and a reduction in customer churn. Figure 3.7 shows the assumptions used in the calculation of incremental cashflows from these efficiency gains.

Figure 3.7: Parameters (2026) for estimating incremental cashflow from efficiency-based benefits in 2026

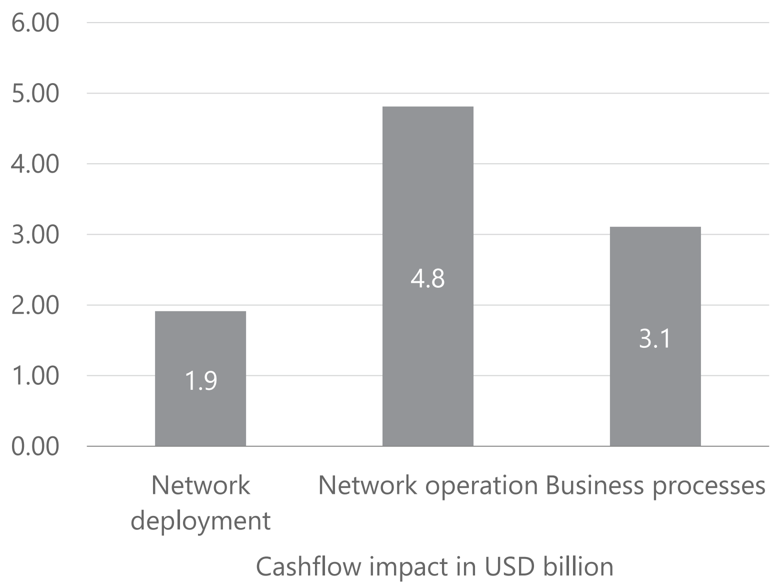
Parameter (2026)	Mobile		Fixed broadband	
	base case	closer tie	base case	closer tie
Network deployment optimisation tool				
Total CAPEX (USD billion)	30	30	8.2	8.2
Percentage of total CAPEX that is network CAPEX	50%	50%	50%	50%
Percentage reduction in network CAPEX	0%	10%	0%	10%
Network virtualisation & cloudification				
Proportion of existing lines/SIMs where savings can be made*	30%	40%	30%	40%
Proportion of new lines/SIMs where savings can be made*	40%	60%	40%	60%
Saving in technical OPEX per mobile line/SIM[115]	9	9	26	26
Total subs (million)	3259	3259	214	214
Change in subs from 2025 (million)	29	29	4	4
Self-healing network				
Percentage of technical OPEX saved*	0%	5%	0%	5%
Technical OPEX (USD billion)	22.7	22.7	2.2	2.2
Improved customer interaction (such as CCAI)				
Incremental customer care cost reduction from CCAI*	0%	20%	0%	20%
Proportion of non-technical OPEX in customer care*	5%	5%	5%	5%
Non-technical OPEX (USD billion)	121	121	66.6	66.6
Reduction in churn rate due to CCAI*	0%	10%	0%	10%
Blended churn rate	2.9%	2.7%	1.7%	1.6%
Churn with CCAI implementation	2.9%	2.9%	1.7%	1.4%

Source: Plum research and analysis, based on discussions with Google.
* denotes parameter estimates based on research by Analysys Mason.

[115] ADLittle and Bell Labs (2015). Reshaping the future with NFV and SDN. The impact of new technologies on carriers and their networks. Available at: https://www.adlittle.com/sites/default/files/viewpoints/ADL_BellLabs_2015_Reshapingthefuture.pdf

Network deployment optimisation tools, such as Google's Network Planner, will help CSPs reduce their capital expenditure on roll-out. Network solutions such as virtualisation & cloudification and self-healing networks reduce the technical operating expenses, chief of which are network repairs and maintenance cost: predictive maintenance using AI will lead to a lower maintenance cost as well as reducing network costs overall. Meanwhile, improved customer interaction, through platforms such as Google's CCAI, could reduce customer care operating expenses as well as reduce churn, reducing both customer care expenses and customer acquisition costs. The 2026 cashflow uplifts through these channels are shown in Figure 3.8.

Figure 3.8: Incremental cashflows in 2026 from improved efficiencies

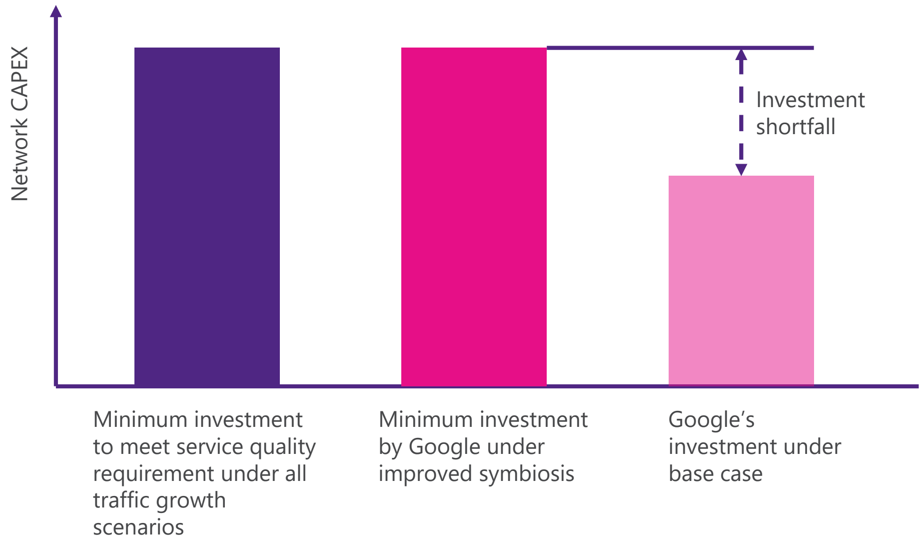


3.3.3 Value estimate of complementary infrastructure investment

Even under the base case, where the existing symbiotic relationship between OSPs and CSPs does not deepen further, there will be traffic growth. There are many competing digital content providers and services that will continue to contribute to traffic growth. Competition amongst operators to offer a higher speed will also lead to more users consuming content and services that require a higher bandwidth.

To date, these developments have been supported by investments made by online service providers to support the quality of experience of their users. This consists of direct investments into network infrastructure, caches and points of presence, as well as the leasing of terrestrial and international bandwidth. A reduction in complementary investment by OSPs will have to be compensated for by increased expenditure by CSPs. This reflects expenses in building or leasing bandwidth capacity in order to reach traffic handover points.

Figure 3.9: Investment gap resulting from a reduction in complementary investment by OSPs

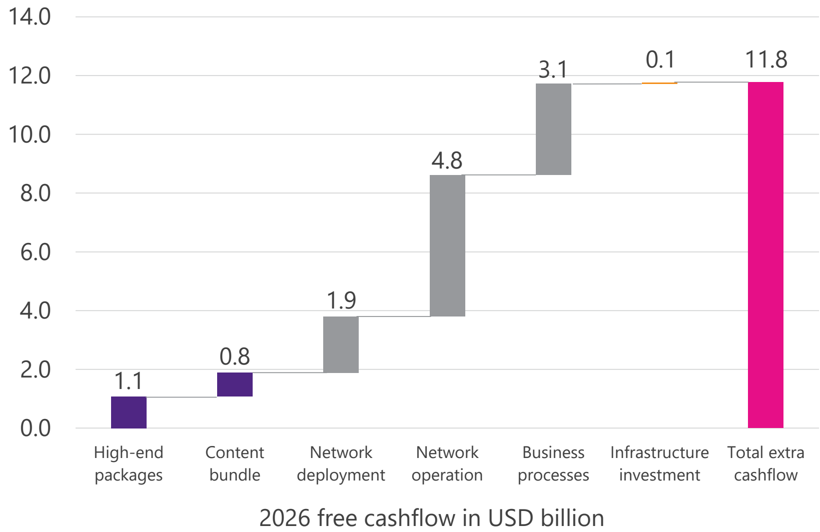


Analysys Mason reported in 2020 that between 2010 and 2019, Google invested (both directly and indirectly) over US$2bn in network infrastructure in Asia Pacific.[116] This comprises 6 submarine cables deployed in 15 cities across 8 countries with Google PoPs, and bandwidth purchased from network operators in 278 cities where Google caches are deployed. It is assumed that this level of investment will be sustained between 2021 and 2030 in the event that the symbiotic relationship between CSPs and OSPs is maintained.

In the base case where the investment incentive for OSPs does not improve, it is assumed that Google's investment would drop by 25% by 2026. The incremental cashflow from avoided CAPEX under the closer tie scenario is estimated to be around $100 million.

Figure 3.10 shows the breakdown of total incremental cashflow in 2026 under closer tie into the components from different areas for symbiosis.

Figure 3.10: Breakdown of total incremental cashflow by area for symbiosis



Source: Plum analysis

[116] Analysys Mason (2020). Economic Impact of Google's APAC network infrastructure.

3.4 Potential barriers to the realisation of benefits

The symbiosis that forms the basis for the benefits computed above has developed through a combination of market incentives and the common goal of the different actors to enhance end users' quality of experience. For example, CSPs carry the traffic from OSPs to end-users because apps and content are what end-users elect to consume through their connectivity service. Apps and content thus make connectivity service a viable end-user product for CSPs and one through which profits can be made.

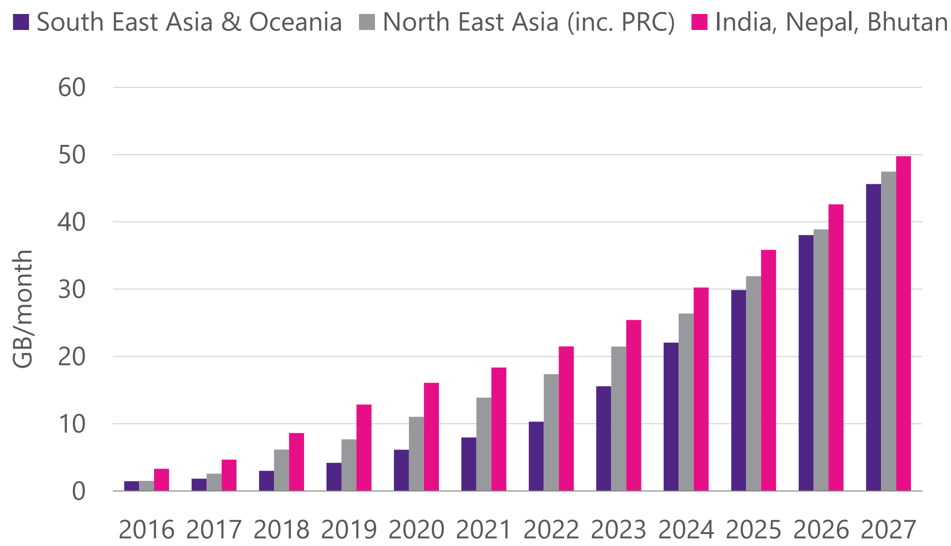
Understanding that the user experience of their content depends on the quality of the delivery network (which is part of the access infrastructure of the CSPs) apps and content providers have incentives to help enhance the overall access infrastructure to give end-users the best user experience.

There are however more recent developments that could lead to a stalling of the symbiotic relationships between key actors, in particular those between OSPs and CSPs. The first is the perception of data traffic as a problem, and the second is the use of regulatory tools to alleviate that traffic.

3.4.1 Data traffic seen as a problem, not an opportunity

Data traffic has grown significantly over the past decade. According to many forecasters, this trend is set to continue as the number of connected consumers increases, and as consumers use their devices more intensively (Figure 3.11).

Figure 3.11: Monthly smartphone data traffic, per device



Source: Ericsson Mobility Report.

At times, it has been argued that traffic growth presents a problem, rather than an opportunity. According to this argument, online services are generating traffic which CSPs are then obliged to carry, and this is creating unsustainable costs for operators.[117]

[117] See for example: https://etno.eu/news/all-news/717:ceo-statement-2021.html#_edn1

There are several problems with this argument.

- **Data traffic is generated by consumers, not by online service providers.** The Body of European Regulators for Electronic Communications (BEREC) has noted that *"the request for the data flow usually stems […] from the Internet access provider's own customer"* from who the access provider is already deriving revenues.[118] Traffic growth thus reflects consumers' appetite for online content, which in turn helps propel demand for connectivity services and devices (the virtuous circle discussed in Section 2.1.1). According to the CTO, online applications stimulate broadband adoption.[119]

- **Online service providers have invested in bringing content closer to users.** This is achieved either through payments to CDNs, or via deploying their own infrastructure. This reduces the need for CSPs to purchase IP transit (which is relatively expensive compared to peering or receiving traffic from CDNs) and helps to reduce the price of IP transit services.[120] In addition, caches embedded in the network bring content even closer to end users, reducing traffic across core and national backhaul networks.

- **Online service providers have incentives to manage traffic volumes to enhance user Quality of Experience.** Aside from investing in their own infrastructure and in caching solutions, online service providers have developed various techniques to reduce the data traffic generated by their services. These include advanced video and audio compression, content pre-loading, adaptive bitrates and time-shifting traffic to off-peak hours.

- **The cost of carrying additional data traffic is, in many cases, likely to be low.** The growth in data traffic has been accompanied by falls in the cost of network equipment, reducing the incremental cost of network capacity.[121] Research from Rewheel suggests that for the period 2013-2016 many European CSPs' capex profiles decreased, despite a sevenfold increase in mobile data traffic.[122]

The argument that data traffic is a problem is not a novel one, and it is worth noting that pessimistic predictions of a congested and unusable Internet made in 2010 never came to pass.[123,124] By contrast, in a 2016 Royal Society paper the authors note that they *"do not foresee any kind of crisis whereby technology in the access, metro or core of the network would be incapable of meeting future Internet needs of consumers"* and noted that *"even without full integration of all the network layers, no capacity crunch is anticipated"*.[125] BEREC has found that prices for transit and for CDN services have fallen significantly over time, reducing the costs of handling traffic.[126]

Nevertheless, the perception of data traffic as a problem could present a barrier to realising the full potential of the symbiotic ecosystem. Sector players who consider data traffic growth a problem may be less likely to enter into future partnerships with online service providers. This perception can also lead to contentious relationships between sector players. One example of this is a high-profile lawsuit between SK Broadband and Netflix in South Korea. In 2021, SK Broadband, the largest South Korean Internet Service Provider, sued Netflix to make

[118] BEREC (2012). BEREC's comments on the ETNO proposal for ITU/WCIT or similar initiatives along these lines. Available at: https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/1076-berecs-comments-on-the-etno-proposal-for_0.pdf
[119] CTO (2020). Over The Top (OTT) Applications & the Internet Value Chain. https://cto.int/wp-content/uploads/2020/05/CTO-OTT-REPORT-2020.pdf
[120] For example, Analysis Mason estimated that, in APAC, IP transit prices in well-connected economies were 74% lower on average, as a result of increased submarine cable investment by OSPs. Analysys Mason (2020). Economic Impact of Google's APAC network infrastructure.
[121] WIK-Consult (2014). The economic impact of Internet traffic growth on network operators. Available at: https://www.wik.org/uploads/media/Google_Two-Sided_Mkts.pdf
[122] Rewheel research (2017). Unlimited mobile data and near zero marginal cost – a paradigm shift in telco business models. Available at: https://research.rewheel.fi/downloads/Near_zero_marginal_mobile_data_cost_25092017_PUBLIC.pdf
[123] ETNO, 07 September 2012. "ETNO paper on Contribution to WCIT: ITRs Proposal to Address New Internet Ecosystem". Available at: https://etno.eu/news/8-news/40-etno-paper-on-contribution-to-wcit-itrs-proposal-to-address-new-Internet-ecosystem.html
[124] AT Kearney (2012). A viable future model for the internet. Available at: https://www.kearney.com/communications-media-technology/article/-/insights/a-viable-future-model-for-the-internet
[125] Lord, A., Soppera, A., and Jacquet, A. (2016). The impact of capacity growth in national telecommunications networks. Royal Society. Available at: https://royalsocietypublishing.org/doi/10.1098/rsta.2014.0431#d3e1149
[126] BEREC (2017). IP-Interconnection practices in the Context of Net Neutrality. Available at: https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/7299-berec-report-on-ip-interconnection-practices-in-the-context-of-net-neutrality

Netflix pay for the increased costs of network traffic and network maintenance associated with a surge in its subscribers' streaming of the firm's content.[127]

Such friction, especially when a legal lawsuit is involved, increases uncertainty for OSPs' business investments. This is because the outcome of such a dispute, which will determine the commercial viability of an investment decision to install complementary network infrastructure, could remain unknown for a long time. This could chill infrastructure investment, to the long-term detriment of end users. The presence of online players in a market could also decrease when business risks increase. For example, OSPs' decision to invest in PoPs and international connectivity depends not only on traffic and content distribution considerations but also on the potential profitability of the investment given business risks.[128]

Moreover, some have argued for network traffic charges to be levied on content providers. As discussed above, traffic charges are unlikely to be necessary to ensure the sustainability of the ecosystem. However, they are likely to discourage OSPs who have already significantly invested in content and infrastructure to deliver content demanded by a particular telecoms operator's subscribers from further investment in the country. They could also run the risk of reversing the virtuous circle of demand, reducing the supply and access to online content, and hence demand for connectivity services. The case of Italy in the early 2010s provides a salutary lesson: low consumption of audio-visual content contributed to sluggish take-up of broadband services, with further knock-on effects.[129]

3.4.2 Regulatory interventions

The perception of excessive network cost due to data traffic growth is not new. In South Korea, local CSPs tried to recover the cost of network investment through transit fees in 2016. The South Korean government introduced the Internet interconnection policy in 2005 to prevent the largest service providers from denying smaller competitors interconnection. The policy was revised in 2014 and came into effect in 2016. Under the new rule, the Sender-Party-Network-Pay (SPNP) principle and a price cap on interconnection charge were established - attempting to impose the voice interconnection model on Internet traffic.[130]

The SPNP required service providers to settle the cost of cumulative traffic volume by making the net sender network (such as a content-heavy network having many content provider customers) pay the net receiver network (normally a network with many end users consuming the content provider's service).[131] The price cap on interconnection charges was set at a high level: it was at least double the charges that local content providers paid to access the Internet.

When the revised policy came into force in 2016, all three operators, KT, SK Broadband and LGU+, set an interconnection charge that was close to the price cap. The result is that the cost of an operator transiting the traffic originating on its network and terminating on another operator's network rose substantially. This sudden rise in cost gave grounds for KT to raise the price of transit traffic for Facebook, whose cache servers were on KT's network but served users on all the major Korean CSPs. Facebook's traffic terminating at end-users on SK Broadband and LGU+'s networks would be subject to the new, high transit fees, which would have to be recovered from Facebook.

As a result of these high traffic termination costs, in December 2016, Facebook decided to change the source of its traffic demanded by Korean users from KT caches close to users to PCCW's (one of the major CSPs in Hong

[127] Reuters (2021). S.Korea broadband firm sues Netflix after traffic surge from 'Squid Game'. www.reuters.com/business/media-telecom/skorea-broadband-firm-sues-netflix-after-traffic-surge-squid-game-2021-10-01/
[128] Plum interviews with Google.
[129] WIK-Consult (2014). The economic impact of Internet traffic growth on network operators. Available at: https://www.wik.org/uploads/media/Google_Two-Sided_Mkts.pdf
[130] Kim K. (2020). Internet Regulation in Korea. https://35v.peeringasia.com/files/Internet.Regulation.in.Korea.pdf
[131] For further discussion of the development of this regime, refer to Internet Society (2022). Internet Impact Brief: South Korea's Interconnection Rules. Available at: https://www.internetsociety.org/resources/doc/2022/internet-impact-brief-south-koreas-interconnection-rules/

Kong) network in Hong Kong, as this was a more cost-effective method of delivery for Facebook. The result was that traffic requested by Korean users took a more circuitous international route, which led to latency problems and increased costs for Korean CSPs.[132]

It is clear that one consequence of the new regime was a reduction in end-user quality of experience and increased costs for Korean CSPs. This indicates that future regulatory intervention should be carefully thought out. Overly blunt tools such as traffic charges could lead to a gaming of the policy by CSPs, and risk undermining the symbiotic relationships that exist between OSPs and CSPs.

Aside from data traffic charges, other regulatory interventions may also affect the potential benefits of symbiotic relationships. For instance, regulations that hinder infrastructure investment (for example, a lengthy approval process) will deter such investment, to the detriment of local consumers and the development of the country's online economy.[133] Data localisation requirements may further restrict the benefits which accrue from the adoption and use of cloud services. And an uncertain regulatory environment is likely to deter investment and the formation of partnerships.

3.4.3 Institutional barriers

In some cases, a sector player may be unable or unwilling to enter into partnerships and thus enjoy the full benefits of symbiosis. There may be several reasons for this:

- **The use of legacy systems**. In some parts of the sector, such as local access networks, legacy equipment may be in use which might generate compatibility issues and prevent the realisation of the full benefits of technologies like MEC and network slicing. For example, many network operators across the world are still in the process of transitioning to all-IP networks.[134] Legacy systems may limit the potential benefits of some types of symbiotic relationship in the short term.

- **Challenges in scaling up operations**. For example, if many CSPs wish to partner with a hyperscale cloud provider to deliver MEC services, it may strain the available computing resources, until the cloud provider can increase capacity.

- **Unwillingness to enter partnerships**. Sector players may simply be unwilling to enter partnerships. This may be because they perceive other players as rivals, rather than potential partners. We understand that in some cases this may stem from a desire to retain as much control over the supply of communications services as possible. However, given the evolution of the telecoms value chain and wider sector towards more complex and demanding communications services, this approach may not be sustainable in the longer term.

3.4.4 Impact of a deterioration in the present state of symbiosis

In the event that the present symbiotic relationship between sector players deteriorates, many of the benefits of the symbiosis could disappear almost entirely. Under such a scenario, it can be expected that:

- User quality of experience would decline;

[132] Bae, Kim & Lee LLC (2018). Facebook sanctioned for server re-routing that led to user access slowdown. https://www.lexology.com/library/detail.aspx?g=ddda4dcc-d9bb-40fb-a272-05a631991fc0

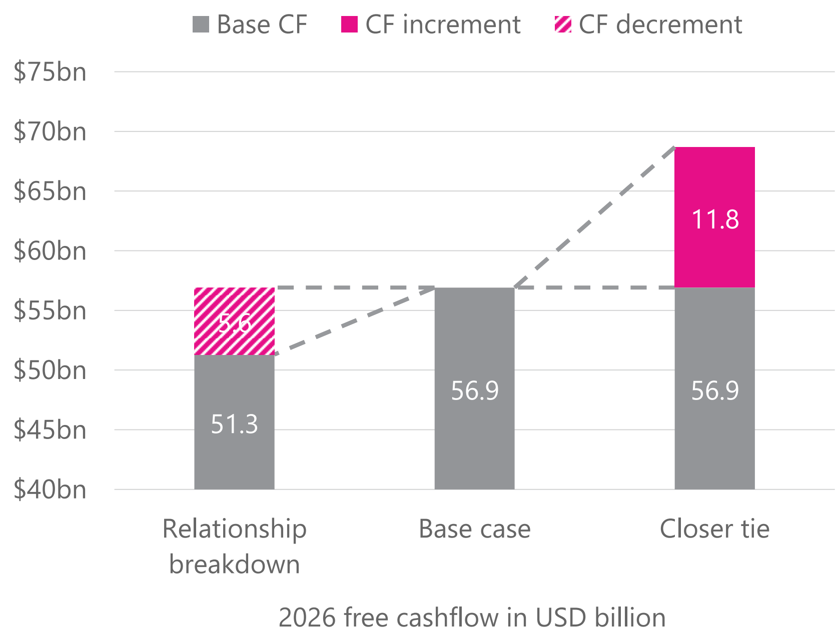
[133] For instance, submarine cable owners in Indonesia face some barriers that could hamper future investments. These barriers include a lengthy process to get submarine cable landing approved and a regulatory requirement to partner with a local company.

[134] Plum (2018). Preparing the UK for an All-IP future: experiences from other countries. Available at: http://www.broadbanduk.org/wp-content/uploads/2018/12/Plum-BSG-Preparing-the-UK-for-all-IP.pdf

- Partnerships on consumer bundles would cease;
- Efficiency-enhancing solutions from hyperscale cloud providers would not be made available or otherwise rejected by the CSPs; and
- There would be a reduction in complementary network investment by OSPs and hyperscale cloud providers.

Figure 3.12 shows the potential reduction in free cashflow in 2026 as a result of such a breakdown of relationship. We estimate that there could be a loss of up to US$5.7bn in free cashflow across the APAC region.

Figure 3.12: 2026 free cashflow comparisons for different scenarios



3.5 Wider economic impact of the symbiotic ecosystem

Thus far the analysis has focused on benefits that accrue to players within the telecoms sector. However, accelerating digitisation is regarded as particularly important in driving the economic recovery from the COVID-19 pandemic, and amid growing concerns about climate change.[135] In this section we discuss how the symbiotic ecosystem is also delivering wider benefits to national economies, societies and the environment.

Economic benefits

Growth of the digital communications sector is not only important in its own right, but because of the knock-on effects on productivity and growth in the wider economy. The spread of telecommunications services through the wider economy also generates network externalities – whereby the benefits generated by the use of telecommunications services increase with the number of users. The adoption of such technologies is widely

[135] See for example ASEAN Digital Masterplan 2025, available at: https://asean.org/wp-content/uploads/2021/09/ASEAN-Digital-Masterplan-EDITED.pdf

acknowledged to be an important driver of economic growth: various studies have drawn the link between penetration of broadband services and economic growth.[136,137]

According to TRPC, digital content is a key driver in extending and accelerating Internet adoption: first-time users today are using the Internet to watch videos, play online games, use social networks and communicate with friends and family.[138] The Commonwealth Telecommunications Organisation notes that online applications stimulate broadband adoption and thus economic growth and tax receipts.[139]

Various studies have also explored how communications services are helping to improve nationwide, sectoral or firm-level productivity.[140,141] The combination of connectivity services and cloud data management, AI and analytics is likely to further drive improvements in business processes. We also expect that novel industrial applications of edge computing in key industry verticals (such as manufacturing, logistics and healthcare) will further enhance productivity.

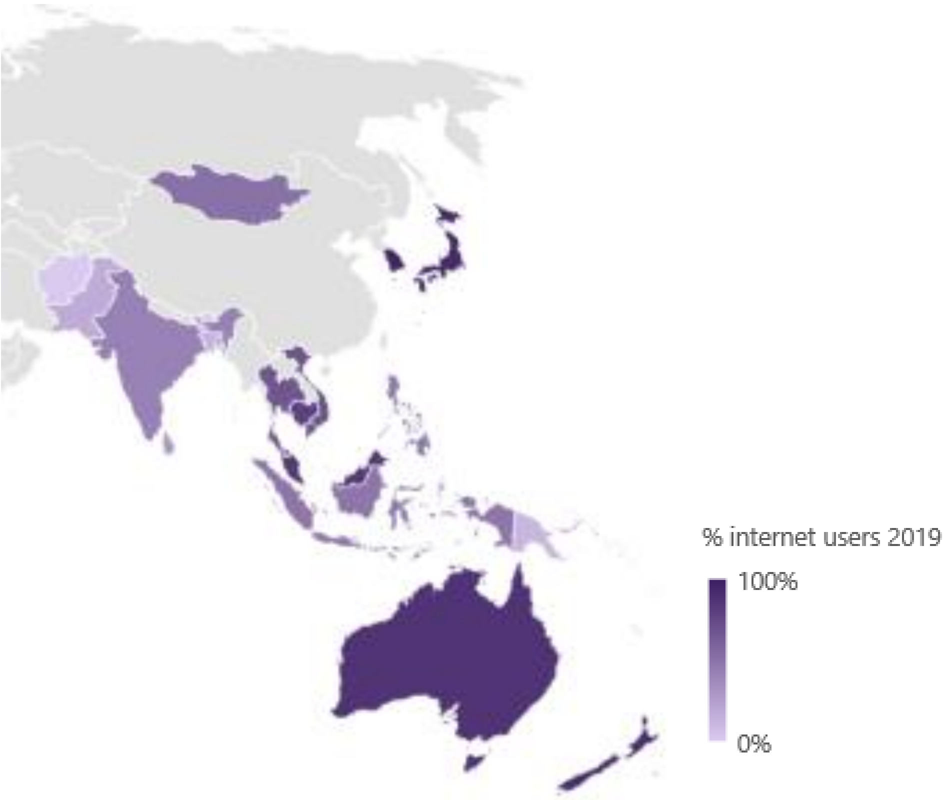
Social benefits

In order to unlock the full benefit of digital services, citizens and businesses need to adopt and make use of these services. Yet around half the world's population does not use the Internet.[142] Across the APAC region, the intensity of Internet use varies considerably, indicating significant opportunities for growth (Figure 3.13). Yet even in markets with high Internet use, such as Japan and the US, a persistent proportion of around 10% of individuals do not use the Internet regularly. In consequence, digital inclusion remains an important objective in many jurisdictions around the world.

The barriers to Internet adoption vary by country. Lack of communications infrastructure and the affordability of devices and connectivity services are important barriers in many economies. Yet this is only part of the challenge: consumers also need incentives to become Internet users. Compelling applications and content can act help entice consumers online: a study for the WEF examined the development of the digital ecosystem in the US, Germany and Korea, finding content and apps (communications apps, media content and gaming) are key motivators for driving Internet adoption and achieving "critical mass" in the local ecosystem.[143]

[136] Ofcom (2018), *"The economic impact of broadband"*, https://www.ofcom.org.uk/research-and-data/telecoms-research/broadband-research/economic-impact-broadband
[137] ACMA (2014), *"The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013"*.
[138] https://trpc.biz/old_archive/wp-content/uploads/FosteringanOpenInternetinAsia_2017_v1.2.pdf
[139] CTO (2020). Over The Top (OTT) Applications & the Internet Value Chain. https://cto.int/wp-content/uploads/2020/05/CTO-OTT-REPORT-2020.pdf
[140] Peter Goodridge et al (2016), *"The economic contribution of the "C" in ICT: evidence from OECD countries"*, https://spiral.imperial.ac.uk:8443/handle/10044/1/43209
[141] Carol Corrado and Kirsten Jäger (2014), *"Communication Networks, ICT and Productivity Growth in Europe"*, The Conference Board EPWP#14-04, https://www.conference-board.org/publications/publicationdetail.cfm?publicationid=2963
[142] GSMA Intelligence (2020). Global Mobile Trends 2021: Navigating Covid-19 and beyond.
[143] Bahjat El-Darwiche et al (2015). Understanding Digital Content and Services Ecosystems: The Role of Content and Services in Boosting Internet Adoption. Appears in WEF (2015). The Global Information Technology Report 2015. Available at: https://www3.weforum.org/docs/WEF_GITR2015.pdf

Figure 3.13: Proportion of adults who are Internet users



Source: ITU World Telecommunication/ICT Indicators Database. Data from 2019 or latest available year. Data unavailable for some jurisdictions.

TRPC notes that once users attain familiarity with Internet portals and platforms, they grow in confidence and become more willing to try new services, such as e-commerce, e-finance, telehealth and online courses.[144] Increasing connectivity and digital skills will enhance social inclusion and increase the reach and effectiveness of e-government initiatives. Connectivity is also key in delivering accessible and inclusive education: the Economist Intelligence Unit has estimated that a 10% increase in schools' connectivity in a country can increase the effective number of schooling years per student (a measure of education quality as well as quantity) and also results in an increase in GDP per capita of 1.1%.[145]

Environmental benefits

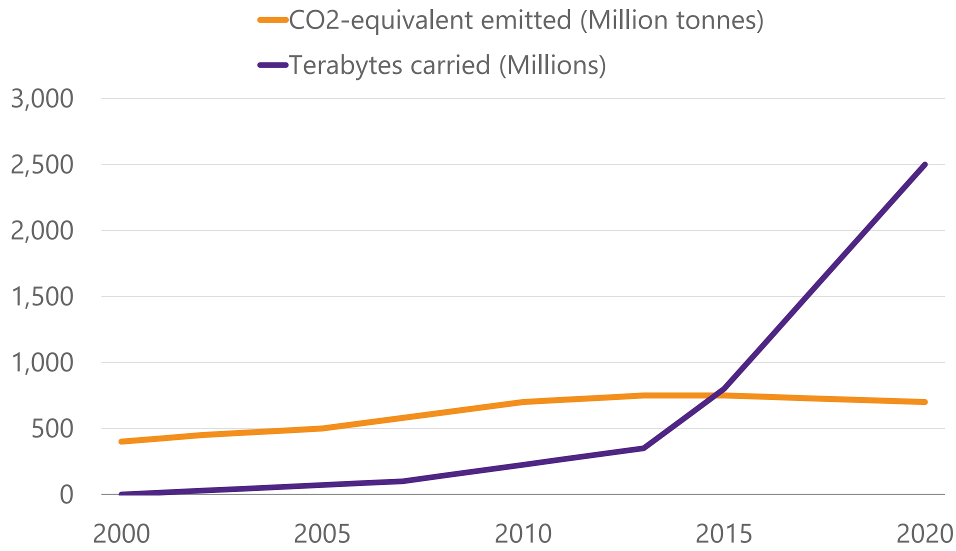
As Figure 3.14 shows, although the amount of data traffic generated by digital services globally has grown significantly over the past decade, the amount of carbon emitted in carrying this growing traffic has fallen slightly. This is driven by several factors:

- global vendors have made their equipment more energy-efficient;
- OSPs like Google, Facebook, and Microsoft have made their data centres more efficient and moved from fossil fuels to renewable energy; and

[144] TRPC (2017). Connectivity, Innovation and Growth: Fostering an Open Internet in Asia,
[145] Economist Intelligence Unit (2021). Connecting learners: Narrowing the educational divide. https://connectinglearners.economist.com/data/EIU_Ericsson_Connecting.pdf

- operators have used data analytics to run their networks in a more energy efficient way, leading to energy savings (Section 2.2.2).

Figure 3.14: Global carbon footprint of ICT vs global data traffic



Source: Ericsson[146]

The use of digital services can also play a vital role in climate change mitigation. The use of connected services to reduce travel, and to enable remote working, shopping, and banking are obvious examples. Usage of such services may increase as services become more compelling (for example, VR-enabled meetings). The Internet of things (IoT) also has a vital role to play in making buildings more energy-efficient, in enabling smarter use of transport systems, and in improving logistical efficiency. According to the GSMA the ratio of energy saved through use of digital services to the energy consumed in using them (the enablement ratio) has grown from 5:1 in 2015 to 10:1 today.[147]

[146] Ericsson, (2020). A quick guide to your carbon footprint. https://www.ericsson.com/en/reports-and-papers/industrylab/reports/a-quick-guide-to-your-digital-carbon-footprint

[147] GSMA (2019). The enablement effect: the impact of mobile communications technologies on carbon emission reductions. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf

4 The future of the telecoms sector

This section provides an overview of technology developments expected in the telecoms and digital sectors in the next 10 years. Both the telecommunications and technology industries are characterised by relatively long R&D, budgeting, and planning cycles, typically of around 10 years. For instance, a timeframe of this length has been observed in the development to implementation of advanced mobile (4G and 5G) technologies and the development of network function virtualisation and open networking.

This cycle may be quicker for software-based developments, although there remain constraints in terms of network and data centre capabilities required to support these developments.

Figure 4.1 provides a high-level overview of expected technology developments. Whilst this assessment is not exhaustive, it summarises key themes across each segment of the wider telecoms sector. The developments discussed are international and R&D focused, reflecting the international nature of technology supply chains.

Figure 4.1: Expected telecoms technology developments (2022-2032)

	2022 to 2026	2026 to 2032	2032 on
Apps & content	Content and apps, cloud services	Widespread AR/VR, cloud gaming, 8k livestreaming	Enhanced AR/VR, 4k cloud gaming, VR livestreaming
Connectivity service	Mobile: SMS, voice, data. Fixed: superfast, ultrafast	VoIP services, M2M, pervasive gigabit (fixed and wireless)	10-gigabit services
Network software	BSS/OSS, SDN, emerging cloud, SD-WAN, emerging verticals	Native cloud, XaaS	Outsourced, layered model
Core & interconnection	Emerging cloud, MVNO, emerging verticals	Naïve cloud, MEC/cluster, data centres	AI, APIs, layered architecture
Fixed access network	FTTC/FTTP	FTTP/FTTX, wholesale networks	FTTP/FTTX, wholesale networks
Wireless access network	Macrocells, emerging indoor, 4/5G	Rural, urban, indoor, 5/5.5G, Open RAN, neutral hosts	Cell-less networks, FTTM, Virtualised Cloud RAN, 5/6G
Radio spectrum	<1GHz, <6GHz, early mmWave	+ spectrum sharing, mmW, access	+ Dynamic Spectrum Access, THz, network of networks
Transport and switching network	Trunking, µwave, Direct Fibre, neutral host	+ pervasive FTTP, SD-WAN	+ pervasive FTTP + quantum networks / advanced photonics
End-user devices & CPE	Smartphones, SIMs	+ IoT, Vehicle-to-everything communications, VR/AR, eSIMs	+ Internet of Services, immersive UHD comms
Chipsets & components	System on a Chip, System in a Package, Reduced Instruction Set Computers	+diversified supply of silicon	+ integrated biotech

Note: Access infrastructure (green) and End-user device segments (blue) are split to highlight expected developments in different parts of these segments. FTTM refers Fibre to the Mast – use of fibre backhaul and fronthaul to antenna sites. eSIM – embedded SIM. SD-WAN software defined wide area network.

This forward-looking assessment is based on current near, mid, and long term expectations informed by Plum's own experience and recent dialogue with various senior level stakeholders identified below.

Figure 4.2: Stakeholder discussions

- Large and established telecoms equipment suppliers (vendors).
- Challengers and new entrants in telecoms equipment supply.
- 'Traditional' telecoms infrastructure and data centre operators.
- Venture capitalists and investors.
- Telecoms investment bank analysts.
- New entrants and 'innovative' telecoms operators (incl. neutral hosts and indoor solution providers).
- Leading universities.

The rest of this section discusses selected developments that are likely to be the most significant for the telecoms sector.

4.1 The next generation of connected services

There are a number of new and emerging connected services and applications which are likely to impact the sector in the near term.

- **Virtual reality and augmented reality**. These technology concepts are creating new experiences and ways of working. Virtual reality is a simulation of a real or imaginary world, whereas augmented reality layers virtual elements over the real world. Both technologies require large amounts of computing power to deliver a low-latency experience to the end-user (high latency can induce feelings of nausea).[148] Combining a device's onboard computing power with edge cloud can enhance the available processing power, provided that the network offers sufficiently low latency and reliability.

  The obvious applications of these technologies are in entertainment, but they are also finding use cases in many industry verticals, including healthcare, manufacturing, retail, business and education.

- **Cloud gaming.** With cloud gaming, a game runs on a remote server and is streamed to the user's device. The advantage of this approach is that it obviates the need for expensive gaming consoles or equipment. Several cloud gaming services are already in existence, including Microsoft's Xbox Cloud Gaming, Amazon's Luna and Google Stadia. With ecosystem developments, the capabilities and immersive potential of these services is likely to increase, including cloud VR gaming.[149] While most cloud gaming traffic is expected to be carried on fixed networks, 5G networks are also predicted to carry significant amounts of cloud gaming traffic.[150]

- **High resolution livestreaming.** Livestreaming refers to video streaming that is simultaneously recorded and broadcast in real time. It has become a popular feature on various platforms, with livestreams covering live performances, sports, video games or daily life. Livestreaming can be demanding both in terms of computational power (the video must be compressed, encoded and decoded) and bandwidth. As the availability of high speed broadband has increased, the resolution of streams has improved, from

[148] Stauffert, J., Niebling, F., and Latoschik, M. (2020). Latency and Cybersickness: Impact, Causes and Measures. A Review. Frontiers in Virtual Reality. Available at: https://www.frontiersin.org/articles/10.3389/frvir.2020.582204/full
[149] Refer to: https://cloud.google.com/blog/products/gaming/streaming-vr-and-ar-content-google-cloud-nvidia-cloudxr
[150] Ericsson (2020). Mobile cloud gaming – an evolving business opportunity. Available at: https://www.ericsson.com/en/reports-and-papers/mobility-report/articles/mobile-cloud-gaming

HD to 4k. Future milestones are likely to include still higher resolutions (i.e. 8k) and VR streaming, allowing live audiences to inhabit the environment.

- **Connected … everything.** The volume of connected consumer and industrial devices is growing rapidly. In the consumer space, these devices include smart home devices, automobiles and wearables. In the enterprise space, there are myriad applications for connectivity, including smart agriculture, automated factories, logistics, and smart cities.

  While many such connected devices can be supported with today's Internet, advances in technology will open up both new opportunities and new ways of managing myriad connected devices. This is likely to include management platforms for connecting and prioritising a variety of different devices with different latency and bandwidth requirements, as well as smart analytics to make sense of all the data produced by connected devices.

We expect that the emergence of these services will strengthen the importance of a symbiotic ecosystem. In some cases, partnerships will be needed to be able to realise the full potential of these services. This may be particularly relevant in industrial applications of virtual reality, where low latency, reliability and computing power may be crucial. In other areas, such as entertainment applications and connected devices, partnerships may augment the total value of the sector by offering attractive bundles and service packages to end-users.

4.2 Connecting everyone

Despite significant growth in the number of Internet users worldwide, there are many who still do not have Internet access. The GSMA estimated that, in 2019, around half of the world's population is not connected to the Internet. Plum estimates that across the APAC region (excluding China) there are around 1.5bn without Internet access.[151]

The challenge of bringing everyone online is not just about deployment of infrastructure, but about affordable devices and compelling online applications and content. According to the GSMA, around 85% of Internet non-users live within the coverage area of a mobile broadband network.[152] Symbiotic relationships between sector players here may be key in providing 'demand-pull' factors, including compelling apps and content, to encourage these users online.

Affordability remains a key barrier to Internet access, which covers not just the cost of a connectivity service but also a device. This represents another opportunity for symbiosis – for example, in India, a partnership between Reliance Industries and Google is bringing a low-cost 4G phone to the market, which will run a bespoke Android operating system.[153]

Innovative approaches may be needed to supply adequate broadband to rural users. A range of technologies may be deployed to serve such users, including low earth orbit (LEO) satellites and 5G-powered fixed wireless access (FWA). The GSMA notes that there are range of market entrants and business models to deliver rural broadband, and that *"serving rural populations will require partnership approaches"*.[154]

[151] Plum analysis based on ITU data for 2019.
[152] GSMA (2020). Global Mobile Trends 2021.
[153] https://www.reuters.com/technology/smartphone-made-by-google-indias-reliance-jio-be-sold-about-87-2021-10-29/
[154] GSMA (2020). Global Mobile Trends 2021.

4.3 Software defined networks and cloud-based solutions

Software defined core networks are well established in the industry, and over the past few years, cloud-based solutions have risen in importance as CSPs continue to seek ways to reduce capital and operational costs. As evidenced by examples such as the recent Dish-AWS deal in the USA and Rakuten in Japan, cloud-based networks and BSS/OSS domains are gaining significant traction.

At the access network level, cloud and virtual RAN (C/VRAN) solutions are continuing to develop, as the physical layer and control functions become increasingly disaggregated. As evidenced by R&D in 6G technologies and ongoing commercial developments in wireless technologies, a key direction of travel in networking is towards optical fibre (including fibre to the mast for wireless systems), supported by software networking running in edge or centralised data centres. We expect future networks will be converged networks that integrate radio, fibre, data centres, and software technologies.

This direction of travel represents a shift away from legacy vertically integrated network elements with proprietary or ostensibly 'open' network interfaces from a select group of suppliers (e.g. Ericsson, Nokia, Cisco) towards a world with datacentres and end users connected by fibre and radio networks, with software suites providing all required system control and operations and services.

The disaggregation of hardware and software elements of the network has opened up the prospect of market entry by new players, and for increasing specialisation within the sector. This is evidenced by growth in the passive infrastructure domain, which suggests shifting business models. In this case, legacy providers of passive infrastructure are developing interests in neutral hosts including edge/MEC solutions, wholesale networks, and even AI solutions. These dynamics are likely to increase the importance of partnerships between sector players.

4.4 Optical switching systems and quantum networking

We expect a potential shift in the transport layer of the sector as optical circuit switching and quantum networking continues to advance – with multi-billion dollar R&D programmes now established in some regions (especially in the USA, China and the UK).

- **Optical circuit switching solutions** have been proposed as alternatives to current data centre networks, which consist of a 'fabric' of electrical switches and optical transceivers.[155] These can provide high bandwidth and low latency connectivity within a data centre, and enable data centres to handle ever-higher amounts of data traffic. They can also allow data centres to become significantly more energy efficient by reducing the need for electrical switches.

- **Quantum networking** uses the properties of subatomic particles to encode and transmit information. Together with quantum computing (where subatomic particles are used to perform computations), the technology could provide drastically enhanced levels of computational power, privacy and security.[156] In particular, quantum networks offer the ability to detect intrusion attempts, potentially making a connection proof against interception or hacking.

Whilst optical processing and quantum networking may be some way off from commercial mainstream usage (we would expect commercial deployments of these to develop in the main in a twenty-year timeframe), any such shift will effectively progressively render the electronic era of transport networking obsolete.

[155] Raja, A.S., Lange, S., Karpov, M. *et al.* Ultrafast optical circuit switching for data centers using integrated soliton microcombs. *Nat Commun* 12, 5867 (2021). https://doi.org/10.1038/s41467-021-25841-8

[156] Ananthaswamy, A., 19 June 2019. "The Quantum Internet is Emerging, One Experiment at a Time". Available at: https://www.scientificamerican.com/article/the-quantum-Internet-is-emerging-one-experiment-at-a-time/

Developments in quantum computing may pose significant national security issues – quantum computers are conceivably powerful enough to decrypt even strong encryption. In consequence, these technologies are seen as strategically important by governments, with the very significant levels of R&D funding already committed.

The development of these technologies is likely to include national trials with governments and cooperation from CSPs. This area is therefore a key opportunity for collaboration between hyperscale cloud providers and other sector players, for example in the development of joint strategic programmes. Cybersecurity is also likely to become an increasingly important consideration across the entire sector, given potential advances in computing power represented by quantum computing.

4.5 The future of the telecoms sector

At the consumer service level, the trend towards service bundling is likely to continue, and the number of bundles and service options available to increase. Future service bundles may include new and emerging services, such as services targeted at particular types of gamer. While open Internet norms are maintained, apps and content are likely to continue to exist in a virtuous circle with devices and connectivity services, even without formal partnerships between sector players.[157]

For industrial applications, edge computing solutions continue to be deployed. The set of potential applications is already long and is set to grow further as the technology becomes more widely adopted throughout the economy. Improvements in networking technology coupled with developments in virtual and augmented reality may open up new applications in remote healthcare and engineering. Edge computing solutions are typically delivered by partnerships between sector players with distinct specialisms. This trend is likely to continue.

As telecoms networks advance with further use of software defined networking (SDN) and cloud solutions, infrastructure is becoming increasingly disaggregated, leading to increased 'layering' in the sector, even as the boundaries between the layers start to blur. As a result, we might expect increased specialisation of individual firms (e.g. developments of firms as best-in-class cloud-based neutral host billing providers). These trends will be driven by technological developments, increased competition, and open standards.

The consequence of these developments is an increasingly complex sector. We expect to see market players increasingly operating across various levels within the sector, as well as the emergence of specialist entrant players in certain niches. In this more complex environment, and as digitisation becomes ever deeper, partnerships are likely to become increasingly important in supporting the delivery of the next generation of consumer and business services.

[157] Plum (2011). The Open Internet – A Platform for Growth. Available at: https://plumconsulting.co.uk/wpdm-package/plum-oct11-the-open-Internet-a-platform-for-growth-pdf/?wpdmdl=1471