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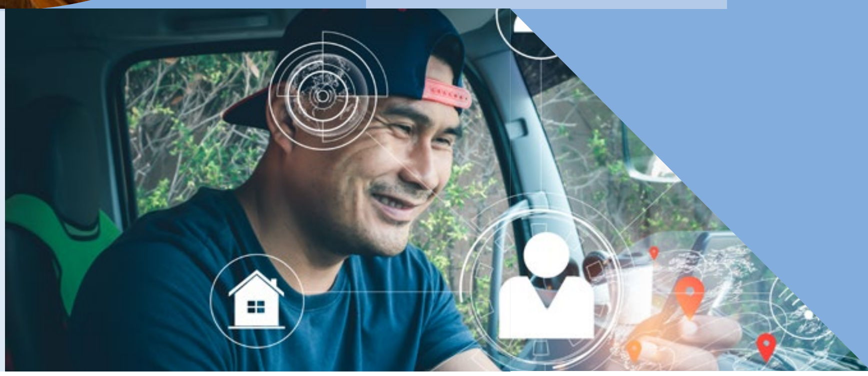
Strategies and policies for the deployment of broadband in developing countries



Output Report on ITU D Question 1/1

Strategies and policies for the deployment of broadband in developing countries

Study period 2018-2021

Strategies and policies for the deployment of broadband in developing countries: Output Report on ITU D Question 1/1 for the study period 2018-2021

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The study groups of the ITU Telecommunication Development Sector (ITU-D) provide a neutral platform where experts from governments, industry, telecommunication organizations and academia from around the world gather to produce practical tools and resources to address development issues. To that end, the two ITU-D study groups are responsible for developing reports, guidelines and recommendations based on input received from the membership. Questions for study are decided every four years at the World Telecommunication Development Conference (WTDC). The ITU membership, assembled at WTDC-17 in Buenos Aires in October 2017, agreed that for the period 2018-2021, Study Group 1 would deal with seven Questions within the overall scope of "enabling environment for the development of telecommunications/ information and communication technologies."

This report was prepared in response to **Question 1/1: Strategies and policies for the deployment of broadband in developing countries** under the overall guidance and coordination of the management team of ITU-D Study Group 1 led by Ms Regina Fleur Assoumou-Bessou (Côte d'Ivoire), as Chairman, supported by the following Vice-Chairmen: Ms Sameera Belal Momen Mohammad (Kuwait); Mr Amah Vinyo Capo (Togo); Mr Ahmed Abdel Aziz Gad (Egypt); Mr Roberto Hirayama (Brazil); Mr Vadim Kaptur (Ukraine); Mr Yasuhiko Kawasumi (Japan); Mr Sangwon Ko (Republic of Korea); Ms Anastasia Sergeyevna Konukhova (Russian Federation); Mr Víctor Martínez (Paraguay); Mr Peter Ngwan Mbengie (Cameroon); Ms Amela Odobašic (Bosnia and Herzegovina); Mr Kristián Stefanics (Hungary) (resigned in 2018) and Mr Almaz Tilenbaev (Kyrgyzstan).

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Executive summary

This report is the culmination of the work completed under Question 1/1 entrusted to Study Group 1 of the ITU Telecommunications Development Sector (ITU-D), which examines strategies and policies for the deployment of broadband in developing countries.

The report includes country experiences and best-practice guidelines to promote affordable broadband networks; strategies to stimulate investment in broadband networks; information on methods of broadband infrastructure deployment; overview of basic principles of transition from narrowband to high-speed, high-quality broadband networks; case studies associated with operational and technical issues of deploying broadband networks; examples of removing practical and regulatory barriers to broadband infrastructure deployment; overview of national experiences in the transition from IPv4 to IPv6; and other indirect aspects of broadband deployment.

Chapter 1 of the report reviews trends in broadband access technologies and deployment and regulatory considerations, including trends in standards for broadband access technologies; trends in national plans for fixed and mobile broadband development; trends in regulation, investment procedures and public-private partnerships; and trends in capacity building and supporting decisions in the process of broadband deployment.

Chapter 2 examines strategies, policies and regulations for broadband, including regulatory interventions, deployment strategies and financing mechanisms. It contains an overview of responsive regulatory frameworks, competitive markets, principles of allocation of spectrum resources, implementation infrastructure co-deployment and sharing guidelines, price regulation, as well as information about the development and implementation of broadband plans.

Chapter 3 concentrates on the transition to high-speed and high-quality broadband networks, including an overview of basic principles for mobile-broadband networks (5G), other wireless-broadband networks and fixed-broadband networks. It also contains best-practice guidelines and an overview of country and regional examples.

Chapter 4 contains information on the indirect aspects of broadband deployment, including transition from IPv4 to IPv6, using network functions virtualization (NFV) and software-defined networking (SDN)-based networks as well as development of Internet exchange points (IXPs).

Chapter 5 summarizes the conclusions drawn in previous chapters.

Introduction and background

Broadband technologies are fundamentally transforming the way we live. Broadband infrastructure, applications and services offer important opportunities for boosting economic growth, enhancing communications, improving energy efficiency, safeguarding the planet and improving people's lives. Broadband access has had a significant impact on the world economy. Rapid evolution and new business opportunities are driving rapid but uneven growth in digital technologies.[1]

According to ITU data, 2019 marked the first full year when more than half the world began to participate in the global digital economy by logging onto the Internet. The latest ITU data show that some 49 per cent of the world's population currently remain unconnected (ITU, 2020 estimates).[2]

In this era of a global pandemic and the attendant social-distancing induced lockdowns that have inhibited the movement of people even within their own communities, network connectivity has fast emerged as a critical – and sometimes, the only – means of providing essential services, such as education and healthcare, and of keeping commerce going. The COVID-19 pandemic has thrown social fissures into greater relief. In these troubling times, the digital divide risks being further widened in the absence of network connectivity for those on the margins of society, whether owing to economic or geographic reasons, such as people in rural areas. This digital divide exists not merely between developing and developed countries, but between the urban/suburban and rural populations of developing and developed countries alike. Unless this divide is skilfully and thoughtfully addressed, it is likely to widen during this global pandemic which, according to experts, may last a while – especially given high contagion risks and an uncertain time-frame for the development and distribution of an effective vaccine globally.[3]

Developing countries have already invested more than USD 1 trillion for the existing mobile networks and continue to invest billions of dollars each year. According to ITU statistics,[4] mobile networks cover 96.7 per cent of the population in developing countries (3G networks cover 93 per cent of the population; 4G networks cover 85 per cent of the population). The next step is to transform these mobile networks into high-speed and high-quality intelligent 5G networks.[5] Therefore, much attention is currently focused on 5G technology, with 5G positioned as an intelligent network that supports data and analytics use cases, driving diverse usage scenarios. For instance, 5G is seen as enabling both developed and developing countries to make full use of new technologies such as Internet of Things (IoT), cloud computing, machine-to-machine (M2M) and data analytics. The COVID-19 situation also clearly shows the importance of 5G, and detailed information can be seen in a presentation on the "Importance of 5G and AI for the Pandemics (COVID-19)" given at the ITU Webinar on solutions for pandemics.[6]

The pandemic has also shown the importance of diverse information and communication technologies (ICTs) in ensuring connectivity.[7] More information can be found in the ITU "Guide

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1 ITU and UNESCO. Broadband Commission for Sustainable Development. The State of Broadband 2019: Broadband as a Foundation for Sustainable Development. Geneva, September, 2019.

2 ITU Statistics.

3 ITU-D SG1 Document SG1RGQ/382 from Ericsson Ltd. (United States)

4 ITU. ITU-D. Measuring digital development: Facts and figures 2020. Geneva, 2020.

5 ITU-D SG1 Document SG1RGQ/375(Rev.1) from Intel Corporation (United States)

6 Turhan Muluk and Mario Romao (Intel). Importance of 5G and AI for Pandemics (COVID-19). *ITU Webinar: New e-health solutions to combat pandemics with ICT*, 6 July 2020.

7 ITU-D SG1 Document 1/441 from EMEA Satellite Operators Association (ESOA)

to develop a TELECOM-ICT contingency plan for a pandemic response",[8] on the Reg4Covid platform[9] and in the World Summit on the Information Society (WSIS) Coronavirus Response Special Report.[10]

Persons with limited digital literacy can use Internet effectively through artificial intelligence (AI) and high-speed broadband networks. They can interact by talking to AI-based digital voice assistants (DVAs) to access online services. DVAs could help to bridge the gap caused by illiteracy in access to valuable information and services ranging from education and agriculture to medical care from the Internet.[11]

8 ITU. ITU-D. Guide to develop a telecommunication/ICT contingency plan for a pandemic response. Geneva, 2020.
9 ITU. Global Network Resiliency Platform (#REG4COVID).
10 World Summit on the Information Society (WSIS). WSIS Stocktaking ICT Case Repository. The Coronavirus Response – Special Report. (Zero draft, 10 September 2020).
11 ITU-D SG1 Document 1/462+Annexes from Intel Corporation (United States)

Abbreviations

Abbreviation	Term
3GPP	3rd Generation Partnership Project
ADSL	asymmetric digital subscriber line
AI	artificial intelligence
AMPS	advanced mobile phone service
AR	augmented reality
ARPU	average revenue per user
BPON	broadband passive optical network
CDMA	code-division multiple access
CEPT	European Conference of Postal and Telecommunications Administrations
DOCSIS	data over cable service interface specification
EIB	European Investment Bank
eMBB	enhanced mobile broadband
EPON	Ethernet passive optical network
FOCL	fibre-optic cable lines
FTTH	fibre-to-the-home
FWA	fixed wireless access
GPON	gigabit passive optical network
GSM	Global System for Mobile Communications
GSMA	GSM Association
HD	high-definition
HTS	high-throughput satellite
IAP	Internet access provider
ICT	information and communication technology
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMT	International Mobile Telecommunications
IoT	Internet of Things

(continued)

Abbreviation	Term
IIoT	industrial Internet of Things
IPV4 / IPV6	Internet Protocol version 4 / Internet Protocol version 6
ISP	Internet service provider
ITS	intelligent transport system
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Standardization Sector
IXP	Internet exchange points
LDC	least developed country
LEO	low Earth orbit
LTE	Long-Term Evolution
M2M	machine-to-machine
MEO	medium Earth orbit
MIMO	multiple-input multiple-output
MoU	memorandum of understanding
MPLS	multiprotocol label switching
NGN	next-generation network
non-GSO	non-geostationary satellite orbit
NMT	Nordic Mobile Telephone
NFV	network functions virtualization
NRA	national regulatory agency
OTT	over-the-top
PDC	personal digital cellular
PPP	public-private partnership
P2P	point-to-point
QoE	quality of experience
QoS	quality of service
SAARC	South Asian Association for Regional Cooperation
SDGs	United Nations Sustainable Development Goals

(continued)

Abbreviation	Term
SDN	software-defined networking
SMEs	Small- and medium-sized enterprises
TACS	total access communication system
TDMA	time-division multiple access
UMTS	Universal Mobile Telecommunications Service
URLLC	ultra-reliable low latency
VDSL	very high-speed digital subscriber line
VNF	virtual network function
VHCN	very high-capacity network
VHTS	very high-throughput satellite
VoIP	voice over Internet Protocol
VR	virtual reality
WBA	Wireless Broadband Alliance
WCDMA	wideband code-division multiple access
WiMAX	Worldwide Interoperability for Microwave Access
WPA	Wi-Fi protected access
WRC	World Radiocommunication Conference
WSIS	World Summit on the Information Society
WTDC	World Telecommunication Development Conference

Chapter 1 – Trends in broadband access technologies and deployment and regulatory considerations

Telecommunications in the modern information society is a key focus of the world economy which determines the level of Member States' competitiveness. Market competition encourages different stakeholders to track and predict the main trends in the telecommunication industry with the aim of investing in the most effective methods for rapid and cost-effective development of modern telecommunication networks.

Among all the elements of modern telecommunication industry development, the following factors have the greatest influence on the deployment of broadband:

- standards for broadband access technologies;
- national plans for fixed- and mobile-broadband development;
- regulation, investment procedures and public-private partnerships;
- capacity building and supporting decisions in the process of broadband deployment.

1.1 Trends in standards for broadband access technologies

Understanding trends in the study and standardization of broadband access technologies is inextricably linked with the evolution of technology generations. A widespread practice is to use commercial designations for different generations of mobile communications, such as 1G (AMPS, TACS, NMT), 2G (TDMA, CDMA, GSM, PDC), 3G (IMT-2000, WCDMA, CDMA2000, UMTS), 4G (IMT-Advanced, LTE-Advanced, WiMAX) and 5G (IMT-2020). Another example of the term "generation" in infocommunications is its use as part of the term 'next-generation networks' (NGN).

To concretize the task of studying the principles of building modern networks, several generations of technologies can be used, depending on which stage of development and implementation provide the key technical ideas for the deployment of broadband.

Generation class 1. Past generations

Generation G-3 (G "minus" 3): Technologies that today, usually, are no longer used for the building of new telecommunication networks. Examples include 1G mobile communication technologies as well as technologies such as BPON (broadband passive optical network) and analogue TV-broadcasting technologies.

Generation G-2 (G "minus" 2): Technologies that continue to be used to ensure compatibility with ageing subscriber equipment. Examples include 2G mobile communication technologies as well as technologies such as EPON (Ethernet PON), ADSL and DOCSIS 1.0.

Generation class 2. Modern generations

Generation G-1 (G "minus" 1): Technologies that are used less nowadays for the building of broadband access networks due to the development of more promising technologies that are related to the G+1 generation (below). These technologies are well studied, standardized and commercialized. Examples include 3G mobile communication technologies, as well as technologies such as GPON, ADSL2+, VDSL and DOCSIS 2.0.

Generation G+1 (G "plus" 1): The technologies that are actively used for the building of broadband access networks. These technologies also are well studied, standardized and commercialized. Examples include 4G mobile communication technologies as well as technologies such as XG-PON1, Vectored VDSL and DOCSIS 3.0.

Generation class 3. Next generations

Generation G+2 (G "plus" 2): Technologies that are currently at the stage of experimental implementations and/or standardization. Examples include 5G mobile communication technologies as well as technologies such as 100 EPON, G.fast and DOCSIS 3.1.

Generation G+3 (G "plus" 3): Technologies that are presented today in the form of innovative ideas and principles and which are under study and approval.

1.1.1 Mobile broadband

For most of the population in developing countries, mobile is the primary way to access the Internet. Mobile Internet brings a wide range of social and economic benefits by helping to promote digital inclusion and supporting the delivery of essential services, such as mobile money, mobile agricultural services as well as mobile-enabled health and education services. Additionally, there is evidence that countries with high levels of mobile connectivity have made the most progress in meeting their commitments to the United Nations Sustainable Development Goals (SDGs).[1]

Despite the growth in mobile telephony, the diversity of services, and the particular features of this technology, many populations do not yet enjoy the benefits of mobile broadband.[2]

The GSMA's Mobile Connectivity Index supports the mobile industry's commitment to connect everyone and everything to a better future.[3] The Mobile Connectivity Index, which can be found online,[4] is built up through 35 indicators feeding into 12 dimensions that are aggregated to give a score for each of the four enablers. Scores fall within a range of 0-100.

The Mobile Connectivity Index measures the performance of 170 countries against the key enablers of mobile Internet adoption. These data can help the mobile industry and other stakeholders understand where to focus action in order to drive increased mobile Internet adoption.

Strong growth in mobile-broadband subscriber numbers continues, driven in part by consumer demand for applications with 4G LTE, now a major means of getting broadband at home in

1 ITU-D SG1 Document 1/244 from GSMA
2 ITU-D SG1 Document 1/30 from the Higher Multinational School of Telecommunications (Senegal)
3 ITU-D SG1 Document 1/247 from GSMA
4 GSMA. GSMA Mobile Connectivity Index.

several regions, as well as access to 4G networking services. These have improved considerably over the last year, particularly in low-income countries where coverage almost doubled**.** LTE and higher generation 4G technologies now account for over half of all global mobile subscribers.

First- and second-generation wireless networks were focused on voice services, then 3G and 4G shifted towards data and mobile broadband. While for mobile broadband the focus in the future will continue to be on 5G, support for a much wider set of diverse usage scenarios is expected. Indeed, 5G is positioned as an intelligent network that supports data and analytics use cases, helping it reach out to drive new industries in ways not previously possible. 5G enables developing countries to make full use of new technologies, such as AI, cloud computing, M2M and data analytics.

Over 90 per cent of broadband subscribers in developing countries use mobile broadband, and it is vital to migrate to 5G successfully in order to harness the full benefits of mobile broadband. 5G/IMT-2020 will provide new applications and services for both developed and developing countries. In fact, some of the 5G/IMT-2020 applications will be much more important for developing countries, such as smart transport systems, e-health, e-education, smart grid, e-agriculture and disaster relief. Developing and emerging economies are leapfrogging older technologies and becoming more mobile-oriented. 5G will have a significant economic impact on these economies.[5]

Widespread ownership and use of the mobile phone can fast-track progress towards a digital age, transforming the daily lives of millions – especially impacting women, the poor and those in remote and rural areas – and igniting the growth of their economies for the benefit of all.[6]

Wi-Fi

Wi-Fi is the most widely adopted wireless technology.[7] Wi-Fi's ubiquity, flexibility and affordability have been instrumental in the growth of connectivity in emerging markets, where it has been a powerful tool for bridging the digital divide, as well as the driver for IoT and M2M applications. Wi-Fi and IMT are both needed to meet 5G requirements. Wi-Fi carries most of the wireless data traffic, and will continue to do so.

Wi-Fi has continued to evolve since the standard's ratification in 1997. Standard updates have improved the air interface (IEEE 802.11n, IEEE 802.11ac, and eventually IEEE 802.11ax (Wi-Fi 6)), added new spectrum bands (WiGig in the 60 GHz band with IEEE 802.11ad, IEEE 802.11ay and 6 GHz with IEEE 802.11ax), and kept up with security needs (WPA, WPA2, WPA3). In addition, the Wi-Fi Alliance and the Wireless Broadband Alliance (WBA) have introduced new functionality to improve traffic management, ease of user access and authentication, roaming, voice calls and, more generally, support for new use cases. Crucial to Wi-Fi's success are backwards compatibility and interoperability, which provide a continuity that has set the foundation for market growth and that benefits vendors, service providers and users alike. Wi-Fi networks can gradually evolve to include new functionality and improved performance, while supporting legacy devices. For instance, there will be no need to replace devices in order to connect to a Wi-Fi 6 AP, and a new Wi-Fi 6 device will still be able to connect to legacy APs (but not all

5 ITU and UNESCO. Broadband Commission for Sustainable Development. The State of Broadband 2018: Broadband catalysing sustainable development. Geneva, 11 September, 2018.
6 ITU-D SG1 Document SG1RGQ/75 from the BDT Focal Point for Question 1/1
7 ITU-D SG1 Document 1/230 from Intel Corporation (United States)

benefits from Wi-Fi 6 will be available due to the possibility of certain channel bandwidths not being available).

Wi-Fi 6 captures most of today's attention with its increase in throughput, spectrum efficiency and device battery life, but the evolution of Wi-Fi covers more ground – including traffic management, security, new spectrum bands, and integration with cellular – to accommodate new use cases. Cellular and Wi-Fi will remain complementary in addressing different traffic demands and application requirements, while becoming more integrated to share the traffic between them.

Availability of the 6 GHz band for unlicensed access will further promote the use of Wi-Fi among wireless Internet service providers (WISPs). As a good example, the United States Federal Communications Commission (FCC) took action in April 2020 to increase the supply of unlicensed spectrum, making 1 200 MHz of spectrum in the 6 GHz band available for unlicensed use. The rules will usher in Wi-Fi 6, the next generation of Wi-Fi.

There are many additional evolutionary paths to extending the functionality, flexibility and efficiency of Wi-Fi and improve its performance in specific use cases:

- Multi-gigabit connectivity in the 60 GHz band (WiGig, IEEE 802.11ad, IEEE 802.11ay) to provide even higher capacity density in the highest-traffic environments, in wireless backhaul and fixed wireless access or in home or other indoor environments where some applications or devices require very high throughput over short distances (e.g. AR/VR, 360-degree video, a home video projector).
- IEEE 802.11ay enhances the initial WiGig standard based on IEEE 802.11ad by supporting peak data rates in excess of 100 Gbit/s through the use of channel bonding and 8x8 MIMO.
- Long-range, low-power connections to devices (HaLow, IEEE 802.11ah) will set the stage for IoT or IIoT deployments. While connections may be in the kbit/s range, devices may have challenging battery-life requirements in the order of months/years. Wi-Fi HaLow technology operates in the unlicensed 900 MHz.

The Wi-Fi Alliance estimated the annual global economic value of Wi-Fi at USD 1.96 trillion in 2018, projecting the figure to surpass USD 3.47 trillion by 2023. Wi-Fi brings the greatest impact to the economy in four key domains:

1. Developing alternative technologies to expand consumer choice
2. Creating innovative business models to deliver unique services
3. Expanding access to communications services for fixed and mobile networks
4. Complementing wireline and cellular technologies to enhance their effectiveness.[8]

LTE

LTE and LTE-Advanced are practical and popular technologies. Improved radio capabilities make mobile-broadband services more efficient, providing higher quality and enabling new sets of services on top of LTE networks. These features are defined in 3GPP Releases 13/14 and are collectively known as "LTE-Advanced Pro".

LTE-Advanced Pro is a key technology for the immediate future of mobile network development and introduces the next step in spectral efficiency with three-dimensional (3D) beamforming,

[8] ITU-D SG1 Document 1/379 from Intel Corporation (United States)

also known as full dimensional MIMO (FD-MIMO). Increasing the number of transceivers at the base station is the key to unlocking higher spectral efficiencies.[9]

5G (IMT-2020)

The first commercial 5G (IMT-2020) services have already started and the coming years will see more launches all over the world.[10]

Although economic benefits are greater in the economies that were early adopters over the period studied, the rate of contribution of mmWave in economies that embraced the technology later outpaces that of early adopters in the final years of the study.

As the telecommunication industry races towards the commercial introduction of 5G technology, the number of operators investing in 5G technologies is growing substantially. Telecommunication operators from all continents have announced involvement with 5G demonstrations, lab tests and field trials.[11]

5G is the fastest growing mobile technology in history.[12] Coverage of 5G networks has reached 15 per cent of world's population (1.17 billion people) by 2020, and we can imagine how the global coverage will progress rapidly (both in urban and rural areas). Despite a global pandemic and economic challenges, 5G powered ahead at four times the speed of subscriber growth of 4G LTE. The world added 225 million 5G subscribers between Q3 2019 and Q3 2020, a feat which 4G LTE took four years to attain. According to Ericsson,[13] in 2026, 60 per cent of the world's population will have access to 5G coverage, with 5G subscriptions forecast to climb to 3.5 billion. With the right policies and regulations, we can further accelerate this transition from existing mobile-broadband networks to 5G networks to achieve digital equity and attain the SDGs.

At the end of 2020, the number of commercial 5G networks reached 143 in 61 countries. As many as 392 operators in 126 countries/territories had announced they were investing in 5G by the end of July 2020. No fewer than 83 operators had been identified as investing in 5G FWA services by August 2020. The number of 5G devices continues to rise and passed the 600 mark in March 2021. There are 628 announced 5G devices as at March 2021, which is an increase of 21 per cent over the last three months.[14]

Around the world, regulators are either in the process of holding 5G auctions or consulting and planning the allocation of 5G-suitable frequencies. At the same time, operators have been working in many of the candidate spectrum bands.

The availability of intelligent high-speed broadband services through 5G is very important for the future of developing countries. 5G is a key technology for digital transformation. 5G, AI and IoT are complementary technologies. According to IHS, 5G will enable USD 12.3 trillion of global economic output in 2035. McKinsey forecasts that AI has the potential to incrementally add 16 per cent, or around USD 13 trillion, by 2030 to current global economic output, and IoT

[9] ITU-D SG1 Document 1/323 from Algérie Télécom SPA (Algeria)
[10] ITU-D SG1 Document SG1RGQ/243 from Intel Corporation (United States)
[11] ITU-D SG1 Document 1/227 from Intel Corporation (United States)
[12] ITU-D SG1 Document 1/462+Annexes from Intel Corporation (United States)
[13] Ericsson. Ericsson Mobility Report. Stockholm, November, 2020.
[14] Global Mobile Suppliers Association (GSA). 5G reports.

will have a potential total economic impact of as much as USD 11.1 trillion per year by 2025. Developing countries have an opportunity to derive the maximum benefit from 5G, IoT and AI.[15]

Recent decades have seen a significant role for ITU in the transition from one technology to another, such as the transition from analogue to digital broadcasting, and the transition from IPv4 to IPv6. These topics are still on the agenda of ITU study groups and other relevant meetings, and the excitement surrounding the deployment of 5G deserves to be tempered by questions about the pace of progress towards this technology.

The transition to 5G is certainly an opportunity for both developed and developing countries to seize. However, a clear and harmonized timetable remains to be defined to help policy-makers and regulators keep pace with the hitherto unbridled speed of adoption of this technology.[16]

Expectations of 5G are high – an improved end-user experience, new applications, new business models and new services riding swiftly on the back of gigabit speeds, improved network performance and reliability.

However, there are some challenges facing the implementation of 5G today. The lack of implementation policies/regulatory mechanisms and commercial incentives, such as grants, or PPPs, to stimulate investment in 5G networks are key areas of concern.

The ITU Report "Setting the Scene for 5G: Opportunities and Challenges 2018" highlights 16 key issues – and responses – for policy-makers to consider as they formulate strategies to stimulate investment in 5G networks. Together, they represent powerful means of calibrating an overall approach across major aspects of migration and, where appropriate, embarking on a judiciously facilitated, accelerated transition to 5G.[17]

Meanwhile, 5G also faces the problems of high base-station density and high power consumption. How to guarantee power supply for 5G base stations at low cost and high efficiency has become an urgent problem that needs to be solved during the construction phase of 5G commercial networks. A possible solution to this problem could be the centralized construction of master power stations and branch power stations heterogeneously to provide three-dimensional space-decentralized power supply.[18]

1.1.2 Fixed broadband

While fixed-telephone subscriptions continue to decline, fixed-broadband subscriptions continue to increase around the world. According to the latest ITU statistics, there were more fixed-broadband connections (1.178 billion) in 2020 (estimate) than fixed-telephone connections (915 million) in 2019.

In 42 per cent of countries, more than half of fixed-broadband subscriptions had a download speed of more than 10 Mbit/s, already surpassing the Connect 2030 Target of 40 per cent by 2023.

In developed countries, growth in fixed-broadband subscriptions is slowing, as these countries are getting closer to saturation levels. Since fixed-broadband connections are usually shared

[15] ITU-D SG1 Document 1/378 from Intel Corporation (United States)
[16] ITU-D SG1 Document SG1RGQ/214 from Côte d'Ivoire
[17] ITU-D SG1 Document SG1RGQ/74 from the BDT Focal Point for Question 1/1
[18] ITU-D SG1 Document 1/340 from China

by all members in the household, penetration rates are unlikely to go over 50 per cent. Indeed, penetration rates in the highest-ranked countries were between 40 and 45 subscriptions per 100 inhabitants, compared with an average of 32.7 for all developed countries. By contrast, in developing countries, after slowing in 2012 and 2013, growth has accelerated in the last five years, reaching 11.4 subscriptions per 100 inhabitants in 2019. This still leaves plenty of room for further growth. In least developed countries (LDCs), growth was strong as well, albeit from a very low base.

While subscriptions for the lowest speed tier (≥256 kbit/s to <2 Mbit/s) have virtually disappeared from developed countries, they are still very much a reality in LDCs, where, in 2017, 30 per cent of fixed-broadband connections were still at speeds below 2 Mbit/s.

Asia and the Pacific registered the highest share of fixed-broadband subscriptions at speeds equal to or above 10 Mbit/s in 2017, at 89 per cent, closely followed by Europe at 87 per cent. At the other end of the scale, in Africa and the Arab States, high proportions of subscribers still had subscriptions at speeds below 2 Mbit/s in 2017, at 39 and 31 per cent, respectively.

1.1.3 Next generation of satellite broadband

With its global reach and immediate availability, satellite is key to connecting people everywhere.[19],[20]Satellite systems can provide timely availability of broadband connectivity to developing countries with the same quality and service level as satellite links in developed countries. While many satellite broadband technologies are available today, the new generation of satellite systems will further extend the capacities of the space-based services. These include low Earth orbit (LEO) and medium Earth orbit (MEO) satellite systems as well as high-throughput satellites (HTS) or very high-throughput satellite (VHTS) systems using multiple spot beams. Satellite systems are increasingly deployed as hybrid satellite-terrestrial systems, thus contributing to a network of networks.

Connecting users directly with satellite broadband is important for suburban, lower-density and more isolated areas with available speeds of 50-100 Mbit/s. As noted above, where other standalone solutions are not economically viable, satellite is often used to backhaul mobile base stations or enable community Wi-Fi. Satellite technologies have been used to affordably expand and upgrade terrestrial mobile networks from 2G to 3G and 4G, often in combination with, and providing resilient protection for, terrestrial fixed links. They are also important for connecting passengers in mobile environments, aircraft and ships, as well as for use in temporary and emergency situations. As such, satellite systems offer compelling alternatives to point-to-point (P2P) microwave backhaul because of their ability to cover all geographies cost-effectively and with quick deployment. Examples of how developing countries rely on satellite systems are provided in **Annex 3** to this report.

The role of satellite was highlighted even more with the COVID-19 pandemic, when the urgent need to ensure complete connectivity was felt. Over 750 million people (around 10 per cent of the global population), concentrated in rural and remote areas, are still not covered by mobile broadband (a 3G connection or higher).[21] This lack of coverage has influenced the deployment of broadband during the last year towards a greater mix of fixed and wireless broadband

[19] ITU-D SG1 Document SG1RGQ/320 from ESOA
[20] ITU-D SG1 Document 1/441 from ESOA
[21] GSMA. Connected Society. The State of Mobile Internet Connectivity 2019. London, July 2019.

developments including satellite, often being deployed together.[22] Deploying solutions based on multiple technologies can (i) speed up the time to connect communities and (ii) reduce the cost of roll-out while enabling meaningful connectivity in developing countries.[23] Mobile operators, for example, continue to partner with satellite operators to extend the reach of 3G and 4G networks into rural and remote areas by using satellite backhaul to connect to the Internet backbone. The result brings transformational mobile connectivity to areas which would otherwise be totally unconnected.[24]

Satellite contribution to 5G

Going forward, satellites will also be backhauling 5G networks. While some applications require low latency, the most common broadband applications such as e-mail, web browsing, video streaming or cloud file syncing do not, and depend rather on reliable connectivity, availability and cost.[25] Recently deployed and upcoming non-geostationary satellite orbit (non-GSO) systems in medium and low Earth orbits can now provide low-latency connectivity supporting a wide range of applications.

In view of the need to ensure broadband connectivity for a maximum of citizens, future 5G architecture has been characterized by the European Commission as heterogeneous networks, i.e. a network of networks, including satellite networks.[26] This approach is supported by ITU in its Report "Setting the Scene for 5G: Opportunities and Challenges".[27] and by the European Conference of Postal and Telecommunications Administrations (CEPT) in ECC Report 280.[28] Accordingly, the technical standardization work to support complete integration of non-terrestrial networks such as satellite into 5G networks is ongoing within 3GPP, the standards-making body for 5G, with the active support of mobile operators.[29] Developing countries therefore have the opportunity to get maximum benefit from 5G, IoT and AI.

The satellite component of 5G will make use of low, mid and high radio frequencies (S, L, C, Ku, Ka, Q-V bands). For developing countries to benefit from all variants of broadband connectivity to meet their diverse and evolving needs, ICT policy and regulatory frameworks need to be up to date, reflect current technology status and be technology neutral to incentivize continued and future investment in different solutions. This includes spectrum policy, which should protect existing users, allow for the future deployment of diverse broadband solutions and implement the decisions of the ITU World Radiocommunication Conference (Sharm el-Sheikh, 2019) (WRC-19) which has made provision for future IMT/5G services, satellite and other services recognizing the role of each one.

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[22] Global Satellite Coalition (GSC). The Global Satellite Industry and COVID-19.
[23] Xataka (Mexico). *Internet de 18 Mbps a 12 pesos la hora: probamos el internet de Viasat para comunidades de México en donde apenas llega la luz*. Updated 23 July 2018. [in Spanish]
[24] SES. News. Press release. SES Networks and OptimERA Scale Capacity in Rural Alaska City Under "Stay at Home" Rule. 21 April 2020.
[25] Imitiaz Parvez et al. A Survey on Low Latency Towards 5G: RAN, Core Network and Caching Solutions. arXiv: 1708.02562v2 [cs.NI], 29 May 2018.
[26] European Commission. Shaping Europe's digital future. 5G Research & standards.
[27] ITU. Setting the scene for 5G: opportunities and challenges. Geneva, 2018.
[28] CEPT. Electronic Communications Committee (ECC). ECC Report 280. Satellite Solutions for 5G. Approved 18 May 2018.
[29] NGMN News. Press release. NGMN Alliance and ESOA Members Collaborate to Extend Rural Connectivity with Non-Terrestrial Networks. Frankfurt, Germany, 5 February 2020.

Thanks to the wide service coverage capabilities of satellite systems and their reduced vulnerability to physical attacks and natural disasters, satellites, either operating alone or integrated with terrestrial systems, are expected to:

- Foster rapid and economic roll-out of 5G service in unserved areas that cannot be covered by terrestrial 5G network (isolated/remote areas, on board aircraft or vessels) and underserved areas (e.g. suburban/rural areas)
- Upgrade the performance of limited terrestrial networks in a cost-effective manner, including enhancing their resilience to support critical 5G services
- Reinforce 5G service reliability by providing service continuity for M2M/IoT devices or for passengers on board moving platforms (passenger vehicles, such as aircraft, ships, high-speed trains and buses) or ensuring service availability anywhere, especially for critical future railway/maritime/aeronautical communications
- Enable 5G network scalability by providing efficient multicast/broadcast resources for data delivery towards the network edges or even user terminals.

Non-terrestrial network components in 5G are expected to play a role in the following verticals: transport, public safety, media and entertainment, e-health, e-learning, energy, agriculture, finance, and automotive.[30]

1.2 Trends in national plans for fixed- and mobile-broadband development

Broadband networks have been recognized internationally as important public infrastructure. They play an increasingly prominent role in promoting economic growth, changing growth drivers and enhancing long-term competitiveness. Their development has become a major criterion for measuring a country's overall national strength. Countries around the world have all included broadband in their priority areas of development.[31]

The number of registered users in virtual society and Internet usage in volume and type differ across countries, levels of society and, sometimes, within countries. They depend on cultural and geographic indicators and Internet development rates in those countries. Understanding the social differences in the characteristics and volume of people using the Internet and broadband services helps to address the digital divide according to the level of technology development in a society. This can be done by prioritizing broadband development and providing related services in cases where more is needed. One of the possible ways of such prioritization is making social surveys of the population regarding their needs in terms of broadband usage. As an example, a "Social survey on Internet in Iran" conducted in 2017 helped compare citizens' use of broadband services and virtual networks on the basis of different indicators in various areas and sectors of the country.[32]

According to the ITU Telecommunication/ICT Regulatory Database, at the end of 2019 more than 164 countries had adopted national broadband plans, up from 136 in 2010.[33]

The main objectives that countries set for themselves in national broadband plans are:

- Build broadband infrastructure

[30] ITU-D SG1 Document 1/326 from Algérie Télécom SPA (Algeria)
[31] ITU-D SG1 Documents 1/351 and 1/456 from China
[32] ITU-D SG1 Document 1/73 from the Islamic Republic of Iran
[33] ITU. ICT-Eye.

- Connect households with broadband
- Promote adoption of broadband services
- Promote public services using broadband.

The main sources of funding for the implementation of national broadband plans are:

- Public-private partnerships (PPPs)
- Government grants/direct subsidies
- Universal service fund.

In several countries, alternatives to national broadband plans are encompassed in overall national development strategies, a digital agenda or economic stimulus strategies. As at the end of 2019, 119 countries reported the availability of documents of this type. Moreover, in almost all cases, these documents contain some aspects of broadband development plans.

One of the most common trends in national broadband plans remains the building of broadband infrastructure.

There is a clear recognition of the importance of ICTs in the LDCs. SDG Target 9.c explicitly refers to providing universal and affordable access to the Internet in LDCs by 2020. There is no single model for LDCs to boost connectivity, but progress to date points to the importance of competition, public interventions when needed, open access, infrastructure sharing, and private investment in the first, middle and last miles. Policy failures, such as market concentration, troubled privatization, excessive taxation and monopoly control over international gateways, remain the principal bottlenecks impeding broadband development in the LDCs.[34]

Turning to the developed countries, the Council of the European Union adopted conclusions on *Boosting Digital and Economic Competitiveness Across the Union and Digital Cohesion* which highlight the importance of a gigabit network society for a competitive, innovative and highly digitized Europe.

The United Kingdom published the *Statement of Strategic Priorities for Telecommunications, the Management of Radio Spectrum, and Postal Services* in July 2019, which clearly set out gigabit-capable broadband deployment nationwide.

Germany put forward the 2050 vision of "Gigabit Germany" where everyone can enjoy "fast Internet access" by promoting broadband infrastructure construction.

The Republic of Korea implemented the Giga Korea strategy as early as April 2012, with an aim of 100 per cent gigabit broadband coverage by 2020. Currently, the gigabit broadband network covers more than 90 per cent of households in the country. The Republic of Korea also launched the 5G Plus Plan to accelerate 5G commercial development in five core services and ten industries.

The United States released the 5G FAST Plan,[35] which includes three key components:

1. Pushing more spectrum into the marketplace by speeding up auction to expedite 5G commercialization

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[34] ITU and UN-OHRLLS. ITU-D. Thematic report. LDCs and small island developing states. ICTs, LDCs and the SDGs: Achieving universal and affordable Internet in the least developed countries. Geneva, 2018.

[35] ITU-D SG1 Document SG1RGQ/328(Rev.1) from the United States

2. Updating infrastructure policy to simplify the deployment process of base stations and promote the rapid deployment of 5G networks
3. Modernizing outdated regulations to stimulate 5G investment and innovation.

In April 2019, the Chinese Government issued a policy document to further promote faster and more affordable broadband networks, proposing to advance dual-gigabit acceleration for fixed and mobile broadband.[36]

Strategies for ensuring that all citizens, wherever they may be, have access to the best possible international infrastructure are therefore an important public policy priority that, together with ensuring quality of service in the ever-changing digital environment, will also assist in achieving the SDGs.

1.3 Trends in regulation, investment procedures and public-private partnership

Digitalization is increasingly and fundamentally changing societies and economies and disrupting many sectors in what has been termed the 4th Industrial Revolution. Meanwhile, ICT regulation has evolved globally over the past 10 years and has experienced steady transformation.[37]

Advances in technology are creating new social phenomena and business models that influence every aspect of our personal and professional lives – and which challenge regulatory paradigms. Recognizing the potential of emerging technologies and the impact that policy and regulatory frameworks can have on their success, regulators should encourage a regulatory paradigm that pushes boundaries and enables digital transformation.

An investment-friendly policy and regulatory framework is needed to support digital transformation, which permeates all industries and impacts markets in all sectors.

ICT policy and regulatory frameworks need to be up to date, flexible, incentive-based and market-driven to support digital transformation across sectors and across geographical regions. Next-generation collaborative ICT regulatory measures and tools are the new frontier for regulators and policy-makers as they work towards maximizing the opportunity afforded by digital transformation.

The high speeds of optical fibre mean that Internet access is improving in households, with many people in the same household able to use the available connection at the same time, free of any stream-sharing constraints. High speeds over long distances will facilitate the development of new offers (triple and quadruple play) and of the applications necessary for development, namely teleworking and telemedicine. Fibre is a source of secondary income for the former mobile (now combined) operators, who profit by selling off the surplus capacity of their optical backhaul and backbone networks. Furthermore, in order to maximize fully the possibilities offered by 5G, IoT, AI and big data, reliable fixed-broadband connectivity is essential.

At a time when broadband remains key to achieving the SDGs and the ITU Connect 2020 objectives, it is important to assist developing countries in raising the level of their fixed-broadband deployment, in particular by establishing:

- an incentive-based regulatory framework to foster investment in fixed broadband;

[36] ITU-D SG1 Document 1/32 from the BDT Focal Point for Question 1/1
[37] ITU-D SG1 Document SG1RGQ/56+Annexes from the BDT Focal Point for Question 6/1

- an ICT infrastructure deployment plan in collaboration with stakeholders;
- lasting partnerships with the private sector and international organizations.[38]

The ICT ITU Regulatory Tracker tracks the transition of countries through five generations of regulation. It covers the early stage of regulation, where a government acts as policy-maker, regulator and sector player, progressing towards a fully competitive environment in which regulators work with other sectors in harmonizing regulation across the entire ICT ecosystem to ensure the systematic use of ICTs in key sectors like health, education and trade.

Countries in the first generation need to create an enabling environment for investment and innovation in the broadband market. This includes liberalization of the sector, privatization of State-owned national incumbent operators, and separation between policy, regulator and sector operation functions, with a view to encouraging competition and foreign direct investment, and promoting universal access, innovation, technology neutrality, content delivery and consumer protection.

Most regulators in developed countries have already moved into the fifth generation, whereby they promote collaborative regulation across the different sectors that oversee ICT-sector development, including those involved in digital financial inclusion, competition, consumer protection, data protection and legal services. However, no LDC has yet reached the fifth generation and built the capability to partner, collaborate and share information in order to address common challenges across sectors, including access, interoperability, security, privacy, data integrity, trust, quality of service and pricing.

Seven design principles have been identified to respond to new technology paradigms and business models stemming from collaborative regulation:[39]

i. *To achieve digital transformation, policy and regulation should be more holistic:* Cross-sectoral collaboration along with revisited regulatory approaches, such as co-regulation and self-regulation, can lead to new forms of collaborative regulation based on common goals, such as social and economic good, and innovation.
ii. *Policy and regulation should be consultation- and collaboration-based:* In the same way that digital cuts across economic sectors, markets and geographies, regulatory decision-making should include the expectations, ideas and expertise of all market stakeholders, market players, academia, civil society, consumer associations, data scientists, end users, and relevant government agencies from different sectors.
iii. *Policy and regulation should be evidence-based:* Evidence matters for creating a sound understanding of the issues at stake and identifying the options going forward as well as their impact. Appropriate authoritative benchmarks and metrics can guide regulators in rule-making and enforcement, enhancing the quality of regulatory decisions.
iv. *Policy and regulation should be outcome-based:* Regulators need to address the most pressing issues, for example market barriers and enabling synergies. The rationale for any regulatory response to new technologies should be grounded in the impact on consumers, societies, market players and investment flows as well as on national development as a whole.
v. *Policy and regulation should be incentive-based:* Collaborative regulation is driven by leadership, incentive and reward. Regulators should keep a wide array of investment incentives at hand to provide impetus for markets to innovate and transform while maximizing benefits to consumers.

[38] ITU-D SG1 Document SG1RGQ/28 from Côte d'Ivoire
[39] ITU. Global Symposium for Regulators (GSR). Best Practice Guidelines: Fast forward digital connectivity for all. *GSR-19*, Port Vila (Vanuatu), 9-12 July 2019.

vi. *Policy and regulation should be adaptive, balanced and fit for purpose:* Regulation-making is about flexibility – continually improving, refining and adjusting regulatory practices. The balance in regulatory treatment of new services is more delicate than ever. A close, continuous link to markets and consumers is important to get digital on the right glidepath to achieving social and economic goals.
vii. *Policy and regulation should focus on building trust and engagement:* Collaborative regulation provides the space for co-creating win-win propositions, working towards regulatory objectives while increasing the engagement of industry. Trust becomes the foundation of the regulatory process, underpinning the growth of digital.

The five main clusters of benchmarks for regulators:[40]

i. *Connectivity mapping:* Tracking the deployment of the various kinds of digital infrastructure can inform the regulatory process and allow regulators to identify market gaps and market stakeholders – to turn them into opportunities for investment and growth.
ii. *Metrics for market performance:* Metrics allow regulators to assess the performance of market segments for digital services against social and economic goals and identify priority action areas for policy and regulation.
iii. *Measuring regulatory maturity and levels of collaborative regulation:* Regulatory benchmarks pinpoint the status of advancement of policy and regulatory frameworks for digital markets. They help track progress and identify trends and gaps in regulatory frameworks, making the case for further regulatory reform towards achieving vibrant and inclusive digital industries.
iv. *Impact assessment:* A combination of quantitative and qualitative econometric studies based on reliable data can enable regulators to explore, understand and quantify how digital technologies, market players or regulation can contribute economically to growing the larger digital ecosystem and make it more inclusive.
v. *Regulatory roadmaps based on established authoritative metrics:* Roadmaps can guide regulators towards achieving digital connectivity objectives in a faster and targeted way.

The past decade has seen considerable evolution of ICT regulatory frameworks. Large groups of countries have aligned their regulatory approaches in key areas – often based on the successful experiences of peers – and these have helped shape ICT regulation over the past decade.

1.3.1 Tackling market dominance and competition

To date, 180 countries have opened their mobile-broadband markets to competition and 122 countries have liberalized their international gateways. These regulatory changes have helped amplify digital inclusion worldwide and have enabled the advent of digital platforms.

1.3.2 Spectrum reform unfolding

Spectrum reform has been ubiquitous, seeking to capitalize on spectrum as a means of achieving economic policy goals in view since the advent of 2G communications. Along with maturing 3G and 4G technologies, regulators have introduced more scrutiny over mobile operators and service providers. Some 47 regulators are now entrusted with an exclusive spectrum monitoring and enforcement role. At the same time, regulators have also introduced flexible, adaptive regulatory practices. Of note, 151 countries allowed band migration by the end of 2019, while 64 have introduced spectrum trading. At least 90 countries have reallocated their digital dividend spectrum as a result of analogue-to-digital migration, of which almost 90 per cent has been

[40] Ibid.

reallocated to mobile services. These developments have laid the groundwork for initial and subsequent 5G launches, their infrastructure requirements and the services that flow over them.

1.3.3 The growing importance of quality of service and experience

A main factor driving the adoption of new technologies is quality of service (QoS) and experience (QoE). If a service is unreliable, it will likely fail to become mainstream. Efficient regulatory tools and broad regulatory mandates in the area of QoS and QoE have helped drive the success of digital services. By the end of 2019, nearly 170 countries had introduced requirements for QoS monitoring. In more than 155 countries, the ICT regulator is in charge of QoS obligation measures and monitoring. Moreover, the QoS of mobile-broadband services is a make-or-break condition for the introduction of digital services, from mobile money to e-health services.

1.3.4 VoIP

VoIP (voice over Internet Protocol) has been one of the most successful digital applications to date. Several options exist for handling VoIP – but all have been on the same part of the regulatory spectrum. Blocking the use of VoIP services on a permanent basis has proven neither desirable nor completely enforceable. At the end of 2019, 160 countries allowed individual users to use VoIP. Around 30 countries still ban VoIP – and most of these do not plan to allow it in the foreseeable future.

1.3.5 Number portability

Mobile has become the main medium of communication for many consumers over the past 10 years. An important factor in enhancing mobile competition and reducing consumer prices has been number portability. By the end of 2019, mobile number portability had been implemented in 87 countries; and was required in 33 other countries, but had not been implemented. Although fixed number portability is lagging behind mobile, nearly 60 countries have either authorized or enforced it over the past decade.

1.3.6 Simplified and converged licensing regimes

Operating licences are key to buoyant digital markets, and leaving the door open to operators and service providers has been effective in boosting competition and helping the establishment of new business models. Over 119 countries had introduced unified licences or general authorization regimes by the end of 2019. Looking for alternative and complementary solutions for connectivity and service provision, some 58 new countries have introduced licence-exempt regimes for spectrum since 2010. This has enabled the global take-up of public – and often free – Wi-Fi systems, and will further pave the way for 5G.

1.3.7 Taxation of the digital economy: Steps to build on

Taxation of the digital economy is a challenge faced globally and various approaches are being established. Governments should collaborate more closely on digital services taxation matters at both regional and international levels.

- It is important to establish effective mechanisms for collaborative regulation, given that taxation decisions fall to finance ministries and tax authorities rather than telecommunication/ICT authorities – for example, working together with all parties before making decisions.

This could help in evaluating the possible distorting effects of each tax on the quality and quantity of services, as well as the possible loss of welfare of the population.

- Governments should not compromise long-term, national economic benefits by targeting short-term revenue.
- It is better to promote fiscal, parafiscal and other incentives to encourage operators and service providers to reduce tariffs (this could include, for instance, the elimination of customs duties on telecommunication/ICT equipment and terminals) rather than apply excessive taxes.
- Governments should promote policies that:

  i. encourage balanced and harmonized taxes;
  ii. avoid excessive burden to all stakeholders;
  iii. promote both innovation and effective competition among all sector players in the digital ecosystem;
  iv. consider affordability as a priority.

1.3.8 Infrastructure sharing

Infrastructure sharing and open access have been key elements of most strategies to promote affordable broadband access,[41] and several countries have introduced regulation permitting infrastructure sharing for mobile operators over the past decade. With IoT on the horizon, sharing practices will multiply, from passive to active to spectrum sharing, and will involve a wide array of technologies and regulatory practices.

1.3.9 Regulatory process is opening up

Regulatory processes have themselves become more open and collaborative. Collaborative regulation has been steadily gaining momentum, federating peer regulators from across the industry, in addition to market players' cycle of successful regulatory reform, which is likely to perpetuate itself on the back of the growth of new technologies and the social and economic phenomena they engender.

Driven by new market dynamics and social expectation, ICT regulators have begun to consult with market players and broader ecosystem stakeholders. Public consultations prior to major decisions have now become mandatory in more than 150 countries over the past decade.

1.4 Trends in international connectivity in developing countries

With the explosive growth in the use of broadband, the bandwidth demands of users have increased tremendously, resulting in soaring international capacity requirements. In 2014, it was estimated that international capacity use was growing at about 44 per cent annually. Reflecting greater pent-up demand, the fastest growth rates occurred in emerging markets, where Africa, Asia and the Middle East have registered annual growth of about 50 per cent between 2010 and 2014.[42]

[41] Document 1/447 from Montenegro
[42] ITU. ITU-D. Regulatory and Market Environment. Maximizing availability of international connectivity in developing countries: Strategies to ensure global digital inclusion. Geneva, 2016.

Prices for international capacity vary widely by region due to differences in available supply, levels of competition and cost of the underlying infrastructure. On large-volume submarine-cable routes, wholesale capacity is usually priced in 10 Gbit/s wavelengths and prices can vary considerably depending on the route. The very low costs for transit capacity at the global hubs highlight the need for developing countries to establish their own regional traffic consolidation points.

Factors having an impact on international Internet connectivity:

- *Uptake of broadband and telephony among the local population:* In countries where access to broadband is unaffordable for many, or there are other basic constraints, such as limited electricity, the need for international capacity will be correspondingly lower.
- *A country's role in providing international capacity to neighbouring States:* Some countries carry international traffic for their neighbours, most often because of the downstream

  i. availability of local applications and content;
  ii. level of interconnection between local networks;
  iii. degree of language isolation of the country;
  iv. level of international content blocking.

Barriers to international connectivity:

- International connectivity projects can be subject to delays
- High cost of cross connects
- Challenges to open-access/equal-access models
- Landing station fees and local ownership requirements.

1.5 Trends in capacity building and supporting decisions in the process of broadband deployment

The rapid growth in demand for new infocommunication services, as well as an increase in the volume of information exchange, are pushing telecommunication operators to update their networks regularly.[43]

The choice of a specific architectural model for building a network is a non-trivial task that is usually based on one of the following approaches:

- Evaluation of current trends and analysis of best practices
- Expert assessment considering the current situation
- Simulation for the purpose of economic feasibility assessment.

All these approaches have their own advantages and disadvantages. For example, the simplicity of the evaluation of current trends can lead to choosing some solutions that are not adapted to concrete realities. And expert assessments can be burdened with a high level of subjectivity and, sometimes, lack of economic evaluation.

As a rule to solving this problem, a technical-economic justification – based on simulation – is developed, accompanied by a consistent evaluation of the cost of building an access network. After comparing economic and technical characteristics, a forward-looking solution can be

[43] ITU-D SG1 Document 1/42 from A.S. Popov Odessa National Academy of Telecommunications (ONAT) (Ukraine)

reached, which is then taken as the basis for further detailed design and construction of the network.

Obviously, the development of such a technical-economic justification often requires considerable time and funds. As a result, network designers worldwide are trying to automate these processes by creating different techniques and tools that can be used as an expert system in the field of developing broadband networks.

ITU has published the *ICT infrastructure business planning toolkit*.[44] Inspired by practical experience in implementation, this new toolkit offers regulators and policy-makers a clear and practical methodology to deliver accurate economic evaluation of proposed broadband infrastructure installation and deployment plans.

The toolkit intends to:

- Serve as a practical manual for regulators and policy-makers working towards extending broadband network deployment and access
- Address key elements for a successful business planning implementation for ICT infrastructure development
- Present and explain best practices on infrastructure installation and deployment plans as well as its economic feasibility assessment to support decision-making
- Provide quantitative examples of the most common projects, such as the construction of optical fibre backbones, wireless broadband networks (including 4G), and fibre-to-the-home (FTTH) access network projects.[45]

The ITU *Last-Mile Internet Connectivity Toolkit*[46] is an effort to support Member States in selecting sustainable connectivity solutions. The toolkit provides guidelines and software tools to support members in closing the connectivity gap. The toolkit aims to support Member States in designing, planning and implementing last-mile connectivity solutions. These include identifying unconnected areas and selecting sustainable technical, financial and regulatory solutions to ensure affordability and accessibility of relevant connectivity services. The toolkit consolidates existing resources towards making available foundations that are a requirement for providing and scaling connectivity to the last mile.[47]

1.5.1 Broadband deployment and digital equity capacity building for State and local stakeholders

As at 2019, 22 million Americans lacked access to affordable, reliable, modern high-speed broadband capability, of which 15 million, or 73 per cent, live in rural areas. The National Telecommunications and Information Administration (NTIA) "BroadbandUSA" programme is spearheading the U.S. Administration's efforts to use all available tools to educate, convene and assist broadband stakeholders to improve connectivity. This includes rural homes, farms, small businesses, manufacturing sites, tribal communities, transportation systems, healthcare facilities, and educational institutions.

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44 ITU. Thematic reports. ICT infrastructure business planning toolkit. Geneva, 2019.
45 ITU-D SG1 Document 1/394 from the BDT Focal Points for Question 1/1 and Question 4/1
46 ITU. The Last-Mile Internet Connectivity Toolkit: Solutions to Connect the Unconnected in Developing Countries. Draft – 20 January 2020.
47 ITU-D SG1 Document 1/362+Annexes from BDT

BroadbandUSA serves as a strategic adviser to communities that want to expand their broadband capacity and promote digital inclusion. The team brings stakeholders together to solve problems, contribute to emerging policies, link communities to other federal agencies and funding sources, and address barriers to collaboration across agencies. Each community is unique, so no "one-size-fits-all" approach will work.

Some lessons learned could be considered:

- *Engage local stakeholders.* Include stakeholders, from local schools and libraries to chambers of commerce, local government agencies and local Internet service providers (ISPs).
- *Encourage public-private partnerships.* Rural communities confront significantly higher deployment costs due to low population density, lengthier middle-mile networks or challenging terrain. A partnership can address such economic challenges through sharing capital costs, thereby enhancing revenue potential.
- *One size does not fit all.* Each community is unique, so a technology solution or partnership that works for one rural community will not work for all.
- *Create, centralize and share information widely.* Creating a one-stop shop for broadband information makes it easier for rural communities to find resources they need.[48]

1.5.2 United States rural broadband network planning and capacity-building workshops

The Rural Broadband Workshops were co-designed to build field capacity in broadband planning in order to help develop local broadband teams, and to improve the pipeline of grant and loan applications. The workshops' short goal was to *inspire, inform and act*.

The *audience* for each workshop included: City mayors, city managers, council; technical leaders, CIOs, CTOs; educational leaders, school CIOs, directors; ISPs, service providers; economic development leaders, chambers; librarians; non-profit partners; local business leaders; and citizens.

Some lessons learned could be considered:

Let community priorities drive the process. For example, if the priority is on fire safety, then you will need the forest service and fire department and road department in your outreach team; if your priority is education, you will need teachers, students, librarians, businesses and philanthropists.

Encourage deep community engagement and outreach. Successful projects bring together a range of stakeholders from the community, such as governments, industry, and academia to improve health, education, job opportunities and transportation, among other goals.

Demonstrate broadband applications in practice and invite local leaders to describe benefits. People want to learn from their peers. Keeping it local makes it real and relatable.

Use a regional multi-states approach. To make project economics work, sometimes projects need to include neighbours or partners. Regional projects can provide stronger economies of scale and create new opportunities to share resources and drive innovation.

[48] ITU-D SG1 Document SG1RGQ/347 from the United States

Leverage federal data and empower local users to add their own wisdom. Explain the data, making them local and easy to visualize and use. This provides context to better understand and interpret the data.

Cultivate win-win partnerships. Formal or informal, through contracts or not, core to these partnerships is always that roles are clear and that all parties feel that they benefit from the agreements.

Leverage local assets. The core to any community-based planning process is a solid assessment of assets and gaps. This should include an asset inventory and detailed information on public rights-of-way.

Articulate a broadband vision. Some call it a vision, some call it an "elevator pitch".

Urge partners that they must plan beyond the event.[49]

1.5.3 Women, ICTs and development

The constantly changing ICT landscape continues to revolutionize and transform how people live and work. To promote women's empowerment and gender equality, women and girls must have access to and an understanding of these technologies. ICTs offer women opportunities to build and strengthen their businesses and become more effective citizens and leaders. However, the gender digital divide in literacy, access, skills, resources and other factors has excluded women from opportunities and benefits that ICTs offer. Gender equality is essential to achieve sustainable development and ensure that no one is left behind. However, the world remains far from achieving gender equity in ICTs. For this reason, it is necessary that efforts to use ICTs to enable women and girls' development continue and grow until a digital divide no longer exists.[50]

1.5.4 ITU spectrum management training programme

In 2016, the African Advanced Level Telecommunications Institute (AFRALTI) entered a partnership with ITU to deliver the Spectrum Management training programme (SMTP) to its members and other entities regionally.[51] In this period, AFRALTI also began the accreditation process to offer the SMTP as a Masters' programme. In addition, the plan is to have an annual Spectrum Monitoring Masterclass included as part of the SMTP. This is a face-to-face initiative that will empower students with practical aspects of spectrum management.

1.5.5 Case studies and resources for ICTs and accessibility

The aim of the GSMA Assistive Tech programme is to drive greater access to and use of mobile technologies for persons with disabilities in emerging markets and to maximize opportunities for social and economic inclusion.[52] The following is a list of reports published by GSMA:

- Understanding the mobile disability gap
- How mobile operators are driving inclusion of persons with disabilities
- Bridging the mobile disability gap in refugee settings

[49] ITU-D SG1 Document SG1RGQ/348 from the United States
[50] ITU-D SG1 Document SG1RGQ/187 from the United States
[51] ITU-D SG1 Document SG1RGQ/64+Annex from the African Advanced Level Telecommunications Institute (AFRALTI) (Kenya)
[52] ITU-D SG1 Document 1/385 from GSMA

Chapter 2 – Strategies, policies and regulations for broadband, including financing mechanisms

The goal of every jurisdiction is that broadband deployment is done in a timely manner, contributes its fair share to the economy and that the industry is competitive in providing affordable and high-quality broadband services. Many citizens in various jurisdictions across the globe lack access to high-speed broadband service. This is particularly true for rural and low-income communities.

It has been noted in some cases that broadband availability does not necessarily mean an increase in subscribers to the services. Although broadband deployments and new broadband subscriptions continue to grow, the rate of growth in urban and high-income areas outpaces rural and low-income areas by a big margin. This may be due to low literacy levels, availability of relevant local content, price of broadband service, poor electricity connections and poor road networks, among other aspects.[53] Policies and regulatory interventions therefore need to look at these and other relevant areas to promote deployment of broadband.

2.1 Broadband policies[54]

The ICT sector has seen rapid developments in recent years, with market liberalization and privatization contributing to healthier competition and increased private-sector investment. To keep this growth going and ensure that the world population continues to enjoy the benefits of broadband, there is a need to strengthen the current policy and regulatory environments to make them more transparent and supportive of greater investment in the sector.

The aim of an effective policy should be to motivate maximum broadband coverage, ensure safety and high quality of broadband service, improve the digital literacy of the population and inspire rich content and applications to shore up demand for the service.

Several countries have come up with effective national broadband policies in various stages of implementation. There are nevertheless opportunities for jurisdictions to enact a wide range of regulatory reforms to create enabling environments for broadband deployment and use.

When establishing policies, it is important to consider a number of factors that are key in defining the success of intended initiatives. Such factors may include differences and the specifics of building national telecommunication networks; geographic and climatic features that affect the possibilities for ICT development; the level of investment attractiveness of national economies in terms of stimulating investment in the development of ICTs; the degree of influence of State regulation on the development of the ICT market; and peculiarities of public administration in

53 ITU-D SG1 Document 1/279 from Sudan
54 Based on the ITU Telecommunications Regulation Handbook. International Bank for Reconstruction and Development (IBRD), World Bank, InfoDev and ITU, April 2011.

the field of ICT, among others. It is also important to undertake relevant studies on trends in a country and internationally to be able to develop and implement the right policies.[55]

Some of the policies that have been implemented successfully elsewhere are highlighted below for consideration in broadband policy decision-making.

2.1.1 Create demand for broadband[56]

Broadband development is driven by demand for broadband services. Investors are normally attracted to areas where they can make a return on their investment. Therefore, there is a need to shore up demand for broadband services for infrastructure deployment to make business sense.[57] The following are various ways in which policy-makers can increase demand for broadband services, especially in developing countries:

i. Digital literacy programmes

As a matter of policy, digital literacy programmes should be integrated into the basic education system, tertiary and university institutions. Education systems should also focus on inculcating a culture of innovation to solve local issues through technology.

One way of financing training and awareness is by mandating service providers to undertake the activities on their own with approval of the regulator. The regulator may also indicate the minimum amount to be spent on such activities.

ii. Development of local content and applications

A major hindrance to the uptake of broadband in several jurisdictions is the lack of sufficient and relevant local digital content and applications. There is a need to develop an innovation framework to stimulate creation of applications and content for the local population to encourage broadband subscriptions.

iii. Availability of affordable devices

Devices are useful in accessing broadband services whether in offices, homes or on the go. Provision of incentives including tax breaks, streamlined licensing processes, provision of land to encourage local manufacture/assembly, and import of parts could go a long way in making devices available for the masses.

iv. Digitization of government records

Government is the largest source of data for any country, on which all citizens depend for critical services. Digitizing government records has the desirable effect of encouraging citizens to undertake literacy programmes, buy digital devices and ultimately subscribe to broadband services to be able to access government records and services.

[55] ITU-D SG1 Document SG1RGQ/363 from ONAT (Ukraine)
[56] ITU-D SG1 Document 1/28 from Burundi
[57] ITU-D SG1 Document 1/279 from Sudan

2.1.2 Protect intellectual property rights

To encourage innovators, governments should put in place measures to protect their intellectual property.[58]

2.1.3 Review of tax policies and regulatory fees[59]

Deployment of broadband infrastructure requires heavy investment in equipment and civil-engineering works. Entities involved in deployment may be subject to taxes on acquisition of materials and equipment and on services provided during deployment. These taxes unfortunately increase the costs of deploying broadband infrastructure and reduce available capital. Taxes and regulatory fees therefore tend to discourage investors from venturing into broadband deployment. A review of tax and regulatory fee frameworks is necessary to incentivize the private sector to venture into underserved regions, more especially in low-income areas with a low return on investment.

2.1.4 Simplifying wayleave access[60]

When an operator wishes to lay infrastructure over or under privately owned land, they are required to first obtain the right to do so from the property owner. An operator is required to enter into an agreement with the property owner to grant the right of access to private property. Because operators must first negotiate wayleaves and ultimately pay for them, this represents a potential barrier to the timely deployment of broadband infrastructure. There is also the possibility that the negotiating parties may not reach an agreement, thereby denying other deserving citizens the necessary access to broadband services.

In the light of the role played by wayleaves, there is a need for governments to develop polices to provide for different access rights, wayleave regimes and wayleave pricing regimes where necessary. This could include:

i. Requiring provision for telecommunication/ICT networks and infrastructure in any infrastructure projects pertaining to transport, electricity and water distribution, and in State civil-engineering works.
ii. Requiring that property developers provide broadband telecommunication infrastructure in buildings.
iii. Non-refusal for any operators or service providers wishing to install broadband telecommunication infrastructure in a property at their own expense with a view to providing connectivity for occupants.

2.1.5 Encourage public-private partnerships

There are competing priorities for limited governmental resources – some more urgent compared to broadband deployment, such as health, food and housing. In order to ensure timely deployment of broadband, there is a need for strong government commitment and extensive collaboration with the industry to ensure its success.[61] Public-private partnerships (PPPs) can be an effective mechanism to facilitate co-investment from different stakeholders and

58 ITU-D SG1 Document SG1RGQ/165 from Côte d'Ivoire
59 ITU-D SG1 Document SG1RGQ/TD/1 from Malawi
60 ITU-D SG1 Document SG1RGQ/28. from Côte d'Ivoire
61 ITU-D SG1 Document SG1RGQ/TD/1 from Malawi

support the extension of network coverage in areas that otherwise represent risky investments with limited commercial potential. PPPs can also leverage public and private synergies to deploy and operate network infrastructure in areas that otherwise do not have sufficient economic potential to attract private investment.[62]

PPPs can take the following forms:

i. *Private sector-led partnerships* – A private entity owns and operates the network while government institutions support the venture through regulatory support, planning and monetary contributions.
ii. *Government-led partnerships with private-sector support* – The public-sector entity has the lead and owns the network. Under this arrangement, the private partners construct, operate and maintain the infrastructure in exchange for financial gains on the one hand and, on the other, deliver services on the laid infrastructure.
iii. *Joint-ownership partnerships* – In this arrangement, the private and public entities jointly invest in the network infrastructure and share capacity.

PPPs come with a number of advantages, including high-quality infrastructure solutions, increased access to innovative designs and financing approaches. The private entity can act as a check against unrealistic government expectations, among other benefits.

PPPs should be considered after exhausting all other enabling policy and regulatory measures to maximize coverage through market-driven mechanisms.

2.1.6 Invest in the latest innovative technology

This is particularly important in developing countries where infrastructure is not likely to be fully developed. Investment in the latest technologies ensures that the population is able to take advantage of benefits that accrue to it, including higher speeds, high efficiency and improved performance, and low costs, among others.

2.1.7 Promote development and use of local Internet exchange points

One of the reasons for slow and costly Internet connections, especially in the developing world, is the routing of local traffic via servers located thousands of miles from the local users.Efficient IXPs are key to lowering the overall cost of broadband, more especially in developing countries whose content tends to be international, resulting in large capital outflows. Caches across the network can help ISPs to offer popular content on the network by storing web content and serving it from a local network, thereby saving bandwidth while delivering faster web access to end users.[63] This calls for the implementation of national data traffic exchange centres,[64] local and regional IXPs to enable Internet service providers and network operators to effectively route local traffic within their networks, thereby improving the quality and reducing the overall cost of broadband services.

2.1.8 Encourage piloting

As broadband deployment projects are capital-intensive, this could lead to massive losses in the event of poor project management decisions. It is advisable that, before embarking on full-scale

[62] ITU-D SG1 Document 1/391 from GSMA
[63] ITU-D SG1 Document SG1RGQ/210 from the Republic of Korea
[64] ITU-D SG1 Document 1/80 from the Iran University of Science and Technology (Islamic Republic of Iran)

deployment, the management undertake a pilot phase that should ordinarily be exempt from the mandatory bidding process for selection of service providers. This will allow some focus on qualitative, collaborative aspects of such innovative projects.[65]

2.1.9 Categorizing broadband infrastructure as critical infrastructure

One major challenge to broadband infrastructure deployment in developing countries is insecurity from theft and vandalism. To encourage investments, governments should categorize broadband infrastructure as critical infrastructure and provide the necessary security including measures to curb cybercrime.[66]

2.1.10 Other policies

Other relevant polices include:

i. Providing access to government rights of way, easing access to construction permits, easements and access to government vertical assets, such as buildings and towers.
ii. Requiring that all public infrastructure projects, such as water, bridges, roads and power grids make provision for broadband facilities.
iii. Establishing policies that promote open-access public network models that are open to operator interconnections at national, State or municipal levels.

2.2 Regulatory interventions

Some of the regulatory interventions that can be implemented include:

2.2.1 Responsive regulatory frameworks

Industry challenges can be handled better if the same participants are allowed to participate in policy formulation and implementation.[67] There is a need to create a platform where industry players can voice their opinions on regulatory policies affecting the deployment of broadband. The platforms can also provide an opportunity for players to share information on roll-out so as to avoid duplication of efforts. In order to support rapid adoption of new technologies, jurisdictions should adopt technology-neutral regulatory frameworks that allow operators to explore the available options in the provision of services.[68]

The regulatory framework should be responsive to the needs of new and alternative carrier entrants to the market. Regulations should allow new entrants to deploy broadband infrastructure in direct competition with the incumbents. Incumbent telecommunication operators should also be accorded the same treatment; with favourable government regulatory and financing assistance, telecommunication service providers will be able to deploy broadband infrastructure with ease.

Licensing regimes should provide timed targets for operators to deploy infrastructure to serve uncovered areas.[69],[70]Failure to meet licence coverage obligations should result in some

65 ITU-D SG1 Document SG1RGQ/32+Annex from India
66 ITU-D SG1 Document SG1RGQ/167 from Burundi
67 ITU-D SG1 Document SG1RGQ/195 from Brazil
68 ITU-D SG1 Document SG1RGQ/28 from Côte d'Ivoire
69 ITU-D SG1 Document SG1RGQ/176 from Kyrgyzstan
70 ITU-D SG1 Document SG1RGQ/320 from ESOA

enforcement action, e.g. penalties, loss of licence. In the light of these requirements, the regulator should receive deployment plans from operators on a regular basis and then evaluate and approve coverage schedules for broadband deployment. Such an arrangement allows governments to guarantee coverage for remote and sparsely populated rural areas, where the building and operation of base stations for the provision of telecommunication services to the local population is not economically viable for operators.

Regulatory regimes should be able to encourage timely deployment of broadband by eliminating impediments that unnecessarily add delays and costs to bringing advanced wireless services to the public.[71]

Actions to improve the deployment environment could include:

- streamlining the wireless infrastructure review process;
- addressing the conduct of states and local governments that needlessly slow down deployments and increase the costs of wireless infrastructure deployments;
- modernizing preservation and environmental regulations for wireless deployments.

Additional regulatory approaches could include use of a more granular approach to licensing, such as licence exemptions for private networks and non-profit organizations, creating specific licences for community networks or fitted within existing exemptions that encourage a simple authorization or notification system for small operators and those serving unconnected populations.[72]

2.2.2 Competitive markets

According to an ITU survey, the market growth seen in nearly 80 per cent of Member States was possible due to the competitive nature of those markets. It is therefore important for jurisdictions to evaluate whether present laws and regulatory interventions meant to ensure that markets are competitive actually meet their purpose, or, conversely, whether such policies and regulatory interventions have become overly burdensome and only serve to discourage investment in, and deployment of, broadband services.

Policies that promote private investment and competition will ensure that broadband networks will be responsive to market signals and societal needs. [73],[74]This includes the adoption of technology-neutral rules, which will spur additional competition. They will provide upgrade quality continually and will also advance models of governance and regulation that support an open, interoperable, secure and reliable Internet.

2.2.3 Allocation of spectrum resources

Sufficient allocation of spectrum resources is necessary for sustained broadband deployment. Additional spectrum allocation in support of emerging industries and technologies will go a long way in promoting timely deployments. There is a need for jurisdictions to be aggressive in pushing spectrum into the commercial marketplace by adopting market-based strategies to support broadband deployment. The allocation and assignment of spectrum should, as much

71 ITU-D SG1 Document SG1RGQ/328(Rev.1) from the United States
72 ITU-D SG1 Document SG1RGQ/385+Annex from the Association for Progressive Communications (APC)
73 ITU-D SG1 Document SG1RGQ/194 from the United States
74 ITU-D SG1 Document SG1RGQ/320 from ESOA

as possible, be undertaken using a flexible licensing approach – i.e. an open and transparent rule-making process – to receive input from all interested parties and adopt technology-neutral rules to accommodate a variety of technologies and business plans.[75]

Spectrum regulations should also allow for re-farming of spectrum to implement the latest technologies and quick incorporation of changes of spectrum allocations in the national frequency band plan based on the outcomes of every world radiocommunication conference (WRC).[76]

Additional spectrum measures for consideration include:[77]

- Ensuring spectrum is available for the deployment of multiple technologies
- Setting aside IMT spectrum for rural connectivity
- Establishing use-it-or-share-it mechanisms for IMT licence
- Implementing dynamic spectrum-sharing regulation and light licensing regulation for microwave.

2.2.4 Development and implementation infrastructure co-deployment and sharing guidelines[78]

Many operators prefer to invest in their own infrastructure, a costly exercise that few can comfortably manage. This is despite the availability of underutilized resources from other operators and players in the market. The result is high cost of services, environmental degradation due to multiple deployments, poor quality services and low investment in rural and low-income areas.[79] Co-deployment and sharing of infrastructure result in regulatory and economic benefits for all parties involved. This is especially true when the following principles are used during the planning, construction and operation of infrastructure networks of different industries:

- Minimize duplication of infrastructure facilities on the same routes
- Minimize environmental impact
- Establish long-term strategic planning for the development of infrastructure networks, taking into account the convergence of technologies and partnerships between the parties involved
- Minimize economic costs during construction
- Offer open access to narrow the digital divide.

Infrastructure sharing can be broadly categorized into two types:

1. *Passive sharing*, which is the sharing of non-electronic infrastructure, such as power, sites, towers, shelters, poles, ducts, equipment rooms, and security.
2. *Active sharing*, which entails sharing electronic infrastructure, such as the access or core network.

Policies should be put in place to encourage deeper sharing arrangements, including spectrum sharing. [80]The guidelines should prohibit the deployment of an infrastructure where one already exists. This will encourage investors to use the funds in deploying the much-needed infrastructure

75 ITU-D SG1 Document SG1RGQ/328(Rev.1) from the United States
76 ITU-D SG1 Document SG1RGQ/92 from Namibia
77 ITU-D SG1 Document SG1RGQ/385+Annex from the Association for Progressive Communications (APC)
78 ITU-D SG1 Document 1/241 from China,
79 ITU SG1 Document 1/275 from ONAT (Ukraine)
80 ITU-D SG1 Document 1/222 from Mali

in unserved and underserved areas. To make it effective, there is a need to regulate the price at which this infrastructure is made available and to ensure that standards are maintained to promote a competitive and cost-effective environment.

Co-deployment and sharing therefore ensure fair competition in the telecommunication market, encouraging operators to focus more on improving the quality of products and services. Infrastructure sharing has many advantages, including cost savings in equipment costs, reduced licence fees, and risk sharing in low population density areas. This enables entities to pool spectrum to increase efficiency and reduce spectrum costs, encourages new entrants and, ultimately, expedites faster deployment time-frames.

2.2.5 Price regulation

In order to encourage demand for broadband, regulators could consider replacing minimum price regulation with maximum price regulation. A minimum price regulation in general leads to increase in supply but a decrease in demand as consumers face higher prices.[81]

2.2.6 Other regulations

Other regulations that should be considered include data protection, net-neutrality, copyright laws, local and regional IXPs, among others.

2.3 Deployment strategies

Some of the strategies that should be considered include:

2.3.1 Development and implementation of formal broadband plans

Broadband deployments are easily realized when nations, states and local governments create and adopt formalized broadband plans. Plans are effective in assessing and addressing broadband needs, stimulating action on broadband issues, developing necessary goals and achieving actual results.

Some of the basic objectives of the national broadband plans include making broadband Internet accessible to all citizens, encouraging production of local content, digitalizing public services, encouraging new players, developing digital literacy of the populace and establishing digital security and confidence to create the conditions necessary to build the confidence of citizens and businesses in the use of digital technology.[82]

Broadband plans are a practical and operational planning tool that can help countries bridge the digital divide in terms of access to high-speed and reliable broadband. The process of developing a broadband plan may include diagnosis of the current national infrastructure and market as well as an overview of the regulatory framework governing the sector, the target situation in regard to the digital network, analyses of the way forward to reach that target, and proposals for operationalizing the roadmap through an action plan and implementation strategy.[83]

[81] ITU-D SG1 Document SG1RGQ/210 from the Republic of Korea
[82] ITU-D SG1 DocumentSG1RGQ/TD/9 from Mali
[83] ITU-D SG1 Document SG1RGQ/178 from Burkina Faso.

2.3.2 Encourage sharing of deployment plans

One of the biggest obstacles to the co-deployment and co-sharing of infrastructure is the lack of coordination in intersectoral, national and international government policies regarding access to infrastructure, including between regulators of various industries regarding large infrastructure projects that are under implementation. By a fortunate coincidence, the cost of building fibre-optic cable lines (FOCL) can be optimized using the infrastructure of other industries, such as transport and energy, thanks to co-deployment and co-sharing.[84]

Sharing deployment plans between operators and the public entity on a regular basis should be encouraged as an input into infrastructure deployment plans. This will ensure effective utilization of available infrastructure development resources and minimize unnecessary multiple deployments.[85]

2.3.3 Government funding to connect government institutions

Government institutions such as hospitals, schools and libraries can be used as anchor tenants to extend broadband infrastructure across the country. Connectivity to these institutions can be introduced through direct government investment, universal service funds, loan guarantees, grants, and tax incentives.[86] In this way, the infrastructure built to serve these institutions can also be made available to others in the community at a cost through private providers.

One such initiative is the development of community telecentres, which includes Internet connectivity and computer equipment in public utilities for use by residents to provide various services, such as telemedicine, teleworking, e-agriculture, e-tourism, e-governance, distance learning, and e-commerce.[87] One major consideration for such rural projects is the technology to be used, which should be reliable and cost effective.

As best practice, provision of broadband to government institutions should not be limited to public providers only. Eliminating such critical mass customers from the market will only serve to discourage private-sector investment.

2.3.4 Direct government investment

Government investment could be in the following forms:

i. Development of national government backbone infrastructure

With the ever-increasing digital divide between urban and rural areas, governments can invest directly in the deployment of national backbone infrastructure to bridge the gap. This infrastructure could be utilized to provide connectivity to public institutions and the sale of excess capacity to private operators for last-mile connectivity.

[84] ITU SG1 Document 1/275 from ONAT (Ukraine)
[85] ITU-D SG1 Document SG1RGQ/28 from Côte d'Ivoire
[86] ITU-D SG1 Document 1/28 from Burundi
[87] ITU-D SG1 Document 1/125 (Rev.1) from Cameroon

ii. Power company-owned networks

In the last century, strategies were implemented to extend electric power grids to rural areas across the globe. These power grids already have wayleave rights and offer towers, poles and conduit access into nearly all homes and businesses in their area of operation, complete with existing systems and staff. Policies should be put in place to encourage collaboration of power companies with private telecommunication operators and governments to extend broadband infrastructure. With their support, power companies could offer the best solution in extending coverage to rural areas.

iii. Municipal networks

Municipal networks are built and owned by municipalities/cities.

iv. Broadband deployment in underserved and unserved areas

When deploying broadband infrastructure for underserved and unserved areas, financially viable and sustainable investment decisions should be made.[88] But if commercially sound and sustainable investment and service operation do not hold, in other words market failure occurs, then the government should play an active role in assisting the unserved and underserved areas, and not leave them behind. Thus, although the market is the key factor for broadband investment, the government needs to intervene in facilitating broadband connectivity in areas where a market failure occurs. For the unserved and underserved areas where the operators do not provide services voluntarily, government action should be warranted to expand broadband infrastructure for the coverage of those areas, including policy measures to provide specific assistance and to lower the costs of deployment. In other words, the government should finance networks for unserved and underserved areas and establish incentives when the market alone is not able to serve them.[89] This should be accomplished on a technology-neutral basis, considering reliability and total cost of ownership aspects associated with broadband deployment.

In order to achieve universal service, there is a need to support the use of broadband services in low-income areas, which would allow the poor to pay very low fees, and even enjoy mobile Internet access for free. For people in poverty, a special discount package can be included in mobile products and broadband. Some of the areas where governments can deploy broadband for the good of a majority include establishing telecentres, Wi-Fi access in public places and upgrading mobile network infrastructure to provide broadband access.[90]

2.3.5 Establishment of community networks[91]

Often, commercial ISPs do not see a viable business model for deploying affordable broadband to some areas due to factors such as low population density, average income per household, and difficult terrain that often lead to little return on investment. To fill these gaps in connectivity, communities can deploy self-sustaining networks to complement commercial providers. Community networks are therefore an important part of connectivity ecosystems, helping

[88] ITU-D SG1 Document SG1RGQ/210 from the Republic of Korea.
[89] ITU-D SG1 Document SG1RGQ/320 ESOA
[90] ITU-D SG1 Document 1/375
[91] ITU-D SG1 Document SG1RGQ/338 from the Internet Society (ISOC)

connect the unconnected in an affordable manner. In addition, community networks help bring digital skills and tools to rural, remote and underserved areas.

The logistics and administration of community networks are less expensive because of their scale and local nature. These factors make community networks sustainable from an economic perspective. In addition, community networks are environmentally sustainable as they frequently make use of renewable energy, such as solar and wind power. However, these networks face a number of challenges, including access to funding mechanisms, access to appropriate licensing/authorization frameworks and access to necessary electromagnetic spectrum and infrastructure.

On the regulatory front, governments should consider creating enabling regulations and policies to specifically address not-for-profit operators and small-scale operators. This could include creating licence-exemption provisions or free and light licensing for local communities with easy-to-understand applications and low- or no-cost application and renewal fees. Streamlining onerous regulatory obligations, such as annual reporting requirements, would reduce undue burdens.

Governments should also review traditional licensing policies that grant exclusive use instead of shared use of portions of spectrum over large geographic areas. This can lead to large portions of spectrum being unused or underutilized, and exclude community networks that could otherwise connect these areas.

Implementation of innovative funding avenues is key to the success of these networks. This includes crowdsourcing, revenue-sharing models, subscription fees, private grants and funding from governments. While these networks have fewer start-up costs than other approaches to connectivity, access to government funding can be a significant help to their success and goes a long way, since they are often launched in low population density areas and in low-income communities. Often, funds are only needed to help launch a community network until they reach a point of economic balance and scale.

2.4 Financing mechanisms

There are two important financial aspects that determine the success or failure of broadband projects: the financial investment model and the financing model.

The investment model considers all revenue streams and the capital and operating expenses related to the project. More importantly, it determines the business viability of the project by measuring the internal rate-of-return (IRR) and net present value (NPV). This is indeed paramount to ensuring that the goal of sustainability of capital-intensive projects is achieved.

On the other hand, when coming up with a suitable approach to fund investment, it is important to consider their suitability to the geography and market in question in addition to the project's reliance on equity, debt or public funds. Due diligence should be undertaken when settling on a financing structure, as it normally imposes stress on the fund providers and ultimately has an effect on the viability of the project.

Financing broadband deployment can be an expensive affair, more especially for landlocked countries. One way of financing deployments is by putting in place a regional initiative with Member States/jurisdictions contributing to the project. Undertaking cross-country projects not only keeps down the costs, but also reduces the challenges associated with getting regulatory approvals.[92] Broadband financing sources that can be exploited include auctions, conduct adjustment declarations, universalization funds, tax relief and concession contracts.[93]

The following funding mechanisms can be considered:[94]

2.4.1 Public-utility model

Under this model, the government can fund broadband deployment through allocations from the universal service fund (USF) (as is the case of Argentina, Japan, Republic of Korea, United Kingdom and France), low-interest rate loans from development banks, and national grants.

This business model can take several forms including:

i. *National open-access network:* In this model, the assets of private operators are purchased by the government with the option of opening up ownership of the public entity to private investors in the future. In addition, the government invests to extend coverage to underserved regions. The private service providers are then allowed to offer services on the platform at regulated prices.
ii. *National open-access alternative carrier:* The national government builds a completely new national network independent of the other existing networks. The new infrastructure serves to break down potential bottleneck prices that may arise during the incumbent's operation.
iii. *Fund last-mile connectivity to government institutions.*

Universal service funds have traditionally been utilized to provide voice services in underserved areas.[95] A USF can be utilized, among others, to support digital literacy programmes, co-funding with operators for infrastructure deployment where applicable and providing connectivity to public schools, hospitals and government administration centres. There is a need to define clear roles between the management of the USF and the regulator. The role of the universal service management should be restricted to operationalization of the fund, while that of the regulator should focus on oversight, including approval of budgets, plans and evaluations.[96]

One of the major hindrances to accelerated deployment in developing countries is high-interest loans that come with multiple conditions.[97] It is important that jurisdictions consider the impact of the models proposed by development partners, especially in the long term. This financing model of negotiating loans from banks or financial institutions for over-the-counter contracts tends to lead to enormous problems for developing countries, including substandard installations, duplication of infrastructure, and exorbitant and unreasonable market prices.

2.4.2 Public-private financing model

This model is very common with high capital-intensive projects, such as national backbone networks. There are three main variations of PPP models:

i. The public entity's role is limited to that of a sponsor, enabling the private entity to gain access to tax-exempt financing.

[92] ITU-D SG1 Document SG1RGQ/185 from Chad
[93] ITU-D SG1 Document SG1RGQ/195 from Brazil
[94] ITU-D SG1 Document SG1RGQ/253 from Kenya
[95] ITU-D SG1 Document SG1RGQ/11 from Rwanda
[96] ITU-D SG1 Document 1/327(Rev.1) from the United States
[97] ITU-D SG1 Document 1/222 from Mali

ii. The public entity's obligation is limited to guaranteeing a private entity's debt for the project.
iii. The most common one is where the public entity and the private entity create special purpose vehicles in which investors hold ownership rights. Under this model, lending is based on the project's projected income, and lenders ring-fence revenues and hold collateral against the project assets. The success of this model depends on having adequate risk-mitigation mechanisms in place. The public fund is normally used as a guarantee against risk factors affecting profitability.

In recent times, governments have been building partnerships with OTTs and financial institutions for the deployment of broadband infrastructure projects. Finance is a major challenge in infrastructure development and thus access to affordable financial capital is key. These partnerships offer a number of advantages, including fostering accountability and transparency mechanisms. They increase the likelihood of Official Development Assistance and provide an ideal way to access new technologies without expending resources.

2.4.3 Operator-funded model

The private service provider assumes ownership of all equity and debt with regard to the project. Funding can be sourced internally and supplemented with debt finance or, in some cases, the operator can finance the project entirely with debt finance. Normally loans are sourced from lenders at negotiated rates depending on project risks and the company's weighted average cost of capital (WACC).

There are two main variants of this model:

i. The operator assumes *sole responsibility* for financing deployment of broadband on the strength of their market share position and broadband demand in the market.

ii. *Competitive partnering*, where two or more operators enter into an arrangement to deploy infrastructure. Each partner is then allocated distinct roles with regard to the construction and operation of passive infrastructure and brings on board a set of capabilities to the venture.

2.4.4 Promoting last-mile connectivity using reverse auctions

One way of financing broadband connectivity in remote, underserved areas utilizing limited government funds is the use of reverse auctions, which have been successfully implemented by the United States to fund broadband infrastructure projects, to enhance nationwide broadband connectivity and close the digital divide. This model is used to efficiently and effectively allocate limited government funds to broadband providers for last-mile broadband deployment and connectivity in hard-to-reach places.[98]

In a reverse auction, broadband providers compete to build out broadband to a specific number of locations in an unserved area for the smallest government subsidy. The bids represent the amount of government support that a broadband provider would accept in order to commit to providing broadband coverage to the specified locations in an area, while still making a profit. The broadband provider that bids the lowest, after adjusting for quality, is awarded the funding and is required to cover 100 per cent of the locations identified in the areas it won within a specified number of years.

98 ITU-D SG1 Document SG1RGQ/209 from the United States

Reverse auctions have several advantages over more traditional methods to achieve government policy goals for connectivity. First, by adjusting bids based on the quality of service being offered (speed, usage allowance, latency, etc.), a reverse auction can encompass many types of services at the same time (satellite, fixed wireless, fibre, etc.) and find the service that is the best fit for each area. Second, by considering many unserved and hard-to-serve areas at once, a reverse auction can efficiently distribute government funds to those areas where government support will make the greatest impact.

2.4.5 Selecting the most appropriate financing models

It is good to note at this point that there is no perfect model to fund the deployment of broadband. One model may be appropriate for a certain project, but it is important for decision-makers to select an optimal model depending on the characteristics of the particular market. It is therefore advisable to have a mix of two or more of these funding options so as to spread the risks and utilize their diverse experience in the projects. Funding constraints vary with the financial muscle of the service provider and the technology to be deployed.

The most suitable model varies depending on the geographical location of the project being deployed. Given the larger number of potential subscribers in cities and urban centres, there are potential benefits when the government co-invests with the private sector in the deployment of passive infrastructure. The government can leverage on the private sector's advantage of controlling the market through an open-access model to access attractive financing terms. This model guarantees that the project can rapidly become self-sufficient and provide additional investment funding from the generated cash flow.

Selecting the most appropriate financing mechanism for rural areas can be tricky given the challenge of low rate of return due to the smaller number of users. Two models have been used and have proved useful in this geography: at one end of the spectrum, public funds are used to finance the entire project while, at the other, the government gives private entities subsidies to venture into rural areas.

Chapter 3 – Transition to high-speed and high-quality broadband networks

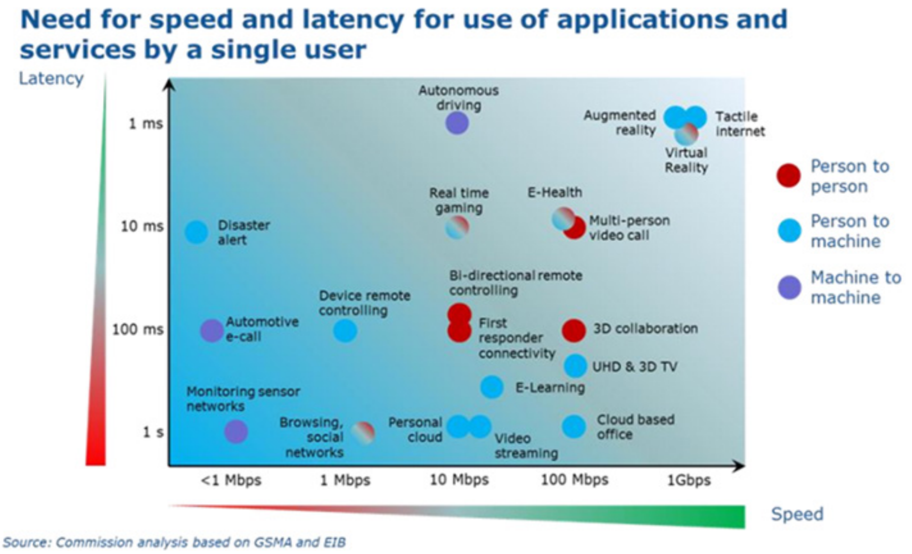
3.1 Importance of high-speed and high-quality broadband

Developing countries need to transition from low-speed broadband networks to high-speed and high-quality broadband networks. This transition is also essential in order to benefit from the social and economic benefits of digital transformation, as in developed countries.[99]

The outcomes of the World telecommunication Development Conference (Buenos Aires, 2017) (WTDC-17), including the definition of Question 1/1, Resolution 43 (Rev. Buenos Aires, 2017), on assistance in implementing IMT and future networks, and the regional initiatives, underline the importance of high-speed, high-quality broadband for developing countries.[100] More than 90 per cent of broadband users in developing countries are using mobile-broadband networks. Therefore, the transition to 5G (IMT-2020), a high-speed, high-quality mobile-broadband network, is very important.

Download and upload speeds can determine what kinds of applications are possible for broadband users. **Figure 3.1** illustrates the need for Internet connectivity speed and responsiveness for a single use of an application or a service. This need increases for multiple uses, which have become the norm since a single user often has simultaneous uses (such as watching TV and using social networks) and a single connection often serves multiple users simultaneously (households with children, SMEs and organizations like schools and libraries).

Figure 3.1: The importance of high-speed broadband



Source: European Commission analysis based on GSMA and EIB

[99] ITU-D SG1 Document SG1RGQ/69 from Intel Corporation

[100] ITU. Final Report of the World Telecommunication Development Conference (Buenos Aires, 2017) (WTDC-17). Geneva, 2018.

Low latency, reliability and guaranteed service level are important factors for high-quality broadband services.

While there is a variety of latency requirements for each specific service or application, some applications that can require low latency include:[101]

- *Factory automation:* Applications such as machine tools operation may allow latency as low as 0.25ms.
- *Intelligent Transport Systems (ITS):* Road safety of ITS requires a latency in the order of 10 ms.
- *Robotics and telepresence:* Touching an object by a palm may require latency down to 1 ms.
- *Virtual reality:* High-resolution 360° VR requires a latency of 1 ms.
- *Healthcare:* Tele-diagnosis, tele-surgery and tele-rehabilitation may require latency in the order of 1 ms.
- *Advanced gaming:* Immersive entertainment and human interaction with high-quality visualization may require latency of 1ms.
- *Smart grid:* Dynamic activation and deactivation in smart grid requires latency in the order of 1 ms.
- *Education and culture:* Tactile Internet-enabled multi-modal human-machine interface may require latency as low as 5 ms.
- *Precision agriculture:* Real-time connectivity with agricultural machines and drones to achieve maximum performance requires latency of less than 1 sec.
- *Emergency, disasters and public safety:* 5G will also play an important role for mission-critical applications, such as early warning systems (earthquakes and tsunami and other natural disasters) embodying high accuracy, low latency and other features.
- *Differently abled people:* New innovative applications will require low latency real-time communication.
- *Speech-to-speech translation:* Real-time speech-to-speech translation will require very low latency.

3.2 Transition to high-speed and high-quality broadband networks

3.2.1 Transition to high-speed and high quality mobile broadband networks (5G)

Unlike previous generations of mobile networks, 5G is expected to fundamentally transform the role that telecommunication technology plays in society. Technically, 5G is a system designed to meet the requirements of IMT-2020 set by the ITU-R specification M.2083 and M.2150 (Detailed specifications of the terrestrial radio interfaces of IMT-2020).[102] 5G will provide more advanced and enhanced capabilities compared to 4G LTE (IMT-Advanced). It can be noted that 5G will aim to provide 20 times the peak data rate (speed), 10 times lower latency (responsiveness) and three times more spectral efficiency than 4G LTE. 5G has three major use case classes: enhanced mobile broadband (eMBB), massive IoT (Ma-IoT) and ultra-reliable low latency (URLLC). The requirements for the use case classes and the use cases within each class vary significantly.[103]

[101] Imitiaz Parvez et al. A Survey on Low Latency Towards 5G: RAN, Core Network and Caching Solutions. arXiv: 1708.02562v2 [cs.NI], 29 May 2018.

[102] ITU. Recommendations ITU-R M.2083, on IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond, and ITU-R M.2150, on Detailed specifications of the terrestrial radio interfaces of IMT-2020.

[103] ITU-D SG1 Document 1/224 from Intel Corporation

To realize the potential of 5G, jurisdictions may consider a number of strategies, including freeing up more spectrum for the commercial marketplace, promoting wireless infrastructure deployment, and modernizing existing regulations to promote more fibre deployment, among others. For possible measures to have a significant impact, it is paramount that regulators actively engage with all relevant stakeholders.

In terms of spectrum bands earmarked for deployment of 5G, they can be sub-divided into three macro categories: sub-1 GHz, 1-6 GHz and above 6 GHz. Sub-1 GHz bands are suitable to support IoT services and extend mobile-broadband coverage from urban to suburban and rural areas. The 1-6 GHz bands offer a reasonable mixture of coverage and capacity for 5G services. Spectrum bands above 6 GHz provide significant capacity, thanks to the very large bandwidth that can enable enhanced mobile-broadband applications.

This variety of requirements and spectrum needs show that there are many options for the introduction of 5G, and different spectrum bands will be needed to support all use cases. Operators must therefore consider the feasibility of different options in meeting their intended initial use cases and interoperability of their choice with other options to ensure their networks deliver the use cases effectively while supporting global interoperability.[104]

3.2.2 Transition to high-speed and high-quality wireless broadband networks

Advancements in wireless technologies such as Wi-Fi have a significant impact in improving access to broadband, especially in rural areas. To promote such deployments, jurisdictions are encouraged to increase the supply of unlicensed spectrum. This will be key in ushering in new generations, such as Wi-Fi 6, that will play a major role in the growth of IoT. Unlicensed devices can be allowed to access this spectrum together with licensed service providers.[105]

3.2.3 Transition to high-speed and high-quality fixed-broadband networks[106]

The explosion of data needs triggered by the digital transformation has opened the way to mass deployment of international fibre infrastructure worldwide. Nevertheless, there are still a large number of population centres, particularly in developing countries, which remain unconnected by fibre while many others are only connected by high-cost or unreliable fibre links. The wide variety and many factors in the affordable connectivity equation underscore the need for an integrated approach to provide affordable access to international fibre infrastructure.

At present, lower wholesale copper access prices are competitive when set against the price of fibre services, adversely affecting the take-up of fibre. There is no consensus on the most appropriate approach to pricing during the transition from copper to fibre. NRAs should consider allowing incumbents to withdraw copper-based access products as soon as they offer fibre-based access services, to prevent the undermining of the business case for more expensive fibre services. NRAs may consider policies and financial incentives to encourage migration from copper to fibre and to stimulate the deployment and take-up of fibre services.

104 ITU-D SG1 Document SG1RGQ/328(Rev.1) from the United States
105 Ibid.
106 ITU. ITU-D Policy and Regulation. Global ICT Regulatory Outlook 2018. Geneva, 2018.

Examples for transition from copper to fibre:

- The **Government of Australia** imposed a deadline of 2020 by which all premises are to be migrated from copper to fibre. In 2014, Telstra (Australia) began to switch off services being delivered over its copper networks. The government-funded NBNCo initiative, which has driven wholesale fibre connectivity across Australia, will switch off copper networks in areas where NBNCo already provides fibre services.
- **Verizon (United States)** requested regulatory permission to migrate its copper network in selected markets from 2018. Verizon delivers services via its fibre infrastructure and wishes to cease maintaining the copper facilities in Virginia, New York, New Jersey, Pennsylvania, Rhode Island, Massachusetts, Maryland and Delaware.
- **ComReg, the Irish telecommunication regulator**, has launched a consultation on the potential of its incumbent operator, Eir, to transition from copper in some parts of the country, particularly in areas of extensive fibre coverage.
- **Singtel (Singapore)** announced plans to discontinue its copper-based ADSL network in April 2018 as it accelerates fibre-based service adoption for its business and residential customers in the city.
- **Chorus (New Zealand)** is set to get regulatory relief from its copper network under plans to deregulate the copper network where it competes with fibre access networks from 2020.

3.3 Best-practice guidelines

A list of best-practice guidelines for the transition to high-speed and high-quality broadband networks is given below:[107]

- Get political support at the highest level (presidents, prime ministers) on the importance of high-speed broadband network investment for digital transformation and the economy.
- Develop a national/regional strategy and targets for the transition to high-speed broadband networks.
- Develop a broadband and 5G plan/strategy taking into account the complementarity of several technologies.
- Prioritize the transition to high-speed broadband networks in the national/regional digital transformation (digital economy) plans.
- Establish a national committee on high-speed broadband connectivity in collaboration with telecommunication operators and industry.
- Determine national and priority coverage areas for high-speed broadband connectivity in urban and rural areas, cities/villages, schools/universities, hospitals/health clinics, government departments, SMEs, transportation (roads, railways, harbours, airports), industrial, business and agricultural areas.
- Provide sufficient amount of radio-frequency spectrum for 5G and adopt a technology/service-neutral approach in the licensed 3G/4G frequency bands for the transition to 5G.
- Provide sufficient spectrum for new advanced Wi-Fi technologies.
- Provide sufficient access to spectrum for use by satellites, including by high-capacity satellite services.
- Implement high-speed fixed wireless access (FWA) technologies both in urban and rural areas.
- Promote facilities-based competition.
- Support high-speed broadband network investment of telecommunication operators through different incentive subsidies, sound tax policy, infrastructure sharing, licence fee and conditions, and financial support such as through a universal service fund (USF).

[107] ITU-D SG1 Document SG1RGQ/371(Rev.1) from Intel Corporation (United States)

- Cooperate with municipalities and local authorities to aggregate demand and ease right-of-way fees, cellular tower sites, etc.
- Promote investments in new fibre-optic networks and other high-speed wireless broadband infrastructure.
- Provide effective use of USF for high-speed broadband network and access programmes.
- Develop funding models for high-speed broadband networks.
- Consider benefiting from the budget/funds of different ministries and municipalities by developing joint projects, such as on e-agriculture, e-health, e-learning and smart cities.
- Implement measures to decrease infrastructure deployment costs.
- Implement a sound taxation regime on broadband-related devices and services to reduce the cost of ownership, making high-speed broadband more affordable.
- Develop a national broadband map and determine the existing resources and gaps for high-speed broadband access.
- Consider obligations in licence terms to meet certain coverage, deployment, speed or other quality of service requirements, or to uphold competition in the market.
- Implement effective ICT policy and regulations to pave the way for the deployment of very high-capacity networks (VHCNs) such as fibre, DOCSIS cable and 5G mobile.
- Plan and distribute/extend the capacities of submarine and regional/national backbones at the national level.
- Stimulate demand by increasing broadband awareness and digital literacy, emphasizing the promotion of high-touch distribution channels, and accelerating the uptake of high-speed broadband.
- Increase relevant local content and applications, particularly those related to education, government services, and economic productivity.

3.4 Country/regional examples

According to **Japan**'s experience, one of the possible strategies for the deployment of 5G infrastructure is to combine it with the promotion of 5G utilization, as two sides of a coin.[108]

Rural areas can benefit from 5G through initiatives such as Local 5G, which allow them to construct their own spot-like 5G networks. Otherwise, the deployment of commercial 5G services in rural areas would come later than in urban areas. 5G is creating many different types of value, and is expected to be able to address rural or regional needs to solve challenges faced by local communities in many fields, such as daily life, industry, healthcare and disaster response.

The Ministry of Internal Affairs and Communications (MIC) of Japan has been conducting 5G comprehensive demonstration tests for three years since the 2017 financial year, with the aim of launching 5G commercial services in 2020, as well as creating new markets.

Local 5G is one new initiative from MIC that allows various entities, such as local companies and local governments, to flexibly construct and use spot-like networks in their own buildings and premises. With Local 5G, regional entities may build and deploy their own networks well before they are covered by nationwide commercial mobile operators, or even outside commercial network coverage areas.

In **Viet Nam**, the number of subscribers with fixed-broadband and mobile-Internet access has increased year by year. Mobile-broadband subscribers benefited most from the deployment of a robust 4G network infrastructure in recent years and the upcoming 5G network. Viet Nam

[108] ITU-D SG1 Document 1/361 from Japan

has been testing 5G since 2019 and is on a roadmap for 5G commercial deployment in 2020. Viet Nam is building a digital transformation strategy, taking advantage of the achievements of the Industrial Revolution 4.0 to achieve the goal by 2025, when broadband Internet will cover all communes in the country. By 2030, there will be 5G mobile network coverage nationwide, and all citizens will have access to low-cost broadband Internet.[109]

Brazil adopted asymmetric measures as a tool for increased competition in broadband and regional deployment of high-speed networks in small and medium-sized cities. Fixed broadband showed steady growth in the last half of 2019, especially characterized by three movements: the leadership of net additions by the group of regional providers that has grown 3.5 times over 2019 compared with larger groups; the increase in fibre-optic connections; and the increase in speeds above 34 Mbit/s.[110]

The regional providers began operations in the second half of the 1990s, initially using the dial-up network. The need for increased access speed and convergence in the regulatory framework has had an impact on the creation of their own networks by these companies, initially with ADSL technology and later through optical technology. Regional providers are spread all over Brazil and operate in 99.8 per cent of Brazilian municipalities.

Small island States are experiencing an ever-increasing improvement in international connectivity ensured by submarine optical fibre cables, as virtually all such States are connected to the rest of the world by several optical fibre links. Users in these countries are satisfied with the resulting improvements, in terms of both the diversity of offer and the quality of broadband services.

The problem lies in the fact that these markets are very limited, and operators find it difficult to recover their investments. The populations of small island States are too small to generate sufficient traffic and revenue for operators, thus only a very small proportion of the capacity made available to users is actually used. Broadband can only be deployed in the small island States based on a model adapted to the size of their populations, as best practices accepted for large countries can pose problems in such island nations.

Comoros has invested large amounts in submarine optical fibre connectivity, placing enormous capacity at its disposal. Comoros is currently using 22 per cent of the capacity purchased and 4 per cent of the capacity hypothetically available. The infrastructure is thus being used extremely inefficiently. As major transformations have occurred in the past decade in both the local industry and the deployment of digital services, Comoros must mobilize this potential in pursuit of its socio-economic development.[111]

In **Chad**,[112] the broadband telecommunication infrastructure using optical fibre links consists of:

- A connection linking N'Djamena to Cameroon via Bongor
- A second connection linking N'Djamena to Port Sudan
- A third link known as the Trans-Saharan Backbone.

Planning an optical fibre grid across the country will help to end the digital isolation of the various regions of Chad. Deploying optical fibres will allow the Internet to become commonplace throughout Chad as a tool for development, to be taken up by as many people as possible.

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109 ITU-D SG1 Document 1/357(Rev.1) from Viet Nam
110 ITU-D SG1 Document 1/387 from Brazil
111 ITU-D SG1 Document 1/333 from Comoros
112 ITU-D SG1 Document SG1RGQ/185 from Chad

The **Central African Republic**[113] moved into the implementation phase of its project to establish a fibre-optic connection (CAB) between itself, **Cameroon** and the **Republic of the Congo** enabling it to obtain access to the submarine cables in the Atlantic Ocean. This followed the signing of a co-funding agreement by the African Development Bank (AfDB) Group and the European Union with the Government of the Central African Republic in Bangui in January 2018. The Central African Republic component, for its part, comprises:

i. Installation of over 1 000 km of optical fibre, connecting the country with Cameroon and the Republic of the Congo
ii. Establishment of a national data centre and an IXP linked to an electronic administration platform, enabling cost reductions in international Internet connectivity in accordance with ITU-T D.50 Supplement 2: 'Guidelines for reducing the costs of international Internet connectivity'.[114]

For the operation and management of its CAB, the Central African Republic opted for an open-access approach in anticipation of a public-private partnership. Operators legally established in the Central African Republic, such as Socatel, the traditional State operator, and the other four private mobile operators, have been invited to take up holdings in the new company responsible for the management and operation of the CAB cable.

Strategically, the cost-effectiveness of the CAB cable will free up capital to connect the remaining 14 prefectures of the Central African Republic to the CAB and their service areas along the route in order to increase ICT connectivity in these areas and in isolated rural areas. Last-mile technology (Wi-Fi, WiMAX, 3G and 4G) will be used to connect villages and sub-prefectures adjacent to the Central African Republic's CAB in order to connect them to the national and international networks.

In **India**,[115] the implementation of a submarine cable project will provide a robust and reliable telecommunication facility to the people of the Andaman and Nicobar islands. It will also boost the tourism potential of these islands. It will fulfil the basic goals of universal service obligation: universal availability, universal affordability and universal accessibility. Experience gained through this project can be utilized for future projects, including laying of a submarine cable between the mainland and the Lakshadweep Islands in the Arabian Sea. In future, this cable can be a part of the South Asian Association for Regional Cooperation (SAARC) cable or can be connected to Myanmar as an alternate connectivity route for India's north eastern region. Further, this can be extended to cover the Association of Southeast Asian Nations (ASEAN) region.

Presently, the Andaman and Nicobar Islands are connected with the mainland through satellite links. In the absence of any alternate connectivity, these islands would be totally cut off from the rest of the country in the eventuality of a breakdown of the satellite links. The absence of a robust and reliable telecommunication network with the mainland has been felt acutely, particularly during natural disasters and calamities.

Providing telecommunication connectivity to these islands is a big challenge, not only with the mainland but also with inter-island telecommunications. With its relatively small population of around 380 000 spread across many islands, providing telecommunication services in all

113 ITU-D SG1 Document 1/29 from the Central African Republic
114 ITU, Supplement 2 to Recommendation ITU-T D.50, on Guidelines for reducing the costs of international Internet connectivity.
115 ITU-D SG1 Document 1/57 from India

inhabited islands is not a viable commercial proposition for the telecommunication service providers. Very few telecommunication service providers have launched their services in these islands.

Some specific challenges in providing telecommunication services to these islands:

i. *Non availability of submarine cable:* At present, no submarine cable connectivity with the mainland is available to these islands, which poses constraints in providing high-speed data and voice services to the citizens of the Andaman and Nicobar Islands.
ii. *High satellite bandwidth cost:* Due to the absence of any submarine cable connectivity, telecommunication connectivity with the mainland and between different islands is provided only through satellite links. The cost of satellite bandwidth is very high at present and it also depends on the footprints of satellites over these islands. Due to these factors, providing telecommunication services in these islands is commercially unviable.
iii. *Topographical challenges:* The Andaman and Nicobar Islands are spread across around 780 km in length, with a total geographical area of 8 249 square km in the Bay of Bengal.[116] Only Port Blair is connected by air service to the mainland. Due to the limited availability of transportation, travel from one island to the other is another challenge. These islands are also prone to natural disasters, such as earthquakes, tsunamis, cyclones and other maritime disturbances.
iv. *Higher cost of infrastructure:* The cost of infrastructure development is much higher as compared to the mainland. The labour force and employees are mostly brought from the mainland, increasing the cost of any project. Due to large inter-island distances and non-availability of jetty facilities on some islands, transportation of material and personnel is a big challenge and comprises a significant component of the total cost of infrastructure development.
v. *Land and power-supply constraints:* The power supply is mainly generated through diesel-powered equipment. Frequent power fluctuations and limited power availability hamper the continuous operation of existing telecommunication infrastructure. The supply of diesel itself is scarce on the islands owing to the non-availability of transportation facilities, further hampering reliable power supply. Environmental protection laws impose restrictions on activity in forest lands, and laws against the acquisition of tribal land held by the local population leaves little space for the installation of telecommunication infrastructure.

In view of these challenges and the non-viable commercial conditions, it was felt necessary for the government to step in and utilize the Universal Services Obligation Fund (USOF)[117] for augmentation and development of telecommunication infrastructure and connectivity in the Andaman and Nicobar Islands. The Indian Government has approved a proposal to provide a direct communication link through a dedicated optical-fibre submarine cable between the mainland (at Chennai, Tamil Nadu) and Port Blair as well as seven other islands.

The submarine cable would equip the Andaman and Nicobar Islands with appropriate bandwidth and telecommunication connectivity for the implementation of e-governance initiatives and the establishment of enterprises and e-commerce facilities.

[116] Directorate of Census Operations – Andaman and Nicobar Islands. Census of India 2011. Andaman & Nicobar. Series - 36, Part XII-A.

[117] The Universal Service Obligation Fund of India came into being with effect from 1 April 2002 with the passing of the Indian Telegraph (Amendment) Act, with the mandate of providing access to telecommunication services to people in rural and remote areas at reasonable and affordable prices. The source of this fund is a universal service levy collected at 5 per cent of adjusted gross revenue of all telecommunication service providers except value-added service providers.

In **Europe**, the recent European Commission policy framework[118] underlines the significance of NGN technology by including NGN deployment as part of a growth strategy for economic and social development. In order to reap the full benefits offered by ICTs, and to remain competitive in international markets, widespread and stable access to high-speed Internet infrastructure and services have been targeted.

The following goals have been set for 2020:

- 30 Mbit/s coverage or more for all EU Member States
- 50 per cent of households to have 100 Mbit/s subscriptions or higher

There is still a need for action before every user has access to NGNs. In 2014, only 68 per cent of all EU households had access to bandwidths of 30 Mbit/s. Meeting the challenge of financing a good-quality and cost-efficient broadband infrastructure is a crucial factor. In the context of investing in high-speed digital networks, mapping of broadband infrastructure is a key success factor that enables policy-makers to plan ahead.

The mapping of broadband infrastructure benefits a variety of stakeholders. For example, for policy-makers and regulators to assess policy interventions, they need large-scale independent measurements to assess network performance when deciding about State aid schemes, and owners of electronic network infrastructure and operators of electronic communications services could be helped with investment planning or market research. With the importance and benefits of mapping of broadband infrastructure in mind, the Electronic and Postal Communications Authority (AKEP) in **Albania** has developed a system for mapping broadband infrastructure.

While initial development was carried out by external contractors, AKEP created additional system requirements when using the tool, upgrading the system to fulfil their requirements, especially for regular and ad hoc analysis and reports. AKEP also carried out benchmark research across Europe with other mapping tools and found that a good broadband mapping tool was being used in **Slovenia**.

In February 2016, a twinning concept was brought forward with the help of ITU whereby the Agency for Electronic Communications Networks and Services (AKOS) in Slovenia worked with AKEP on a project to map the telecommunication infrastructure in Slovenia.

The Agency for Electronic Communications and Postal Services (EKIP) of **Montenegro** has developed a system for mapping broadband infrastructure and broadband network, as well as broadband infrastructure plans, with a tool that meets their requirements for analysis and reporting. Continuous monitoring of trends in mapping is an important tool for the effective development of broadband networks.[119]

The state of broadband connectivity in **Europe**[120] and the current trends in its modernization will not fulfil the growing needs for better and faster Internet, enabled by very high-capacity networks. They are needed for citizens and businesses to develop, deliver and enjoy online goods, applications and services across Europe. The success of e-commerce, the reliability of e-health applications and the user experience of video and audio content in gaming and streaming all depend on the quality of networks.

118 ITU-D SG1 Document SG1RGQ/46 from BDT Focal Points for Question 1/1 and Question 5/1
119 ITU-D SG1 Document 1/447 from Montenegro
120 ITU-D SG1 Document SG1RGQ/70 from Intel Corporation (United States)

Very high-capacity networks are also necessary to maximize the growth potential of the European digital economy. Instantaneous transmission and high reliability will allow hundreds of machines to cooperate in real time in industrial, professional or domestic settings. Ubiquity will allow cars to drive autonomously. Responsiveness and reliability are key factors enabling doctors to conduct surgery remotely and for cities to adapt energy consumption or traffic lights to reflect real-time needs. High upload/download speeds will allow businesses to hold high-definition (HD) videoconferences with many participants in different locations or to work on common software in the cloud. Students will be able to follow courses provided by universities located in other Member States.

Very high-capacity networks are needed to ensure territorial cohesion, for every citizen in every community across Europe to be part of, and to benefit from, the Digital Single Market. For Europe's growth, jobs, competitiveness and cohesion, very high-capacity networks are becoming a necessity. A recent study estimates that successful deployment of 5G could bring about EUR 113 billion per annum in benefits in four industries (automotive, healthcare, transport and utilities), with benefits widely spread over business, consumers and the wider society.

In order to define more precisely what Europe's future Internet connectivity should look like, a set of objectives for network deployment by 2025 was established. They aim at building a gigabit society, relying on very high-capacity networks, that will ensure the benefits of the Digital Single Market for all.

In the past few years, a new family of wholesale services has been introduced in **Spain**.[121] The new reference offer has been called NEBA, standing for *Nuevo servicio Ethernet de Banda Ancha* (New Broadband Ethernet service). This new service is a level-2 bitstream offer, which allows alternative operators to access both copper and FTTH subscribers.

NEBA services allow alternative operators to connect directly to the regional Ethernet network (Layer 2). NEBA services include access to both copper and fibre services with throughputs currently up to 600 Mbit/s symmetric (only in fibre) and under three QoS modes (Best Effort, Gold and Real Time) which ensure certain levels in terms of packet losses, latency and jitter.

From a technical perspective, NEBA-related services differ from previous offerings in two main aspects:

- Interconnection is effected at OSI Layer 2, instead of Layer 3
- They allow access to FTTH accessories, while traditional services are related only to copper.

Like other countries in Africa, **Burundi**[122] has realized what society stands to gain thanks to telecommunications. In order to build the Burundi of tomorrow, the government decided to draw up a broadband policy that would serve as a roadmap for all telecommunication/ICT stakeholders.

For Burundi, the broadband – or high-speed – strategy is intended to promote a knowledge society of communities with access to high-speed national connectivity promoting the socio-economic development of all citizens. It is also in line with the government's vision of ICT development. As the President of Burundi, Pierre Nkurunziza, said on 19 December 2016, the government's vision is to make Burundi a regional centre of ICT excellence by 2025.

[121] ITU-D SG1 Document 1/158 from Axon Partners Group Consulting (Spain)
[122] ITU-D SG1 Document SG1RGQ/167 from Burundi

The general objective of Burundi's *National Broadband Plan* is to maximize the socio-economic benefits for citizens, notably to:

- promote broadband deployment throughout the country (in stages);
- increase broadband use and the number of users:
- guarantee the availability of broadband services at an affordable price.

The plan's anticipated outcome is a significant increase in the broadband Internet penetration rate. All major cities should have an optical fibre network.

The *Burundi Broadband 2025 strategy:* The strategy defines how to provide, as quickly as possible, the means needed to achieve broadband connectivity and enable the operation of associated services throughout the country at an affordable cost. Implementation of the broadband strategy requires the investment of colossal sums.

There are three major sources of investment and funding for the installation of broadband infrastructure:

- private finance;
- government funding;
- funds from public-private partnerships.

The aim of the broadband strategy is to provide a roadmap setting out all the measures required in the short term, medium term and long term to turn Burundi into an emerging society through digital technologies. Its implementation requires a long-term commitment and considerable action on the part of the State, local authorities, the executive and parliament, and strong private sector participation.

Chapter 4 – Indirect aspects for the deployment of broadband

4.1 Transition from IPv4 to IPv6

Using Internet Protocol version 6 (IPv6) and its related strategies is an inevitable necessity for the development of information technology in any country.

Burundi[123] is preparing to migrate from Internet Protocol version 4 (IPv4) to IPv6. On 30 August 2017, the *Agence de Régulation et de Controle des Télécommunications* (ARCT), the country's regulatory agency, organized, in collaboration with the *Agence universitaire de la francophonie* (AUF), the African Network Information Centre (AFRINIC) and the Burundian Internet access provider (CBINET), an awareness-raising workshop for the Burundian authorities on the theme of migrating IPv4 to IPv6. The latter is more reliable and presents a number of benefits, including reliability, resilience, flexibility, interoperability, compatibility and high security.

In the **Islamic Republic of Iran**,[124] IPv6 development and migrating from IPv4 is done with nationally coordinated management and the establishment of software and hardware infrastructure.

The most important activities conducted in the Islamic Republic of Iran are:

- IPv6 island implementation in the infrastructure communications and the country's major operators
- Establishing the Iran IPv6 task force by the Ministry of Communications and Information Technology with the participation of universities and other organizations in the country
- Formation of the IPv6 country team
- Codifying the IPv6 migration map
- Codifying IPv6 implementation requirement instructions
- Codifying an IPv6 requirement document on ICT equipment.

In **Mexico**,[125] the Federal Telecommunications Institute (IFT) developed initiatives to promote and foster transition to the use of the IPv6 protocol. The IFT developed a microsite to provide information about the benefits and advances of its adoption in Mexico. The microsite is addressed to Internet users, academics, industry, those interested in the sector, dependencies and federal, state and municipal entities.

In **Oman**,[126] the Telecommunications Regulatory Authority (TRA) published, in April 2018, the National IPv6 Transition Plan for all public and private entities, with emphasis on adherence to the action plan according to the designated time-frame.

[123] ITU-D SG1 Document 1/28 from Burundi
[124] ITU-D SG1 Document 1/78 from the Iran University of Science & Technology (Islamic Republic of Iran)
[125] ITU-D SG1 Document 1/185 from Mexico
[126] ITU-D SG1 Document 1/204 from Oman

TRA formed a task force to prepare the National IPv6 Transition Plan and to oversee its implementation in order to achieve the following objectives:

- Drive IPv6 adoption in Oman through initiatives
- Facilitate IPv6 deployment for government entities that are connected to the Oman Government Network (OGN)
- Direct government entities, banks, oil and gas companies and others to migrate to IPv6 by 2020
- Address issues for nationwide implementation of IPv6, including address allocation, migration process, equipment, human capacity and policy assistance.

The **Central African Republic** is not being bypassed by the IPv6 revolution.[127] In order to ensure a smooth transition from IPv4 to IPv6 and the necessary political will and orientation of the principal stakeholders, given the country's socio-economic situation and military and political backdrop, the strategic objectives have been separated into three groups:

i. for the general administration;
ii. for telecommunication operators and Internet access providers (IAPs);
iii. transitional process prior to migration from IPv4 to IPv6.

IPv6 addresses are not compatible with IPv4 ones, and communication between a host with only IPv6 addresses and another with only IPv4 addresses poses a problem for the administration and stakeholders, including operators and IAPs. Consequently, there needs to be an interim provision in place prior to the complete migration to IPv6. The goal of this transitional phase is to allow Central African workplaces with IPv6 and/or IPv4 addresses to be able to communicate among themselves, with IPv6 routers gradually being put online at the national level throughout the country. The second phase will involve extending double stack to the greater part of the Central African Internet. Tunnelling will therefore gradually become increasingly unnecessary. The final phase will be the gradual jettisoning of IPv4 at the national level.

ARIN – one of the five regional Internet registries (RIRs)) – maintains a community blog called *"Team ARIN"* (www.teamarin.net) as a public service to inform individuals, businesses, civil society and governments on issues facing the Internet community. Team ARIN also features a library of IPv6 case studies which offer detailed accounts from organizations that have already made progress on their IPv6 journey.[128]

On the blog, guest authors from different organizations, including government, the private sector and academia, post material on ways to overcome challenges at all levels and to share all the opportunities related to IPv6 implementation and encourage others to adopt IPv6. The case studies are available at https://teamarin.net/get6/ipv6-case-studies/

4.2 Using NFV- and SDN-based networks

4.2.1 Software-defined networking (SDN)

SDN[129] has the following principles:

- separation or disaggregation of control plan and data plan;

[127] ITU-D SG1 Document SG1RGQ/27 from Central African Republic
[128] ITU-D SG1 Document 1/221 from the American Registry for Internet Numbers (ARIN)
[129] ITU-D SG1 Document SG1RGQ/339 from Algérie Télécom SPA (Algeria)

- centralized control;
- programmability and automation through APIs using scripting languages: Python, C/C++, Java, R, Ruby, and others.

SDN is a set of techniques that enables users to directly programme, orchestrate, control and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner.

SDN provides the following high-level capabilities:

- *Programmability*
  The behaviour of network resources can be customized by SDN applications through a standardized programming interface for network control and management functionality. The user of the interface may be network providers, service providers and customers, including end users. This enables the SDN applications to automate the operations of network resources according to their needs.
- *Resource abstraction*
  The property and behaviour of underlying network resources can be appropriately abstracted and understood, orchestrated, controlled and/or managed by those who programme them, thanks to relevant, standard information and data models. These models provide a detailed, abstracted view of physical or virtualized network resources.

4.2.2 Applying SDN in segment routing-MPLS service provider networks

Defined as a modern variant of source routing, segment routing simplifies the network by removing network state information from intermediate routers and placing path state information into packet headers.[130] Segment routing can leverage either Multiprotocol Label Switching (MPLS) or IPv6 on the forwarding plane. When segment routing uses the MPLS forwarding plane, it is referred to as SR-MPLS. SR-MPLS supports both an IPv4 and IPv6 underlay. The introduction of SDN plays a key role in automation and programmability in segment routing-MPLS networks, allowing several advantages. Segment routing (IETF name: SPRING) delivers network simplification by eliminating MPLS signalling protocols such as LDP and RSVP. A key benefit of the SDN controller is its ability to provide bandwidth reservation, which segment routing by itself does not do well.

4.2.3 Telco cloud

Telco cloud[131] is an essential piece towards the evolution from a communication service provider (CSP) to a digital service provider (DSP). The telco cloud combines the benefits of cloud computing, network functions virtualization (NFV) and SDN.

The telco cloud aims to take the cloud computing model into telecommunication infrastructure by building software that can run on commercial off-the-shelf (COTS) hardware to deliver virtual network functions (VNFs).

Flat, scalable cloud architectures increase the need for robust overlays (virtual networks) to achieve greater agility and mobility and for a vastly simplified operational model for the underlay physical networks. SDN attempts to address these requirements by allowing networks and

[130] ITU-D SG1 Document SG1RGQ/362 from Algérie Télécom SPA (Algeria)
[131] ITU-D SG1 Document SG1RGQ/330(Rev.1) from Algérie Télécom SPA (Algeria)

network functions and services to be programmatically assembled in any arbitrary combination to produce unique, isolated and secure virtual networks on demand and in a rapid manner.[132]

4.3 Development of Internet exchange points (IXPs)

4.3.1 IXP in Bhutan

The Department of Information Technology and Telecom (DITT), Ministry of Information and Communications (MoIC) of **Bhutan**, is in the process of establishing the Bhutan Internet Exchange (BIX), an IXP, in Thimphu Tech Park, Thimphu.[133] The BIX operates as an open neutral platform for interconnecting Internet networks in Bhutan. BIX membership is open to all qualifying entities – network operators, service providers, infrastructure operators and content providers – on a voluntary basis. The IXP infrastructure consists of a single Ethernet switch supporting 1 Gbit/s and 10 Gbit/s port speeds. The IXP infrastructure also includes a host with a web server providing a list of BIX members, joining information, aggregate traffic graph, and a *Looking Glass* giving access to the list of prefixes available at the IXP. The IXP infrastructure may include other devices only at the discretion of the IXP Board.

4.3.2 Model memorandum of understanding on the interconnection of the CGIX (Republic of the Congo) and GAB-IX (Gabon) IXPs

A model MoU between two IXP authorities in neighbouring countries could help develop IXP in different countries, as illustrated by the case of the **Republic of the Congo** and **Gabon**.[134] This MoU allows the entities responsible for managing IXPs to strengthen cooperation between the States. It facilitates the establishment of Internet data servers around the world. It is a promising policy for the development of broadband.

132 ITU-D SG1 Document SG1RGQ/337 from Algérie Télécom SPA (Algeria)
133 ITU-D SG1 Document 1/34 from Bhutan
134 ITU-D SG1 Document SG1RGQ/18 from the Republic of the Congo

Chapter 5 – Conclusions

- Telecommunications in the modern information society is a key focus of the world economy, which determines the level of Member States' competitiveness. Market competition encourages different stakeholders to track and predict the main trends of the telecommunication industry with the aim of investing in the most effective methods for the rapid and cost-effective development of modern telecommunication networks.
- Among all the elements of development in the modern telecommunications industry, the following factors have the greatest influence on the deployment of broadband:
  - standards for broadband access technologies;
  - national plans of fixed and mobile broadband development;
  - regulation, investment procedures and public-private partnerships;
  - capacity building and supporting decisions in the process of broadband deployment.
- Nowadays three major groups of broadband access technologies are continuing to develop: mobile broadband, fixed broadband and satellite broadband. For most of the population in developing countries, mobile is the primary way to access the Internet. While fixed-telephone subscriptions continue to decline, fixed-broadband subscriptions continue to increase. With its global reach and immediate availability, satellite is key to connecting people everywhere.
- Broadband networks have been recognized internationally as an important public infrastructure. They play an increasingly prominent role in promoting economic growth, changing growth drivers, and enhancing long-term competitiveness. Their development has become a major criterion for measuring a country's overall strength. Countries around the world have all included broadband in priority areas of national development.
- Digitalization is increasingly and fundamentally changing societies and economies and disrupting many sectors in what has been termed the 4th Industrial Revolution. Meanwhile, ICT regulation has evolved globally over the past 10 years and has experienced steady transformation.
- An investment-friendly policy and regulatory framework is needed to support digital transformation, which now permeates all industries and impacts markets in all sectors.
- Regulatory regimes should be able to encourage the timely deployment of broadband by eliminating impediments that unnecessarily add delays and costs to bringing advanced wireless services to the public.
- Broadband deployments are easily realized when nations, states and local governments create and adopt formalized broadband plans. Plans are effective in assessing and addressing broadband needs, stimulating action on broadband issues, developing necessary goals and in achieving actual results.
- Developing countries need to move from low-speed broadband networks to high-speed and high-quality broadband networks. This transition is essential to benefit from the social and economic benefits of digital transformation, in line with developed countries.

Annex 1: Key takeaways from workshops/seminars and other activities related to the Question

ITU Regional Workshop on Broadband Development (Dushanbe, Tajikistan, 29-30 May 2018)

The ITU Regional Workshop on Broadband Development, which was held in Dushanbe, Republic of Tajikistan,[135] was devoted to topical issues such as:

- global trends in broadband strategy and policy, including activities of international organizations;
- overview of initiatives and programmes that are related to broadband deployment in developing countries;
- selecting appropriate technologies for broadband deployment in rural and remote areas;
- technical, organizational and economic aspects of broadband networks design and implementation;
- case studies of broadband deployment in developing countries.

Conclusions and recommendations:

I. There is a need for more active involvement of educational and academic institutions along with national research and educational networks in the region in the activities of ITU-D, as well as other international organizations involved in the development of infocommunications infrastructure.

II. The importance of further research in developing newer methods of telecommunication networks designing should be stressed.

III. The high value of the implementation results of the regional initiative "Broadband access development and introduction of broadband in CIS" approved at WTDC-14 (Dubai, United Arab Emirates) should be noted along with the need for spreading information on these results among the communications administrations of the region.

IV. The need for further research of the issues of classifying broadband Internet access as a universal service along with mechanisms for organizing public-private partnerships, in order to ensure access to them in hard-to-reach and remote areas, including rural areas.

V. The advisability of more active involvement in the work of the ITU-D of private companies, which have practical experience in the development of broadband access infrastructure, including access in hard-to-reach and remote areas as well as in rural areas.

VI. The importance of the communications administrations of the region to provide on time the information required for the calculation of the ICT Development Index (IDI), taking into account the most relevant changes in the methodology of its calculation.

VII. The need to increase reliability of the international telecommunication infrastructure in the region due to the increase in the number of inter-country interconnections and their throughput.

VIII. The importance of developing and improving State strategies for the development of broadband access networks, including aspects of building human resources for the design, construction and maintenance of modern infocommunication infrastructure.

[135] ITU-D SG1 Document SG1RGQ/8 from ONAT (Ukraine).

Regional workshop on emerging technologies (Algiers, Algeria, 14-15 February 2018)

Conclusions and recommendations on 5G/IMT 2020 from the Algiers workshop included the following:[136]

i. Telecommunication operators can act as facilitators in the transformation towards a digital economy. Relying on all IP and softwarized networks and the use of SDN and virtualization technologies play an important role in that regard.
ii. Open standards for 5G will be vital for access to the technology, in particular for developing countries.
iii. Various opportunities are offered by 5G to developing countries, yet key issues have to be addressed, including ensuring that technical expertise is developed and that an R&D ecosystem is facilitated. Countries in the region should adopt a phased deployment strategy, with a gradual upgrade of their current networks while ensuring return on investment.
iv. 5G standardization must ensure that the technology meets different requirements, including different frequency bands for broad spectrum coverage, standards for infrastructure flexibility and agility to support a large variety of applications and business models, end-to-end quality of service and management coping with the increased complexity due to network softwarization, full fixed-mobile convergence with both service and network benefits, and network integration of machine-learning technologies with their potential for network design, operation and optimization.
v. ITU-T Study Group 13 plays the leading role within ITU-T when it comes to IMT-2020 standardization ("IMT-2020" is the standard and set of specifications for 5G established by ITU) and has adopted a "deliverable package" approach (one package for each key technical area, such as slicing, and FMC) to facilitate the understanding of the standards framework by the user community.

Facilitating 5G roll-out and adoption will depend on adopting the right regulatory policy:

i. ensure fair/non-discriminatory spectrum auctions;
ii. prioritize infrastructure deployment, not state revenues;
iii. reform planning and administrative rules;
iv. create the right incentives for investment in 5G;
v. enable efficient network management, thus allowing innovative services with specific quality needs to develop;
vi. support fibre backhaul by ensuring access to passive infrastructure for fibre roll-out;
vi. ensure the public sector acts as an early adopter of 5G.

ITU regional week on Emerging technologies for sustainable development and digital transformation in the Arab region (Dubai, UAE, 26-29 August 2019)

The activities of the ITU regional week on Emerging technologies for sustainable development and digital transformation in the Arab region were organized by ITU and hosted by the Telecommunications Regulatory Authority (TRA) of the United Arab Emirates and the University of Dubai, with collaboration from the National Telecommunications Regulatory Authority of Egypt (NTRA). The meeting was supported by Intel, GSMA and Global Innovation and Entrepreneurship (GIE), with contributions from Huawei, Siemens, Google, Nokia, Ericsson, Microsoft, Sharjah Research Technology and Innovation Park Free Zone (SRTI Park), Weightless SIG-UK, National Digital Transformation Unit of Saudi Arabia and HERE Technology.[137]

136 ITU-D SG1 Document 1/55 from the BDT Focal Point for Question 3/1
137 ITU-D SG1 Document SG1RGQ/245 from the BDT Focal Point for Question 1/2

These activities included:

- An ITU-GSMA 5G capacity-building training programme, held on 26-27 August 2019, was organized and delivered by GSMA's instructor Mr Michele Zarri, Technical Director, Networks and Technology.
- A subregional Hackathon for the Gulf region on IoT, big data and smart cities, organized by Arab IoT and AI Challenge stakeholders and supported by ITU, was held on 26-27 August 2019.
- The 4th ITU Annual Forum on "IoT, big data, smart cities and societies" for the Arab region was held on 28-29 August 2019.

Annex 2: Case studies

Satellite broadband[138]

Viasat Community Wi-Fi in Mexico

Viasat connects underserved communities in rural, suburban and urban locations of Mexico to high-speed broadband through the Community Wi-Fi programme, based on a very small aperture terminal (VSAT) located at a store or other location in a community. The terminal is connected to a router and modem, which is in turn connected to a Wi-Fi antenna that creates a local Wi-Fi network extending up to 500 m in each direction.

Hughes Express Wi-Fi in Mexico

The integration of optimized high throughput satellite (HTS) and the powerful JUPITER VSAT with advanced wireless Wi-Fi radio access technologies provides a reliable and cost-effective solution for the fast deployment of new broadband Internet connectivity services to geographically dispersed underserved and unserved areas where terrestrial infrastructure is not available, is highly unreliable or is not feasible to implement due to high CAPEX and low average revenue per user (ARPU). Hughes Express Wi-Fi has been successfully tested and implemented in Mexico. It provides guaranteed network performance and high-quality broadband service to end users.

iMlango***, Avanti connecting schools in Kenya***

iMlango provides a learning platform that delivers content in multiple formats to students and teachers. The high-speed reliable broadband connectivity delivered in each of the iMlango schools is provided over Avanti's super-fast HTS Ka-band satellites that have 100 per cent coverage across Kenya, thus ensuring that even the most remote/rural schools are included.

SES (satellite operator) providing 3G in Chad

Many parts of Chad, a landlocked country in north-central Africa, have been notoriously hard to reach for MNOs, due to its sheer vastness, lack of terrestrial infrastructure and extensive flooding during rainy seasons. By leveraging SES's fully managed satellite backhaul service driven by its multi-orbit fleet, a mobile operator, Tigo Chad, has been able to expand coverage into the country. Using a combination of SES's high-capacity, low-latency O3b MEO constellation, and GSO satellites, the solution allowed Tigo Chad to introduce 2G and upgrade to 3G in rural and previously unserved areas.

SES MEO backhaul in the Democratic Republic of the Congo

Gilat Telecom has expanded its partnership with SES to provide more bandwidth to rural areas. It extends services to customers such as Orange DRC in the Democratic Republic of the Congo (DRC) – a landlocked country – beyond Kinshasa and Lubumbashi, reaching unserved or underserved Kisangani, Mbuji-Mayi and Bunia. Under the new agreement, Gilat Telecom is using multiple Gbit/s of bandwidth on the O3b MEO system and is now also adding services via SES's GEO satellites.

[138] ITU-D SG1 Document SG1RGQ/318+Annexes from ESOA

From 3G to 4G in Peru ***with SES***

In Iquitos, Peru, SES partnered with Axesat to provide a managed network solution using SES's O3b MEO satellites to upgrade ENTEL's network in the city from 3G to 4G-LTE. Iquitos, Peru's sixth-largest city, borders the Peruvian Amazon, and is only accessible by air or water. As a gateway to the Amazon rainforest, the city of close to 500 000 residents is a major centre for finance, sales, transportation and tourism, with a growing market in timber, petroleum, and oil and gas production.

Supporting faster 3G services in the Central African Republic ***with SES***

Orange will be using the SES IP Transit solution to deliver faster 3G services and better-quality Internet connections for enterprises. The solution will be delivered by SES, using its MEO fleet and extensive ground infrastructure. Customers of Orange Central African Republic will have access to unparalleled availability and speed of Internet services, which has not been available earlier in the country with its challenging terrain and lack of terrestrial infrastructure, resulting in low Internet penetration.

Burkina Faso connectivity solution ***with SES***

An entire end-to-end solution is being provided by SES, including terrestrial wireless communication and integration with the already available fibre backbone network to connect 881 sites in Burkina Faso, enhancing connectivity and providing e-government, e-education and e-health services. This project is part of an agreement concluded with Lux Dev and the Government of Burkina Faso to roll out nationwide connectivity and further drive innovation in the country. Several entities came together to make this a reality, including Lux Dev (funding), the Government of Burkina Faso (funding and owning the project on the ground) and SES.

TeleGlobal-Bakti project in Indonesia ***by SES***

Under an agreement signed in 2019, Teleglobal and SES Networks will be partnering with the Indonesian Ministry of Communication and Information Technology's universal service obligation (USO) project via its USO agency, *Badan Aksesibilitas Telekomunikasi dan Informasi* (BAKTI), to provide broadband Internet access and mobile backhaul services to up to 150 000 sites in remote parts of the country. It will use 1.3 GHz of capacity on SES's high-throughput satellite (HTS), SES-12, operating in geostationary Earth orbit.

Intelsat community Wi-Fi for refugee camp in Ghana

Globally there are nearly 25.4 million refugees, over half of whom are under the age of 18. At the end of 2016, Africa hosted 5 531 693 refugees. This was surpassed only by Asia, with 8 608 597 refugees. The lack of digital connectivity increases the vulnerability of people who were forced to flee by depriving them of opportunities for communication, information, education, financial transactions, and self/community/social development work.

Intelsat 'Internet for All' pilot project in South Africa

The 'Internet for All' initiative brings together stakeholders from the public and private sectors, non-profit organizations, academia, international organizations, donors and civil society to create multistakeholder partnerships aimed at bridging the digital divide. Intelsat has developed a pilot programme aimed at testing commercial and social scenarios that may impact the roll-out of the 'Internet for All' programme to rural areas in developing countries.

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