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5G AND BEYOND

REWIRING TELECOM REGULATION



ROHIT PRASAD
V. SRIDHAR

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To my grandmother, Smt. Girija Varma—a devoted schoolteacher and a woman of great fortitude—who carried a child's essay on the telephone in her handbag all her life.

—Rohit Prasad

To my wife Kala for her enduring support and ideas; our doctor-daughter Vindhya for showing curiosity in my work; and my mother Prema for being there for us.

—V. Sridhar

Preface

Across the world, Internet-based over-the-top (OTT) applications have emerged as both valuable complements and formidable competitors to traditional telecommunications services. Unlike the highly regulated telecom sector, OTT services are inherently transnational, decoupled from the underlying networks, and extremely difficult to regulate. This regulatory lightness has allowed them to innovate rapidly and offer services to consumers at little or no cost. The resulting asymmetry between licensed telecom operators and unlicensed OTT providers has been a source of persistent debate and litigation in many jurisdictions.

As 5G deployment reaches completion in a growing number of countries and attention shifts towards the standardization and roll-out of 6G by 2030, the nature of services and use cases will continue to evolve. This transition point provides an opportunity to fundamentally reconsider existing telecom regulations and to explore how they might be reshaped for the future.

The urgency for such a re-examination is heightened by several concurrent developments: the growing market power of Big Tech firms, which face antitrust scrutiny particularly in the European Union; the completion of nationwide 5G roll-outs in several regions; the strain on telecom networks caused by exponential growth in content consumption and new applications; and the elongation of the telecom value chain, now involving cloud providers, software vendors, tower companies, and virtual network operators alongside traditional carriers. These shifts call for a fresh look at regulatory balance across all entities in the ecosystem—while remaining mindful of the risks of regulatory overreach.

Against this backdrop, this book sets out to chart possible transition paths for telecom regulation, informed by legacy practices, technological evolution, market dynamics, and the growing maturity of regulatory frameworks worldwide. We propose a series of regulatory interventions, some of which represent significant departures from the past and are intended to stimulate debate. Our aim is to provide

educators, policymakers, regulators, and industry stakeholders with new approaches to regulating—or, in some cases, de-regulating—telecommunications as we move towards an integrated digital economy.

The book introduces and develops new concepts such as functional separation, diagonal equity, and digital neutrality, and applying them to critical regulatory domains including interconnection, spectrum management, net neutrality, and universal service. While some of the applications and use cases we discuss are specific to India, the principles and frameworks advanced here have broader global relevance. It is our hope that these proposals help unleash the full potential of the digital economy.

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Contents

List of Figures xvii
List of Tables xix
Glossary xxi

1. 5G and Beyond: Technologies of the Future 1
   1.1 Introduction 1
   1.2 Key Characteristics of 5G Technologies 5
      1.2.1 Densification of Networks 5
      1.2.2 Datafication of Networks 6
      1.2.3 Software-isation and Virtualisation of Networks 7
      1.2.4 Modularisation of Networks 8
         1.2.4.1 The Emergence of O-RANs 11
   1.3 Wi-Fi as a Complement to Cellular Broadband 13
      1.3.1 Wi-Fi 6 and Beyond 15
      1.3.2 Wi-Fi Offloading 16
      1.3.3 Voice-over Wi-Fi 17
      1.3.4 The Economic Value of Wi-Fi and the Extended Value Chain 18
         1.3.4.1 Wi-Fi in Residences 18
         1.3.4.2 Wi-Fi in Offices 18
         1.3.4.3 Public Wi-Fi 19
   1.4 Network Slicing 20
   1.5 Captive Non-Public Networks: A Game Changer 22
      1.5.1 Entry of NHs in the Telecom Value Chain 23
   1.6 Conclusion 24

2. The Economics of the Digital Ecosystem 31
   2.1 Introduction 31
   2.2 The Entities 32
      2.2.1 Wireline Telecom Operators: Plain Old Telephone Service to Broadband 32
      2.2.2 Mobile Service as a Game Changer 35
      2.2.3 The Internet as an Enabler 36
      2.2.4 OTT Applications and Services 37

2.2.4.1 OTT Communication Services: OTT Coms 39
2.2.4.2 OTT Video Services 40
2.2.4.3 OTT Other: Digital Platforms 42
2.3 Economics and Regulatory Aspects of Digital Platforms 43
2.3.1 Cross-Group Externalities 45
2.3.2 Waterbed Effect 45
2.3.3 Vertical Integration of Platform Provider and Platform Participants 46
2.3.4 Network Effects 46
2.3.5 Digital Capitalism 47
2.3.5.1 Decoupling of Valuation from Profit 47
2.3.5.2 The Consumer Becomes the Product 48
2.3.5.3 Too Big to Fail 49
2.4 Conclusion and Looking Ahead 50

3. The Integrated Sphere of Co-opetition of Digital Services and Diagonal Equity 55
3.1 Introduction 55
3.2 The Complementarity of OTT Services 55
3.3 The Hybridisation of Network Provision 56
3.4 The Substitutability of Services 57
3.5 Walled Gardens 59
3.6 Diagonal Equity: A New Regulatory Approach 61
3.6.1 Vertical, Horizontal, and Diagonal Equity 62
3.7 The Application of the Diagonal Equity Approach 64
3.7.1 Net Neutrality 64
3.7.2 App Neutrality 66
3.7.3 Regulatory Parity between OTT Coms and Virtual Network Operators 66
3.7.4 Interconnection and Data Portability 67
3.7.5 Moderation of Regulatory Levies 68
3.7.6 Universal Service 69
3.8 Conclusion 70

4. Licensing: From the Communications Convergence Bill to Functional Separation and Infrastructure Integration 73
4.1 Introduction 73
4.2 Licensing in India: The Story So Far 74
4.2.1 Entry of Virtual Network Operators 76
4.2.2 Current Licensing Structure 78
4.3 Proposals for a New Licensing Framework and International Experiences 80
4.3.1 New Proposals 81

4.3.2 International Experiences 82
4.4 The Heightened Need for Convergence and Functional Separation 83
4.4.1 Functional Separation 83
4.4.2 Convergence in the Infrastructure Layer 86
4.5 The Special Case of OTT Video Services 86
4.6 A New Licensing Regime 89
4.6.1 Incentive Structure to Catalyse the New Framework 93
4.6.2 Revenue Estimates 95
4.7 Conclusion 95

5. Spectrum Regulation for 5G+ Networks 103
5.1 Introduction 103
5.2 The Role of NR-U: Wi-Fi as Complement or Substitute 106
5.2.1 Wi-Fi Networks 106
5.2.2 Wi-Fi 6 and Beyond 107
5.2.3 The Unique Case of 60 GHz Band 109
5.2.4 The Coexistence of 5G NR-U and IEEE 802.11 Networks 110
5.3 The Method of Licensed Spectrum Allocation in India 111
5.3.1 Simultaneous Multiple-Round Ascending Auction 111
5.3.2 Combinatorial Auction 113
5.4 The History of Spectrum Allocation in India 114
5.4.1 Analysis of C-Band Spectrum Prices 119
5.4.2 Analysis of 700 MHz Spectrum Prices 120
5.5 Variables That Affect 5G Spectrum Price 121
5.5.1 Spectrum Holding by Indian TISPs 122
5.5.2 The Number of Bidders in the Indian Spectrum Auctions 125
5.5.3 The Model and Analysis of 5G Spectrum Prices in India 126
5.6 Coexistence in the C-Band 127
5.6.1 The CBRS Band in the United States 128
5.7 The Spectrum for Satellite Networks 129
5.8 New Approaches to Effective Spectrum Management 132
5.8.1 Light Licensing and Flexible Spectrum Regulation 133
5.8.2 Flexible Spectrum Management: From Static to Dynamic Approaches 133
5.8.2.1 Dynamic Spectrum Sharing 136
5.8.3 Redesigning the LSAs 137
5.9 Conclusion 138

6. From Net Neutrality to Digital Neutrality: In 5G+ Networks 143
6.1 Introduction 143
6.2 Classical NN and Its Variants 144

6.3 New Drivers of Competition 145
6.3.1 The Abundance of Data and Applications 145
6.3.2 The New Value Chain 146
6.3.3 The Increased Power of OTTs 148
6.3.4 Closer Collaboration between OTTs and TISPs: An Example of Network Slicing 148
6.4 NN in 5G+ 150
6.4.1 NN in India 151
6.4.1.1 RTMPs and Specialised Services 151
6.4.2 The New Conception of NN 152
6.5 Digital Neutrality 154
6.5.1 App Neutrality 154
6.5.2 The Carriage Levy on OTT Non-Communications Providers 156
6.6 Conclusion 157

7. Interconnection and Data Portability Regulation 159
7.1 Introduction 159
7.2 Termination Charges 161
7.3 Interconnect Congestion 163
7.4 Interconnection Charges for Internet Protocol-Based Calls 164
7.4.1 Internet Telephony Calls Terminating on the Carrier Network 165
7.4.2 International Internet Telephony Calls Terminating on the Local Carrier Network 167
7.5 The Interconnection between OTT Com Apps 169
7.5.1 Evolving Communication Technologies for Internetworking 169
7.5.2 Regulations on the Interoperability of OTT Coms 171
7.5.3 Regulation on the Interconnection of Internet Telephony with PSTN/PLMN Networks in India 172
7.6 Access to Emergency Services 173
7.6.1 Emergency Services of VoIP Providers 173
7.7 Number and Data Portability 175
7.7.1 Number Portability 175
7.7.2 Data Portability 176
7.8 Containing SPAM Calls 177
7.9 Conclusion 180

8. Universal Service Policy 183
8.1 Introduction 183
8.2 The Universal Service Levy 183
8.3 Uses of the USL 184

8.4 Theoretical Issues: What to Build 187
8.4.1 Good 4G: A Consumption Norm 189
8.4.2 Fixed-Line Infrastructure for 5G in Urban and Semi-Urban Areas: A System Requirement 190
8.5 Theoretical Issues: Who to Charge 191
8.6 The Twin Engines of Digital India: Infrastructure Supply and Demand 192
8.7 Conclusion 192

9. The Future of Telecom Regulation 195
9.1 Introduction 195
9.2 Impact of Regulatory Interventions 195
9.3 Recent Developments in 6G Networks 198
9.3.1 Neutral Hosts 200
9.4 Emerging Regulations in the 6G World 201
9.4.1 Spectrum Regulation 201
9.4.2 The Ethics of AI 202
9.4.3 Cybersecurity and Privacy 204
9.4.4 Net Neutrality 205
9.4.5 Towards Green 6G 206
9.5 Conclusion 207

Index 211

Figures

1.1 Various functionalities of 5G technologies 3

1.2 The evolution of mobile technologies 4

1.3 Timeline of 3GPP and IEEE standardisation activities 16

1.4 Network slicing 21

1.5 Areas of focus in 6G 26

2.1 The technical architecture of OTT services 39

2.2 Schematic of the telecom and Internet services 43

2.3 The architecture of the Internet value chain 44

3.1 Schematic diagram of the handset application platform 60

4.1 Timeline of various types of telecom licensing in India 78

4.2 The current licence structure in India 79

4.3 The layered approach to digital communications 89

5.1 The taxonomy of the radio spectrum in use for commercial mobile services 104

5.2 Variation of spectrum prices over the years in the sub-GHz and mid bands 117

5.3 Comparison of winning bid prices versus reserve prices in India's 2022 auction 118

5.4 Variation of spectrum prices of the C-band across countries 119

5.5 Variation of spectrum prices of the C-band across LSAs in India 120

5.6 Variation of spectrum prices of 700 MHz across LSAs 121

5.7 Variation of spectrum prices of 700 MHz in different countries 122

6.1 The Internet value chain with associated charges 147

7.1 The call flow across LSA within a country 160

7.2 The call flow of an international call 160

7.3 Changes in MTC and ITC over time in India 163

7.4 Schematic diagram of IP device <–> PSTN/PLMN device call 165

7.5 Schematic diagram of international Internet telephony call flow 167

8.1 The growth of USOF in India over the years (fund status in Rs. Cr.) 184

9.1 Regulatory challenges in 6G 207

Tables

1.1 Summary of Wi-Fi technologies 14
1.2 Comparison of key performance indices of 5G and 6G 28
2.1 The taxonomy of OTT services 38
2.2 Comparison of the classical and digital capitalism 47
3.1 Complementarity OTT services 56
3.2 TISP services substitutable by OTTs 59
4.1 Details of the licensing framework 80
4.2 Market competition of mobile services in India 85
4.3 Details of the licensing framework 94
4.4 Regulatory fees as per the current regime 97
4.5 Regulatory fees as per the proposed regime 98
4.6 Regulatory fees as per the proposed regime in 2026 99
5.1 Licensing of 6 GHz in various countries 108
5.2 Licensing arrangements of the 60 GHz spectrum band in various countries 110
5.3 The LSAs in India 114
5.4 Spectrum auction revenue over the years 115
5.5 Variation of spectrum holdings by a TISP across LSAs 123
5.6 Spectrum holding by various TISPs in India 124
5.7 Variation of spectrum holdings by a TISP across countries 124
5.8 Summary statistics of spectrum auctions held in India 125
5.9 Spectrum bands used by different satellite systems 131
5.10 Examples of light licensing sharing approaches 134
6.1 Dimensions of net neutrality 145
6.2 The type of charges possible in the Internet value chain 147
7.1 Existing regulations on interconnection and emergency services 175
7.2 Proposed regulation on the number of independent OTT communication services 179

Glossary

Acronym	Explanation
3GPP	The Third-Generation Partnership Project (3GPP) is a collaborative project between a group of telecommunications associations with the initial goal of developing globally applicable specifications for third- (3G) and future-generation mobile systems.
5G	Fifth-generation network—fifth-generation wireless (5G) is the latest iteration of cellular technology, engineered to increase significantly wireless networks' speed and responsiveness. The 3GPP standards committee migrated from 4G long-term evolution (LTE) to next-generation 5G in 3GPP Release 14 in 2016. The New Radio (5G NR) requirements for 5G communication networks were defined in 3GPP Release 15, started in 2017 and concluded in 2018.
5G+	5G and beyond networks include the currently deployed 5G networks and 6G networks and services to be standardized by 2030.
6G	Sixth-generation cellular mobile technology, standards for which will be finalized by 2030, augments the capabilities multi-fold in terms of performance and applications.
AGR	Adjusted gross revenue—the gross revenue accruing to the telecom licensees by way of operations of the cellular mobile service as per their licence conditions.
API	Application programme interface—a set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service.
AR	Augmented reality—an interactive technology that overlays digital information in the real world, enriching users' perception of their environment. Unlike virtual reality (VR), which immerses users in a completely virtual environment, AR enhances the real world by adding digital elements.
ASP	Access service provider—licensed/authorised to provide telecommunication access services, including wireline and mobile services.
BATX	The Chinese Big Techs—Baidu, Alibaba, Tencent, and Xiaomi—are near-monopolies in their defined markets and can compete with the US-based Big Techs.

BTS Base transceiver station—the radio access network node of the cellular mobile network that communicates with the mobile user terminals or handsets. BTS is connected to the base station controller (BSC). The BTS, with its antenna, transmitter, and receivers, is generally mounted on a cellular tower to provide limited geographical coverage.

CAP Content and application provider—these provide content and applications to the end users, typically through landline or mobile network services.

CBRS Citizens Broadband Radio Service is a mobile service operating mainly in the United States in the Federal Communications Commission (FCC)-authorised band of 3,550–3,650 MHz (3.5 GHz C-band) currently used for military and satellite communication in shared use mode.

CCA Combinatorial clock auction

CCB The Communications Convergence Bill—drafted in 2020 but not enacted in parliament. It envisioned 'triple play', including the convergence of voice telephony, Internet connectivity, and video services.

CDMA Code division multiple access—the multiple access scheme developed by Qualcomm Inc., United States, to support multiple simultaneous communications over the wide band frequency by adding a unique code for each data signal sent to and from each radio transceiver. CDMA development group is a consortium of companies that promotes the evolution of CDMA.

CDN Content delivery network is a system of distributed servers (network) that deliver pages and other web content to a user based on the user's geographic location, the webpage's origin, and the content delivery server.

CMTS Cellular mobile telecommunication services—communication services provided by a licensed mobile operator dividing a specific geographic area into 'cells'. Each cell typically extends from a few hundred metres to about 4–5 km. A BTS services each cell.

CNPN Captive non-public networks—deployed mainly for enterprise use, either by mobile network operators (MNOs) or non-MNOs, using spectrum that is exclusively allocated or otherwise. The CNPNs, by definition, shall not be connected to the public PSTN/PLMN or the Internet.

CPP The Calling Party Pays scheme—in which the party making the call pays for the charges. Most countries, including India, practise this.

C-RAN Cloud RAN (radio access network)—a cloud-native software solution that handles computing functionality in the RAN. Cloud RAN is

a viable option for communications service providers (CSP) that offers increased flexibility, faster delivery of services, and greater scalability in networks.

DoT Department of Telecommunications—a unit of the Ministry of Communications of the Government of India, with a vision to provide secure, reliable, affordable, and high-quality converged telecommunication services anytime, anywhere, for an accelerated inclusive socio-economic development.

DPDP Digital Personal Data Protection Act 2023—legislated by the Government of India to provide legal privacy protection to natural persons of India.

DSL Digital subscriber loop—transmission/service that provides digital transmission over copper wires traditionally used for voice telephony. The service is accessed using a modem and is usually provided by the BTOs.

DSM Dynamic spectrum management—dynamically allocates radio spectrum resources based on current demand and network conditions. Using machine learning and artificial intelligence (AI) techniques can enable the network to adapt to changing traffic patterns and dynamically adjust the allocation of spectrum resources.

DTH Direct Home—a television broadcasting service that uses Ku and associated high-frequency radio frequencies to transmit video programmes from geostationary satellites to small antennas mounted on the rooftops of households.

eMBB Enhanced mobile broadband—in simple terms, an extension of services first enabled by 4G LTE networks that allow for a high data rate across a wide coverage area.

eNUM The standard for converting E.164 international numbering format to the Internet Protocol (IP) address using the e.164 arpa domain.

FCC The Federal Communications Commission—an independent agency of the United States federal government that regulates communications by radio, television, wire, satellite, and cable across the United States.

FWA Fixed wireless access—telecom carriers use FWA to provide broadband access to homes using a fixed antenna connected to the 5G networks using high frequencies. The carriers call these 'air fibre' as they provide high bandwidth, similar to optic fibre cables using wireless technologies.

GAMMA Google, Apple Meta, Microsoft, and Amazon, also called the Big Techs or Gatekeepers, wield enormous power in their defined markets.

GDPR The General Data Protection Regulation (EU) 2016/679—a regulation in the EU law on data protection and privacy for all individual citizens of the EU and the European Economic Area (EEA).

GSM Groupe Speciale Mobile (Global Systems for Mobile)—a public all-digital cellular network standard using the transmission band around 900 MHz, 1,800 MHz, and 1,900 MHz developed by the European Telecommunication Standards Institute (ETSI). Besides telephony services, a GSM network can provide short messaging services (SMS) and data communication in circuit and/or packet mode. The GSM Association represents the corresponding interest group.

HAP Handset application platforms—the bundling of mobile handsets and associated applications provided typically by the mobile carrier in collaboration with handset and application firms.

IEEE Institute of Electrical and Electronics Engineers—the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity.

IoE Internet of Everything

IoNT Internet of Nano Things—a new and modern part of the Internet of Things (IoT). Applications that operate on a nano scale show a new advantage in communication networks.

IoT Internet of Things—refers to the collective network of connected devices and the technology that facilitates communication between devices and the cloud.

ISP Internet service provider—licensed/authorised to provide access to the public Internet. However, they cannot provide traditional voice communication, much like the telecom and Internet service providers (TISPs), due to licence restrictions.

ITC International termination charge—the foreign telecom service provider (TSP) pays ITCs to the Indian TSP for terminating an international incoming call to either a landline or mobile phone.

ITU The International Telecommunication Union—an agency of the United Nations (UN) that coordinates telecommunication operations and services worldwide.

IUC Interconnection usage charges—one telecom operator levies to another for interconnecting their networks. These charges include termination charges and carriage charges. There are associated regulations, especially regarding the charges levied.

LSA Licensed service area—there are twenty-two LSAs in India, divided across four categories: metros of Delhi, Mumbai and Kolkata; Category

A (Andhra Pradesh, Gujarat, Karnataka, Maharashtra excluding Mumbai, and Tamil Nadu), Category B (Haryana, Kerala, Madhya Pradhesh, Punjab, Rajasthan, Uttar Pradesh-East, Uttar Pradesh-West and West Bengal excluding Kolkata), and Category C (Assam, Bihar, Himachal Pradesh, Jammu & Kashmir, North East, and Orissa). The licences are given for providing telecommunication (mobile/landline) and Internet services for each LSA.

LTE Long-term evolution—the next-generation 4G technology for GSM and CDMA cellular carriers. Approved in 2008 by 3GPP with download speeds up to 173 Mbps.

LTG Large traffic generators—over-the-top (OTT) video service providers whose various types of video services (including streaming, downloads, and broadcasting) are offered over the Internet and consume large amounts of bandwidth.

MeITy Ministry of Electronics and Information Technology, Government of India

MIMO Multiple-input multiple-output—while it involves multiple technologies, MIMO can essentially be boiled down to this single principle: a wireless network that allows the transmitting and receiving of more than one data signal simultaneously over the same radio channel. Standard MIMO networks tend to use two or four antennas. On the other hand, Massive MIMO is a MIMO system with an exceptionally high number of antennas.

mMTC massive machine-type communication—supported in 5G that can connect more than 1 million devices per square kilometre and provide support for the Internet of Things; vehicle-to-vehicle communication; and Smart Cities, wherein sensors and machines communicate in a semi-automated way.

MNO Mobile network operators—licensed to provide cellular mobile communication services.

MNP Mobile number portability—the facility to keep the same mobile number while switching (porting) to a different operator/geography/service.

MTC Mobile termination charges—paid to the terminating mobile carrier for calls either originating within the country or in a foreign country.

MVNO Mobile virtual network operator—a licensed mobile service provider that typically leases/rents spectrum and other facilities from an MNO to provide mobile communications and Internet services.

NEM Network equipment manufacturer—produced 3GPP-compliant hardware and software platforms that the telcos deploy for providing telecommunication services.

NFAP National Frequency Allocation Plan—prepared by the Wireless Planning and Coordination wing of the Department of Telecommunications periodically to designate different spectrum bands for different usages.

NFV Network function virtualization—a network architecture that aims to accelerate service deployment for network operators and reduce cost by separating functions like firewall or encryption from dedicated hardware and moving them to virtual servers, collapsing various functions into a physical server, and ultimately reducing overall cost.

NH Neutral host—where operators share the network infrastructure in private and enterprise networks wholesale with mobile network operators to augment their service offerings, including network slices.

NN Net neutrality—coined by Professor Tim Wu of Columbia Law School in 2003 to represent the fact that 'a maximally useful public information network aspires to treat all content, sites and platforms equally'.

NSO Network service operator—leases network services on a wholesale basis to virtual network operators.

O-RAN Open radio access network—a concept based on interoperability and standardization of RAN elements, including a unified interconnection standard for white-box hardware and open-source software elements from different vendors.

OTT Over the top—an information and communication technology service provided over the Internet, untethered from the underlying network. Examples include instant messaging and Voice-over-the-Internet Protocol.

OTT com Over-the-top communication services—such as WhatsApp, Skype, and Telegram, which provide electronic communication services over the Internet, untethered from the underlying physical network.

PLMN Public land mobile network—the mobile telecommunication network that provides voice/data services.

PoI Points of interconnect—wherein one carrier network interconnects with another.

POTS Plain old telephone service

PSTN Public switched telephone network—the telecommunication network typically has wireline access and provides voice/data services.

QoS Quality of service—uses mechanisms or technologies that work on a network to control traffic and ensure the performance of critical applications with limited network capacity.

RAN Radio access network—a significant component of a wireless telecommunications systems that connects individual devices to other parts of a network through a radio link. The RAN links user equipment, such as a cell phone, computer, or any remotely controlled machine, over a fibre or wireless backhaul connection.

RPP The Receiving Party Pays scheme—the receiver of the call pays for the call charges. Though not practised widely, it is used partially in the US and Chinese markets.

RTMP Reasonable traffic management practices—those used by the TISPs to manage network congestion without violating net neutrality regulations.

SAS Spectrum access system—a cloud service that protects higher-priority users by controlling lower-priority devices' operating parameters (channels or transmission power). SAS is an entity authorized and certified by the FCC to coordinate and control the operation of devices using dynamic spectrum management.

SDN Software-defined network—a networking architecture that aims to improve overall network performance and make networks agile and flexible by enabling dynamic and programmatically efficient network configuration.

SIM Subscriber identification module—an integrated chip that contains subscriber identification provided by the telecom companies to subscribers for authentication and access. SIMs typically contain international mobile subscribe identity (IMSI). Physical SIMs are being replaced today by e-SIMs, a software-defined unique authentication identification.

SMRA Simultaneous multiple-round ascending auction—the widely used auction methodology for allocating radio spectrum to mobile operators. This method allows simultaneous bidding for radio spectrum bands across licence service areas. The Government of India has been using SMRA since 2010.

SMS Short message service—short, 160-character text messages can be transmitted over digital cellular networks.

SSO Standard-setting organisation—an entity that is primarily engaged in activities such as developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise maintaining hundreds of thousands of standards applicable to a broad base of users outside the standards-developing organisation.

TCP/IP Transmission Control Protocol/Internet Protocol—developed by the University of California, Berkeley as a transport and network layer protocol for the Internet. The protocol supports synchronous and continuous communication of packets between two endpoints on the network instead of the alternative User Datagram Protocol that supports asynchronous and discontinuous transmission of packets. TCP is implemented at the end nodes of the network and provides error and flow control.

THz Terahertz communication—being standardized for 6G and includes very high frequencies in the Terahertz range (0.1–10.THz).

TISP Telecom and Internet service provider—a licensed entity that provides traditional telephony and Internet access service.

TRAI The Telecom Regulatory Authority of India—a regulatory body set up by the Government of India under section 3 of the Telecom Regulatory Authority of India Act, 1997. It is the regulator of the telecommunications sector in India.

TSP Telecommunication service provider—typically a licensed entity that provides a telephony service.

UASL Unified-access service licence—this type of access service licence was formulated in 2003 by the Government of India to provide any service using any technology.

UCC Unsolicited commercial communication— any commercial communication that is neither per the recipient's consent nor registered preference(s).

UL Unified licence—awarded to service providers with an accompanying authorisation for providing services such as access service, Internet service, satellite service, virtual network operations services, and so on.

URLLC Ultra-reliable low-latency communication—support in 5G that guarantees less than 1 millisecond latency to provide services such as automated robotic surgery, self-driving cars, and real-time fleet management that require highly reliable instant communication.

USL Universal service levy—collected from the licensed service providers towards the universal service obligation (USO) fund.

USO Universal service obligation—the telecom policy that enables the non-discriminatory availability of telecommunication services to all country citizens. Usually funded by the USO Fund, collected through the USO Levy (UASL) collected from the telecom operators.

VNO Virtual network operator—a licensed telecom operator that typically leases/rents spectrum and other facilities to provide telecommunications and Internet services.

VoD Video on demand—provided by broadcasting channels or OTT broadcasting providers as and when needed by the subscribers.

VoIP Voice-over-the-Internet Protocol—the process of sending voice traffic in the form of packets over IP networks. VoIP digitizes analogue voice and compresses, packetizes, and sends it to the receiver.

VoWiFi Voice Over Wi-Fi Refers to mobile phone voice calls and data made over IP networks using Wi-Fi instead of the cell towers provided by cellular networks. Using this feature, compatible handsets can route regular cellular calls through a wireless LAN (Wi-Fi) network with broadband Internet while seamlessly changing connections between the two where necessary.

V-RAN Virtualized RAN—disaggregates software from hardware. It enables all RAN workloads to run on general-purpose servers and benefit from various suppliers, as well as a silicon road map driven by Moore's law. This approach also helps improve operational efficiencies in configuring and orchestrating the network and enhances network optimisation, fault detection, correction, and prevention.

WANI Wireless-access network interface—a modular Wi-Fi network architecture that enables the provisioning of public Wi-Fi, including roaming and payment, promoted by the Telecom Regulatory Authority of India to improve Wi-Fi penetration in India.

Wi-Fi Wireless fidelity—local area wireless networks based on IEEE 802.11 b/g/n standards operating in the license-free industrial, medical, and scientific (ISM) radio frequency bands of 2.4 and 5 GHz. The ISPs usually provide Internet services using this technology.

WiGig 60 GHz Wi-Fi—refers to 60 GHz wireless network protocols. It includes the current IEEE 802.11ad standard and also the upcoming IEEE 802.11ay standard. The WiGig specification allows devices to communicate without wires at multi-gigabit speeds.

XMPP eXtensible Messaging and Presence Protocol—an open standard for instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalised routing of eXtensible Markup Language (XML) data.

1

5G and Beyond

Technologies of the Future

1.1 Introduction

Advancements in telecommunications technology are fundamentally transforming how human society functions, including how humans work, seek recreation, and live. Naturally, these developments are also changing the nature of telecom and Internet service providers (TISPs) and over-the-top (OTT) application providers and introducing new stakeholders in the telecommunications ecosystem. These rapid paradigm shifts require a complete rethink of the approach to the regulation of TISPs. Without such rewiring of regulation, the potential of digital technologies will be underutilised or serve only a chosen few. Towards this goal, this book provides a new perspective on optimum regulation to unlock the potential of the digital revolution.

Notably, the rapid pace of current changes in telecommunications technology is in stark contrast to the leisurely pace of initial developments. Though wireless mobile services were started in the United States way back in the 1950s, the second-generation (2G) digital communication service—also referred to as the public land mobile network (PLMN) service- was launched worldwide only in the 1990s (De Vriendt et al., 2002). The Global Systems for Mobile (GSM) was created as a standard-setting organisation (SSI) in 1982 to create a common European mobile telephone standard to formulate specifications for a pan-European mobile cellular radio system operating at 900 MHz. The GSM networks transmitted data at a very low speed of 9.6 Kbps. Enhancement of the 2G GSM standard resulted in 2.5G technology, also called the General Packet Radio Service (GPRS), which increased the speed of connections to a theoretical maximum of 144 Kbps. The code division multiple-access

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(CDMA) technology was invented by Qualcomm in the United States in the early 1990s as an alternative to GSM technologies. CDMA further improved the system capacity and spectrum efficiency of 2G digital mobile systems.

In the early 1990s, the International Telecommunication Union (ITU) devised a plan to harmonise ongoing developments of a next-generation wireless network, referred to as the international mobile telecommunications (IMT) 2000. Under the IMT 2000 initiative, the third-generation (3G) wireless system was developed in 1996 with the sponsorship of the European Telecommunications Standards Institute (De Vriendt et al., 2002). The 3G system was an upgrade of GSM/GPRS that enhanced its spectral efficiency up to six times with data speeds reaching up to Mbps. The Third-Generation Partnership Project (3GPP) standardisation committee enhanced the 3G technologies and defined standards for high-speed packet access (HSPA) with enhanced downlink data speeds up to 42 Mbps and up to 84 Mbps.

In the 2000s, the standard bodies such as 3GPP and the industry alliances started the deployment of fourth-generation (4G) technologies that allowed for significantly higher bit rates per user (ranging from 10 Mbps to 100 Mbps) and supported the interoperability of diverse and heterogeneous wireless and mobile networks. This next generation of wireless technologies extended beyond voice and Internet connectivity to support mobile digital applications, namely m-commerce and mobile business. The technology was designed to support interactive gaming, high-definition (HD) video streaming, and mobile TV. The factors distinguishing the 4G networks were roaming interoperability and higher speeds (Prasad & Sridhar, 2014).

In 2016, the 3GPP standards committee started migrating from the fourth generation to the fifth generation (5G) to cater to the ever-increasing demand for higher speeds and varied requirements, including machine-to-machine communications (MMC).

The key features of 5G as per 3GPP Release 16 are as follows (NI, 2018);

1. enhanced Mobile Broadband (eMBB): that supports more than 10 Gbps peak data rates to enable mobile users to view high-definition mobile Television and video streaming services, various Augmented Reality/Virtual Reality services while on the move;

2. Ultra-Reliable Low Latency Communication (URLLC): guarantees less than 1-millisecond latency to provide services such as automated robotic surgery, self-driving cars, and real-time fleet management that require highly reliable instant communication;
3. massive machine type communication (mMMC) that can connect more than 1 million devices per square kilometre and provide support for the Internet of Things, vehicle-to-vehicle communication, and Smart Cities wherein sensors and machines communicate with each other in a semi-automated way.

An overview of the extensive range of service capabilities 5G communication provides is given in Figure 1.1, ranging from machine–machine to massive mobile broadband communication services.

The popular view of 5G communication services revolves around their ability to facilitate high-speed data transfers. However, more importantly, 5G promises to bring about a paradigm shift in how things and humans are interconnected. It has been estimated that using the 5G connectivity paradigm in key sectors such as health care, retail, mobility, and manufacturing will increase global gross domestic product (GDP) by about USD 2 trillion (Grijpink et al., 2020).

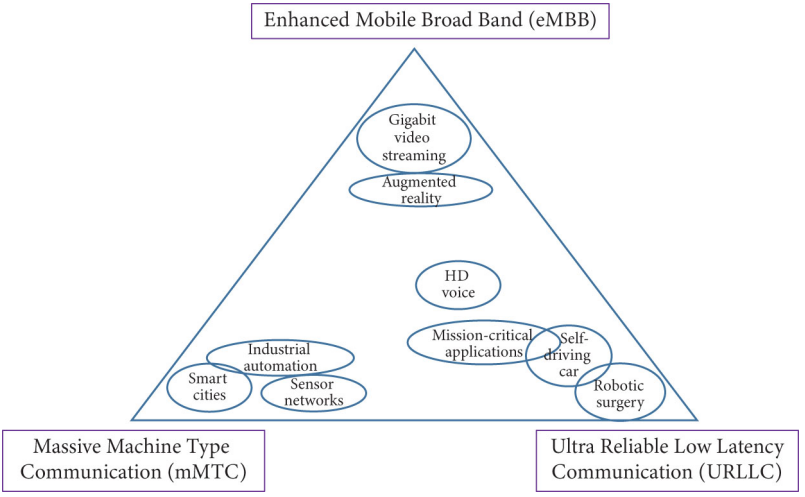


Fig. 1.1 Various functionalities of 5G technologies
Source: Authors' own.

Recognising the potential of telecom technology advancement, countries worldwide have already begun work on the next generation of telecom technology—6G. 6G is anticipated to surpass 5G in numerous technical aspects, such as peak data rates, traffic capacity, connection density, spectral efficiency, and latency. This technological leap is augmented by unprecedented artificial intelligence (AI) and machine learning (ML) developments. Furthermore, it will seamlessly merge the physical and digital realms, instigating unprecedented sensory experiences. 6G will also ensure exceptional performance and extensive coverage and foster advancements in network-enabled robotics and autonomous systems, among other benefits. The first 6G white paper defined it as ubiquitous wireless intelligence, indicating the convergence of connectivity and AI to offer novel services to humans and machines alike (Latva-Aho & Leppänen, 2019). Since then, several use cases have been developed across sectors such as transportation, agricultural value chains, health care, manufacturing, and education, to name a few (One6G, 2021). Appendix 1-1 summarises the technology components of 6G.

The evolution of various mobile technologies is presented in Fig. 1.2.

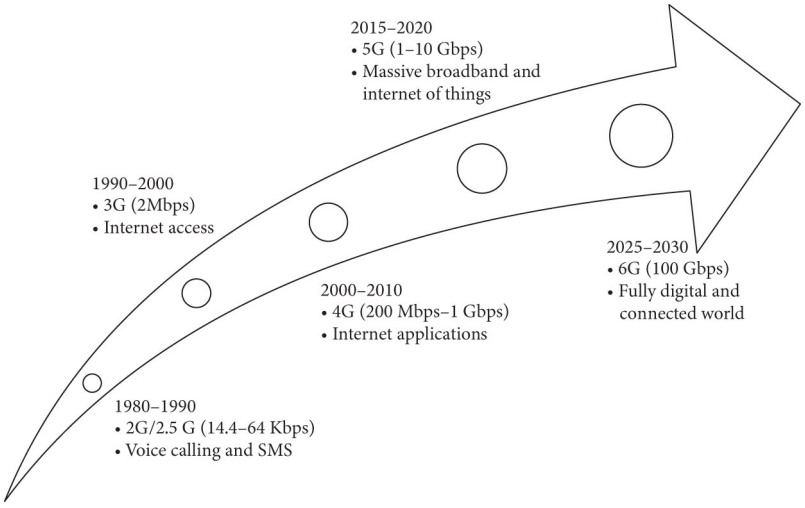


Fig. 1.2 The evolution of mobile technologies
Source: Authors' own.

This book analyses the fundamental changes in telecommunications and digital technologies precipitated partly by deploying 5G networks and services worldwide. These changes have altered the structure of the telecom and Internet value chain, with new services and stakeholders becoming integral parts of the ecosystem.

As explained in this chapter, 5G technologies require much more investment in backhaul infrastructure, including fibre backhaul. They allow for creating private networks over small contiguous land areas to service specific, mission-critical enterprise needs. Such private networks may be serviced by 'neutral hosts' (NHs) that are not licensed telecom operators but are responsible for connectivity in specific locations and connecting the local area to public networks, either themselves or through telecom operators (Sridhar & Prasad, 2022). 5G also allows the creation of 'network slices' that can partition one physical network into multiple virtual networks, each architected and optimised for a specific application/service/customer. Finally, a 5G world is characterised by the vastly improved possibility of using unlicensed spectrum to provide or complement telecom services. Using the unlicensed spectrum expands the set of connectivity providers and creates tensions and synergies between licensed and unlicensed players.

These changes have transformed the TISPs, led to the evolution of the OTT player as a major contributor to network provisioning, and made regulatory rewiring urgent. We discuss each of the technological aspects in depth. The rest of the book then addresses a detailed description of the regulatory framework.

1.2 Key Characteristics of 5G Technologies

In order to support varying bandwidth and performance requirements, the 5G and beyond networks (hereafter referred to as 5G+ networks) have evolved from the earlier generation of mobile technologies. The following four key developments characterise them.

1.2.1 Densification of Networks

Network densification by deploying small cells to augment the macrocellular architecture is the dominant approach in 5G networks to

boost capacity. It is achieved by densely deploying small cells, such as microcells, picocells, or femtocells, which bring access points closer to users so that network capacity can be dramatically increased and latency can be reduced. Those small cells are the access points with lower transmission power and smaller coverage areas, using high-frequency spectrums such as millimetre waves in the case of 5G and Terahertz frequencies in the case of 6G networks (Zhang et al., 2015). While providing increased bandwidth, these high-frequency spectrum bands' propagation characteristics are limited, requiring many smaller cells to provide the intended coverage. Moreover, data traffic originating from indoor users can also be served by Wi-Fi, such as the next-generation Wi-Fi 802.11ac, which expects to support multi-gigabit data transmission rates. Such multi-tier networks with various radio access technologies are called heterogeneous networks (HetNets).

However, the large-scale deployment of small cells is expensive for network operators in terms of operating and capital expenditures, such as site lease, installation costs, additional costs for electricity and backhaul, and operating expenses. Therefore, the issue of how to deploy the small cells densely in an easy and cost-efficient way needs to be carefully addressed in 5G+ networks. There are opportunities for many new entities to participate in network provision. For instance, city municipalities can contribute by leasing street furniture such as street lamp posts. An example is the innovative city projects in Finland with brilliant lamp posts and small 5G antennas providing street coverage (Heino et al., 2020). This also calls for much more significant investment in backhaul infrastructure, including extensive fibrisation, to accommodate the traffic demands of various applications. It also allows the creation of private networks over small contiguous land areas to service specific, mission-critical enterprise needs.

1.2.2 Datafication of Networks

The 5G+ networks are extensive, decentralised systems where intelligent decisions are made at different network nodes based on extensive datafication. Intelligent edges (IE) are the techniques employed in 5G+ networks where AI/ML algorithms gather, store, or process vast amounts of

data at the network edge. An edge device gathers data produced by various devices connected to it, shares it with other edge servers, and uses it to train models that are subsequently used for analysis and prediction. As a result, the connected devices might gain from faster feedback, decreased latency, and lower costs. In health care or transportation, 5G+ communication with edge-driven AI will be prominent in the specific domain (Peltonen et al., 2020). Distributed AI utilises distributed computation, communication, caching, and control (C4) resources in the network by deploying parallel training methods on large amounts of captured data. The Big Data being captured, stored, and processed by the AI algorithm at the edges also increases the vulnerability of these systems (Huang et al., 2019).

1.2.3 Software-isation and Virtualisation of Networks

In radical contrast with hardware-based deployments of previous generations, the design of 5G and 5G+ networks takes advantage of the developments in software-based technologies. The twin paradigms of *software-isation* and *virtualisation* are targeted as two disruptive technologies to be adopted in 5G+ networks to allow flexibility and fast reconfiguration of the network based on the delivered services. The joint use of software-isation and virtualisation allows network functions to run in software instead of hardware and decouples network functions from the underlying hardware platform. This allows functionalities to be upgraded and installed in any location of the network in order to meet the requirements of the services to be delivered.

As software-isation breaks the relationship between functions and the underlying hardware, it has the associated benefits of decreasing the capital and operational expenditure of networks and services. On the other hand, virtualisation enhances the benefits of software-isation by creating abstracted (i.e. virtual) instances of hardware platforms, operating systems, storage devices, and computer network resources. With virtualisation, the software runs in commercial off-the-shelf (COTS) servers and devices instead of dedicated hardware, offering tremendous flexibility in network deployment (Condoluci & Mahmoodi, 2018).

The mobile or cellular/wireless network comprises two main segments: the radio access network (RAN) and the core network (core). The

RAN provides the last mile between the mobile handset and the network. The visible components of the RAN include the antennae that we see on top of nearby mobile towers and base stations (BSs). When we call or connect to a remote server (e.g. to watch a YouTube video), the antenna transmits and receives signals to and from our phones or other hand-held devices. The signal is then digitised in the RAN BS and fed into the network. The core has many functions: it provides access controls ensuring that users are authenticated for the services they are using, it routes telephone calls over the public switched telephone network, it enables operators to charge for calls and data use, and it connects users to the rest of the world via the Internet. It also controls the network by making handovers as a user moves from coverage provided by one RAN tower to the next (Nokia, 2021).

With virtualisation, the RAN functionalities are being migrated from the BSs in the nearby cellular towers to the cloud services, also known as virtual RAN (V-RAN). In V-RAN, the virtual elements, such as software and storage infrastructure, predominate over traditional radio equipment such as transmitters and antennae. 5G technologies have accelerated the move toward virtualisation of the network. This virtualised network is critically dependent on cloud infrastructure for storage and routing. The V-RAN fosters efficient network and resource sharing as well as real-time and flexible scheduling in a centralised fashion (Gavrilovska et al., 2020).

Software-isation and virtualisation have also paved the way for a multiservice infrastructure. In this approach, instead of relying on building new overlay networks to support each new service that will emerge, with a small amount of insight, networks can be conceived to be part of a broader multiservice infrastructure. A multiservice network converges, and all services are integrated into a single infrastructure. The 5G+ infrastructure supports any network traffic and any transport technology, helping to enable streamlined, end-to-end provisioning of new services, regardless of customer premises equipment or network interfaces (Akhtar et al., 2009).

1.2.4 Modularisation of Networks

Until now, the telecommunication industry supply chain has predominantly consisted of two types of entities: (i) the network equipment

manufacturers (NEMs) and the TISPs. The NEMs built proprietary monolithic network solutions using 3GPP standardised protocols embedded in hardware. This has resulted in an oligopoly market of two or three large firms worldwide. The licensed TISPs deployed these network solutions to provide telecommunications and Internet services. However, with software-isation, we are witnessing a change in how hardware and software are manufactured and used in the telecommunications and Internet industries.

The modularity of technical components started with the advent of the Internet. The Internet Protocol is a layered architecture that promotes the development of the different layers, which are then vertically glued together for end-to-end connectivity. The principle expounded by the open systems interconnect (OSI) model lays down modularity in network architecture. Each layer is modular and depends on the layer below. The communication across the layers is achieved through programming interfaces. Tanenbaum and Wetherall (1996) provide an excellent exposition of the OSI's modularity and logical layers. Modularity, in turn, promotes openness, as the different modules can be created and developed by various firms or individuals and then can be integrated as a whole to provide the desired service.

Until the 1970s, the computer industry used proprietary closed architecture, thanks to IBM. However, Apple's innovation created the personal computer (PC) era. With Intel making chips and Microsoft developing the operating system, the PC industry promoted openness and created intense competition in the components industry across chips, memory, input/output devices, displays, and printers. IBM struggled to transform its mainframe monolithic computer architecture to the federated architecture of the PCs. Consequently, the Windows–Intel PCs took the market share from Apple and IBM in the 1980s (Farrell & Weiser, 2003). Microsoft's software operating system complemented the hardware produced by Intel, resulting in modular hardware and software architectures in the PC industry.

Product architectures are considered modular if the engineering interfaces defining how product components interact are standardised. Standardised interfaces allow some variance in the design details of individual product components, leading to 'modular innovation' of product components (Argyres & Bigelow, 2009). The result is evident in the

innovation witnessed in the semiconductor industry, including the development of high-performing memory, processors, and display devices.

In software, the modularity of components such as operating systems, applications, and middleware has accelerated the development of a competitive component ecosystem. Developing various standards on the specification of the interfaces is a significant step towards the interoperability of components manufactured by different vendors. Interface standards ensure that a system built from 'conforming' components from different sources will be functional. Initially, standards defined physical things. Then, they evolved to support the industrial wave and define the physical relationship between things. Later, in the information wave, standards defined the virtual relationship between a radio transmitter and a receiver.

The telecom industry also initially resisted modularity and openness. This was evident in the multi-year-long *Hush-A-Phone* controversy in which AT&T in the United States objected to using a cup-like device over the phone receiver to limit background noise. The US Federal Communications Commission (FCC) agreed with AT&T's decision and directed that such third-party devices that affect the integrity of the telecom network should not be used. However, the FCC learnt its lesson and subsequently rejected AT&T's efforts to block the use of the 'Carterfone', a device that connected a telephone line to a two-way radio so that people using the radio could gain access to the telephone network and those on the network could communicate with those using radio (Nuechterlein & Weiser, 2013). The above two cases illustrate the monopolistic control of incumbent telecom carriers across services and devices. However, with the onset of the GSM technology, the development of handset modularity, especially for mobile phones, and the subscriber identification module have provided logical and physical separation of handsets and network services.

Further, in telecommunications, the air interface standards for mobile telephony, such as CDMA and long-term evolution (LTE), set by standard-setting organisations (SSOs) such as 3GPP enabled telecom equipment makers and mobile handset firms to build compatible products for the provisioning of mobile telephony and broadband. In the computer industry, the codification standards set by the American Standard Code for Information Interchange (ASCII) and Unicode provide for

consistent encoding, representation, and handling of text characteristics, including structuring the domain name systems used in the Internet. The standards on the application programming interface (APIs) promote compatibility and interworking of different software components built by different vendors and promote vertical separation in the components industry. Hence, the modularity of components and the interoperability between components through standard interfaces create a competitive environment for the component industry.

The NEMs have built proprietary architectures in the telecom industry, including the critical RAN based on 3GPP standards. However, for the past three or four years, we have seen the modularisation of different components of the RAN and the emergence of open radio access networks (O-RAN).

1.2.4.1 The Emergence of O-RANs

Open access is 'the possibility for third parties to use an existing network infrastructure', according to the Best Practice Guidelines for Enabling Open Access, adopted by the 2010 Global Symposium for Regulators. While there is no single definition of open access, the general principles include non-discriminatory access to physical network infrastructure to provide telecom and associated services. In Europe, for a long time, open access was discussed in the context of public-sector participation in building a network infrastructure that is opened up for non-discriminatory access. The proponents of open access argue that it provides a good balance between static and dynamic efficiencies (Krämer & Schnurr, 2014), that is efficient allocation of resources, given fixed technologies, and efficient allocation of resources for optimising technological progress.

The definition of open access by Forzati et al. (2010) is given below:

> In the open access network model, the roles of the service provider and the network owner are separated, and the service providers get access to the network and the end customers on fair and non-discriminatory conditions.

The hardware-based proprietary architecture of the telecom equipment manufactured and deployed by a few NEMs is rapidly changing with

the evolution of O-RAN. The O-RAN architecture focuses on two fundamental pillars: openness and intelligence. Open interfaces are vital to support smaller vendors and operators in swiftly introducing novel services and enabling operators to tailor the network based on their requirements. Openness enables multi-vendor V-RAN deployments, resulting in a more competitive and interoperable ecosystem. Moreover, open-source software and hardware designs can facilitate faster and more efficient innovation and commercial deployment while preserving backward compatibility with legacy systems. For this, standardisation and interoperability are critical.

The O-RAN architecture attempts to break the 'vendor lock-in' between the telecom carriers and the large NEMs. The core idea of O-RAN is to enable interoperability among the RAN components and interfaces and to increase the flexibility of network deployment through the development and use of open interfaces and open hardware/software (Garcia-Saavedra & Costa-Perez, 2021). The conflict between the United States and China has grown over the security of Chinese equipment supplied to US carriers and the uncertain geopolitical relationship between the United States and China in recent years. This is one of the primary reasons for the O-RAN movement in the United States. After this initiative, carriers in many countries, including Canada, Finland, Germany, India, Israel, Japan, Singapore, South Korea, Taiwan, and the United Kingdom, have become members of the O-RAN alliance. The movement is gaining support (Kim et al., 2023).

Several entities could combine to provide O-RAN architectures, including the telcos, software vendors, Internet firms, equipment vendors, cloud service providers, fixed-line providers and tower companies. The key concept of O-RAN is 'opening' the protocols and interfaces between these various building blocks (radios, hardware, and software) in the RAN. The O-RAN Alliance has defined eleven interfaces within the RAN for interoperability across devices and vendor systems. The O-RAN makes the RAN architecture more flexible and interoperable, thus paving the way for a more resilient, reliable, and scalable architecture.

The emergence of O-RAN has enabled a new look at the infrastructure layer for telecom and associated services. Chapter 3 discusses this convergence and the need to incorporate it into the regulatory framework.

The modularisation of the connectivity value chain, along with software-isation and virtualisation, opens up opportunities to enter new types of entities in the connectivity value network—software companies, start-ups, and system integrators. This phenomenon is called the 'hybridisation' of networks and services. Hybridisation changes the nature of the connectivity value chain and potentially shifts power dynamics in the telecommunications industry.

1.3 Wi-Fi as a Complement to Cellular Broadband

The cellular mobile service uses radio spectrum in specific bands licensed and assigned to TISPs after much deliberation amongst government policymakers, regulators, and mobile operators using defined methodologies such as auctions. However, a silent revolution took root in large US University campuses in the 1990s in the form of wireless local area networks (WLANs), later ratified by manufacturers as Wireless Fidelity (Wi-Fi). Like the Internet and Web, WLANs have become a mass-market technology due to open standards and the use of unlicensed spectrum. While many WLAN technologies were sold throughout the 1990s, the Institute of Electrical and Electronics Engineers (IEEE) established the 802.11b standard, which set the stage for mass-market development. After many other market entries, by the summer of 2002, there were an estimated 15–18 million 802.11b networks. Wi-Fi gained popularity in the unlicensed industrial, scientific, and medical (ISM) bands of 2.4–2.4835 GHz (i.e. between licensed S-bands of 40 and 41). Many devices operate in the ISM band, including cordless phones at home. However, using an ultra-wide band of 20 MHz, Wi-Fi uses spread spectrum technology and low power levels for indoor coverage, thus minimising interference problems with devices operating in the same band.

Directional antennas and amplifiers could sculpt a coverage zone using low-power transmitters by unlicensed operators for larger areas or outdoor spaces such as parks and plazas. As in the case of other open-source movements, the proponents of WLAN had the utopian dream of completely undermining the stranglehold of cellular and landline telecommunications companies.

Without having to wait and pay vast sums of money for spectrum, Internet service providers (ISPs) quickly adopted the new technology. They started developing Wi-Fi hot spots in public areas, cafeterias, and restaurants to enable Internet access. Needless to say, Wi-Fi is an access technology that has to be backed up by a robust, high-capacity backhaul.

The IEEE 802.11 forum, with appropriate modifications to the physical layer, encoding algorithms, and multiplexing techniques, has kept the evolution of Wi-Fi access networks almost on a par with the mobile operators' 2G/3G/4G networks. Table 1.1 illustrates the evolution of Wi-Fi technologies.

Table 1.1 Summary of Wi-Fi technologies

IEEE 802.11 Standard	Release	Frequency (in GHz)	Maximum data rate (in Mbps)	Indoor range (in m)
a	September 1999	5	54	35
b	September 1999	2.4	11	35
g	June 2003	2.4	54	38
n (Wi-Fi 4)	October 2009	2.4/5	600	70
ac (Wi-Fi 5)	November 2011	5	7 Gbps	70
ad (WiGig)	January 2013	2.4/5/60	7 Gbps	10
ay	2019	60	20–40 Gbps	30
ax (Wi-Fi 6)	2020	2.4/5	9.6 Gbps	30
Wi-Fi 6E	2020	2.4/5/6	19.2 Gbps	–
.be (Wi-Fi 7)	2024	6	46 Gbps	–
Wi-Fi 8	2028	2.4/5/6/mm wave (42.5-71 GHz)	100 Gbps	–

Source: Authors' own.

1.3.1 Wi-Fi 6 and Beyond

IEEE 802.11ax, known now as 'Wi-Fi 6', is the first amendment in the Wi-Fi family to go beyond small, indoor environments and aim to optimise its performance in large outdoor deployments. Although it enhances the nominal data rate by 37 per cent compared to Wi-Fi 5, it aims to provide a four-fold improvement in terms of throughput and spectrum efficiency in dense deployments through new features such as orthogonal frequency division multiple access (OFDMA), multi-user MIMO (MU-MIMO), and spatial reuse. At the same time, Wi-Fi 6 reduces the power consumption per device. Whereas legacy Wi-Fi technologies use 2.4 and 5 GHz frequencies, the deployment of Wi-Fi 6 E relates explicitly to the use of the new 6 GHz spectrum band, which has already been assigned in frontier markets (e.g. the United States, Korea, and the United Kingdom) and is expected to receive similar allocation elsewhere (e.g. Europe).

The 5G and Wi-Fi 6 enhancements have narrowed the disparities in the legacy use cases that the cellular and Wi-Fi technology families may each address while simultaneously creating opportunities to address new market demands for applications with ever more intensive throughput and quality-of-service (QoS) requirements. The first effect tends to bring the two technologies closer as potential substitute alternatives for meeting end-user demand (Oughton et al., 2021). Many equipment vendors have positioned 5G and Wi-Fi 6 to coexist, providing enhanced indoor coverage and seamless integration.

However, the insatiable hunger for bandwidth-intensive real-time applications (RTAs) that can support 4 K and 8 K video streams and those that require sub-5-millisecond delay have led to the creation of future Wi-Fi. Although the standard development process is at the very initial stage, submissions for Wi-Fi 7, also known as IEEE 802.11be, are being received by IEEE. Apart from increasing the data rates and reducing latencies, many other features, such as multiple-access-point (Multi-AP) cooperation, will form the basement for further Wi-Fi evolution (Khorov et al., 2020). The 11be project has incorporated ambitious goals related to higher nominal data rates, higher spectrum efficiency, better interference mitigation, and providing RTA support.

These developments indicate synergy and convergence between the macro cellular network technologies standardised by 3GPP and micro

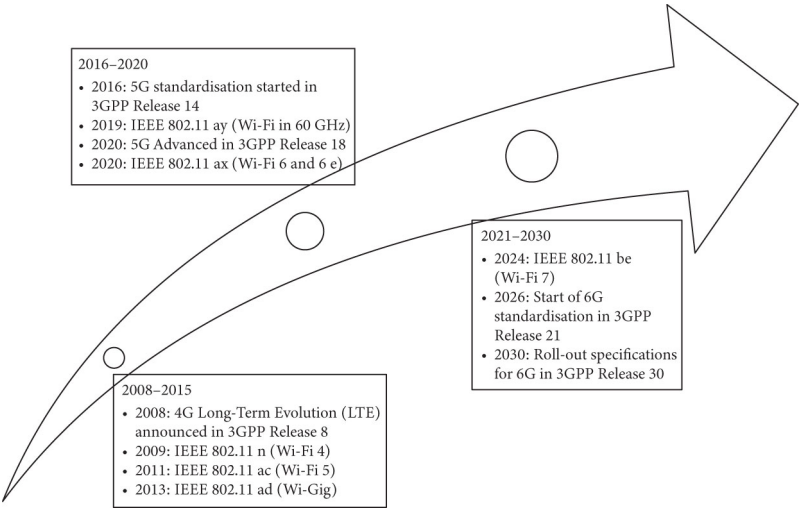


Fig. 1.3 Timeline of 3GPP and IEEE standardisation activities
Source: Author's own.

coverage technologies such as Wi-Fi standardised by IEEE. The timeline of various standardisation activities is presented in Fig. 1.3.

1.3.2 Wi-Fi Offloading

Wi-Fi offloading is a method by which the traffic is diverted from the carrier's macro cellular network to a localised Wi-Fi network, installed typically in homes, enterprises, or public locations, thus relieving the licensed spectrum used. The owner of the venues can deploy such Wi-Fi hot spots as 'private hot spots' (e.g. homes, office premises, cafés, and restaurants such as Starbucks, Costa Coffee, and hotels); or the ISPs can deploy 'public hotspots' typically in areas such as airports and malls; or mobile operators either by themselves or in partnership with ISPs as 'carrier Wi-Fi hotspots'.

In the case of private or public Wi-Fi, the hand-off from the carrier network often requires human or application intervention. Typically, the hand-off requires authentication by the user or the application to the

nearby hot spot. Moreover, since the carrier and Wi-Fi networks do not necessarily collaborate in the hand-off, the IP address must be allocated when the device moves into the Wi-Fi zone. The connection needs to be re-established at the session or data link layer levels, leading to possible jitter and delay or even disconnects. Moreover, when traffic is offloaded from the operator's cellular traffic to the Wi-Fi network, the same level of security and integrity as in the cellular network must also be applied to the Wi-Fi air interface. The Wi-Fi Protected Access (WPA) Protocol deploys subscriber identification module (SIM)-based authentication very similar to the authentication in a telecom network, as one of the options to achieve cellular network-level security and integrity along with the seamless mobility between the cellular and Wi-Fi networks. The SIM credentials are used for authentication in the Wi-Fi network, obviating the need for manual or application intervention (Sridhar & Buchi, 2012).

1.3.3 Voice-over Wi-Fi

While the technology evolution and standardisation continue in parallel in telecom and Wi-Fi areas, the synergy in both these could be garnered for better QoS. One such advancement is voice-over Wi-Fi (VoWiFi). Voice telephony over cellular mobile networks that generally tend to have poor coverage indoors can be complemented by Wi-Fi networks to provide an enhanced experience. It uses the existing Wi-Fi connection provided by the TISP or ISP to carry users' voice traffic to the mobile network operator (MNO) through the Internet backbone. An extension to the network architecture is required to enable VoWiFi. Most of the MNOs have integrated VoWiFi into their networks. According to polling from wireless users in four different developed countries, more than 90 per cent of users expect their calls to be seamlessly switched to Wi-Fi even if indoor cellular coverage is strong. When cellular and Wi-Fi are available, nearly 40 per cent prefer Wi-Fi, and 45 per cent prefer their device to choose the strongest signal. These are all evidence of increasing users' propensity towards utilising WLANs for everyday needs (Ngongang et al., 2016). The VoWiFi uses subscriber identity module (SIM)-based authentication, providing revenue generation opportunities to the MNOs.

1.3.4 The Economic Value of Wi-Fi and the Extended Value Chain

The prevailing view among policymakers is that most economic value is derived from the licensed spectrum. The value of unlicensed spectrum (for instance, spectrum in the 2.4 GHz and 5 GHz bands used for Wi-Fi) has always been undervalued. However, many studies have illustrated the economic value of unlicensed spectrum using data from the United States under different scenarios, including cellular-Wi-Fi offloading; Wi-Fi Internet service provisioning; Wi-Fi in communication-intensive locations such as hospitals and malls; community Wi-Fi in public places; and finally, residential Wi-Fi. As per the recent work of Katz (2014), the sum of consumer and producer surplus of the technologies operating in unlicensed spectrum bands in the United States amounts to a total annual economic value of USD 222 billion in 2013 and contributed USD 6.7 billion to the nation's GDP. It is also estimated that by 2017, at least USD 547.22 billion in economic value and USD 49.78 billion in GDP will be contributed by unlicensed spectrum and associated technologies (Sridhar & Prasad, 2015).

1.3.4.1 Wi-Fi in Residences

Residential Wi-Fi is poor in India due to very low landline broadband penetration at about 6 per 100 households, which is required to backhaul Wi-Fi hotspots at home. Despite the poor penetration, it was found that users switched their data access to residential Wi-Fi as best as they could due to (i) lower landline broadband tariff and (ii) improved quality of experience. While most landline broadband providers offer bundled Wi-Fi access points, they are not promoting it as a better alternative to mobile broadband, possibly to avoid cannibalising their mobile data revenue.

1.3.4.2 Wi-Fi in Offices

Most organisations are actively deploying Wi-Fi infrastructure mainly to (i) provide mobility to the workforce, (ii) enhance flexibility at work, and (iii) provide a better quality of experience. These Wi-Fi networks are deployed by real-estate developers, building/premise owners, and pure-play ISPs, apart from the TISPs. System integrators or Wi-Fi equipment

providers deploy large Wi-Fi installations engaged by the firms for their Wi-Fi needs.

1.3.4.3 Public Wi-Fi

With examples such as Starbucks in the United States, most restaurants and coffee houses have Wi-Fi to improve brand loyalty and customer retention. About 8 million hotspots are installed globally in venues like the ones mentioned above and on trains and flights. City municipalities typically deploy community Wi-Fi to provide public access to the Internet. Starting in San Francisco, many cities now provide community Wi-Fi.

Public Wi-Fi coverage in India is inferior. Public Wi-Fi hotspots per million population in the United Kingdom, United States, and China are 175, 50, and 75 times that of India (Sridhar, 2023). Noting the lack of public Wi-Fi infrastructure in India, the Telecom Regulatory Authority of India (TRAI) initiated discussions on an open Wi-Fi access protocol in 2016–2017 and conducted many stakeholder meetings. The TRAI recommended an open-standard specification referred to as 'Wi-Fi Access Network Interface (WANI)' in 2017 (TRAI, 2017). Subsequently, the government of India launched the Prime Minister WANI (PMWANI) scheme, as approved by the Cabinet in December 2020, to improve affordable Wi-Fi access for the nation's citizens.

WANI is a technical and regulatory innovation that unbundles the Wi-Fi ecosystem to provide affordable, high-speed Internet access to the masses. Most Wi-Fi deployments, enterprise or public, are provided by a single entity. In most cases, the ISP or TISP provides these functions. This may be due to existing telecom regulations where licensed entities such as ISP/TISP can only offer Wi-Fi services. Besides regulatory limitations, it is also driven by business cases where a single entity controls a complete network. Such a controller is justified in cases where deployment is confined to an enterprise or small-scale deployment. However, large-scale deployments can only be achieved if the ecosystem is unbundled, where separate/independent functions are offered by different entities and integration/interoperability is taken care of by the well-defined interface, application programme interface (API), message flow and standards.

The WANI architecture is designed to be highly scalable and distributed across different telecom layers. It is interoperable at each layer and provides end users with a seamless and secure Wi-Fi experience. Another

objective of WANI is to create an abundance of last-mile Wi-Fi access providers in the form of micro-entrepreneurs so that the proliferation of the Wi-Fi network is fast and easy. The WANI architecture, by design, enables the layered approach where a separate player supports each function of the Wi-Fi ecosystem. This makes the architecture scalable from a technical point of view and low cost from an economic point of view. The model envisioned the setting up of public Wi-Fi hotspots in public data offices (PDOs) by local entrepreneurs with methods for monetising Internet services and, at the same time, providing affordable Internet access to users.

Hence, Wi-Fi has included Wi-Fi equipment providers similar to the NEMs for the telcos in the telecom and Internet value chain. Pure-play ISPs with less stringent licence conditions than the TISPs have started to provide these complementary services, especially for better indoor coverage. This also caught the fancy of Internet firms such as Google and Meta, who experimented with their own Wi-Fi services in India, such as GoogleFi and Express Wi-Fi.

1.4 Network Slicing

Network slicing refers to partitioning one physical network into multiple virtual networks, each architected and optimised for a specific application/service. A network slice is a virtual network created on top of a physical network to give the slice tenant the illusion of operating its dedicated physical network. This configuration has become essential to the overall 5G architectural landscape. Each 'slice' or network portion can be allocated based on the application's specific needs, use case or customer (Viavi Solutions, 2022). Network slicing in 5G can be designed to accommodate different types of services (see Fig. 1.4), such as URLLC and massive machine-type communication (mMTC), with varying QoS requirements.

The following are the advantages of network slicing in 5G networks:

(1) The network has better performance tailored to all the different types of networks.

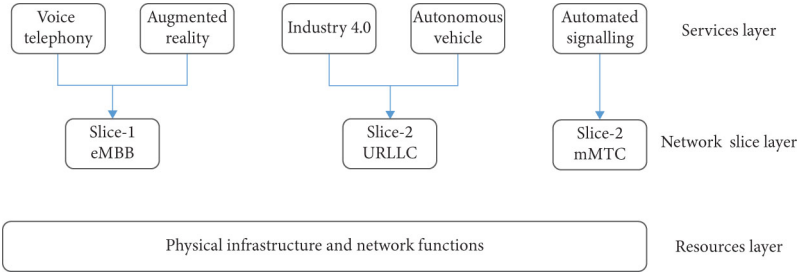


Fig. 1.4 Network slicing
Source: Authors' own.

(2) It is easier to scale up or down depending on the number of users and associated requirements.
(3) Networks can be isolated, thereby increasing reliability and security for each slice.
(4) Network slices can be customised for each type of service or business.

For example, in China, there are time-sensitive networks for electrical grids and wide-area private networks for mines, which run on network slices. Private networks and network slicing are two very different ways of providing users and subscribers with the best possible service quality while balancing efficiency and security.

The following are potential disadvantages of network slicing (Enea, 2023):

(1) Spectrum and capacity fragmentation: if network slices are not adequately managed and coordinated, they can lead to network fragmentation, making it harder to manage and optimise network resources. This can result in inefficiencies and poor network performance.
(2) Network security: while network slicing can provide enhanced security by isolating traffic between different slices, it can also introduce new security risks if slices are not adequately secured. For example, a security breach in one slice could spread to others and compromise the entire network. Vulnerable private networks can

be used to launch attacks on other devices or networks, including the public network.

(3) Investment: additionally, implementing network slicing can be complex and expensive, requiring significant investments in new infrastructure and technologies. This can be a barrier for some network operators, particularly smaller ones with limited resources.

(4) Effect on private networks: since private networks consume allocated network and spectrum bandwidth, if over-allocated, it can decrease available bandwidth in the public network, impacting the QoS of the public network users.

1.5 Captive Non-Public Networks: A Game Changer

In the pre-5G era, the last-mile connectivity (i.e. from the cellular towers and associated base transceiver station (BTS) to end-user devices) was exclusively provided by the MNOs. Even on landlines, the telcos provided Wi-Fi connectivity to wired broadband. Large enterprises supplemented the MNO services by constructing their campus Wi-Fi networks. Though public Wi-Fi has existed since the 1980s, commercial deployments of large-scale public Wi-Fi, including municipal Wi-Fi, have not been viable.

The 5G microcellular deployments have changed the competition landscape. The 5G technology enables high-capacity broadband communication suitable for industry automation in a contiguous local area. This area could be indoors or include the adjacent outdoors. The network might be private and used by a single enterprise, such as in a factory, corporate, or university campus, also called captive non-public networks (CNPNs). These networks can be TISP-led, through options such as network slicing or spectrum leasing, or deployed by entities other than MNOs, such as NEMs, tower companies, and Wi-Fi gear providers, to name but a few. Examples of direct deployment by enterprises include the one constructed for Lufthansa Technik by Nokia in Finland; Bosch setting up private 5G networks in about 250 of its locations in partnership with Nokia; and Volkswagen constructing its own '5G island' in its manufacturing plant in Dresden, Germany.

There are various reasons for enterprises to construct their private networks, including increased security, lower latency and congestion, greater network control, and the ability to leverage existing campus infrastructure, such as indoor Wi-Fi networks. Such networks are possible in 5G due to the increased availability of high-performance, low-cost network equipment with software that assists self-configuration. However, due to the increasing complexity of 5G technology and the more demanding factory and industrial use applications, telcos/MNOs are becoming the preferred deployment partners (network providers or delivery partners). As a result, TISPs across the globe are forming partnerships with equipment suppliers, specialised network service providers, and systems integrators to provide 5G private network services.

An important aspect of direct deployment by enterprises pertains to allocating spectrum to enterprises. The spectrum management policy needs to be carefully planned to avoid the risk of fragmenting the scarce 5G spectrum resources (see Chapter 5 for spectrum allocation for private networks). For example, if the MNOs use large quantities of spectrum in constructing CNPNs, spectrum allocation for public networks will correspondingly reduce, resulting in reduced speeds and poorer QoS.

The CNPNs extend the telecom value chain by bringing in managed service providers and infrastructure providers, including real-estate and building developers.

1.5.1 Entry of NHs in the Telecom Value Chain

The private network services, such as CNPNs, can also be shared for public use either within the campus itself or in adjacent outdoor areas to provide a seamless experience to the users. This complementarity of a private network for public use can enable the formation of NHs. The NH combines two concepts: host and neutrality. The host component signifies an entity that makes a pool of resources accessible to users so that the hosted clients can continue to deliver connectivity services. The 'neutrality' component refers to the host's ability to serve diverse clients as a shared platform. The resources available to each client are governed by a commercial agreement and policy-based administration between the

NH and the hosted client (Bajracharya et al., 2022). The NH is generally not a licensed entity such as a TISP.

An NH firm provides wholesale infrastructure-sharing services through digital platforms to the downstream markets, enabling customers to take advantage of economies of scale and scope of local networks. Further, the radio network slicing and network function virtualisation as part of the 5G network protocols enables the NHs to apportion bandwidth across public and private networks with associated QoS requirements. This is a paradigm shift from what we have witnessed before 5G. For example, until now, the MNOs have shared their network elements partially or fully with the mobile virtual network operators (MVNOs) to provide service. In landline, 'local loop unbundling (LLU)', as discussed in detail by Sridhar (2019), is the methodology for sharing the network elements ranging from passive copper wire/optic fibres to bandwidth. Unfortunately, neither MVNO nor LLU has been successful in many countries for economic reasons.

The following are the broad categories of NHs:

(1) NH for private networks: ideally suited for constructing and managing private networks for industrial uses;
(2) multi-operator small cell as a service (SCaaS): this type of NH does not have its spectrum. However, the NH function is accomplished by clustering many small cells and sharing the backhaul of MNOs;
(3) spectrum-based NHs: this type of NH is a fully fledged local MNO, which has full rights and its radio resources (shared or dedicated) and network that also hosts other diverse MNOs.

While spectrum-based NHs are licensed/authorised MNOs, SCaaS shall be authorised to provide interconnection to the public switched telecom network/PLMN/Internet. The NH for private networks is for captive use and is not interconnected with public networks.

1.6 Conclusion

The technologies of 5G+ networks differ from those witnessed in prior generations of mobile technologies. These technologies enable

high bandwidth and support many autonomous applications with low delay tolerance. At the same time, there is a silent revolution in the form of moving most of the network algorithms, especially those in the RANs, which are being migrated as software components hosted in cloud platforms. This modularisation and software-isation have led to extended telecom value chains, including software vendors, managed service providers, and cloud platforms, apart from the traditional telcos and NEMs. Wi-Fi networks have evolved almost as fast as 3GPP cellular broadband technologies and standards to provide complementary network coverage, especially in indoor locations. Several initiatives, especially in India, also exist to provide ubiquitous public Wi-Fi access. The 5G+ network technologies also enable customised network slicing to create private networks with stringent QoS characteristics. Further, the research and the standardisation process for 6G networks capable of supporting advanced AI applications, human body communication, tactile Internet, and holographic presence have already started. These technologies are expected to profoundly affect user experience, necessitating the conventional regulatory mechanisms to be revisited.

Appendix 1.1

Emerging 6G Technologies and Services

The 6G technology is expected to perform better than 5G on various technical parameters, such as peak data rates, traffic capacity, connection density, spectral efficiency, and latency. Such technological advancement will bolster AI and ML-based performance enhancement, seamless fusion of the physical and human world to trigger enhanced sensory experiences, extreme performance and coverage for mission-critical applications, and network-enabled robotics and autonomous systems, among other things.

The potential use cases in which 6G will be deployed, including transport, health, smart cities, agriculture, and industry 4.0 are indicated in Fig. 1.5.

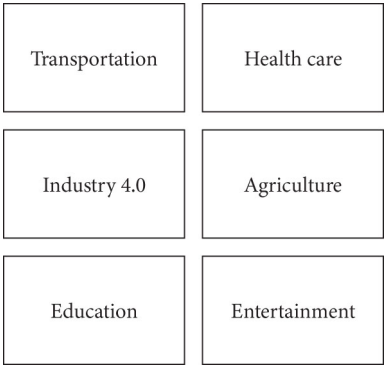


Fig. 1.5 Areas of focus in 6G
Source: Authors' own.

Below are some of the important technologies that will be present in 6G:

- Terahertz communication: 6G will augment the operation over the Terahertz (THz) frequency range in the sub-millimetre wave band owing to extremely wide bandwidths. The availability of incredibly high bandwidths would change the emphasis from spectrally optimised solutions to improved coverage solutions. The 6G systems will also use a combination of licensed and unlicensed spectrum, in millimetre wave, THz frequencies, and visible light communication, for extremely high bandwidth. THz communication will enhance the 6G potential by supporting high bandwidth-consuming applications such as wireless cognition, sensing, imaging, and precise positioning.
- Internet of Everything (IoE): apart from the very high speeds expected out of 6G in the area of eMBB, 6G is also expected to be able to connect as much of the Internet of Things (IoT) as possible by 5G. 6G is also expected to provide full support for the IoE, with intelligence to bind all people, data, processes, and physical objects into one system. Using energy-efficient sensor nodes is considered one of the critical constraints supporting massive IoE connectivity in 6G. The 6G-enabled low-power extensive area networks (LPWANs) have the potential to support broad area coverage (up to 20 km)

networking with long battery life (> ten years) and low deployment costs (Chowdhury et al., 2020).

- Molecular communication: electromagnetic waves used in standard wireless communication are neither practical nor advantageous in some locations, such as inside the human body. One potential answer is molecular communication, in which information is transmitted via chemical signals. The 6G systems support molecular communication for specific niche applications. A new generation of human in-body nano-networks for targeted medicine administration and health-care applications under the auspices of the Internet of Nano-Things (IoNT) can be made possible by molecular communication. Devices communicate with one another by exchanging and absorbing molecules. The domain of health-care systems is one of the main areas where 6G is attempting to improve services. As a result of molecular communication, medicine and the health-care application areas will witness colossal transformation.
- Tactile Internet: tactile Internet provides a platform for enabling real-time applications, which range from actuating robotics to haptic communications, including telesurgery, autonomous driving, augmented reality, virtual reality, and extended reality. In the tactile-enabled network, lower latency is combined with enhanced reliability and security. It is considered the key enabler of haptic communication, which incorporates the actual immersion of human beings in the virtual world empowered with the sense of touch and physical interaction from a remote place. The 6G networks and systems enable tactile communication and facilitate health-care, entertainment, and commerce applications.
- 3-D holographic imaging and communication: the propagation models of radio communication established before the development of 6G networks show that the height of the communication devices is unimportant. Satellites, unmanned aerial vehicles (UAVs), and underwater communications are important technologies that have previously included a third dimension. To be effective in the 6G context, the analytical framework developed for 2D wireless communications derived from stochastic geometry and graph theory must be suitably modified. By considering the device height, elevation beamforming is made possible via

Table 1.2 Comparison of key performance indices of 5G and 6G

Features	5G	6G
Peak data rates	20 Gbps	~1 Tbps
Traffic capacity	10 Mb/s/m^2	1 Gb/s/m^2
Latency	1 millisecond	10–100 microseconds
Frequency spectrum	24–52.6 GHz	Sub 6GHz mm wave band, Terahertz band (visible light band)
Connection density	1m devices/km^2	10m devices/km^2
Mobility	500 km/h	>1,000 km/h
Spectral efficiency	3 ×	≥ 15 ×
Network energy efficiency	≥ 10 ×	≥ 100 ×

Source: Authors' own.

full-dimensional multiple input–multiple output designs (Bhat & Alqahtani, 2021). Interesting applications include fusing the physical and digital world using concepts such as 'digital twins'. The 3D THz imaging can improve traffic safety with accurate position determination and object detection with applications in UAVs (Latva-Aho & Leppänen, 2019). The 3D holographic imaging will augment the experience of telepresence.

Table 1.2 below comprehensively compares the key performance indices distinguishing the 5G and 6G networks.

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2

The Economics of the Digital Ecosystem

2.1 Introduction

The telecommunication services are typically licensed and regulated by the country regulators. In this chapter, we review the evolution of the market structure in telecommunications and Internet services. The wireline telecom market, once viewed as a natural monopoly, migrated to an oligopoly market with the introduction of competition in the United States in 1994, subsequently in Europe and India. The chapter traces the historical developments of broadband market in the US and elsewhere due to competition in the fixed wireline market. However, in emerging markets, in India in particular, the mobile first strategy led to faster deployment of cellular mobile communication services, thereby bringing telephony, then mobile broadband, to hundreds of millions. Along with the evolution of Internet broadband, a host of services referred to as over-the-top applications that operate over untethered Internet connections disrupted the markets. However, the network economics dictate that these Internet services, much like telecom services, are provided by few firms that exhibit significant market power in their defined markets. The digital capitalism we see today due to the emergence of these large tech firms is being noticed by regulators around the world. The chapter finally discusses competition, price, and interconnection regulations, which are being reassessed in the context of these evolving OTT services. This chapter examines the entities and the economics in turn, then describes a new avatar of capitalism operative in the digital industry.

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2.2 The Entities

2.2.1 Wireline Telecom Operators: Plain Old Telephone Service to Broadband

Telecommunication services are traditionally classified into two distinct types: wireline and wireless (aka mobile). Wireline telecommunication service is the provisioning of the POTS over local access networks (generally referred to as the 'last-mile' connection). Traditionally, this last-mile connection is provided by the TISP using a fixed wireline consisting of a pair of copper cables. Hence, this service is often referred to as a fixed-line service.

The wireline telecom service traditionally designed for synchronous voice communication was built using circuit switching technologies (hence also referred to as the PSTN). Circuit-switching technologies allow communication between devices using dedicated circuits, therefore allowing communication across long distances without delay. However, these networks are also susceptible to failure if there are breakdowns or interruptions in the circuit (Tanenbaum & Wetherall, 1996).

Most countries regarded wireline communication as a 'natural monopoly' service (Nuechterlein & Weiser, 2013). The primary reason that wireline services are considered natural monopolies is the huge fixed cost associated with the investment, making duplication of the local loop uneconomical. Further, enabling economies of scale to be reaped facilitates the goal of providing universal services to all households in the country. Under these conditions, it is undesirable to have more than one firm from the perspective of both efficiency and equity.

The natural monopoly factor is more pervasive and long-lasting in the rural telecom market due to the relatively small size of the market, low revenue potential, and slow growth prospects. Serving only limited rural localities may not be economically feasible for the service providers. Further, the rural population has a lower willingness to pay. This results in a two-way problem: since economies of production are not fully realised, service cannot be provided at the lowest cost; at the same time, since the paying capacity of the target consumer group is low, higher prices cannot be charged for the service (Sridhar, 2012).

The monopolistic wireline companies can be licensed private carriers or state-owned public carriers. In the case of a private carrier, the monopolist may indulge in the abuse of market power, thus leading to a socially inefficient outcome in the form of high prices and low quantities. Governments also like to keep monopoly control over the telecom infrastructure so that resources can be mobilised against any threat to national security and sovereignty.

Until the late 1980s, publicly owned national monopoly telecommunication carriers provided wireline service in most European countries. India, too, followed the government-owned monopoly operator model to provide voice telephony (for details, refer to Sridhar, 2012). In the United States, until the Telecommunications Act of 1996 was implemented, wireline service was provided by monopoly private operators such as Regional Bell Operating Companies (RBOCs).

In most countries, due to limited market potential, wireline connectivity in rural and remote areas is covered under the 'Universal Service' programme, with different mandates including the provisioning of village public telephones to provide each household access to a wireline broadband connection using government subsidies (Sridhar, 2019).

Over time, new modes of thinking emerged about the ownership and market structure of the wireline industry. It was felt that public-sector monopolies restricted output, charged unnecessarily high tariffs, operated with bureaucracy and inefficiency, and enjoyed vast power. It also became apparent that the vast infrastructure needed for universal access could not be provided without private-sector capital (Athreya, 1996).

Privatisation of telecommunications services, along with the introduction of competition, was seen as the new mantra (Melody, 2000). Competition could be introduced without the duplication of infrastructure costs by unbundling the physical infrastructure from the service and providing service providers with non-discriminatory access to the infrastructure. This process was termed 'local loop unbundling'. Long-distance telephone service was seen as particularly suited for introducing competition, provided long-distance carriers could access the local loop in a non-discriminatory manner.

In a landmark case in 1982, the US Supreme Court broke up AT&T, a private monopoly, to facilitate competition in the long-distance market. AT&T would continue to be a provider of long-distance service. At the

same time, the newly independent RBOCs, nicknamed the 'Baby Bells', would provide local service to AT&T and its competitors, such as MCI and Sprint.

The United States reached nearly 99% of wireline household coverage in 1994. The United States introduced competition in the local exchange carrier market to spur further innovation and reduce abuse of market power by the private monopoly operators through the Telecommunications Act of 1994. This resulted in the country's evolution of many competitive wireline telecom operators (also called competitive local exchange carriers—CLECs) in 1996. The CLECs could provide telecom services or lease their infrastructure from the incumbent telcos. Most European and Asian countries, such as India, started the liberalisation of wireline telecom and introduced competition in the 1990s, thereby breaking the monopoly of government or state-owned enterprises.

With the development of digital subscriber loop (DSL) technology in the mid-1990s in the United States, wireline carriers started to provide Internet services along with the plain telephony service. Starting with narrowband, offering hundreds of kilobits/sec speeds, all the telecom carriers now offer broadband services providing high-speed Internet connectivity of hundreds of megabits/sec. With the developments of Wireless Fidelity (Wi-Fi), access to wireline broadband has become common for most households, as discussed in earlier sections. Residents at home can access the backhaul of the TISP via a Wi-Fi access point and the DSL modem, thereby extending the landline broadband connections to limited mobility within the premise.

The landline broadband penetration in India is less than 10 per 100 households. In this context, asking 'Is the landline dead?' is essential. The considerable fixed cost and lack of clear right-of-way (RoW) guidelines for laying down telecom cables have limited the penetration of landlines in the country. However, due to newer technologies, such as the fixed-wireless-access (FWA) service, we may see the resurgence of household-based fixed lines (wired or wireless) in India. This technology replaces the copper or optic fibre-based last-mile access with wireless access, enabled by an outdoor/indoor fixed antenna that is connected to the BTS of the cellular access providers. FWA is expected to use the C-band (i.e. 3.3–3.8 GHz) and mm Wave to improve 5G penetration, especially in emerging

markets (Ericsson, 2024). This is being used by the TISPs for providing broadband connectivity not only in dense urban areas of the country, without having to lay down the wires to homes, but also for providing reliable broadband connectivity to rural and remote-area households.

2.2.2 Mobile Service as a Game Changer

The 2G revolution of the 1980s changed the market structure of telecommunications. The ability to provide last-mile access wirelessly altered the nature of the industry from a monopoly to an oligopoly. Due to the paucity of wireline infrastructure, most developing countries have adopted the 'mobile first' strategy to provide telephony and Internet access to users (Venkatesh & Sridhar, 2014). Mobile services in most countries have an oligopoly structure with between three and five operators providing the service in the licensed service area (LSA). There are exceptions to this rule. For example, up to ten operators in India provided mobile services in an LSA until 2016. Since then, there has been a downward trend, with four operators currently operating.

One of the critical resources required to provide mobile services is the radio spectrum. The radio spectrum allocation to mobile operators involves trade-offs between fostering competition by licensing many operators, on the one hand, and providing adequate spectrum for each operator for improved operational efficiency, on the other, as pointed out in detail by Prasad & Sridhar (2014).

By moving from analogue to digital technology, 2G laid the foundation for data transmission on mobile networks. Advancements like GPRS enabled basic Internet access on 2G networks, allowing for email and limited web browsing on mobile devices. However, voice calls continued to use analogue signals sent over circuit-switched networks. In 4G+ networks that use packet switching, VOLTE technology enables digital telephony transmission. As mobile and fixed-line networks improved at transmitting data, content and applications with greater data richness and lower latency were transmitted over telecom networks. Such content included video and low-latency industrial content. These developments paved the way for digital-only networks and a new kind of TISP that provided voice, messaging, and Internet service.

2.2.3 The Internet as an Enabler

The Internet is a network of networks and evolved as part of the project on the ARPANET of the DoD in the United States in 1969. The objective behind the project was to build a reliable network called ARPANET with distributed computing power that could withstand calamities (for further details on the history of the Internet, refer to Sheldon, 2001). The current architecture allows users at home or in offices to connect to the Internet through a local ISP. The ISPs are typically connected by 'wholesalers', also referred to as 'network service providers'. These wholesalers connect to the Internet backbone using Internet connection points called 'Internet exchanges' (Stallings, 2001). The ISPs can also have peering arrangements to interconnect their networks. The widely used protocols for different devices to communicate over the Internet are the TCP and the IP developed by the University of California, Berkeley.

The Internet uses packet switching (compared to circuit-switching technologies traditionally used for POTS in telecom networks) and uses store-and-forward communication (Stallings, 2001). Initially designed to provide email service, Internet technologies traditionally focused on providing reliable service at the expense of synchronicity. Hence, as a delay-tolerant network, the Internet was more suitable for messaging services rather than voice (aka Internet telephony). However, advancements in the IP, including the migration to IP version 6, have introduced additional support for data-intensive synchronous services as well. Further, since the Internet uses the store-and-forward mechanism of shared communication as opposed to dedicated circuits in circuit-switched telecom networks, the cost of communication services (and, hence, the price over the Internet) is always very low compared to comparable services provided over wireline or mobile networks.

In most countries, telecom service providers—both wireline and mobile, provide Internet services as well. Both wireline DSL and wireless 4G/5G technologies support packet switching, thereby enabling telcos to offer Internet service using their existing networks and systems.

However, there are also pure-play ISPs in certain geographies that provide broadband Internet service without offering voice telephony. Such pure-play ISPs have to pay the high fixed costs of last-mile access unless they can use non-discriminatory access provided by incumbent TISPs or

Wi-Fi for last-mile connectivity. Given the high fixed costs and the reluctance of TISPs to lease bandwidth to pure-play ISPs, the ISP market tends to be oligopolistic.

The Internet is a democratic network loosely governed by the Internet Corporation for Assigned Names and Numbers (ICANN), the Internet Engineering Task Force (IETF), and respective country-level organisations. The technical components of the Internet, such as the domain name system, the assignment of IP addresses, and the IPs, are developed and guided by these organisations for the effective and reliable working of the Internet (see details of Internet governance in Sridhar, 2019). Since the TCP and IP protocols of the Internet operate above the physical layer of the open systems interconnection (OSI) model, the lowest layer of the network responsible for the physical transmission of data between devices over a medium such as cables or wireless signals, they have spawned a whole host of Internet applications and services, often referred to as OTT applications.

2.2.4 OTT Applications and Services

The recent revolution in communication, content, and applications over the Internet has resulted in a new breed of services called OTT services.

The definition of OTT services varies across countries, industry bodies, and regulators. One of the definitions floated by the Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Study Group 3 is as follows (TRAI, 2018):

> OTT to be any Internet application that may substitute or supplement traditional telecommunication services, from voice calls and text messaging to video and broadcast services.

OTTs started as content, community, or commerce applications that rode on public networks. Today, they include services traditionally provided by telcos. The Body of European Regulators for Electronic Communications (BEREC, 2016) uses this definition to categorise the various types of OTT services. We modify the extended definition provided by Esselaar and Stork (2019), details of which are given in Table 2.1.

Table 2.1 The taxonomy of OTT services

	OTT com	OTT video	OTT other
Description	Applications that allow voice calls and instant messaging provided to the end user over the public Internet, including those who interconnect with the PLMN/PSTN	Video services of different types, including short and long video streaming, pay-per-view, and live TV over the public Internet	E-commerce and online services in various sectors provided to the end user, also called digital platform services
Examples	WhatsApp, Skype, Facebook Messenger	Netflix, Hotstar, Amazon Prime	Amazon, Flipkart, upGrad, Practo, Uber, Edutech
Competing with licensed TISPs	Yes	No	No
Competing with cable TV/direct-to-home service providers	No	Yes	No
Potentially responsible to	Telecom regulator	Telecom and broadcast regulator	E-commerce, privacy, and data protection regulators

Source: Authors' own.

These services are 'untethered' from the underlying physical network. Thus, they can be provided using a variety of modes ranging from land-line DSL to satellite broadband. The technical architecture of the OTT services is shown in Fig. 2.1.

OTTs started as innovative start-ups that created new markets that were highly competitive. However, today, the space of OTTs has become layered and concentrated. It is layered because certain categories of OTTs (such as search engines, video-sharing networks, or e-commerce sites) act as influential entry points to the Internet. Further, OTT markets like e-commerce have become concentrated as incumbents have acquired a commanding position by attaining a critical mass of users.

As telecom carriers deploy 5G+ networks, the enhanced connectivity capabilities enable content and applications provided over broadband

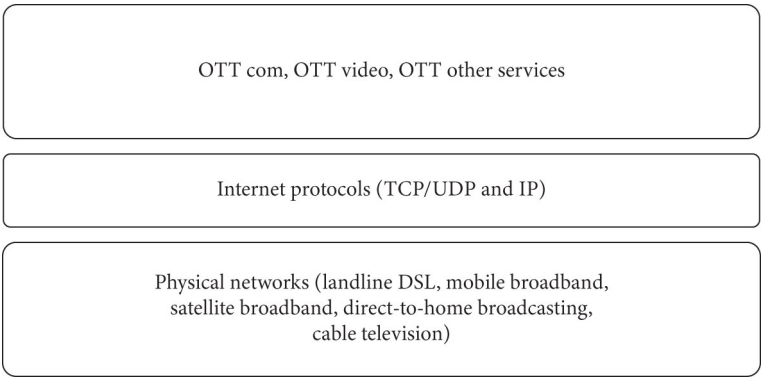


Fig. 2.1 The technical architecture of OTT services
Source: Authors' own.

networks to gain more importance than the connectivity service itself. The telecom carriers who once dominated the connectivity market are challenged by content and application providers operating over any Internet connection.

We divide the space of OTTs into OTT communication services, OTT video services, and OTT other services, including digital platforms.

2.2.4.1 OTT Communication Services: OTT Coms

Communication platforms such as WhatsApp and Telegram are often referred to as OTT coms as they provide communication services over the Internet. To an extent, these OTT coms are substitutes for some traditional services, such as telephony and short messaging services provided by the telcos. On the other hand, some other telecom services such as toll- and toll-free services, emergency calling services, and roaming services cannot usually be provided by pure-play OTT service providers, as the Internet is not typically connected to the PSTN/PLMN. However, realising the potential of content and applications, most telecom carriers have bundled their own OTT applications and services.

OTT coms are offered over the Internet connectivity supplied to end users by the telcos. Hence, they are operationally distinct from TISP services that are directly provided to, and paid for, by end users. However, on account of their functional equivalence in the mind of the end user, the telcos have consistently argued in favour of regulating the OTT coms

like regular TISP services. However, so far, the OTT coms have avoided regulation across the globe. Moreover, net neutrality regulation restricts the ability of TISPs to charge OTT coms for bandwidth provision. OTTs argue that such a charge is unnecessary as the TISPs collect bandwidth charges from the users when they consume OTT applications and services. Chapters 3 and 4 discuss new approaches to regulation and licensing structure that balance the different points of view within the overall regulatory framework.

2.2.4.2 OTT Video Services

Just as the OTT coms have ventured into the territory traditionally occupied by TISPs, OTT video firms have started providing broadcasting services usually supplied by broadcasters. These services include Internet radio, live TV, time-shifted TV, and VoD. While radio and live TV are synchronous, time-shifted TV show programmes are usually broadcast live with a few seconds/minutes/hours of delay, and the on-demand video streams typically supply movies and shows as per the customer's needs at any time.

There are typically two modes of OTT broadcasting and viewing:

(1) Real-time vs pre-coded: some videos are watched as they are generated in real-time, for example sports, news, and weather videos. However, the vast majority of OTT video content is pre-coded: the content is already encoded and stored on servers. In some cases, each video is stored with hundreds of different versions, each with a different playback format or bit rate. Real-time videos are more sensitive to delay, while pre-coded videos can be adapted to different download speeds.
(2) Streaming or download: some videos, like those on Netflix and YouTube, are streamed to the user, meaning that the user's device does not keep a local copy of the video (although Netflix movies can sometimes be stored on a local computer). In other cases (e.g. in iTunes), the entire video is downloaded first before being played back at some later point. Between these two modes, partial download and playback are possible. This method reduces the chance of jitter and is almost always followed in practice except for 'extremely real-time content'.

Since Netflix expanded its operations to streaming media in 2007, VoD has become ubiquitous. Along with Netflix, companies such as Amazon and Hulu have created a new market, changing how people view movies, TV shows, and video content. The worldwide revenue from OTT video services is around USD 120 billion, with Netflix being the market leader (Statista, 2023). Netflix started its streaming services in 2007 and its international operations in 2010. With 200 million subscribers worldwide, Netflix generated revenue of about USD 39 billion in 2024, and accounts for 34 per cent of video streaming market share in the United States (Netflix, 2024). As of 2020, Amazon's on-demand service, Amazon Prime Video, ranked third among companies with the most significant impact on digital video, after Netflix and Disney. It occupies the second position in the growing VoD industry in the United States, and although an increasing number of VoD services are entering the market, such as Disney Plus, the number of Prime Video subscriptions is projected to rise (Statista, 2023). Amazon Prime Video services are tightly integrated with the Amazon e-commerce platform in terms of subscription plans and associated services.

At the other end of the spectrum of OTT video is YouTube. It started in 2005 and was later acquired by Google in 2006. It has the largest market share in the user-generated short video segment. YouTube has about 2.3 billion users (at the time of writing this book) and is the second largest, next only to Facebook. Incidentally, YouTube is the second most popular search engine, next only to the Google search engine, sifting through 500 hours of video uploaded onto the YouTube platform every minute by users worldwide. It receives more monthly searches than Microsoft Bing, Yahoo, AOL, and Ask.com combined. The YouTube search engine does not use the page-ranking algorithm used by Google but a *co-visitation count* to show related videos to the users. Co-visitation count is how often each pair of videos is watched together by a viewer over, say, twenty-four hours. This gives rise to a set of related videos for each video, a link relationship among the videos, and thus a graph with the videos as nodes. From the set of videos in k hops from a given video, together with the matching of the keywords in the video title, tags, and summary, YouTube then generates a top-n recommendations page.

Unlike Netflix and Amazon Prime, which earn revenue through subscriptions and rentals, YouTube earns its revenue through

advertisements in the same way as Google searches. YouTube earns annual revenues of around USD 20 billion (at the time of writing this book). It can embed targeted advertising directly into the video clips its users watch and promote featured content. The Adwords platform in Google's Sponsored Search algorithm is also integrated with YouTube. However, unlike Google Search, YouTube still struggles to break even due to the enormous costs of servers and the platform for hosting user-generated videos.

Apart from the behemoths such as Netflix and Amazon Prime, which provide services globally, many start-ups, such as Hulu in the United States, Viki in South Korea, Youku Tudou in China, and Hotstar in India, compete with niche content in different countries.

According to the Global Internet Phenomena Report 2023 released by Sandvine, the Internet carried 23 per cent more traffic in 2022 than in the previous year (Sandvine, 2023). Though the increase was primarily witnessed during the COVID-19 pandemic resurgence periods of 2020–2021, Internet traffic continues to grow. About 65 per cent of all Internet traffic is attributed to video sites, up from 51 per cent in 2016. Every day, people watch around 1 billion hours of video on YouTube; Netflix is responsible for 15 per cent of global Internet traffic; Amazon Prime Video has more than 200 million subscribers worldwide and continues to grow. These OTT video services can be classified as large traffic generators (LTGs) (Sridhar et al., 2023).

Video OTT services have become a double-edged sword for the TISPs. As consumption of long and short-format videos picks up, the TISPs earn revenue through corresponding bandwidth charges. However, the traffic generated by video services, especially on mobile networks, leads to massive congestion, which starts to affect the QoS on the public network of the TISPs. Telcos need to invest in infrastructure and upgrade continuously to match QoS regulations. The critical question is, 'Who will pay for the increased investment demands on network infrastructure?'

2.2.4.3 OTT Other: Digital Platforms

A digital platform is 'a business based on enabling value-creating interactions between external producers and consumers digitally' (Parker et al., 2016). Common examples of platforms are ride-hailing service

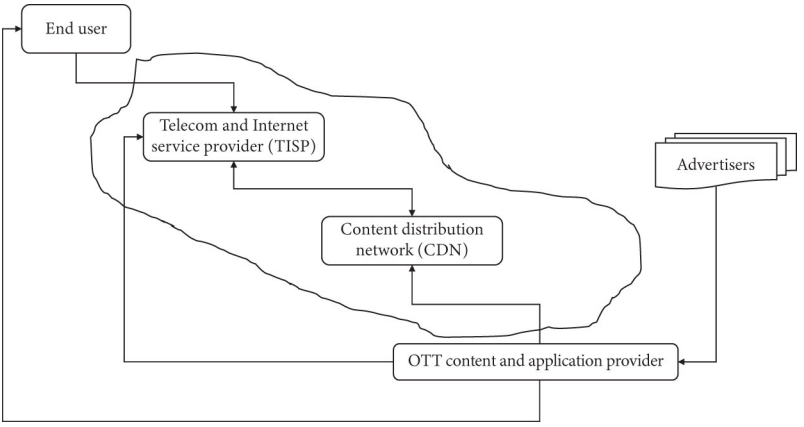


Fig. 2.2 Schematic of the telecom and Internet services
Source: Authors' own.

providers, such as Ola and Uber; e-commerce firms, such as Amazon and Flipkart; education platforms, such as Coursera and upGrad; and news providers, such as Google News, Facebook News, and DailyHunt.

The different technologies in telecom and Internet services that are explained in this chapter and are relevant for discussion in the subsequent chapters are captured in Fig. 2.2.

2.3 Economics and Regulatory Aspects of Digital Platforms

In economics, a 'platform' refers to a digital or physical infrastructure service that facilitates interactions between different groups of users (typically buyers and sellers) by acting as an intermediary to enable communication, transactions, and exchange of goods or services without necessarily directly producing goods themselves. Traditionally, a marketplace was the best example of a platform. The widely used Visa and Master Card networks are also examples of platforms connecting retailers with sellers of goods and services.

Many platforms are 'two-sided' in the sense that they connect sellers and buyers. There can also be other players constituting the third and more sides, in which case they are referred to as multi-sided platforms.

However, the theories of two-sided platforms are generally applicable to multi-sided platforms as well.

Traditional platforms like marketplaces used to be facilitated by communities or government bodies at different levels, including municipalities. In the digital era, such platforms are often controlled by private enterprises. Since platforms serve an essential public purpose, one needs to design suitable regulations based on an understanding of their intrinsic dynamics.

It is noteworthy that in the general architecture of the Internet, the TISP performs the platform role, connecting users on one side and the OTTs on the other, as shown in Fig. 2.3. The users usually pay for the bandwidth they use while consuming the content. The OTTs charge the users for the content they provide. Advertisers pay the OTTs for displaying their advertisements to the end users. The OTTs may also use intermediaries such as content delivery networks (CDNs) to distribute their content to the end user efficiently. It is to be noted that while the OTTs provide their content as OTT services, the content reaches the end user via the last-mile access offered by the TISPs. The TISPs also use the infrastructure of CDNs to augment their reach to the end users.

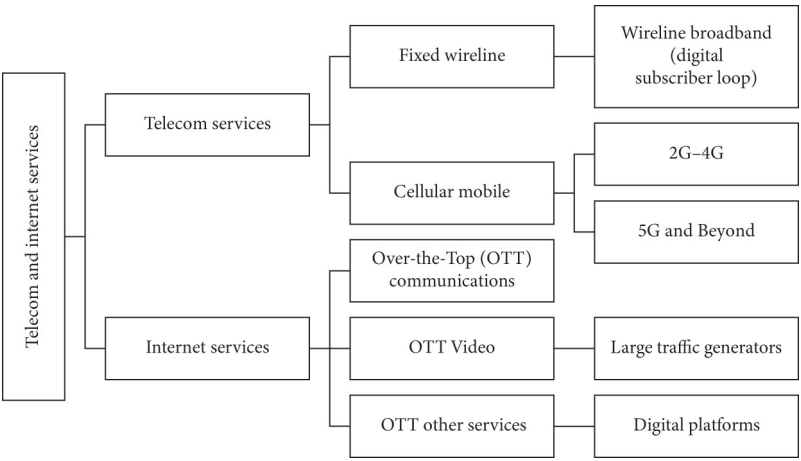


Fig. 2.3 The architecture of the Internet value chain
Source: Authors' own.

However, there is a tighter integration of TISPs and OTTs, leading to various business models and service delivery. This is cause for concern for net neutrality advocates, which is further explored in Chapter 6.

The unique economic characteristics of digital markets are described in the following subsections.

The competition between platforms is characterised by the following features (Rochet & Tirole, 2003).

2.3.1 Cross-Group Externalities

The benefits enjoyed by a member of one side of a platform (e.g. a buyer) depends upon how well the platform attracts agents from the other side, that is good-quality sellers. This is a cross-group externality (Eisenmann et al., 2006). In the context of TISPs and OTTs, the attractiveness of a TISP to an end user depends on the number of OTTs accessible via the TISP. Similarly, the value of a TISP to an OTT relies on the number of end users connected via the TISP. A platform has to address a chicken-and-egg problem where its attractiveness to one side depends on its attractiveness to the other.

In a two-sided market with positive cross-group externalities, the intermediary, even a monopolist, is incentivised to reduce platform profit. This is because, in order to compete effectively on one side of the market, a platform needs to compete well on the other side. This creates a downward pressure on the prices offered to both sides compared to the case where no externalities exist. This is an argument for the regulator to exercise forbearance.

2.3.2 Waterbed Effect

A significant feature of the two-sided market of the Internet is that one group of agents—the end users—choose to use only one platform, that is they 'single-home'. The other group—the OTTs—typically provide content on multiple platforms, that is they ' multi-home'. In such a market, if an OTT wishes to interact with an end user, it has no choice but to interact with the user's chosen platform. Thus, platforms have monopoly

power over providing access to their single-homing customers for the multi-homing side. This leads to the possibility of high prices being charged to the multi-homing side. By contrast, platforms have to compete for single-homing agents, and their high profits from the multi-homing side are largely passed on to the single-homing side in the form of low, or even zero, prices. This is known as the waterbed effect and has been demonstrated in analytical models under the assumption that OTTs value an additional end user more than end users value an additional OTT (Economides & Tåg, 2012). The waterbed effect is accentuated when powerful platforms prohibit sellers from selling at lower prices on competing platforms.

2.3.3 Vertical Integration of Platform Provider and Platform Participants

Many platform providers are also participants on their platforms. For instance, Amazon participates in its e-commerce platform as a provider of goods and services, apart from its Amazon Cloud Service and Amazon Pay service. Such arrangements can hurt the prospects of other sellers on the platform. Proponents of vertical integration argue that the closer integration of the seller and the marketplace benefits consumers in terms of higher quality and lower prices. However, opponents of this viewpoint argue that the platform facilitates the anti-competitive effects of vertical integration on the markets. Market participants other than those promoted by the platform would have to create similar relationships with a platform of comparable size to compete. This increases the barriers to entry in the market. The barrier is exacerbated when powerful platforms impose injunctions on sellers to stop selling at lower prices on other platforms. The Federal Trade Commission is litigating cases against Amazon on such issues.

2.3.4 Network Effects

Network effects refer to the increase in the value and utility of goods or services as their adoption and consumption increase. The utility/value of

such networks can increase linearly, as specified in Sarnoff's law, which applies to broadcast networks. The more pragmatic Zipf's law demonstrated that the value of most practical networks in operation is proportional to the log of the network size (Briscoe et al., 2006). In the case of platforms, the power of direct network effects is enhanced by cross-group externalities. Once a platform can overcome the chicken-and-egg problem of persuading the different sides to converge, it becomes very hard for competitors to break into the market. Thus, the attractiveness of a platform increases quadratically in voice telephony networks, as specified in Metcalf's law, or exponentially in social networks, as illustrated in Reed's law. A detailed exposition of network effects is illustrated by Yang (1997).

The power of network effects tends to create winner-takes-all markets where one or two players dominate (Brinton & Chiang, 2016). This tendency is accentuated by a new manifestation of the capitalist system, which we call 'digital capitalism'.

2.3.5 Digital Capitalism

Digital capitalism is a new kind of capitalism, which differs from classical capitalism in fundamental ways, as shown in Table 2.2.

2.3.5.1 Decoupling of Valuation from Profit

The Modigliani–Miller theorem states that under certain conditions, the value of an enterprise is equal to the present value of the streams of profits it generates. This implies that it is possible to observe enterprises making current losses enjoy high valuations based on the expectations of future

Table 2.2 Comparison of the classical and digital capitalism

Classical capitalism	Digital capitalism
Valuation correlated with profit	Decoupling of valuation from profit
Consumer sovereignty	Consumer is product
Perennial wave of creative destruction	Too big to fail

Source: Authors' own.

profits. However, when losses continue to increase for a significant period, company valuations are expected to plummet.

There is no consensus on how long, and to what extent, a company can continue to make losses before its value gets affected. However, it is indubitable that the tolerance for protracted loss-making enterprises has increased in the digital era. High losses are often associated with higher valuations.

We analyse data for digital unicorns in India, that is digital companies with a valuation greater than USD 1 billion. We find that the valuation of a unicorn increases with an increase in the absolute value of losses and the number of years of existence. The most valuable company was making losses of USD 49 billion; however, it had a valuation of USD 37.6 billion. The high positive correlation between high valuations and high losses resulting from the network effects in digital industries begs explanation. These effects incentivise firms to aim to acquire a critical mass of subscribers in the shortest possible time. Thus, these firms are willing to bear losses for the time required to attain the critical mass. However, the question arises: how can firms acquire the resources required to continue to exist despite continuous, rising losses?

The fundamental feature that enables the business model of digital capitalism to thrive is the high level of wealth creation that has taken place over the past forty years since the dawn of the liberal consensus in the 1980s that privileged market forces over government regulation. This has also led to huge disparities in income. Specifically, the United States has a massive disparity in median household income. The median upper-income household income is ten times that of lower-income households. The high level of wealth became the bedrock of an ecosystem of private capital that seeks to make disproportionate returns in emerging technologies by funding companies until they can reach critical mass.

This model is a bonanza for the consumer. However, there are hidden costs.

2.3.5.2 The Consumer Becomes the Product

The sovereignty of the consumer is an article of faith for classical capitalism. A consumer earns income by working for firms and spends it on buying goods and services according to their preferences.

However, the consumer behaves differently in digital capitalism. They can access many services with any explicit payment. Of course, there is an

implicit payment. The consumer's data is sold, with or without their consent, to third parties for a charge. These third parties use the data to target goods and services to the consumers. Thus, while the economic engine of classical capital converted labour into products, the engine of digital capitalism converts the raw data of consumers into insights used for selling products to them. In this sense, the consumers themselves have become the products that digital companies sell to advertisers.

Consumer information can be regarded as a non-rival good, as it can be shared with additional entities at virtually zero economic cost. However, non-economic costs include the loss of privacy and the ability of firms to modify consumer behaviour significantly.

The use of data-driven insights modifies the behaviour of consumers to the point that they are left with only a vestige of the autonomy they once enjoyed. This is a significant concern. New regulatory measures such as the European Global Data Protection Regulation (GDPR) are attempting to check the violation of consumer autonomy. The measures adopted by the GDPR include the following: if informed consent is used as the lawful basis for data processing, consent must be sought explicitly for all data collected and for each purpose for which data is used. In addition, multiple types of processing may not be 'bundled' together into a single affirmation prompt, as this is not specific to each use of data, and the individual permissions are not freely given. Data subjects must be allowed to withdraw this consent at any time, and the process of doing so must not be more complicated than it was to opt in. A data controller may not refuse service to users who decline consent to processing that is not strictly necessary to use the service (EC, 2016).

An important tool for protecting privacy could be to increase the competitiveness of the services layer so that start-ups prioritising privacy can compete in the marketplace.

2.3.5.3 Too Big to Fail

There are broadly two types of structures of digital capitalism: (i) the liberal internationalised digital capitalism fostered by the Big Techs such as Google, Apple, Meta, Microsoft, and Amazon (GAMMA) and (ii) state-managed digital capitalism leading to Chinese rivals of the Big Techs—Baidu, Alibaba, Tencent, and Xiaomi (BATX). While the GAMMA have captured the world market, other than China, through

extensive internationalisation of their products and services, the BATX have taken the opposite digital and data sovereignty strategy, leveraging the huge local market to achieve technology and market superiority. The 'red stack', China's digital ecosystem, is controlled by Chinese companies and encompasses different layers of mutually dependent components necessary for digital communication and computation, ranging from physical digital infrastructure and end devices to operating systems, technical standards, software, apps, and mobile app stores (De Seta, 2021). The red stack includes functional equivalents to leading US digital companies: Tencent for Meta, Alibaba, JD.com, Temu for Amazon, Baidu for Google, and Huawei and Xiaomi in place of Apple.

Classical capitalism was based on the perennial wave of creative destruction, a continuous cycle of innovation where new technologies and business models disrupt and replace older ones, causing some industries and companies to decline while simultaneously creating opportunities for new growth. However, on account of network economies and an abundance of investible resources, digital capitalism creates large entities that fulfil vital functions in the economy and, therefore, are too big to fail.

This model was most visible with respect to financial services companies during the 2008 Financial Crisis. However, as great power rivalry takes the form of technological competition, the big technology companies are too big to fail and break up. The Federal Trade Commission has initiated cases against Alphabet, arguing that Google acquires rivals through anti-competitive mergers and coerces publishers and advertisers into using the company's ad technology. However, significant action is unlikely to happen, given the importance of staying ahead in technology vis-à-vis China.

Thus, both structures of digital capitalism—liberal internationalised digital capitalism and the state-managed digital capitalism—are witnessing a close cooperation between corporations and the government to achieve security objectives.

2.4 Conclusion and Looking Ahead

We live in a world where technology is advancing at a rapid pace, corporations are becoming much more powerful than ever before (although

they are having to support the geopolitical interests of their countries), a select group of business leaders are wielding enormous power, and the consumer has access to a large variety of services while slowly losing autonomy over their decisions. There are also immense possibilities emerging for radical new opportunities in health care, transportation, and industry 4.0.

We explore the regulatory implications of these developments. The structure of the book is as follows. Chapter 3 analyses the competitive landscape of the telecom and Internet-based OTT services, their complementarity and substitutability, and the possible creation of walled gardens. We introduce the concept of 'diagonal equity' to balance the power of telecom and Internet companies. Chapter 4 discusses the extant licensing framework for telecommunication and associated services, especially in the Indian context. The principle of 'functional separation' is introduced and applied to the licensing framework for telecom and OTT coms. We also propose regulatory intervention with respect to the LTGs. In Chapter 5, spectrum regulation and management are analysed in depth with the results of the latest spectrum auctions in India. New approaches to spectrum allocation and management, including flexible and dynamic spectrum sharing with light-touch licensing, are discussed. In Chapter 6, we take a deep dive into net neutrality issues arising from changing technology and market landscapes and propose a novel concept of 'digital neutrality' as applied to the dominance of Internet firms. Chapter 7 delves into the details of interconnection and associated regulation as applied to telecommunications and the possible extension to OTT coms. The universal service regulation is discussed in Chapter 8, with special emphasis on building infrastructure for 5G+ networks. We conclude, in Chapter 9, with a forward-looking view of regulation beyond telecom to include data protection, cyber security, and responsible and ethical use of artificial intelligence.

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3

The Integrated Sphere of Co-opetition of Digital Services and Diagonal Equity

3.1 Introduction

TISPs and OTT services are traditionally regarded as complementary. This view is not surprising. After all, OTTs provide content and applications that ride on connectivity provided by TISPs. However, the growth of 5G technologies has led to the growth of an integrated sphere of competition and cooperation between TISPs and OTTs. The new elements of this competitive landscape stem from the hybridisation of network provision; the growth of services provided by OTT communication service providers that can substitute services provided by TISPs; and the battle for revenue share in markets served by 'walled gardens' that are end-to-end value networks comprising devices, connectivity services, and a variety of content and application companies. The new dynamics occasion the application of a new regulatory framework referred to as 'diagonal equity'.[1]

We start by acknowledging the continued element of complementarity between TISPs and OTTs.

3.2 The Complementarity of OTT Services

A greater demand for OTT services translates into greater use of the TISP network. Conversely, the availability of high-quality telecommunications networks spurs greater innovation in OTT services. Hence, there

[1] The term 'Diagonal Equity' was coined by Dr. Mansi Kedia, representing a significant refinement over the earlier usage of 'Asymmetric Equity'.

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Table 3.1 Complementarity OTT services

Services by OTT firms	Nature of complementarity
Audio/video messaging services	Complements the voice telephony and SMS services offered by the TISPs
Mapping services	Location service shared through messaging/email transmitted through the Internet connectivity provided by the TISPs
News services	Aggregated news shared through messaging/email transmitted through the Internet connectivity provided by the TISPs
Cloud services	Provides shared cloud services for storing messages/email transmitted through the Internet connectivity provided by the TISPs

Source: Authors' own.

is a strong element of complementarity between OTTs and TISPs. For example, if one wants to share one's current location, the map service of OTTs and Internet messaging services of TISPs complement each other.

Table 3.1 illustrates the services provided by the OTT firms that are complementary to those provided by the TISPs.

Next, let us examine the new element of competition in the relationship between TISPs and OTTs flowing from the hybridisation of network provisioning, the growth of substitute services, and the emergence of walled gardens.

3.3 The Hybridisation of Network Provision

The formerly monolithic telecommunications network is experiencing a vastly heightened differentiation of functions, and the telecommunications service provider is acting as an integrator of a wider variety of provisioning entities (Gavrilovska et al., 2020). Earlier, the TISP had a much smaller number of entities to deal with and had evolved stable commercial relationships with each of them. These relationships included the managed services model, under which equipment vendors would manage the telecommunications network owned by the service

provider, and the sharing of passive infrastructure, under which tower companies would provide physical infrastructure on a shared basis to TISPs.

Software development companies and cloud service providers, earlier operational only in the applications layer, are now active participants in network provisioning. O-RAN architectures have made the network modular and allowed many new entrants to participate. The entry of new players increases the efficiency of the 5G service but introduces a level of uncertainty for the telecommunications service provider. It remains to be seen how the new telecommunications architecture will affect the competitive strength of telecommunications companies. All one can say at this point is that certain OTT entities will now be an integral part of network provisioning while simultaneously riding on the network to provide their services.

Further, OTTs provide a number of substitute services that are in direct competition with TISP services.

3.4 The Substitutability of Services

Traditionally, TISPs provided the entire service of voice telephony or messaging from the user application to the telecommunications network. Now, several OTTs are providing user-facing applications related to voice connectivity and messaging that are functionally equivalent to traditional telecommunications services. We refer to such OTTs as *OTT communication service providers* (OTT coms). However, all such services still use the TISP's underlying fixed-line or mobile networks networks to transmit data. In such cases, the OTTs and TISPs are substitutes in the eyes of the subscriber but complements from an operational point of view. In a currently small percentage of use cases, when the subscriber uses Wi-Fi, both the Wi-Fi access point and the backhaul to the Internet are provided by the OTT. In such cases, OTTs and TISPs are substitutes from a functional and operational point of view.

Our view is that, irrespective of whether the substitution is only functional or both functional and operational, it constitutes a significant change in the competitive landscape of the TISP. For instance, the

growth in OTT messengers has been accompanied by significant reductions in the usage and revenues of short messaging services (SMSs) of the TISPs in the past years. In 2015, the consumption of text messaging declined in Germany by 41 per cent, in Italy by 40 per cent, and in the UK by 15.3 per cent (AGCOM, 2015; Ofcom, 2015). Similarly, the growth of voice-over Internet Protocol (VoIP) services provided by OTT players could potentially take business away from traditional mobile or fixed-line telephony. While the limited empirical analysis suggests complementarity between Internet messengers and SMS, the studies are relevant to limited geographies. They are constrained by the inherent difficulty of estimating demand for services that are not charged (Wellman, 2019).

Further, while most OTT services ride on Internet connectivity provided by TISPs, there is a growing trend of OTTs venturing into key elements of the value chain of Internet connectivity, as mentioned in the section on the hybridisation of network provision. This phenomenon is enabled by the increasing availability of unlicensed spectrum and its potential to provide high-quality Wi-Fi connectivity without relying on mobile broadband. Thus, there is a rising degree of substitutability between OTT coms and TISP services.

Table 3.2 compares the mutual substitutability of OTT and TISP services.

There have been discussions about the need for similar regulatory treatment of functionally equivalent services that may be delivered in different modes, such as satellite and terrestrial radio (Hazlett, 2007). This debate concerns a relatively straightforward question that classical principles of competition regulation, including the computation of cross-price elasticities of the relevant services, can address. However, the diagonal equity approach goes beyond previous discussions, as it is driven by the hybridisation of the network and the fight for revenue share of the digital ecosystem.

As OTT services begin to substitute telecom services and OTTs and other entities carry out backward integration into the provision of the network, TISPs are also engaging in forward integration into the application layer and backward integration into the product and device space as they attempt to compete in this changing landscape. This process is leading to the creation of walled gardens.

Table 3.2 TISP services substitutable by OTTs

OTT service	Remarks
VoIP, instant messaging, video calls and video broadcasting	VoIP, messaging, and video calls are functionally equivalent to services TISPs provide. In the case of broadcast video, TISPs provide substitutable mobile video services.
VoIP with termination on a public switched telecommunications network/public land mobile network	These are functionally equivalent to traditional mobile or fixed-line telephony. However, they are operationally complementary, as VOIP requires the conversion of IP address to the telephone numbering system using a PLMN/PSTN bridge. While TISPs and VNOs can provide this service, as they are licensed to interconnect to the PSTN/PLMN, regulations in some countries, such as India, prohibit OTT coms from doing the same unless licensed or authorised.
Emergency services that require interconnection to the PLMN/PSTN or other networks that connect devices to the emergency service provider	Since OTT applications are closed apps and do not interconnect with other types of OTT services, this service is not a substitute service at present. However, this may change in the future. Even though the QoS provided by OTT firms is based on the underlying Internet connectivity, one can place the responsibility of providing emergency services on significant OTT coms, assuming they will make the necessary contractual arrangements with the TISPs (see Chapter 4 for more details).
The toll-free 1-800 and 1-900 services.	These services need interoperability across originating and terminating service providers and services. They cannot be provided by closed OTT service providers (hence they are non-substitutable as of now), but this may change in the future.
Bulk messaging using broadcast services such as SMS/VoIP	Current SMS/voice calls can be substituted by OTT-based messaging/VoIP apps. This service is substitutable.

Source: Adapted from Prasad and Sridhar (2023).

3.5 Walled Gardens

The phenomenon of overlapping markets of TISPs and OTTs is attended by the growth of 'walled gardens' comprising network operators, handset manufacturers, platform vendors, and content providers coming together to provide the entire suite of digital services and products (Hazlett et al., 2011). These 'walled gardens' produce products and services in

competition with rival ecosystems and often benefit from a 'platform captain' who provides coordinating mechanisms, rules, key products, intellectual property, and financial capital. In several countries, such as the United States, handset manufacturers (e.g. Apple) and content providers (e.g. Google) have emerged as ecosystem/platform captains. In handset application platforms (HAPs), handset manufacturers negotiate terms on which buyers of their phones (subscribers) gain access to given mobile networks through the sharing of revenues with TISPs, effectively purchasing network services to provide a superior experience to handset users. In a few countries (e.g. Japan), TISPs such as NTT Docomo and KDDI are the ecosystem/platform captains.

A schematic diagram of a HAP is presented in Fig. 3.1.

A classic example of a walled garden is the 'Free Basics' programme introduced by Facebook (now Meta) in 2013 in collaboration with TISPs in some developing countries. In India, Facebook teamed up with Reliance Communications. The applications in the Free Basics programme were closely tied with Reliance's telecommunication services and, hence, created a walled garden that benefited these applications. However, the programme faced massive resistance from start-ups and the public, primarily as a violation of net neutrality. The regulator, the Telecom Regulatory Authority of India, decided to put in place regulatory hurdles to the operationalisation of the programme (for details on this case, refer to Sridhar, 2019).

Platform captains generally derive business benefits from their pole position, especially in 'closed' ecosystems characterised by low levels

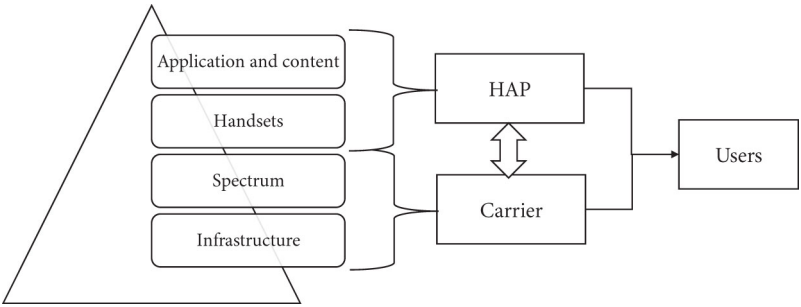


Fig. 3.1 Schematic diagram of the handset application platform
Source: Authors' own.

of flexibility for participants. Apple's walled garden is an example of a closed business ecosystem. Participating in this ecosystem requires recognising Apple's intellectual property guidelines and abiding by Apple's rules, which are often non-negotiable. The rules are designed to simultaneously secure a superior customer experience and protect Apple's business model. While members of walled gardens gain from the value added by the platform captain, they may aspire for the position of captain. This aspiration brings a new element of competition into the relationship between TISPs and OTTs.

The simultaneous presence of complementarity and competition between TISPs and OTTs implies that the digital space has become an integrated sphere of co-opetition (Nalebuff & Brandenburger, 1997).[2]

3.6 Diagonal Equity: A New Regulatory Approach

Despite the growing hybridisation of network provisioning, the substitutability in services, and growing competitive pressures within walled gardens, there is an asymmetric regulatory stance with respect to TISPs and OTTs. Some of this asymmetry stems from fundamental differences in the nature of their businesses. For instance, TISPs use licensed spectrum as an essential input, while OTTs are not directly licensed to use spectrum. TISPs also benefit from right-of-way legislation, which enables them to build out physical networks, and from the exclusive right to use national numbering schemes. They must preserve subscriber privacy and confidentiality, comply with government requests on call origination and related details, and ensure that the network is secure. On the other hand, OTTs traditionally ride on networks built by TISPs and, in most countries, are subject to free speech and content regulations that are not directly applicable to TISPs.

However, undoubtedly, a significant part of the asymmetry merely reflects an anachronistic world view with regard to the regulation of

[2] The term 'co-opetition' was coined by Adam Brandenburger and Barry Nalebuff to describe a situation in which competitors begin to collaborate along certain dimensions. In the case of the digital value network, the word is used to describe a situation in which collaborators begin to compete along certain dimensions. While the trajectory taken to arrive at a co-opetitive state is diametrically opposite, the end state is similar. Hence, the same word should be used.

competition across the two types of industries. Telecommunications companies are regarded as part of the critical infrastructure of a country. They involve the use of critical natural resources such as spectrum. On the other hand, OTTs are regarded as content companies that do not fall into the category of critical infrastructure and do not have access to public resources like spectrum. Thus, it is believed that the regulatory framework for TISPs needs to be different and, indeed, more stringent than that of OTTs.

Given the trajectory of the evolution of the digital economy, this view is no longer appropriate. The increasing importance of software and the large data volumes in the network imply that software and data storage facilities now form an integral part of telecommunications infrastructure. Thus, companies developing network software and data storage facilities must be regarded as co-providers of critical telecommunications infrastructure. Further, the embedding of the Internet into every aspect of our lives implies that certain Internet services, such as Internet search, can be regarded as essential facilities. Indeed, the Internet as a whole, not just the infrastructure part, can be regarded as essential for a country's security and prosperity.

Thus, there is a strong case that similar principles should be applied to regulating telecommunications networks and certain elements of the Internet ecosystem. The rationale for such an approach is strengthened by the emergence of the integrated sphere of co-opetition between TISPs and OTTs. We revisit some fundamental principles of regulation before presenting the regulatory stance of 'diagonal equity' that should supplant the current framework.

3.6.1 Vertical, Horizontal, and Diagonal Equity

The objective of vertical equity leads to recommendations that bring about greater equality between entities that operate in the same industry and are, hence, similar but at different levels of financial resources.[3] An

[3] The words 'vertical' and 'horizontal' are also used in the context of regulating vertical mergers of upstream and downstream firms and horizontal mergers of intra-industry firms. However, as is clear from the definition, these terms are used in a different sense in this book.

example is to give start-ups in the search industry some benefits that enable them to compete with the larger search engines.

The objective of horizontal equity leads to recommendations for similar regulatory treatment of dissimilar entities in the same industry. For instance, regulation could be used to bring parity in the regulatory approach toward public-sector companies and private-sector companies in an industry or between two business schools, one with only women participants and the other with a mixed intake of students (Musgrave, 1999).[4]

We now introduce a new concept: diagonal equity. The objective of diagonal equity leads to recommendations for similar regulatory treatment of entities operating in different industries (Prasad & Sridhar, 2024). This stance flows from the recognition that there is a blurring of lines between the concerned industries that occasions a convergence of regulatory approaches.

In the 5G+ world, as argued above, the time has come to move away from approaches that treat TISPs as providers of essential services and thereby subject to more stringent regulation than OTTs. It is time to adopt principles of diagonal equity across TISPs and significant OTTs, the details of which are discussed in section 3.7. Diagonal equity does not imply that the two kinds of entities are to be brought under the same regulatory umbrella. We propose a bifocal mode of regulation with a razor-sharp focus on issues critical to telecommunications connectivity and, simultaneously, a clear picture of the transformative developments of the entire digital ecosystem that require certain OTTs to be treated on a par with TISPs. The intertwining of services provided by telecommunications equipment vendors, content distribution networks, connectivity service providers, software vendors, cloud infrastructure service providers, and content and application developers makes such a holistic view necessary for appropriate regulatory frameworks for any part of the entire digital ecosystem.

There is a related literature on platform integration that discusses the impact of the vertical merger of platforms with downstream companies. This literature focuses on the benefits and drawbacks of platform integration on downstream markets in which the platform competes as a service provider with other firms providing substitute goods. However,

[4] For a conceptual discussion of vertical and horizontal equity, see the seminal discussion of Musgrave (1999).

the substitutability of OTT coms and TISP services is not the only factor driving the diagonal equity approach. As explained above, it is also driven by the participation of OTTs in network provision and the competition for the revenue share earned by walled gardens.

We now apply the principle of diagonal equity to specific regulatory issues: net neutrality, interconnection and data portability, universal service, and regulatory levies.

3.7 The Application of the Diagonal Equity Approach

3.7.1 Net Neutrality

In the early days of the Internet, a plug-and-play model prevailed, where OTTs only needed to connect with hosting and Internet service providers to access the vast market of the World Wide Web. In such a landscape, it was crucial to prevent TISPs from exploiting their gatekeeper role. Net neutrality regulations, aimed at curbing traffic management and discriminatory pricing by TISPs, emerged as a response to this need (refer to Chapter 6 for a detailed definition of net neutrality).

Originally conceived by idealistic technologists envisioning a transformative digital world, net neutrality has since been analysed through an economic lens. As Faulhaber (2011) notes,

> The inclination of economists is to see this problem as imbued with market power issues, with network neutrality serving as a tool, albeit an imperfect one, to address them. While other market imperfections, such as externalities in two-sided markets, may exist, many economists view net neutrality primarily through the lens of market power and potential anticompetitive behaviour.

In economic terms, net neutrality regulation stems from three primary factors (Prasad & Sridhar, 2014):

1) the significant market power held by TISPs;
2) the potential for vertical integration between TISPs and OTTs inhibiting competition in Internet markets and

3) the lower price elasticity of OTTs compared to end consumers, which enables TISPs to recover costs from the former more easily, thus creating high barriers to entry for new entrants.

These factors give TISPs substantial leverage over OTTs, potentially stifling innovation. By limiting the ability of TISPs to engage in price discrimination and traffic management, net neutrality mitigates these risks. In the spirit of diagonal equity, if similar economic conditions exist for OTTs, comparable neutrality-orientated regulations should apply to them. It is evident that such factors are present in the case of search engines. A large portion of Internet traffic originates from search queries, and this share increases when accounting for visits to websites initially discovered via search engines. Consequently, search engines can be considered an essential facility (Mays, 2015). The search market is highly concentrated, with Google dominating: as of April 2021, it held 82.95 per cent of the US market, 83.9 per cent in Germany, 92.58 per cent in Brazil, and 75.71 per cent in Japan (Bianchi, 2023). Google's global market share increases further when excluding China, where Baidu monopolises the market. Alphabet, Google's parent company, is vertically integrated with numerous OTTs, including services such s maps, digital payments, and smart home technology.

Additionally, as an advertising platform, Google can charge advertisers' higher rates due to their lower price elasticity compared to end users. This possibility creates significant entry barriers for smaller companies and new competitors. Therefore, the same economic factors driving net neutrality regulations apply to dominant search engines. The principle of search neutrality—ensuring that search engines do not manipulate or exclude results (Crane, 2012) is arguably as critical as net neutrality in fostering competition.[5] A parallel argument can be made for powerful e-commerce platforms, video streaming services, and social networks.

[5] In August 2024, a US District Court ruled that Google held a monopoly in online search and text advertising, violating Section 2 of the Sherman Antitrust Act. (a) The Department of Justice (DOJ) proposed significant structural changes, including the potential divestiture of Google's Chrome browser and restrictions on exclusive deals. (b) The DoJ initiated an antitrust investigation into Google's advertising technology practices, scrutinising its dominance in the digital ad market. (c) The DoJ has proposed that Google be barred from forming exclusionary agreements with third parties such as Apple and Samsung. It also recommended prohibiting Google from prioritising its search service within its own products.

We propose extending the principles of net neutrality to the broader digital ecosystem under the framework of 'digital neutrality'. This regulatory approach seeks to ensure that the primary objective of net neutrality—promoting innovation—applies across the digital landscape, not just at the interface between TISPs and OTTs. While similar to the concept of platform neutrality discussed in the literature (Krämer & Schnurr, 2014; Pasquale, 2016), we prefer the term 'digital neutrality' to avoid addressing free speech concerns within our definition. It is worth noting that some scholars contest the necessity of net neutrality for fostering efficiency and innovation. For instance, Owen (2011) argues, 'Empirical evidence that vertical integration or vertical restraints are harmful is weak, compared to evidence that vertical integration is beneficial—even in cases where market power appears to be present. Thus, it is reasonable to conclude that prophylactic regulation is unnecessary and may even reduce welfare.'

We are not as interested in taking a position for or against net neutrality as much as we are in asserting that whatever principles are deemed appropriate for TISPs should be applied equitably to OTTs (please refer to Chapter 6 for more details, including the formulation of a new approach of 'digital neutrality').

3.7.2 App Neutrality

Big Tech companies such as Google and Apple act as gatekeepers for the entry of Android and iOS applications respectively into their app stores. This exercise has a dampening effect on application competition, just as the gatekeeper role of TISPs potentially distorts competition in the OTT layer. Therefore, measures to limit such gatekeeping need to be promulgated under the ambit of 'app neutrality'. More details on app neutrality are provided in Chapter 6 in the discussion on digital neutrality.

3.7.3 Regulatory Parity between OTT Coms and Virtual Network Operators

In Chapter 4, we will present a licensing framework that incentivises (but does not mandate) functional separation of the infrastructure and

services layers of the network. This structure is incentivised by the creation of a network provider that integrates all the entities involved in network provisioning in a 5G+ world. All service providers are deemed to be virtual network operators (VNOs) that lease network capacity from the network provider, whether they lease capacity from their 'own' network provider or not. Non-discriminatory treatment of VNOs by network providers is mandated.

VNOs that lease network capacity from the network provider, and OTT coms that do not lease network capacity, provide functionally equivalent services as the end user treats communication services provided by TISPs and by OTTs as substitutes. According to the principle of diagonal equity, there must be a measure of regulatory parity between VNOs and OTT coms. We recommend that all VNOs and significant OTT coms are charged a broadband infrastructure levy at the rate of 3 per cent of their revenues from India operations obtained from public networks, net of revenues flowing from specialised services that involve direct contracts with the network operator. Details of this scheme and other measures to achieve parity are provided in Chapter 4. Of course, the differences in these two kinds of entities that stem from their different operational models must be kept in mind.

3.7.4 Interconnection and Data Portability

As in the case of net neutrality, an exercise in identifying underlying economic principles and applying them equitably across TISPs and OTTs needs to be carried out in the case of interconnection. For telecommunications networks, interconnection is mandatory for all licensed operators. The setting of interconnection charges must reconcile the objectives of facilitating competition, enabling wholesale cost recovery, and promoting investment in infrastructure to achieve rapid diffusion of telecommunications services. Low access charges would disincentivise infrastructure investment and ignore potential economies of scale and network externalities. On the other hand, high charges would disincentivise market entry and amount to the exercise of market power. An underlying driver of interconnect regulation is the perception of voice telephony as a basic need.

Similar principles can be invoked for VoIP services, social networks, instant messengers, and any service exhibiting network externalities. The inability to interconnect restricts competition. Given the role social networks and other Internet sites play in a country's politics, the ability to interconnect, like voice telephony, could well be regarded as a public good. Hence, some form of interconnect regulation is relevant for OTTs, just as it is for telecommunications regulators, and we must ask whether or not it has been levied to the required degree.

The ability of an end user to migrate to an alternate network is an important complement to their ability to connect with users in other networks. Telecommunications networks are required to facilitate such migration by measures like mobile number portability. Number portability increases the contestability of the telecommunications market and mitigates the possible abuse of a dominant position.[6] End users could benefit from similar portability possibilities for Internet messengers, social networks, email applications, and so on. Therefore, just as it is important to insist on mobile number portability to promote competition in telecommunications markets, it is important to hold OTTs to similar standards about data portability (see Chapter 7 for more details).

3.7.5 Moderation of Regulatory Levies

Telecommunications companies pay the government various fees, including upfront spectrum charges, spectrum usage charges, and licence fees. Spectrum prices in India are among the highest in the world, even without normalising for per capita income.

In contrast, OTTs are not required to comply with any regulatory levies or even pay telecommunications companies for the use of the public telecommunications infrastructure. There shall be regulatory parity between providers of functionally equivalent services. While too much regulation will stifle innovation, a balanced approach is required to improve the quality of mobile broadband experience, especially in

[6] The theory of contestable markets associated with William J. Baumol asserts that markets characterised by low barriers to entry and exit and possibilities of rapid strategic shifts are 'contestable' and yield competitive outcomes irrespective of the presence of firms that appear dominant due to high market shares.

countries such as India, where landline infrastructure is woefully inadequate (see Chapter 4 for more details on rationalising the levies paid by TISPs and OTTs).

3.7.6 Universal Service

Governments aim to achieve universal provision of basic telecommunications services through a universal service obligation imposed on TISPs. Earlier, this obligation would require TISPs to build out the network in remote areas. Currently, this obligation takes the form of a universal service levy along with limited roll-out obligations. The proceeds of the levy are used to fund infrastructure projects such as the national Internet backbone, frequently through a public tendering process.

Gasmi and Recuero Virto (2005) highlight the importance of the universal service fund in addressing a 'viability gap', a scenario where market forces, even under optimal conditions, cannot sustain the provision of a service. Sawhney (2003) adds two additional criteria: first, a communication technology should be universally accessible once it becomes a 'consumption norm', in the sense of being widely adopted by a significant portion of the population. Second, universal access to a service is essential if its absence creates systemic barriers or inefficiencies. Prasad (2013) introduces a further criterion of 'temporality', the time to build an information and communications technology (ICT) network. If an ICT network takes time to build, then it makes sense to start the process in advance of the service becoming a consumption norm or system requirement (Prasad & Sridhar, 2023).

While OTT services have not yet achieved the status of a 'consumption norm', access to digital technologies is rapidly becoming a systemic necessity due to their transformative potential across all aspects of life. The deployment of fibre-optic infrastructure in urban and semi-urban areas is critical in a 5G-driven world characterised by high-frequency spectrums, small cells, and low-latency applications. Given the extended timelines required to develop such infrastructure, it is essential to commence these projects without delay.

As co-creators and beneficiaries of advanced digital infrastructure, relevant OTTs and other entities in the infrastructure layer could be

required to contribute to the substantial funding required for its development, just as TISPs are required to do. This injunction would be in conformance with the principle of diagonal equity. However, the multiplicity and heterogeneity of such entities would make such a levy complicated to implement. Hence, we do not recommend such a levy.

As part of our recommendations, we propose a 'broadband infrastructure levy' on significant OTT coms and OTT video services that are large traffic generators. The rationale for this levy does not originate in the principle of diagonal equity. Rather, it is based on efficiency considerations and alignment with net neutrality principles. Please see Chapter 4 for more details on the broadband infrastructure levy. The government and TISPs should direct the funds generated from this levy towards enhancing telecom infrastructure, including fibrisation of the network backbone, installation of street furniture to improve connectivity, and other critical initiatives.

Please see Chapters 4 and 8 for more details on the broadband infrastructure levy.

3.8 Conclusion

In the era of 5G+ networks, the digital space has become an integrated sphere of co-opetition between TISPs and OTTs. Hence, it is necessary to examine whether or not they are subject to similar regulatory burdens when the underlying triggers for intervention are the same. Of course, separate regulatory stances need to be formulated in areas where the nature of business predicates unique regulations for TISPs and OTTs.

As will be specified in later chapters, regulators in the EU have already adopted many of the regulatory stances espoused in this chapter. It is time for all regulators to develop an integrated view of digital communications.

One of the most important ways in which diagonal equity can be operationalised is by restructuring the licensing framework for OTTs and TISPs. Chapter 4 provides details of such a framework. Specifics on spectrum regulation, net neutrality regulation, interconnection regulation, and universal service regulation are provided in Chapters 5, 6, 7, and 8, respectively.

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4

Licensing

From the Communications Convergence Bill to Functional Separation and Infrastructure Integration

4.1 Introduction

In the 1980s and 1990s, the telecommunications industry went through a process of privatisation (Hulsink, 2012).[1] The transformation was driven by a variety of factors, including the emergence of mobile technologies with lower levels of fixed cost than fixed-line telephony and a new liberal consensus that favoured private enterprises. However, telecommunications remained a critical sector for national security, economic development, and social cohesion. Hence, post-privatisation, governments have used the licensing framework to achieve public policy objectives in the context of the new ownership structures.

The policy objectives are wide-ranging, including the allocation of limited resources such as radio spectrum and telephone numbers in a transparent manner, generating revenue for the government, providing accessible, high-quality telecommunication services to the public at large, facilitating technological innovation, creating regulatory certainty, and protecting consumers (Latipulhayat, 2014). Indeed, in many countries, the provision of the telecommunications network remains, officially, the exclusive privilege of the government, with the government exercising its privilege by granting licences and authorisations to various entities.

Given the rapid pace of technological change, technology neutrality is an avowed part of the licensing objectives of most jurisdictions. Neutrality usually takes the form of licences for specific services without mandating associated technologies. However, it must be recognised that

[1] A version of this chapter was first published in Prasad et al. (2025).

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the licensing framework is not limited to the terms and conditions within the licence. It includes how the industry value chain has been partitioned (for instance, between infrastructure and services), the types and numbers of licences issued, the associated licensing fee structures, and the geographical definition of markets. These elements always play a significant role in the trajectory of the industry. Thus, the licensing framework in its entirety is always non-neutral and must be carefully designed.

There are three kinds of licences—individual licences, class licences or general authorisations, and open entry (Flanagan, 2005). An individual licence is granted to an operator to provide specified telecommunications services. It spells out detailed obligations and conditions. In some cases, the licensor may specify the technology to be used by the licensee. A special individual licence is the universal licence, which enables an operator to offer a portfolio of services.

In the general authorisation approach, the licensing authority publishes a set of eligibility criteria and general conditions. Any entity that meets the criteria is automatically authorised to provide the designated service or facility after a simple process of registration. Under open entry, any entity is allowed to provide equipment, infrastructure, or service, often after registration.

This chapter outlines a new licensing framework for the Indian telecommunications industry. In section 4.2, we summarise the existing licensing framework in India; in section 4.3, we examine the proposals for a new framework that have come up from time to time; in section 4.4, we discuss the heightened need for convergence in the infrastructure layer and the functional separation needed in the layers above; in section 4.5, we highlight international experiences; in section 4.6, we provide details of a new licensing regime, including a migration plan; with concluding remarks in section 4.7. Detailed revenue implications are provided in Appendix 4.1.

4.2 Licensing in India: The Story So Far

The current telecommunications industry in India predominantly consists of vertically integrated TISPs that cater to large markets and are able to pay the hefty charges for spectrum revealed in auctions with high

reserve prices. The Indian market is currently highly concentrated, with a Herfindal–Hirschman index of 0.31 (see Table 4.2). The trajectory of the licensing framework has played a significant role in the evolution of the industry.

From 1994 to 2003, individual cellular mobile telecommunications service (CMTS) licences were awarded to mobile operators for providing cellular mobile services. Due to the paucity of spectrum, the licence came bundled with the minimal amount of spectrum required for starting the service (Prasad & Sridhar, 2014). Further, the licensing terms and conditions specified the technology, initially Global Systems for Mobile (GSM) for 2G wireless services. The price of the licence was discovered in various ways, including beauty pageants and auctions. Additional spectrum was awarded to the licensees after they achieved certain subscriber thresholds. Apart from the CMTS licence, BTS licences were awarded to the operators for providing fixed-line service. The licence also allowed the BTS licensee to use the wireline and fixed wireless modes for last-mile connectivity.

Initially, the Indian telecommunications market was divided into twenty-three LSAs, which were further categorised into four categories—metros, category A, category B, and category C. In 2005, the number of LSAs was reduced to twenty-two by including Chennai with the state of Tamil Nadu. Each LSA is relatively large, containing rural and urban areas with varied demographics and income levels. Most of the LSAs align with the geographical boundaries of states. The LSAs are further discussed in Chapter 6.

After the 'limited mobility' controversy in which an operator with a BTS licence was able to provide mobile services, in November 2003, the Indian government announced the guidelines for a unified access service licence (UASL) (Sridhar, 2012). The UASL allowed the use of any technology (both wireline and wireless) for the provisioning of network access service, with an option for the BTS licensees (i.e. fixed-line service providers) to migrate to UASL by paying a prescribed fee (for details, refer to Sridhar, 2012). In 2013, the government announced the unified licence (UL) regime (DoT, 2013), under which entities obtain a single licence in the first stage and subsequently obtain service-level authorisations for various services, including Internet, national long-distance, international long-distance, satellite communication, and very small aperture

terminal (VSAT) satellite services. By allowing a single entity to provide telephony and Internet services, the UL acknowledges the technological possibility of convergence under which telephony and Internet can be provided using any medium—fixed line, wireless or cable.

As the telecommunications market grows, it evolves into many niche areas addressing a variety of end users, including corporate customers, and high, medium, and low-end retail subscribers. Service providers who can cater to the needs of the different customer segments become necessary. Such operators should be able to plug into existing networks rather than having to build out their own networks.

In this context, several countries have used accounting, legal, or functional separation as a regulatory remedy. Accounting separation is the least stringent, legal separation is the most stringent, with functional separation falling between these two options. Cave (2006) defined six separation options: accounting separation, creation of a wholesale division, virtual separation, business separation with localised incentives, business separation with separate governance arrangements, and legal separation. We use the generic term 'functional separation' to refer to all such attempts to separate infrastructure and service provisioning.

4.2.1 Entry of Virtual Network Operators

The introduction of the VNO licence in 2016 partly enabled functional separation. The VNO can obtain connectivity for access as well as long-distance and Internet services from a network service operator (NSO). Thereby, it can market and provide numbering and associated services. Though the new provision was expected to unleash new service offerings and improve competition, it had no material impact. An important cause was that the new licensing framework stopped short of incentivising the separation of network and service provisioning using differentiated licensing fees.

The one-time entry fee for authorisation of VNO services is the same as that of vertically integrated TISPs under the UASL. Further, each VNO is subject to the same licence fees and spectrum usage charges (SUCs) as incumbent operators. VNOs who wish to provide wireline service can operate at a district level. However, for other services, including the

high-growth wireless service, each VNO has to cater to an entire LSA, which is a heterogeneous market that is not aligned with the market niches of interest to the VNO.

The licence period is ten years for VNOs compared to the twenty years assigned to TISPs. The non-refundable entry fee can be up to INR 75 million (USD 850,000), with an annual licence fee of about 8 per cent of the adjusted gross revenue (AGR) (DoT, 2016b). Though the VNO licensing process was much simplified, the applicants for the licence could not even pay the entry fee and submit the associated bank guarantees. Consequently, in 2022, over seventy letters of intent issued by the DoT were cancelled (Registrationwala, 2022). Further, there were restrictions on homing onto a single TISP, which the Telecom Regulatory Authority of India (TRAI) further relaxed in its recommendations in 2024. In its recommendations, the TRAI has indicated no cap on the TISPs for connectivity access for the wireline VNOs (TRAI, 2024). It further stated that an access service VNO intending to provide both wireless and wireline access services in an LSA should be permitted to take connectivity from one TISP for wireless access service and other TISPs for wireline access service in the LSA. This option is expected to provide a certain amount of flexibility, in contrast to the extant regime, in which an access service VNO, intending to provide both wireline and wireless access services in an LSA, has to take connectivity for both wireline and wireless access services from the same TISP in the LSA. However, these minor modifications have yet to significantly impact the VNO market in India.

The timeline of telecom licensing is depicted in Fig. 4.1.

Similarly, the UASL allows the creation of pure-play ISPs who secure the licence and only activate the authorisation for Internet service. The authorisation can be obtained at the national level, at the level of an LSA, or for a secondary switching area (SSA), which represents a smaller geographical jurisdiction than the LSA. Though the entry fee for pure-play Internet service is relatively low, the huge fixed investment required to provide last-mile connectivity has dissuaded smaller ISPs from rolling out their pure-play Internet services at the SSA or even the telecom circle level.

Interconnection regulation is an integral part of the licensing framework. Under the UASL, it is mandatory for the licensee to provide interconnection to all eligible telecom service providers as well as national

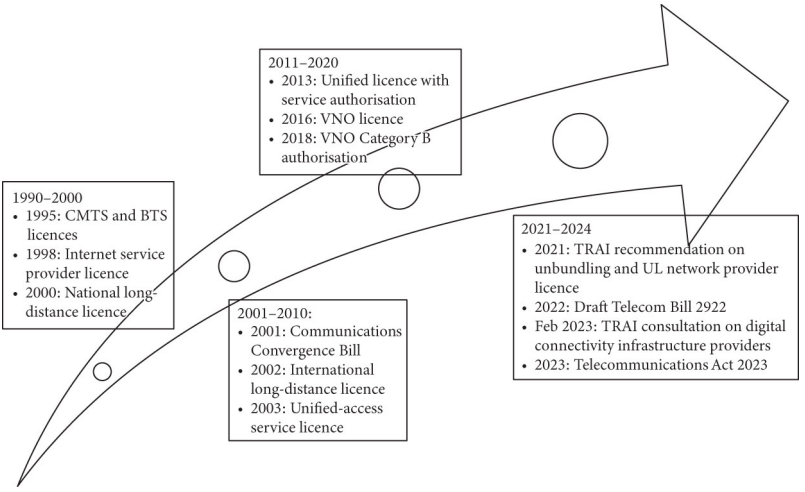


Fig. 4.1 Timeline of various types of telecom licensing in India
Source: Adapted from Prasad et al. (2025).

long-distance operators. Since 1 January 2021, the interconnection usage charge (IUC) for domestic voice calls in India has been zero, implying that mobile operators no longer have to pay each other to terminate calls. This system is called 'bill and keep', since the network of the call originator can bill their subscribers for off-net calls and keep the revenue without sharing it with the terminating network.

OTT communication service providers (OTT coms) do not come under the ambit of the licensing scheme. In effect, their services are treated as distinct from telecommunications services.

4.2.2 Current Licensing Structure

The current structure of the UL is presented in Fig. 4.2 (DoT, 2016a; DoT, 2016b; DoT, 2018a; DoT, 2018b):

Of the various levies charged to licence holders, the spectrum prices are particularly high relative to international benchmarks. The reserve prices for most bands have been increasing over the years, details of which are provided in Chapter 5.

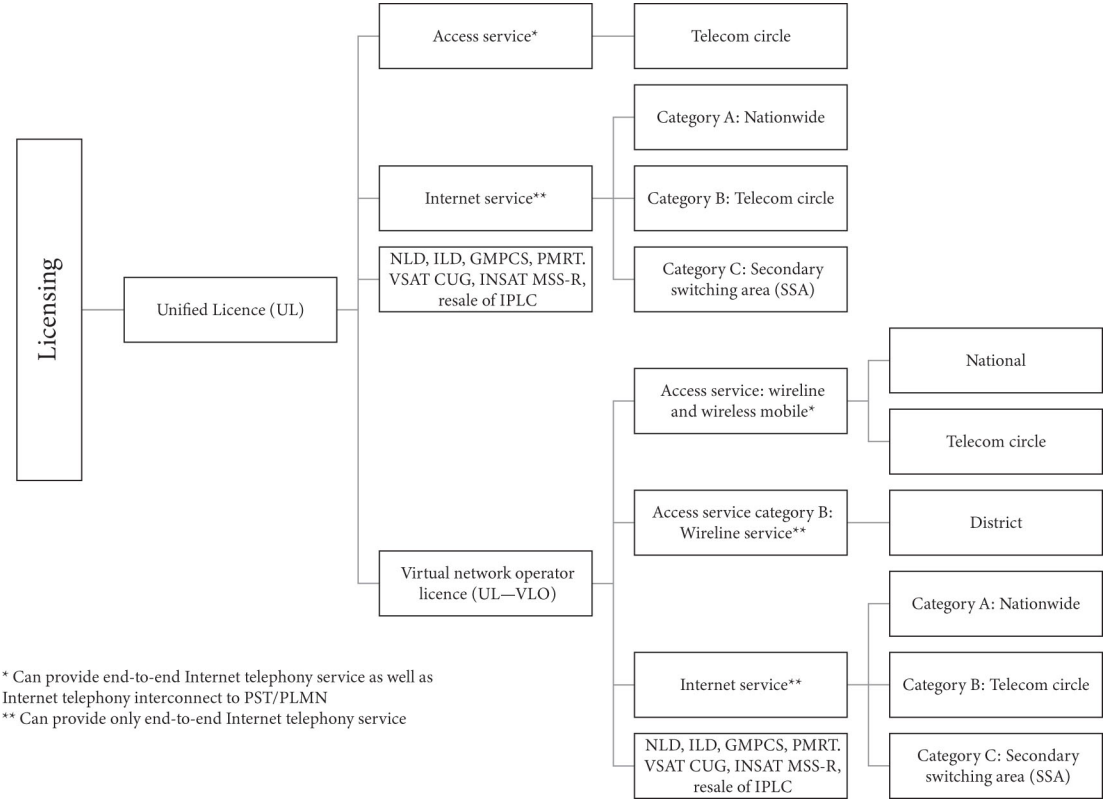


Fig. 4.2 The current licence structure in India

Source: Adapted from Prasad et al. (2025).

Table 4.1 Details of the licensing framework

	Access service provider	Internet service provider	VNO
Type of licensing	UASL with access service authorisation	UASL with Internet service authorisation	UASL with VNO authorisation
Interconnection regulation	Mandatory to provide interconnection to all eligible telecom service providers and VNOs	NA	All network interconnection to be provided by the parent TISP
Licence and regulatory fees	Licence fees @ 8% as a percentage of AGR, including a 5% contribution to the Universal Service Fund	Licence fees @ 8% as a percentage of AGR, including a 5% contribution to the Universal Service Fund	Licence fees @ 8% as a percentage of AGR, including a 5% contribution to the Universal Service Fund
Spectrum	Spectrum usage charge as a percentage of AGR	NA	No spectrum charges
Emergency services	Yes	Yes	Yes
QoS	Yes	Yes	Yes
Net neutrality	Yes	Yes	Yes
Geographical boundaries of the market	At the LSA level	Authorisation can be obtained at the national level, at the level of an LSA, or for an SSA	Wireline service can operate at a district level; wireless service at the LSA level

Source: Authors' own.

Table 4.1 is a useful way of picturing the key aspects of the current licensing framework, details of which are discussed in the subsequent chapters.

4.3 Proposals for a New Licensing Framework and International Experiences

There has long been a recognition that fast-paced technological developments necessitate a rethink of the licensing framework. The debate in India has taken place in the context of a dynamic international scenario.

4.3.1 New Proposals

Prior to 2001, telecom regulation in India largely followed a 'command-and-control' approach (Prasad & Sridhar, 2014). A key disadvantage of this approach is the regulator's predetermination of technologies to be deployed by operators.

The Communications Convergence Bill 2001(Parliament of India, 2001) was drafted at a time when the paradigm of 'one pipe, one service' under which telephony, Internet, and broadcasting were provided through different media—fixed line or wireless, broadband, and cable/over the air, respectively—was on its way out. From a technological point of view, the prospect of 'triple play' in which all three services—telephony, Internet, and broadcasting—could be provided using the same medium had become a reality. Further, each service could be provided using any of the three media. This multiplicity of possibilities spawned a bold new vision based on two fundamental principles:

(1) convergence of infrastructure functions in an integrated entity and
(2) functional separation of services and infrastructure.

For actualising the functional separation principle, the bill conceptualised the creation of a new entity, referred to as the 'network service provider', which would use infrastructure facilities, including earth stations, cable infrastructure, wireless equipment, towers, and ducts to provide bandwidth services (Prasad et al., 2025). The bill also envisioned a 'technology neutrality' regime in which carriers have the flexibility to deploy appropriate technology without the administratively determined mandate of the regulator (El-Moghaz et al., 2019).

In 2019, the DoT), under its 'Propel India' mission, requested the TRAI to furnish recommendations on enabling the unbundling of different layers of the telecommunications value chain through differential licensing. The aim was 'reforming the licensing and regulatory Regime to catalyse investments and innovation and promote ease of doing business'. In response, in 2021, the TRAI recommended a separate authorisation of an access network provider (network layer) under the UL, similar to the network infrastructure facilities provider envisaged in the Communications Convergence Bill 2001, to provide network services on

a wholesale basis to VNOs (TRAI 2021). The access network provider would be responsible for all the network-related terms and conditions specified in the access service authorisation under the UL. However, service delivery clauses would not apply to this category of providers.

While the access network provider was meant to be a new entity in the telecom landscape, the extant entities were meant to continue, and no incentives were recommended to encourage a transition to a functionally separated industry. As a result, the concept of the access network provider did not gain much traction. In fact, the DoT has not yet amended the UL to include authorisation for the access network provider.

The Draft Telecom Bill 2022 (DoT, 2022) defines 'telecommunication services' to include a wide variety of services, including broadcasting services, electronic mail, e-voice, video and data communication services, fixed and mobile services, Internet and broadband services, satellite-based communication services, Internet-based communication services, machine-to-machine communication services, and OTT coms. By recognising the profusion of services possible in a 5G world, and by including OTT coms in the list of telecommunication services, the Draft Telecom Bill acknowledged the functional equivalence of a wide variety of services. This acknowledgement creates a rationale for reducing the barriers to entry for service providers by unbundling the services and infrastructure layers. To this extent, it represented a step towards the functional separation of services and infrastructure. However, the specific mention of OTT coms has been taken out in the final wording of the Telecommunications Act 2023 (GoI, 2023).

4.3.2 International Experiences

As mentioned earlier, functional separation has been used as a regulatory remedy by several countries.

As early as 2008, Sweden implemented functional separation by amending the Swedish Telecommunications Act to include mandatory functional separation as one of the powers of the Swedish telecommunications regulator (Teppayayon & Bohlin, 2010). It is along the lines of voluntary functional separation introduced by Italy, where vertical separation remains the decision of the individual company. Other countries,

such as the United Kingdom and New Zealand, have imposed involuntary separation. In 2006, the United Kingdom functionally separated its fixed-line network (Curwen & Whalley, 2010), and New Zealand opted for structural separation (Congedo, 2015), mandating the break-up of telecom operators to create open basic networks (ETNO, 2010). Ireland, Poland, and Australia have also adopted functional separation.

Cave & Mariscal (2020) analyse the effect of accounting, functional, and structural separation adopted as part of the 2013 Telecom Reform in Mexico and conclude that indeed they were successful policy reforms in making mobile services affordable to the low-income groups in the country. In contrast, the US telecommunications industry offers a comprehensive case study highlighting the difficulties of employing separation requirements to address competition concerns in a dynamic technological environment. Gilbert (2021) pointed out that the history of deregulation in the US telecommunications industry teaches the United States that there are potential economic benefits to separating monopoly services from services that can be supplied in competitive markets. However, there are also formidable obstacles to creating durable boundaries that do not interfere with competition and innovation. Policymakers must be conscious of their efforts to address structural or functional separation based on monopoly bottlenecks and enable rules that do not hinder innovation and facilitate competition.

4.4 The Heightened Need for Convergence and Functional Separation

The need for convergence in the infrastructure layer and functional separation between structure and services, which has been articulated with varying degrees of intensity since 2001, is now more pressing than ever before.

4.4.1 Functional Separation

Functional separation has been used as a regulatory remedy by several countries. Vertically integrated firms that operate at both the

infrastructure and service layers with significant market power can self-preference their own retail services. Functional separation breaks the walled garden within the network infrastructure and retail services entity, enabling better access to essential facilities by other competitors. It leads to different services or activities being performed by separate operating divisions of the same firm. Sometimes, it may also involve separate management for relevant divisions (Dounoukos & Henderson, 2003).

The need for functional separation is being driven by the following forces:

(1) *Rapid innovation in the services layer*: as highlighted in the Draft Telecom Bill 2022, a wide variety of services and service providers are coming into being as the world adopts 5G technologies. To facilitate this innovation, regulators must ensure that the multiplicity of service providers do not need to own elements in the infrastructure layer to enjoy a level playing field with other service providers. This principle is sometimes called the Bell Doctrine (Joskow & Noll, 1998), which was used in the anti-trust case against AT&T in 1982. Under this principle, when an industry has two layers comprising an essential network/infrastructure layer and a layer that rides on top, the two layers must be unbundled in order to allow a new entrant or a start-up in the overriding layer to compete without having to incur the heavy capital expense of building out the infrastructure layer.

    In the context of India, in recent times, there has been a consistent increase in the concentration of telecom services, as shown in Table 4.2. In the table, HHI refers to the Herfindahl–Hirschman index (HHI), a measure of competition. It is defined as the sum of the squares of the market shares of each firm. The HHI can range from 0 to 1, moving from a very large number of tiny firms to a single monopolistic producer. Decreases in the HHI generally indicate a loss of pricing power and an increase in competition, whereas increases imply the opposite. As can be seen, the telecom industry started with a duopoly in 1996 with a high HHI, then witnessed intense competition with about ten licensed TISPs during the period 2008–2015 and later began to consolidate with four national operators with an HHI of about 0.31.

Table 4.2 Market competition of mobile services in India

Year	HHI by subscribers
1996	0.52
2003	0.34
2009	0.19
2015	0.18
2019	0.28
2024	0.31

Source: Authors' own.

The sector in India appears to be inching towards a duopoly, despite the government's efforts to strengthen the ailing public-sector service provider. In order to pre-empt anti-competitive and discriminatory conduct by incumbents, infusing competition in the services layer is necessary.

(2) *Greater investment and sharing needed in the infrastructure layer*: as 5G technology operates in small cells, especially while using the 3.3 GHz mid-frequency band, the fibre and tower network will have to be extensively expanded to interconnect the cell transceiver stations. Efficiency requires that this expanded infrastructure be provided in a neutral and cost-effective manner to the various service providers in order to avoid inefficient duplication of network costs. Therefore, it is necessary that the infrastructure layer operates at arm's length from the services layer. Steps have already been taken in the UL (VNO) licence that separates the service from the infrastructure layer. However, the structure of an infrastructure integrator has not yet been introduced.

(3) *Diagonal equity*: the emergence of functionally equivalent telecommunications services provided by OTT coms and TISPs requires the separation of the services and the infrastructure layers to enable regulatory parity, as discussed in Chapter 3. Functional separation is a necessary condition to achieve diagonal equity between OTT coms and VNOs.

4.4.2 Convergence in the Infrastructure Layer

The need for convergence in the infrastructure layer is being driven by the greater unbundling in the infrastructure layer. The telecom network has evolved from an elementary architecture comprising radio equipment and physical infrastructure to a software-led ecosystem that includes cloud storage companies, software developers, and municipalities, besides the traditional network entities (see Chapter 2). This unbundled ecosystem would be of great benefit to service providers, provided there is an entity—referred to as the network infrastructure facilities provider in the Communications Convergence Bill 2001 or the access network provider (network layer) in the TRAI (2021) recommendation—to integrate all the various elements. Without such an entity, transaction costs for service providers would become unmanageable, as they would have to negotiate separately with individual members of the infrastructure ecosystem.

The current licensing scheme has already recognised specific categories of infrastructure providers (Ips). For instance, tower companies that own, maintain, and lease passive infrastructure such as towers, duct space, dark fibres, and RoW to licensed telecom service providers are covered under an IP-1 category through a simple registration process (DoT, 2021). However, tower companies are only one out of a large set of infrastructure companies including data storage companies, software services companies, and network operators. These other types of companies need to be included in the licensing framework, and a new category of infrastructure integrators, entitled to spectrum licences, right of way, and the national numbering scheme, should be created.

Hence, we recommend a functional separation of infrastructure and services and an integration/convergence of the infrastructure layer.

4.5 The Special Case of OTT Video Services

Video downloads, video streaming, and pay-per-view video services provided by OTT video service providers consume large amounts of bandwidth. This traffic puts stress on the underlying network. In India, revenue from the OTT video segment is projected at USD 3.76 bn in

2023 and is expected to grow to USD 5.51 bn by 2027, with an annual growth rate of 10.01 per cent (Statista, 2023a). The largest segment is video streaming, with a market volume of USD 1.70 bn in 2023. The user base for the OTT video segment is about USD 528.90 m. The OTT video segment in India is projected to reach USD 3.76 bn in 2023. According to Neumann et al. (2022), around 80 per cent of Internet traffic comes from the three segments of video, social media, and video games, of which the share of the video segment is the highest.

Most of the TISPs in India also provide video services. A notable example in this segment is Jio Cinema, owned by Viacom18, which was launched in 2016. The official broadcaster of Indian Premier League (IPL) cricket 2023, Jio Cinema, clocked 1.47 billion views on the weekend of IPL 2023 (Mitta, 2023). Similarly, Airtel XStream is the OTT video service provided by Airtel.

With a 20 per cent share, Amazon Prime Video and Netflix are India's leading OTT video services. Disney's recently acquired Hotstar occupies third place with a 17 per cent market share. With roughly 10 per cent of the market, ZEE5, which has a substantial base in Hindi, Telugu, Tamil, and Malayalam, is in fourth place. These are followed by Jio Cinema, Alt Balaji, Sony Liv, SUN NXT, and Aha Apps, which have the highest OTT market share in India's top ten.

The network providers must accommodate this demand for OTT video services by upgrading their network infrastructure investment. There are proponents of the argument that large traffic-generating (LTG) OTTs should pay the ISPs network fees, as their traffic places a disproportionate burden on the networks. In a highly cited case of *Netflix vs SK Telecom*, the ISP tried to pass on the sending network payment charges to the OTT. This initiative triggered multiple litigations in South Korea (Feigenbaum & Nelson, 2021). On the other hand, the opponents, mainly the large OTTs, argue that such levies will dissuade them from placing their cache servers nearer to the ISPs' point of presence, affecting the quality of their video services. It is also asserted that large OTTs have their own software-defined networking protocols and cache servers. Hence, their decisions on where to place their cache servers depend on whether or not they need to pay carriage charges to the ISPs.

In summary, the choice is between (i) TISPs starved of resources partnering with OTTs in upgrading their networks to ensure high-quality

services and (ii) TISPs who have adequate resources to build out high-quality networks due to OTT contributions, with OTTs not having to invest in silos. The former approach favours OTTs with deep pockets. It also results in an inefficient use of resources due to silo-based decision-making by OTTs. The latter approach allows TISPs to raise resources from OTTs, thus requiring lower contributions from end consumers. In general, large OTTs have lower price elasticities than end consumers, as they are multi-homing (i.e. they have to be present on all networks), while consumers are single-homing (i.e. they need only one network) and can, therefore, be choosy. Therefore, static efficiency requires TISPs to transfer the financial burden onto large OTTs. They can do so without significantly impacting the OTTs' ability to invest in research and development (R&D), that is without affecting dynamic efficiency.

Thus, placing a financial responsibility on large OTTs is efficient and warranted. However, OTTs paying TISPs for public Internet use could be seen as violating net neutrality. Hence, the significant OTT coms and OTT video service providers pay a 'broadband infrastructure levy' (BIL), which will then be distributed to the TISPs/ISPs based on the total traffic volume in their networks. We do not propose direct payment of carriage charges by the OTTs to TISPs/ISPs, as this is prone to litigation, as exemplified in the South Korea case.

Further, when a TISP provides video services, functional separation of network provider and OTT video services will demarcate the boundaries of operations between the two, resulting in unambiguous and equal regulatory treatment across the industry.

Video services are also being intensely used by EdTech firms for providing live online sessions and video streaming of lessons (e.g. upGrad, Byjus, Simplilearn, Coursera) and by HealthTech firms for providing teleconsulting and telemedicine. The consumption of bandwidth by these firms over their platforms is also increasing. Hence, much like OTT video services, bandwidth-heavy OTT services in education and health should also be considered for the BIL if they become LTGs.

We recommend a BIL at the rate of 3 per cent in order to achieve revenue neutrality in a reasonable period of time (see Appendix 4.1).

There are criticisms of such a levy that envisage the costs being passed on to the consumers, resulting in a lower use of the service. Such a development would harm not only the OTTs but also the TISPs (Shy, 2001).

However, the alternative can be equally harmful. If TISPs are made to bear the burden of infrastructure expansion for 5G+, they could pass on the costs to the end user, thus reducing the use of connectivity services. This would also harm the OTTs.

4.6 A New Licensing Regime

The proposed structure of the new licensing regime based on all the arguments presented above is shown in Fig. 4.3.

A noteworthy feature of our approach is that we are treating VNOs that lease network capacity from the network provider and OTT coms that do not lease network capacity as imperfect substitutes from the point of view of regulation. This feature is because the end user treats communication services provided by telcos and by OTTs as substitutes. Thus, these services are functionally equivalent even though they are operationally disparate and, hence, need to be viewed from the same regulatory lens.

This approach is in line with the Directive (EU) 2018/1972 of the European Parliament and of the Council (EU, 2018) that states,

> [E]nd-users increasingly substitute traditional voice telephony, text messages (SMS) and electronic mail conveyance services by functionally equivalent online services such as Voice over IP, messaging services

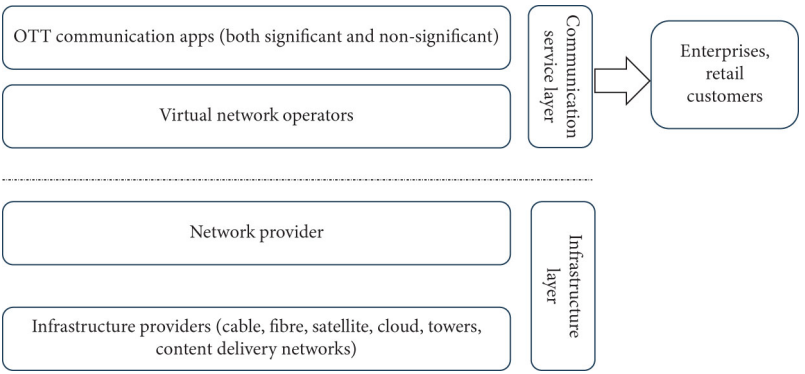


Fig. 4.3 The layered approach to digital communications
Source: Authors' own.

> and web-based e-mail services. In order to ensure that end-users and their rights are effectively and equally protected when using functionally equivalent services, a future-oriented definition of electronic communications services should not be purely based on technical parameters but rather build on a functional approach . . . While 'conveyance of signals' remains an important parameter for determining the services falling into the scope of this Directive, the definition should cover also other services that enable communication. From an end-user's perspective it is not relevant whether a provider conveys signals itself or whether the communication is delivered via an Internet access service.

Of course, one must also be sensitive to the differences between these two entities, which stem from their different operational models.[2] There are associated implications for the provisioning of emergency services, compliance with net neutrality, and so on, which are discussed in later chapters, considering the possibility of functional separation in the regulatory framework.

It is also useful to revisit the notion of the exclusive privilege of the government with regard to the provision of telecommunications services, and ask whether or not this privilege remains relevant in the new digital landscape. Given the low barriers to entry in the services layer, the significant participation of start-ups in the infrastructure and services layer, and the use of the network for a number of non-core functions, one could argue that the licensing framework need not flow from the notion of an exclusive privilege. It is pertinent that the new Indian Telecommunications Act 2023 no longer invokes such a privilege as a preamble to its policy formulations (GOI, 2023).

Further, the current licensing framework has evolved with several amendments. The terms and conditions are very different for each type of service authorisation. In a converged digital era, it may be preferable to simplify the existing licensing framework into a simple, tiered structure of a few types.

[2] One perceived difference between VNOs and OTT coms is that VNOs are able to use the publicly assigned numbering system. However, the EU treats any entity whose users can connect to number-based systems as a number-based interpersonal communications service. Hence, OTT coms providers would fit into this category.

We now elaborate upon a differentiated licensing regime for the infrastructure and communications services that would reflect the *functional separation of infrastructure and services and an integration/convergence of the infrastructure layer*. As mentioned earlier, individual licensing implies that the entity requires prior permission to operate and must pay licence fees. General authorisation implies that entities must satisfy certain criteria but do not need to pay licence fees. Open entry/registration means that entities only need to register to operate. They can commence operation without prior permission. However, they may be restricted from operating in case they do not follow the general guidelines. A broad overview of this regime is provided below.

(1) In line with our regulatory model of functional separation, we create a two-layer system of licences and authorisations for infrastructure and services, respectively.
(2) In the infrastructure layer, we conceive of a licensed entity (namely, the network provider) that integrates all the entities in the physical and network layer provided by content delivery networks (CDNs), cloud service providers, tower companies, and fibre and duct providers to provide network bandwidth on a wholesale basis to communication service providers. This integrated entity aligns with the TRAI's unbundling recommendations (TRAI, 2021). The licensed network provider is authorised to acquire radio spectrum for exclusive use in the deployment of networks in a relatively concentrated market. Network providers should be mandated to provide *equal access on equal commercial terms* to communication service providers. They need to fulfil roll-out obligations and are charged a universal service levy as part of the licence fee. The levy will be used for the build-out of the network in underserved areas, often through a tendering process in which network providers participate.
(3) In the communication services layer, we distinguish between entities that lease network bandwidth from the network provider (namely, the VNOs) and those that provide communication services over the Internet, untethered from the underlying network (namely, OTT coms).

(4) VNOs and OTT coms are divided into significant and non-significant service providers based on the proportion of traffic they carry relative to the overall traffic by VNOs and OTT coms.[3] The definition of significant OTT coms can be similar to that of significant social media intermediaries comprising entities with more than 5 million active subscribers, as defined in the Information Technology Intermediary Guidelines and Social Media Ethics Code 2021 (GoI, 2021). All VNOs and significant OTT communication providers are charged a BIL of 3 per cent of their revenues from Indian operations obtained from public networks, the net of revenues flowing from specialised services that involve direct contracts with the network operator. In line with the regulations of the EU, the revenues include all forms of remuneration, including direct fees and advertising, as well as cases where payment is made by a third party and not by the service recipient.[4]

(5) Since OTT video services demand large capacity from the underlying broadband, we propose that the BIL also apply to them. This levy should be extended to other OTTs, depending on their bandwidth consumption. As with communication service providers, the applicable revenues should be revenues obtained from public networks, net of revenues flowing from specialised services that involve direct contracts with the network operator. The network providers shall initiate a self-auditing process to submit quarterly reports on bandwidth consumption by the OTT apps to the TRAI, based on which the DoT shall initiate the collection of the BIL.

(6) The proceeds of the BIL shall fund infrastructure development across the country, especially in urban and semi-urban areas.

(7) QoS requirements shall apply to all communication service providers, namely the VNOs and OTT coms.

[3] When the market matures, one could decide significance based on the traffic carried by a service provider as a proportion of overall traffic, VNO and OTT combined.

[4] Point 16 of Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (Recast)Text with EEA relevance.

(8) Emergency service requirements will be applied to VNOs, details of which are discussed in Chapter 7.
(9) Net neutrality will apply to all VNOs in the form of minimum QoS of the public network, details of which are discussed in Chapter 6.
(10) Network security/data privacy and data protection and lawful interception will be regulated through contemporaneous specific laws on these topics.
(11) As the market heterogeneity is likely to increase with 5G, we suggest that the granularity of LSAs be increased in line with the UL (VNO) wireline access service licence for the communication services layer.

The structure outlined above is summarised in Table 4.3.

4.6.1 Incentive Structure to Catalyse the New Framework

It is important to note that our recommendations are not meant to be mandates but 'nudges' that would be operationalised through tax and other incentives. Since previous proposals were unsuccessful because the required incentives were not in place, designing a suitable incentive structure is essential. The proposed incentive structure is as follows:

(1) Currently, licensed TISPs that undertake functional/legal separation will pay SUCs only on revenue of network services sold wholesale to the VNOs. This will reduce the regulatory burden on the network providers and will incentivise the existing TISPs to migrate to the new regime.
(2) Lower rates of universal service levy (referred to as the BIL) in the services layer compared to the infrastructure layer shall incentivise the separation of networks and services layer by the TISPs. Consequently, the VNOs will pay lower regulatory charges.
(3) The BIL proposed to be paid by the VNOs and OTT coms will compensate the network providers for using the network capacity and provide enough finances to augment the network capacity in urban and semi-urban areas of the country.

Table 4.3 Details of the licensing framework

	OTT com	VNOs	Network provider	Other entities in the infrastructure layer, including software vendors, system integrators, and cloud storage providers
Type of licensing	General authorisation, if significant, otherwise registration	General authorisation, rationalisation of entry fees	Licence required, licence fees to recoup administrative costs, spectrum usage charge if applicable	Registration
Interconnection regulation	Universal interconnection and portability between all types of service providers, including VNOs	Universal interconnection and portability between all types of service providers, including OTT coms	Universal interconnection between all types of service providers	No regulation (governed through contractual agreements)
Licence and regulatory fees	Fixed authorisation fee plus BIL @ 3% as a percentage of AGR for significant OTT coms and video service providers;* Fixed registration fee for non-significant OTTs	Fixed authorisation fee plus BIL @ 3% as a percentage of AGR	Licence fee plus universal service levy @ 5% as a percentage of AGR plus annual spectrum usage charges as a percentage of AGR as applicable	Fixed Registration Fee
Emergency services	Yes, if significant	Yes, if significant	No (applied through contractual agreements)	No (applied through contractual agreements)
QoS	Yes	Yes	No (applied through contractual agreements)	No (applied through contractual agreements)
Net neutrality	No	Yes (minimum QoS for public networks)	Yes (non-discriminatory access for all VNOs)	No (applied through contractual agreements)
Geographical boundaries of the market	NA	At the LSA level	At the LSA level, with a more granular definition of LSAs	NA
Additional comments	OTT video services and LTGs are charged the BIL.			

* Note that OTT video service providers must pay a fixed authorisation fee plus the BIL. However, they are not required to fulfil the other conditions applicable to OTT coms.

Source: Adapted from Prasad et al. (2025).

(4) There will be a more granular definition of LSAs to allow all market players to take advantage of industry niches.

A broad spectrum of industry configurations is possible within our regulatory framework, ranging from the current vertically integrated structures to completely unbundled formations and everything in between. The precise configuration would be dynamically determined via the options the TISPs choose from the proposed licensing regime.

It is interesting to note that calls are emerging from within the industry to engage in 'delayering' (i.e. functional separation) to improve competitive capability (McKinsey & Co., 2024).

4.6.2 Revenue Estimates

The proposed licensing structure would reduce the revenue collected under the licence fees, SUCs, and the universal service levy to the government exchequer. However, it would more than compensate through the BIL. In three to five years, as the broadcasting and video services business increases, the total revenue earned will be restored to current levels. The detailed estimation of revenue is given in Appendix 4.1.

4.7 Conclusion

The extant licensing structure in telecommunications needs to be revisited as 5G+ networks and services are being deployed. In this chapter, we provide a new licensing structure based on functional separation and diagonal equity principles.

The notable features of our proposal are as follows:

(1) We create a two-layer system of licences and authorisations for infrastructure and services, respectively.
(2) In the infrastructure layer, we conceive of an entity—the network provider—entitled to bid for spectrum and that integrates

all the entities in the physical and network layer to provide network bandwidth wholesale to communication service providers. Network providers shall be mandated to provide *equal commercial access* to communication service providers. They need to fulfil roll-out obligations.

(3) In the communication services layer, we distinguish between entities that lease network bandwidth from the network provider (namely the VNOs) and those that are untethered from the underlying network (namely, OTT coms).

(4) The OTT coms are divided into significant and non-significant service providers based on the proportion of traffic they carry. All VNOs and significant OTT coms are charged a BIL at the rate of 3 per cent of their revenues from the public network. The proceeds of the BIL shall fund infrastructure development across the country, especially in urban and semi-urban areas.

(5) Since OTT broadcast and video services demand a large capacity from the underlying broadband, we propose that the BIL be applied to them.

(6) QoS requirements shall apply to all communication service providers, namely the VNOs and OTT coms.

(7) Emergency service requirements will be applied to VNOs.

(8) Net neutrality will be applied to all VNOs as minimum QoS for the public network.

(9) As the market heterogeneity likely increases with 5G, we suggest that the granularity of LSAs be increased in line with the UL (VNO) access service licence.

The licensing and regulatory framework needs to be sensitive to the greater modularity possible with 5G technologies. This chapter reflects our attempts to design a licensing structure that would nudge the industry towards exploiting the new opportunities, in line with conceptualisations that date back to the Communications Convergence Bill 2001.

Appendix 4.1

Revenue Estimates of the Proposed Regulatory Changes

We project revenue estimates for the government per our recommendation and compare them with the revenue accrued under the current licensing regime. The baseline used is the AGR licence fee at 8 per cent (3 per cent licence fee + 5 per cent USL/BIL) and annual SUC, as provided by the TRAI (2023). Following are the other data that we have used in the calculations,

(1) The OTT coms such as WhatsApp and Zoom earn revenue through (i) business users and (ii) advertising. The annual revenue from WhatsApp business is estimated to be around USD 1 billion/year (MoneyControl, 2023).
(2) The estimated annual revenue of OTT video service providers is USD 3.5 billion (Statista, 2023a).

Tables 4.4 and 4.5 above show the results of comparing the existing licence fees with the proposed fee structure. Though the quarterly estimated regulatory fee is less in our proposed structure, it will likely match up soon due to the increased usage of broadband for both communication and video services.

Table 4.4 Regulatory fees as per the current regime

		Quarterly regulatory fees (in INR millions)			
Item: quarterly estimates based on TRAI December 2022	**AGR**	**Licence fee @ 3%**	**USL @ 5%**	**Spectrum charges**	**Total**
Annual adjusted cross revenue of UL (Q3 2022)	5,10,000	15,300	25,500	8,050	48,850
Annual adjusted cross revenue of ISP (Q3 2022)	37,000	1,110	1,850	–	2,960
Total	**5,47,000**	**16,410**	**27,350**	**8,050**	**51,810**

Source: Adapted from Prasad et al. (2025).

Table 4.5 Regulatory fees as per the proposed regime

		Quarterly regulatory fees (in INR millions)				
	AGR	**Licence fee @ 3%**	**USL @ 5%**	**BIL @ 3%**	**Spectrum charges**	**Total**
Annual AGR of network providers @ 50% of the current regime	2,55,000	7,650	12,750	–	4,025	24,425
Annual AGR of VNOs @ 50% of the current regime	2,55,000	–	–	7,650	–	7,650
Estimated AGR of OTT coms: USD 1 billion	20,000	–	–	600	–	600
Estimated AGR of OTT video services, including ad revenue, pay-per-view, video downloads, and video streaming: USD 3.5 billion/year	70,000	–	–	2,100	–	2,100
Total	**6,00,000**	**7,650**	**12,750**	**10,350**	**4,025**	**34,775**

Source: Adapted from Prasad et al. (2025).

We have simulated the scenario for 2026 with the following assumptions:

(1) a compound annual growth rate (CAGR) of 20 per cent in AGR of network providers and VNOs for the next three years,
(2) OTT coms and video services revenue growth to USD 7 billion by 2026 (Statista, 2023b),
(3) a reduction of the licence fee from 3 to 1 per cent and USL and BIL from 5 to 3 per cent. Spectrum charges as a percentage of AGR remain the same.

From Table 4.6, the regulatory fee increases due to an increase in revenue for various operators and service providers, despite the reduction in fee as a percentage of AGR. Hence, we recommend reviving the licensing fee structure, considering the growth of broadband networks and usages across segments of society. This will also send a positive signal to the industry to invest in infrastructure and services to provide quality and affordable broadband services to the nation at large.

Table 4.6 Regulatory fees as per the proposed regime in 2026

	AGR	Quarterly regulatory fees by 2026 (in INR millions)				
		Licence fee @ 3%	USL @ 3%	BIL @ 3%	Spectrum charges	Total
Annual AGR of network providers with CAGR of 20%	4,50,000	13,500	22,500	–	7,103	43,103
Annual AGR of communication service providers with a CAGR of 20%	4,50,000	–	–	13,500	–	13,500
Estimated AGR of OTT coms: USD 2 billion by 2026	40,000	–	–	1,200	–	1,200
Estimated AGR of OTT video services, including ad revenue, pay-per-view, video downloads, and video streaming: USD 7 billion/year by 2026	1,40,000	–	–	4,200	–	4,200
Total	**10,80,000**	**13,500**	**22,500**	**18,900**	**7,103**	**62,003**

Source: Authors' own.

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5

Spectrum Regulation for 5G+ Networks

5.1 Introduction

Radio spectrum for commercial mobile services refers to the part of the electromagnetic spectrum that can be used for communication over the air between mobile handsets and the BTSs mounted atop towers. Radio spectrum is an essential scarce resource for the provisioning of commercial mobile services. The radio spectrum for commercial mobile services can be broadly classified into four categories: (i) the sub-GHz band, which contains spectrum with frequencies below 1 GHz or 1,000 MHz; (ii) the mid band, which is in the range of 1–3 GHz; (iii) the upper mid band, which is in the range of 3–6 GHz; and (iv) the high-frequency band in the range above 6 GHz. The sub-GHz band provides good coverage (hence, it is also called coverage spectrum) and is ideally suited for covering large areas in semi-urban and rural areas. However, the mid- and high-frequency bands provide large capacities (hence, they are called capacity spectrum). The operators use them to provide high-speed broadband connectivity in dense urban parts of their service areas (Sridhar & Prasad, 2021). As we move towards 5G+ networks, standardisation bodies such as the 3GPP have been working on millimetre wave (above 40 GHz) and Terahertz (THz) frequency bands (in the range 0.3–3 THz; 1 THz = 1,000 GHz) that offer very high bandwidth. The taxonomy of typical frequencies used for mobile services is provided in Fig. 5.1.

This spectrum is managed at international and national levels for allocation and assignment. The central body coordinating at an international level is the ITU, which has jurisdiction over spectrum from 9 KHz to 275 GHz. Below the ITU are organisations at a regional and national level. For instance, the Confederation of European Post and Telegraph Agencies and the EU operate at a Pan-European level, and various

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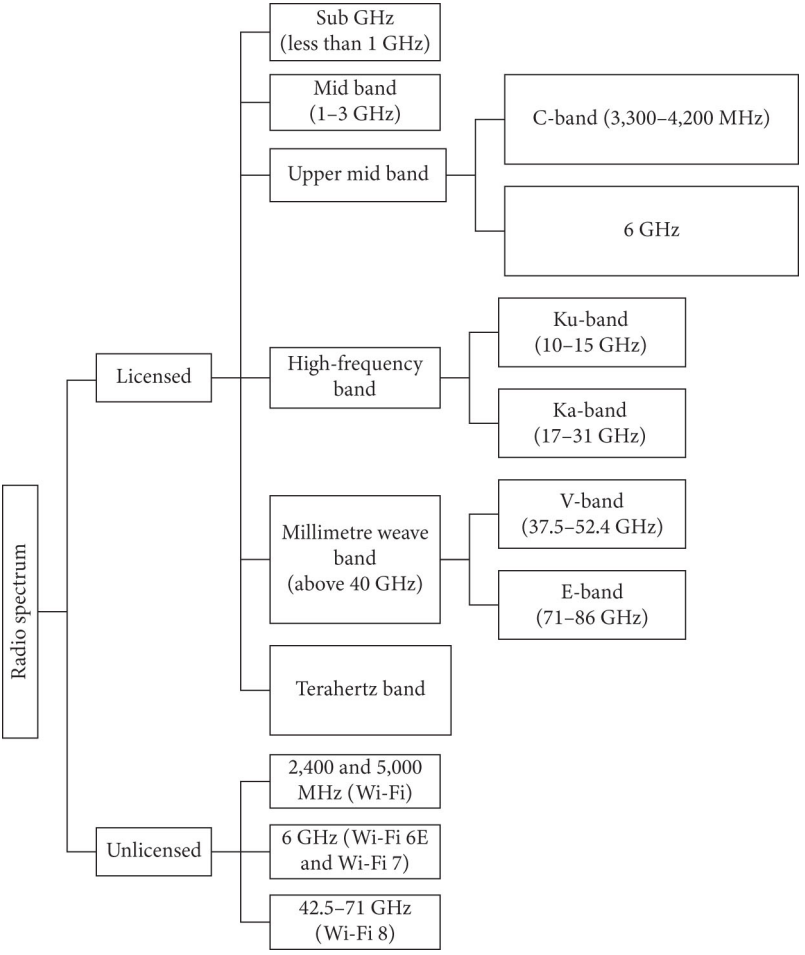


Fig. 5.1 The taxonomy of the radio spectrum in use for commercial mobile services

Source: Authors' own.

European country jurisdictions operate in individual domains. In India, the National Frequency Allocation Plan (NFAP) is the policy document that outlines the allocation of different parts of the frequency spectrum for various purposes. The plan is entrusted to the Wireless Planning & Coordination Group (WPC) under the DoT of the Government of India.

However, as discussed in Chapter 1, the unlicensed spectrum (NR-U) that saw the emergence of Wi-Fi is also evolving to complement the

licensed spectrum. As with the licensed spectrum, NR-U in millimetre wave bands is also being standardised by the IEEE to support similar bands in cellular mobile service.

While radio spectrum is mainly used to provide access service (i.e. connecting mobile handsets to BTSs and vice versa), it is also used extensively in developing countries such as India for backhaul connections. This backhaul spectrum is used to connect BTSs across cellular tower infrastructure where there is inadequate deployment of optic fibre. A complete exposition of spectrum bands for commercial mobile services is provided by Prasad & Sridhar (2014).

The developments in both licensed and NR-U have resulted in the following conflicting or overlapping uses of spectrum in certain bands:

(1) In 5G, the 6 GHz spectrum band is sought after by both TISPs and Internet firms such as Google and Meta, to name a few. While the TISPs want it to be licensed, the Internet firms propose that it be unlicensed.
(2) The coveted mid band in 5G is the 3.3–3.8 GHz band (also called C-band), which is used for providing cellular service and is also sought after by enterprises for constructing private networks such as CNPNs, as discussed in Chapter 1. This band also manages reasonably good coverage with high bandwidth capabilities and is being actively deployed by TISPs worldwide.
(3) The 600 and 700 MHz bands, traditionally used for terrestrial TV broadcasting, are finding alternative uses in providing 4G/5G services in rural and remote areas.
(4) The 60 GHz band, originally used for microwave backhaul, is also being sought for unlicensed use for providing Wi-Fi.
(5) The bands traditionally used for TV broadcasting and VSAT-based private networks in the C-band (4–8 GHz) are also actively used by satellite communication providers to provide geostationary satellite-based data connectivity.
(6) The Ku and Ka bands, used for satellite TV broadcasting, such as direct-to-home (DTH) service, are being actively pursued by the Satcom providers for providing non-geo stationary (NGEO) satellite system-based mobile broadband service.

(7) In 5G+ networks, the coexistence of licensed and NR-U is essential to providing high bandwidth, high coverage, and extremely low-delay services.

The 5G+ networks have brought many stakeholders, such as satellite communication providers, Internet companies, over-the-top communication service providers, and cloud service providers, to lobby for spectrum acquisition and use. Hence, methods of spectrum allocation and usage need to be revisited.

5.2 The Role of NR-U: Wi-Fi as Complement or Substitute

5.2.1 Wi-Fi Networks

As indicated in Chapter 1, Wi-Fi networks complement cellular mobile networks. Hence, it is important to understand the role of NR-U in Wi-Fi networks.

For larger areas or outdoor spaces such as parks and plazas, directional antennas and amplifiers could be used to sculpt a coverage zone using the meagre one watt of power permitted by the US Federal Communications Commission (FCC) for unlicensed operators. Like other open-source movements, the proponents of wireless local area networks had the utopian dream of completely undermining the stranglehold of cellular and landline telecommunications companies.

The ISPs quickly adopted the new technology without waiting to pay vast sums of money for spectrum. They started developing Wi-Fi hot spots in public areas, cafeterias, and restaurants to enable Internet access. The IEEE 802.11 forum, with appropriate modifications to the physical layer, encoding algorithms and multiplexing techniques, has kept the evolution of Wi-Fi access networks almost on a par with the 4G/5G networks of mobile operators. The evolution of Wi-Fi technologies is provided in Chapter 1.

In India, the amount of spectrum release for unlicensed use includes 83.5 MHz in 2.4 GHz (2,400–2,483.5 MHz) and about 605 MHz (5,150–5,350; 5,470–5,725; 5,725–5,825; 5,825–5,875) in 5 GHz (GoI, 2022). In

the United Kingdom, as in India, 83.5 MHz is unlicensed in 2.4 GHz, while 1,105 MHz is available in 5 GHz.

5.2.2 Wi-Fi 6 and Beyond

IEEE 802.11ax is the first amendment in the Wi-Fi family to go beyond small indoor environments and aim to optimise its performance in large outdoor deployments. Although it enhances the nominal data rate by 37 per cent compared to Wi-Fi 5, it aims to provide a four-fold improvement in terms of throughput and spectrum efficiency in dense deployments through new features such as OFDMA, MU-MIMO, and spatial reuse. At the same time, Wi-Fi 6 reduces the power consumption per device. Whereas Wi-Fi has operated in the 2.4 and 5 GHz frequencies until now, the Wi-Fi 6 E standard includes the 6 GHz spectrum band (5.925–7.125 GHz). Given increasing demand from consumers and enterprises, the 6 GHz band is also expected to be a key mid-band spectrum for 5G expansion. The next World Radiocommunications Conference (WRC-23) will consider the 6,425–7,125 MHz range for international mobile telecommunications (IMT) identification in Region 1. The TRAI recommendation for IMT identification also includes a 6,425–7,125 MHz band, which has already been assigned in frontier markets (e.g. the United States, Korea, the United Kingdom) and is expected to receive similar allocation elsewhere (e.g. Europe). In the Americas, such as the United States, Brazil, Chile, and Guatemala, all 1,200 MHz of the 6 GHz band have also recently opened up for unlicensed use. In Asia, South Korea has recently announced the near-future unlicensed use of 1.2 GHz (5.925–7.125 GHz) in the 6 GHz band. Recently, the 5.925–6.425 GHz spectrum has been proposed by the European Commission (EC) under part 15 rules for unlicensed access. Hence, the amount of the NR-U available in Europe is 500 MHz. In Europe, both low-power indoor (LPI) and very-low-power (VLP) (without any outdoor operation) are approved to operate across 500 MHz. The list of countries with delicensed part or full frequencies in the 6 GHz spectrum band is included in Table 5.1 (Prasad & Sridhar, 2023). However, in India, the recently released NFAP 2022 does not mention any licence exemptions for the 6 GHz band (GoI, 2022).

Table 5.1 Licensing of 6 GHz in various countries

	Delicensed	Partially delicensed	Licensed
6 GHz (5.925–7.125 GHz)	• In April 2020, the FCC in the United States adopted rules that make 1,200 MHz of spectrum in the 6 GHz band (5.925–7.125 GHz) available for unlicensed use. • Other countries that have delicensed the whole 6 GHz band (5.925 GHz–7.125 GHz) include South Korea, Canada, Brazil, Colombia, Peru, the Dominican Republic, Honduras, Costa Rica, Peru, and Saudi Arabia.	• In July 2020, Ofcom in the United Kingdom decided to make the lower 6 GHz band (5.925–6.425 GHz) available for Wi-Fi and other RLAN devices on a licence-exempt basis, enabling indoor and very low-power (VLP) outdoor use. It is considering delicensing the upper band (6.425–7.125 GHz). • On 30 June 2021, the EU delicensed 480 MHz of (low) 6 GHz spectrum (5.945–6.425 GHz) to Wi-Fi. It is considering delicensing the upper band (6.425–7.125 GHz). • Japan, Qatar, Chile, Mexico, Australia, and Hong Kong have also delicensed the lower band (5.925–6.425 GHz) and are considering delicensing the upper band (6.425–7.125 GHz).	Countries like Argentina, Oman, Thailand, and large parts of Africa are yet to allow any licence-exempt use, although delicensing in these regions is under consideration for the lower 6 GHz band (5.925–6.425 GHz).

Source: Adapted from Prasad and Sridhar (2023).

A considered and calibrated approach needs to be adopted for the 6 GHz band so that 5G expansion is not jeopardised while garnering the benefits of Wi-Fi. The 5G and Wi-Fi 6 enhancements have narrowed the disparities in the legacy use cases that the cellular and Wi-Fi technology families may each address while simultaneously creating opportunities to address new market demands for applications with ever more intensive throughput and QoS requirements. The first effect tends to bring the two technologies closer as potential substitute alternatives for meeting end-user demand (Kumar & Oughton, 2023). Many equipment vendors

have positioned 5G and Wi-Fi 6 to coexist, providing enhanced indoor coverage and seamless integration.

These developments indicate synergy and convergence between the macro cellular network technologies standardised by 3GPP and micro coverage technologies such as Wi-Fi standardised by the IEEE.

5.2.3 The Unique Case of 60 GHz Band

The V-band (57–71 GHz) is suitable for short-range transmission with potentially high bandwidth. This band is typically split into two sets of frequencies: 57–64 GHz and 64–71 GHz. While some countries have allowed V-band for use by TISPs in both sets, some have restricted licensed use to the lower band of 57–64 GHz. However, on both sets, the bandwidth is 7 GHz, providing large capacities. This band can be used for short-range communication for point-to-point and point-to-multipoint configurations, making this V-band an interesting case study (Sridhar, 2020). A detailed analysis of the V-band for consideration for both access and backhaul is provided in Sridhar (2019).

Wireless access systems in this 60 GHz band in unlicensed mode have been developed through a series of amendments in IEEE 802.11 protocols (notably .ad and .ay) and have been adopted by the Wireless Gigabit Alliance (WiGig) to provide Gigabit speed 'wireless fibre'. The above developments have enabled firms to innovate around this critical band to offer various solutions. Internet companies such as Facebook and Google have been working on technologies using WiGig standards to deploy high-speed public networks.

On the other hand, telcos lobby for licensing V-band for high-powered line-of-sight, point-to-point links that can act as high-speed backhaul. OfCom, the UK telecom regulator, after its regulatory impact assessment (RIA) of V-band, opted for a licence-exempt authorisation method. European countries such as Austria, Belgium, Poland, Slovakia, Spain, China, Korea, Malaysia, Australia, and New Zealand have unlicensed the V-band. Through several regulatory directives, the FCC has released spectrum in 57–71 GHz for licence-exempt use. The TRAI has recommended delicensing this band for access and light licensing for backhaul (TRAI, 2014). However, mixed use will entail interference studies before

Table 5.2 Licensing arrangements of the 60 GHz spectrum band in various countries

60 GHz (57–71 GHz)	• In July 2016, the FCC in the United States adopted rules to allow unlicensed operations in the 64–71 GHz band, thus creating a contiguous spectrum segment with the 57–64 GHz band, which was already operating unlicensed. • In 2018, Ofcom adopted regulations for licence-exempt operations in the 57–71 GHz band.	• Countries allowing licence-exempt use of the 57–64 GHz band include Canada, Japan, Singapore, Australia, and the EU.

Source: Authors' own.

any allocation can be made. Table 5.2 provides details of licences of 60 GHz spectrum bands in various countries.

5.2.4 The Coexistence of 5G NR-U and IEEE 802.11 Networks

While 3GPP and the IEEE have approached spectrum management from opposite sides (namely, licensed versus unlicensed), there is a convergence of ideas in 5G New Radio. New Radio-based access to NR-U intends to expand the applicability of 5G NR access technology to support operation in unlicensed bands by adhering to the listen-before-talk (LBT) requirement for accessing the channel (Patriciello et al., 2020). The 3GPP Release-15-based model extends the capability of 3GPP radio to be used in unlicensed bands while complying with regulatory requirements. The 3GPP Release 16 promotes the NR-U in the 6 and 60 GHz spectrum, paving the way for the coexistence of Wi-Fi 6E and Wi-Fi Gig networks, respectively (Saha, 2021).

Further, many countries, including the United States, allow unlicensed devices to operate at extremely low power throughout the 6 GHz bands. These devices, referred to as VLP devices, can operate within the exclusion zones of incumbent users and in both indoor and outdoor environments. Such VLP devices enable personal area network applications such as wireless AR and VR through wearable devices and in-car connectivity (Naik et al., 2020). These developments indicate that 5G and Wi-Fi coexistence and seamless connectivity are possible in the 6 and 60 GHz bands.

5.3 The Method of Licensed Spectrum Allocation in India

Since spectrum is scarce, it has to be allocated efficiently to prospective buyers, namely MNOs. Various methods are used for spectrum allocation, including fixed fees; first-come, first-served, auctions; and beauty parades.

Spectrum auctions first saw the light of day in New Zealand in 1990, later to be developed extensively and used in the United States from 1994 onwards. Auctions of spectrum for mobile communications became a standard methodology used worldwide by countries. They offered revenue to governments and gave spectrum regulators the prospect of some relief from beauty contests—the increasingly contentious alternative method of spectrum assignment (Cave & Nicholls, 2017).

5.3.1 Simultaneous Multiple-Round Ascending Auction

In 1994, Milgrom and Wilson, along with McAfee, proposed to the Federal Communications Commission the conduct of the first-ever simultaneous multiple round ascending auction (SMRA) as the mechanism design for allocating radio spectrum for commercial mobile services in the United States (Milgrom, 2011). The auction resulted in the sale of the 900 MHz spectrum for personal communication services (PCS) for revenue to the government exchequer of more than USD 1 billion. Since then, the SMRA has become the de facto standard for allocating radio spectrum worldwide (Cramton, 1997). The ascending bid design allows the bidders to react to information revealed in prior rounds. This reduces the winner's curse, resulting in truthful bidding. By auctioning a large set of related licences simultaneously, bidders can react to prices across licences. This is especially true when allocating regional licences or auctioning different spectrum bands simultaneously. Outlined below is the functioning of SMRA:

(1) Bidders simultaneously submit bids in each auction, round by round, until a round is reached in which no new bids are received in any auction. This gives bidders the flexibility to target each

region based on the bidding progress in all the regions. For example, if bidding is in progress in only one remaining region with all the other regions closed, and if it goes very high, then some bidders may want to re-open bidding in other regions that are substitutes for the last remaining region.

(2) After each round, the auctioneer announces a 'provisionally winning bidder' if that bidder has the highest bid. A 'provisionally winning bidder' is responsible for paying their bid price unless outbid by another bidder in a later bidding round. In earlier versions of the simultaneous ascending auction, bidders could choose their bid increment. However, this freedom became a signalling device in the hands of the bidders. Hence, they were restricted to selecting from a drop-down menu of possible increments and, more recently, to an automatic 5 or 10 per cent increment every round.

(3) Bid withdrawals were a valuable tool for giving bidders flexibility to build a desired package of items. However, they became another tool for signalling as operators made and withdrew bids in certain regions to signal their interest in other regions and induce like behaviour in their competitors. Currently, the possibility of withdrawal is present but limited.

(4) In early auctions, bidder identities and their respective amounts were public information. Given the need for operators to partner to provide national coverage and for technologies to be compatible, revealing bidder identities would enable more informed bidding. However, this transparency became a conduit for collusion. As a result, bidder identities are not revealed until the end of the auction, and only the provisionally winning bid amount is declared.

(5) In order to ensure that bidding in the rounds proceeds in an orderly manner and results in the revelation of market information for the benefit of all concerned, it is important to ensure that bidders act consistently through the auction; inconsistency may be occasioned by not having thought through one's strategy or from a snake-in-the-grass strategy whereby bidders lie quiet in early rounds and then surprise others by entering and bidding aggressively in later rounds. In order to achieve consistency of bidder

behaviour, different regions are assigned 'bidding units' based on their business potential, and bidders are required to indicate the total number of bidding units they are interested in through an upfront payment. This determines their 'eligibility', that is the upper cap on the number of bidding units they can bid for in each round. In order to ensure regular participation in line with eligibility, there are 'activity rules' which stipulate that a bidder must score a minimum percentage of their eligibility in each round, that is participate in a minimum number of auctions. This percentage increases as the rounds proceed. As the auction progresses and prices rise, the activity rule forces bidders to place binding pledges at the current prices or leave the auction.

(6) The winners of the simultaneous ascending auction (the only ones willing to pay the provisionally winning bid of the last round plus the increment stipulated by the auction designer) pay the bid of the second highest bidder plus the bid increment. The auction is, therefore, a second-price auction, with an additional 5 or 10 per cent added on, in line with the bid increment.

(7) After identifying the provisional winning bidders, the auction proceeds to the second stage, where the exact spectrum bands are allocated to the winners.

5.3.2 Combinatorial Auction

In some countries, especially in the United States, the LSAs are granular, and hence, the bidder might find it helpful to bid for a combination of LSAs to attain economies of scale in operations.

The term 'combinatorial auction' (also referred to as a package auction) is used to describe any auction mechanism that (i) simultaneously sells multiple items and (ii) allows 'all-or-nothing' bids or a combination of items. For example, if items *a*, *b*, and *c* are auctioned, a bid on the combination {*a*,*b*} will win either *a* and *b* or neither. The problem of determining auction winners is typically a trivial exercise in noncombinatorial auctions because all that has to be done is to identify the bidder who placed the highest bid. However, in a combinatorial auction, the highest bid on a combination of items is not guaranteed to win. This puts a massive

cognitive load on the bidders. Further, the algorithm to determine the winner of packages is also very complex (Pekeč & Rothkopf, 2003).

The FCC in the United States has used a combination of SMRA and package auction in what it terms a 'combinatorial clock auction' (CCA) in Auction 108 (Azic et al., 2024). This comprises two phases: (i) first is an SMRA in which per-item prices are discovered and (ii) second is where bidders place their bids for bundles or packages in a sealed bid format. However, laboratory experiments have established that SMRA, which is simpler than CCA, yields greater efficiency and flexibility compared to CCA.

5.4 The History of Spectrum Allocation in India

The assignment of spectrum in India has a chequered history. It started in 1994 with a sealed-bid, first-price auction to assign a duopoly licence (apart from the government operator) in twenty-two LSAs divided into four categories—metros and categories A, B, and C. Following Table 5.3 provides the categorisation of LSAs.

Apart from the third entry by the government operator for the provisioning of mobile services, the fourth operator was introduced using an English ascending auction in 2001 to allocate the 1,800 MHz band. The Indian telecom sector subsequently moved to the assignment of incremental spectrum allocation based on the first-come, first-served fixed fee-based method (for details, refer to Prasad & Sridhar, 2014). In 2010,

Table 5.3 The LSAs in India

Category	LSAs
Metros	Delhi, Mumbai, Kolkata
A	Maharashtra, Gujarat; Andhra Pradesh; Karnataka; Tamil Nadu. including Chennai
B	Kerala, Punjab, Haryana, Uttar Pradesh (UP) (E), UP(E), Rajasthan, Madhya Pradesh, West Bengal, and Andaman & Nicobar
C	Himachal Pradesh, Bihar, Orissa, Assam, North East, Jammu & Kashmir

Source: Authors' own.

the first SMRA auction allocated 2,100 MHz and 2,300 MHz spectrum bands. The spectrum licences were technology and service-neutral, enabling the winners to deploy the technology of their choice. The auction resulted in 183 rounds over 34 days, yielding a total revenue of USD 8 billion to the country's exchequer. Unfortunately, the success of this auction became a stumbling block for the success of future auctions, as the price discovered in this auction was set as the reserve price or the first-round starting price for subsequent auctions by the Government of India. Thereafter, the SMRA became the standard mechanism for allocating spectrum. The last auction was held in 2024, wherein about 3,700 MHz of radio spectrum was auctioned at a price of about USD 1.36 billion.

Compared to access, microwave backhaul has thus far been assigned administratively in India, with payment of spectrum charges on an escalating basis for incremental assignments. Since radio spectrum is scarce, the backhaul spectrum, such as V- and E-bands, erstwhile exclusively used for backhaul, is also being actively sought by 5G access providers—both the TISPs and Internet firms. The method of allocation of these bands also needs to be revisited.

Table 5.4 shows the spectrum auction proceeds over the years, which have fetched more than USD 70 billion to the government exchequer.

Table 5.4 Spectrum auction revenue over the years

Year	Spectrum revenue (in billions of USD)
2010	8.43
2012	1.81
2013	0.62
2014	6.00
2015	16.98
2016	7.86
2021	10.14
2022	17.44
2024	1.36
Total	**70.64**

Source: Authors' own

Some of the important parameters to be set by the auctioneer in the auction include the following:

(1) The reserve price is the starting bid price in the first round of the auction process and price increments at each clock round; the higher the reserve price, the higher the winning bid prices for the corresponding item; huge reserve prices might dissuade the bidder from bidding, resulting in unsold items.
(2) Eligibility points are based on specific criteria, including the bank deposits the bidders have submitted before the auction starts; the larger the deposits, the higher the eligibility points, enabling the bidders to stay in the auction for a more extended period at increased prices.
(3) The amount of available spectrum in each band, including the lot size and number of slots on the block are set by the auctioneer; the smaller the spectrum put on the block, the scarcer it is. Hence, the bid prices are expected to increase due to the supply–demand gap as the auction proceeds.

Of the above, the reserve price is the primary determinant of the winning bid price in the auctions conducted in India (Sridhar & Prasad, 2021).

The trend in price per MHz per capita from 2010 to 2024 across spectrum bands can be seen in the following graph. As noted, while the price of the sub-GHz band continues to be high, the price of mid-band and high-frequency bands tends to be lower. The MNOs trade off investment in tower infrastructure and BTS requirements vis-à-vis upfront spectrum acquisition cost. Since the sub-GHz bands provide coverage across a larger area, the cellular infrastructure required is often less than that of higher bands, hence the correspondingly higher prices that the sub-GHz spectrum demands.

The trends in median spectrum price (in price/MHz per point of presence (PoP) in USD) for both the sub GHz and mid bands are presented in Fig. 5.2. We observe that the price of the 900 MHz shows a downward trend, with a very high price in 2014 and a sharp decline over the years, down to USD 0.112 in the 2024 auction. The 800 MHz band maintains a relatively stable price of around USD 0.20 throughout the period except in 2022, where the price plummeted to USD 0.06. The 700 MHz band was bought only once in the spectrum auctions in 2022, with a slightly higher median price of USD 0.197 than the other bands.

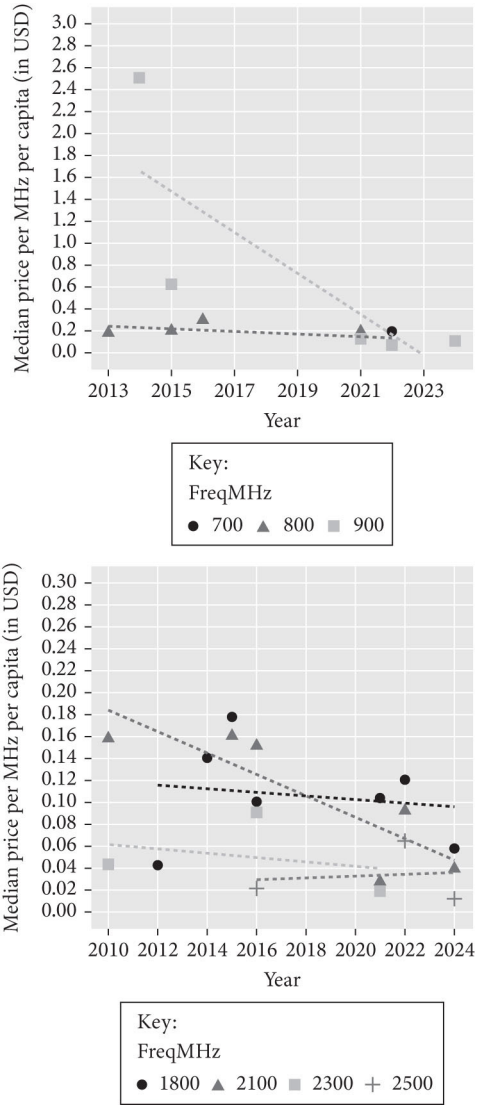


Fig. 5.2 Variation of spectrum prices over the years in the sub-GHz and mid bands

Source: Authors' own.

In the mid band, 1,800, 2,100, 2,300, and 2,500 MHz prices started high in 2010, declining to USD 0.06, 0.04, 0.02, and 0.01, respectively. As expected, the mid-band prices are, on average, less than those of the sub-GHz bands. The 3,300 MHz band put on auction in 2022 was sold at an average price of USD 0.0329, while the high-frequency band of 26 GHz was picked up at an average price of USD 0.00077.

It is also important to analyse how the winning bid prices vary in relation to the corresponding reserve prices. The results of the 2022 auction that fetched the maximum revenue are presented in Fig. 5.3. Across bands and LSAs, it shall be noted that the winning bid price is the same as the reserve price, barring just two items—1,800 MHz in Odisha and Uttar Pradesh (E). This indicates that the reserve prices are higher, and the bidder (if left with no options except to get some blocks of the spectrum) bids only at the reserve price.

All the 5G spectrums that were put in the auction (3,300 MHz and 26 GHz) were sold at reserve prices. Even at the reserve price, only 5,500 MHz out of 7,600 MHz (about 72 per cent) put on auction was sold in the 3,300 MHz bands. In the 26 GHz band, out of a total of 62 GHz put on

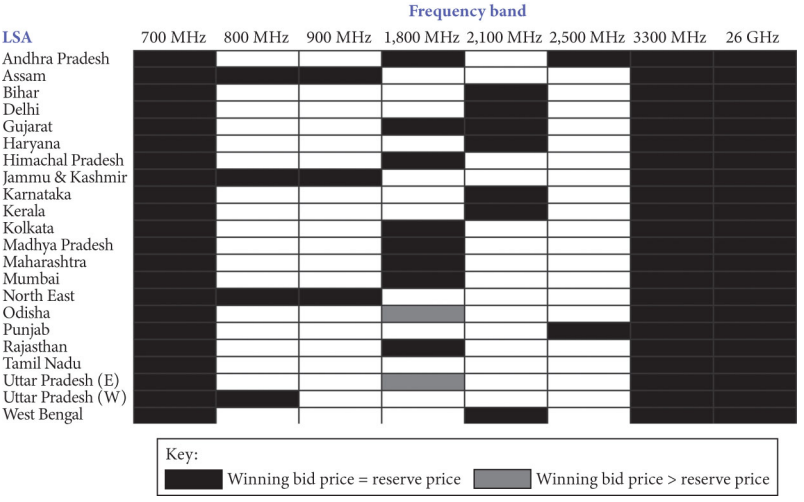


Fig. 5.3 Comparison of winning bid prices versus reserve prices in India's 2022 auction

Source: Authors' own.

auction, only 4.5 GHz were sold at the reserve price, indicating the possibility that the reserve prices were higher than the valuation of the bidders across bands, which inhibited spectrum acquisition.

Many studies have indicated that high reserve prices are one of the reasons why spectrum prices in India are higher than international averages (Sridhar & Prasad, 2021).

5.4.1 Analysis of C-Band Spectrum Prices

As indicated in Chapter 1, the most preferred band for 5G+ is the upper mid band in the 3,300–3,800 MHz (also called the C-band). The first tranche of C-band was auctioned in India in 2022. The chart below in Fig. 5.4 provides the winning bid prices of the 3,300 MHz band across different countries in recently held auctions. The average spectrum price of USD 0.05388 aligns with most countries. The variation of the prices of this band across LSAs is shown in Fig. 5.5. While India's average winning bid price is in line with most countries, the prices are USD 0.29, 0.23, and 0.13, respectively, much higher than international prices.

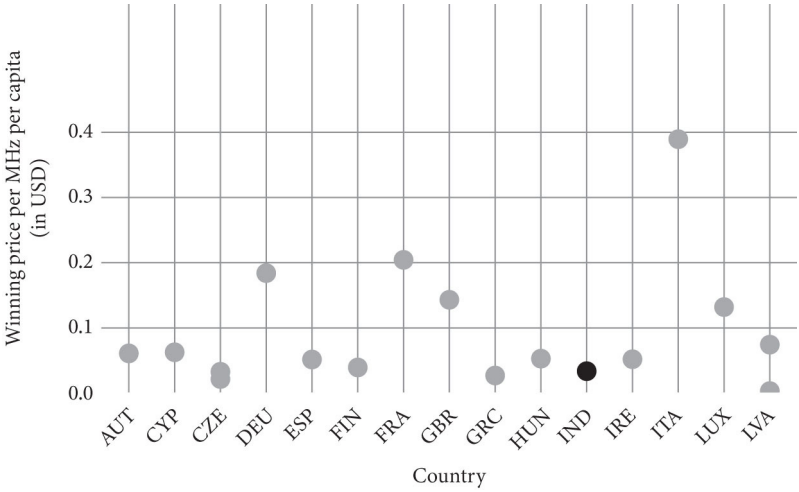


Fig. 5.4 Variation of spectrum prices of the C-band across countries
Source: Authors' own.

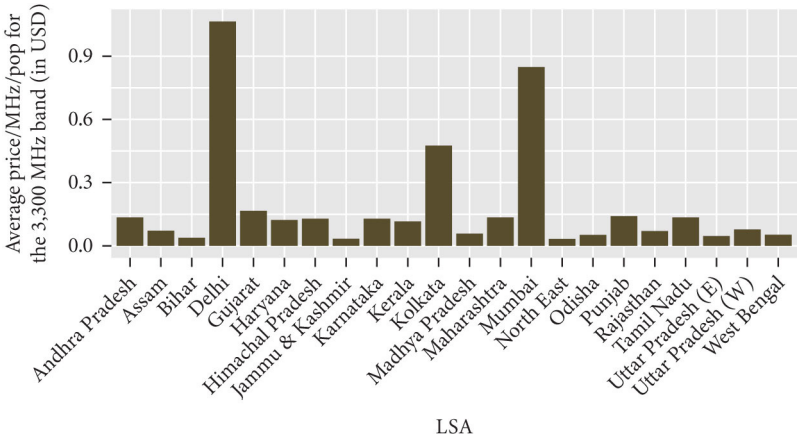


Fig. 5.5 Variation of spectrum prices of the C-band across LSAs in India
Source: Authors' own.

5.4.2 Analysis of 700 MHz Spectrum Prices

Though 3,300 MHz is a preferred spectrum band for providing 5G services, the sub-GHz bands, such as 600 and 700 MHz, are also being refarmed for 5G+ networks. Recognising the superior propagation characteristics of sub-GHz bands, TISPs have been acquiring and deploying the sub-GHz band to provide 5G services in rural and remote areas and IoT connectivity over geographically dispersed regions. The first 700 MHz spectrum band auction for commercial mobile service was conducted in the United States in 2000. The spectrum went for an average price of USD 0.27 per MHz per PoP. Since then, many countries (including Argentina, Brazil, Canada, Switzerland, Finland, Italy in Europe, Taiwan, Tanzania, and Uruguay) have conducted auctions of the 700 MHz.

In India, about 2 × 35 MHz per LSA (a total of 1,540 MHz) was put on block in the spectrum auction held in October 2016. However, due to no bidding activity in this band, possibly due to high reserve prices at an average of USD 1.16 per MHz per PoP, the whole lot went unsold, leaving the government exchequer with a massive loss in monetisation. The subsequent auctions held in 2021 also witnessed no activity in this band. Finally, in the auction held in July 2022, about 2 × 10 MHz per LSA

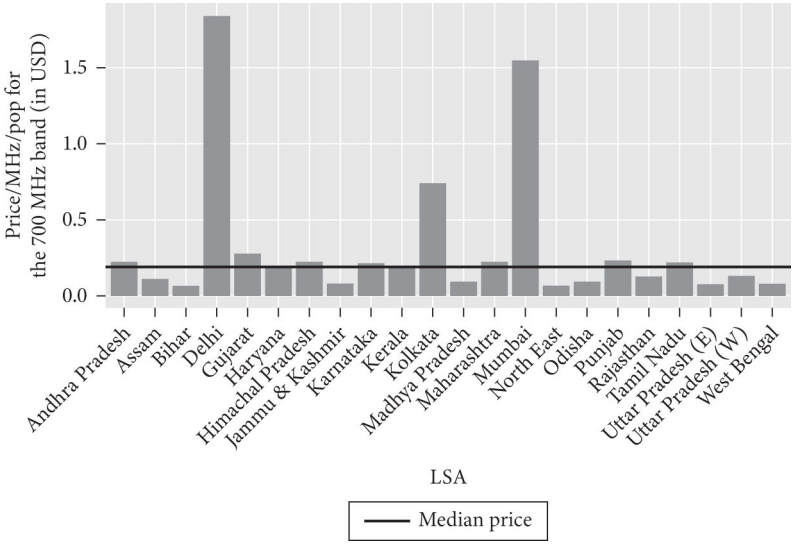


Fig. 5.6 Variation of spectrum prices of 700 MHz across LSAs
Source: Authors' own.

was picked up by one of the TISPs across all LSAs at a winning bid price of USD 0.32, equivalent to the reserve price. However, the metro areas of Delhi, Mumbai, and Kolkata witnessed very high prices of USD 1.84, 1.54, and 0.74, respectively. Variation of prices of 700 MHz across different LSAs is shown in Fig. 5.6. The price of the 700 MHz band over the years sold in various countries is shown in Fig. 5.7. It is evident that in the metros and category-A LSAs, the price is much higher than international averages. Due to the high reserve prices, this band's spectrum has been unused for the last eight years! Further, the 600 MHz band, 1,320 MHz across the country, was auctioned in 2022, and remains unsold.

5.5 Variables That Affect 5G Spectrum Price

In a cross-country study of spectrum prices, Sridhar & Prasad (2021) point out the following:

(1) Reserve price is one of the significant determinants of spectrum prices. A strong positive correlation exists between the reserve and

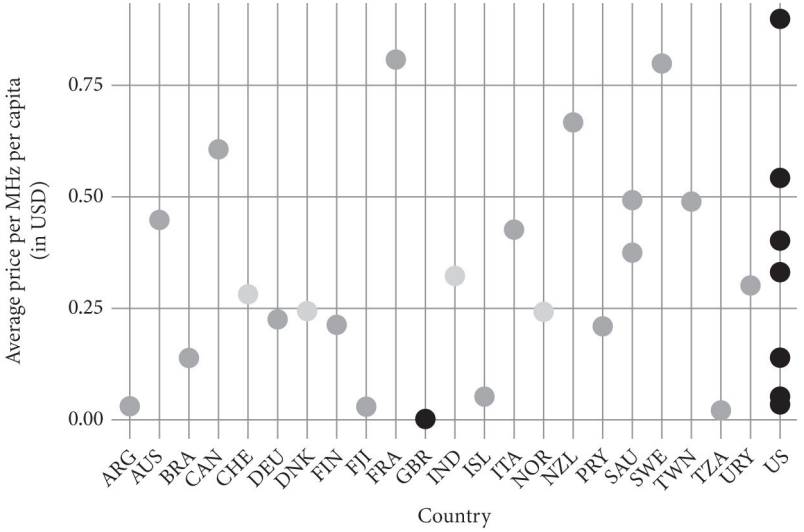


Fig. 5.7 Variation of spectrum prices of 700 MHz in different countries
Source: Authors' own.

winning bid prices. However, since 2016, the winning bid prices have been very close to the reserve prices across spectrum bands, indicating that the winning bid prices may not indicate accurate valuations.

(2) Spectrum availability has a negative impact on spectrum prices. Higher availability, indicative of a higher spectrum supply, tends to lower the spectrum prices. Despite spectrum availability, the TISPs picked up smaller amounts, indicating factors that have deterred demand for the spectrum bands. Higher reserve prices could be one of the reasons for this.

5.5.1 Spectrum Holding by Indian TISPs

The average spectrum held by a TISP in India is about 860 MHz per LSA, comparable to or even better than that held by TISPs in other countries. The TISPs in India have adequate capacity in this band for rolling out 5G services. Table 5.5 summarises spectrum holding by the leading operators across LSAs.

Table 5.5 Variation of spectrum holdings by a TISP across LSAs

LSA	Category	Sub-GHz	Mid band	Higher mid band	High band
Andhra Pradesh	A	26.40	57.90	80.00	712.50
Assam	C	27.95	75.00	67.50	650.00
Bihar	C	24.20	77.40	80.00	650.00
Delhi	M	28.08	59.40	80.00	700.00
Gujarat	A	28.93	70.40	80.00	787.50
Haryana	B	27.43	70.70	80.00	750.00
Himachal Pradesh	C	26.95	60.80	75.00	650.00
Jammu & Kashmir	C	26.70	71.90	75.00	650.00
Karnataka	A	28.08	60.00	87.50	712.50
Kerala	B	28.58	73.20	87.50	812.50
Kolkata	M	27.80	63.10	80.00	700.00
Madhya Pradesh	B	26.90	72.40	87.50	750.00
Maharashtra	A	27.70	71.20	80.00	750.00
Mumbai	M	28.70	58.50	80.00	725.00
North East	C	27.95	76.30	75.00	650.00
Odisha	C	26.33	77.00	67.50	650.00
Punjab	B	27.85	72.50	80.00	725.00
Rajasthan	B	26.60	78.90	87.50	737.50
Tamil Nadu	A	26.28	61.70	80.00	737.50
Uttar Pradesh (E)	B	26.60	77.40	80.00	712.50
Uttar Pradesh (W)	B	27.95	67.50	87.50	737.50
West Bengal	B	28.70	77.40	80.00	750.00
Average allocation across LSAs	–	27.40	69.60	79.90	713.65

Source: Authors' own.

Hence, only about 180 MHz spectrum has been allotted per LSA per operator across all bands, except for the 26 GHz band across the four major operators in the country.

The distribution of spectrum holding per operator per LSA is provided in Table 5.6. The spectrum HHI for the spectrum holding is about 0.26, indicative of some fragmentation in the allocation. As shown in Table 5.6, while Reliance Jio has a more extensive spectrum than others, Vodafone Idea has less. It is important to note that the spectrum the operators hold

Table 5.6 Spectrum holding by various TISPs in India

Operator	Spectrum holding in MHz					Percentage share of spectrum
	Sub-GHz	*Mid band*	*Upper mid band (C-band)*	*Mm wave band*	*Total*	
Bharti Airtel	17	89	100	800	1,006	28.25
BSNL	32	31	64	720	847	23.77
Reliance Jio	40	67	110	1,000	1,217	34.20
Vodafone Idea	14	68	39	243	364	10.23
Average	**26**	**64**	**78**	**690**	**858**	Rest to others, including Adani, Reliance Communication, Aircel, and MTNL

Source: Authors' own.

in the lower frequency bands is much lower than the high-frequency spectrum. However, each operator's total spectrum holding is close to 1,000 MHz.

Table 5.7 provides a similar comparison of spectrum holding in other countries. Note that the sub-GHz and mid-band allocation is much higher than that of the Indian TISPs.

Table 5.7 Variation of spectrum holdings by a TISP across countries

Country	Average spectrum holding per operator in MHz				Average total holding
	Sub-GHz	*Mid band*	*Upper mid band (C-band)*	*mm wave band*	
Germany	63	195	83	–	342
Japan	50	100	200	400	735
United Kingdom	52	145	100	–	295

Source: Authors' own.

5.5.2 The Number of Bidders in the Indian Spectrum Auctions

In general, the telecom markets worldwide witness the rule of between three and four as the number of operators. However, in India, the number of operators varied very much. Table 5.8 indicates the number of TISPs in India over the years. It should be noted that from 2004 to 2016, there were as many as twelve operators in an LSA. Prasad & Sridhar (2008) analysed

Table 5.8 Summary statistics of spectrum auctions held in India

Year	Spectrum bands on auction (in MHz)	Spectrum band not picked up	Average			
			Winning bid price (WBP—in USD/ MHz/Pop)	*Reserve price (RP—in USD/ MHz/Pop)*	*Number of bidders (NB)*	*Spectrum put on auction (in MHz) (SA)*
2010	2,100, 2,300	–	0.41	0.07	10	1,112
2012	1,800	–	0.12	0.12	5	590
2013	800	–	0.42	0.42	1	190
2014	1,800	–	0.56	0.36	8	862
2015	800, 900, 1,800, 2,100	–	0.43	0.27	8	932
2016	700, 800, 900, 1,800, 2,100, 2,300, 2,500	700, 900	0.23	0.23	6	4,102
2021	700, 800, 900, 1,800, 2,100, 2,300, 2,500	700, 2,500	0.23	0.23	3	4,840
2022	600, 700, 800, 900, 1,800, 2,100, 2,300, 2,500, 3,300, 26,000	600, 2,500	0.08	0.08	4	73,945
2024	800, 900, 1800, 2100, 2300, 2500, 3300, 26,000	800, 2,300, 3,300, 26,000	0.11	0.11	3	11,106
		Average	0.29	0.21	5.33	

Source: Authors' own.

the number of TISPs in India and predicted that the average number of bidders could be seven or eight due to the large subscriber base. The more TISPs and bidders in the auction with interest in acquiring spectrum, the more the competition affects the auctions, resulting in higher winning bid prices.

5.5.3 The Model and Analysis of 5G Spectrum Prices in India

In order to analyse what impacts spectrum prices in India, we compiled a panel data set that covered all the spectrum auctions that took place during the period 2010–2024. The summary statistics of the various variables in the data set are provided below.

Based on prior research, we formulated the model shown in Equation (1) to understand the effect of various variables on the winning bid prices in India (Sridhar & Prasad, 2021).

$$WBP_{it} = \alpha_{it} + \beta^{1}_{it} RP_{it} + \beta^{2}_{it} NB_{it} + \beta^{3}_{it} SA_{it} + \beta^{4}_{it} POP_{it} + \beta^{5}_{it} SB_{it} + \epsilon_{it} \quad (1)$$

In Equation 1, all the variables in Table 5.8 are included, along with the population that represents the addressable market in each LSA (*i*) at period *t*. We also added a dummy variable (*SB*) to indicate whether the band on auction was a sub-GHz band or not to determine whether or not there is any significant variation in spectrum prices for low- versus high-frequency bands.

We performed a pooled ordinary least square (OLS) linear regression to understand the correlation between the following independent variables and the winning bid price. The independent variables were the same as those in Sridhar and Prasad (2021). Further, we performed fixed-effect models on the panel data set with (i) time-dependent effects, (ii) LSA-dependent effects, and (iii) both LSA and time-dependent effects.

The analysis indicates the following:

(1) The reserve price has a significant positive effect on the spectrum price. Any USD 1 increase in reserve price will increase the winning bid price by USD 1.25 per MHz per capita.

(2) The number of bidders representing the competition significantly positively affects winning bid prices. The more intense the competition, the higher the spectrum prices.
(3) The dummy for the low band indicates a positive effect on winning bid price, meaning that the sub-GHZ band invites higher winning bid prices compared to the reference group, which consists of all prices for spectrum above 1 GHz.
(4) The available spectrum has the expected adverse effect, indicating that we can expect a lower price if more spectrum is available.

The conclusion is that lowering the reserve price, which is one of the configuration variables in the SMRA auctions, and letting the methodology of SMRA decide the winning bid price is likely to result in better valuation and uptake of unsold spectrum. The increased holdings of appropriate spectrum will likely result in a better quality of mobile and broadband services in the country.

5.6 Coexistence in the C-Band

The C-band, which extends from 3,100–4,200 MHz is one of the bands more sought after by the TISPs for providing 5G connectivity. This band, called the C-band, has the following attractive characteristics:

(1) Due to high frequencies, the antenna sizes can be smaller, making installing in street furniture such as lamp posts possible, thereby providing ubiquitous coverage.
(2) The band is less susceptible to attenuation due to rain, making it an ideal candidate for satellite TV broadcasting.
(3) The band is also ideal for constructing CNPNs, as organisations can construct captive in-premise networks or places such as airports and seaports providing 5G connectivity.
(4) There is a possible interference, especially in the higher frequencies, with radar altimeters used in aircraft that operate at 4,200–4,400 MHz (Sridhar, 2022). In India, the director general of civil aviation has also raised concerns over the C-band frequencies allotted in the recent 2022 auction to the TISPs.

(5) However, as the TISPs have been allocated 3,300–3,670 MHz, there is enough guard band to prevent possible interference with the radar altimeters (Sridhar, 2022). TISPs have highlighted this and cited international practices where much smaller buffers are maintained to address the concerns of aviation authorities—Japan, for instance, has permitted 5G operations in the 4.1 MHz band.

Given the above, this allocation of the most sought-after C-band for 5G IMT services has often been tricky for the regulators.

5.6.1 The CBRS Band in the United States

The FCC proposed the release of 150 MHz in 3,550–3,650 MHz (3.5 GHz C-band), erstwhile used for military and satellite communication, for shared use in 2012. In 2012, the FCC issued a notice of proposed rule making (3.5 GHz NPRM) to create a new Citizens Broadband Radio Service (CBRS) centred around a spectrum access system (SAS). The SAS envisions three tiers of service: (i) incumbent access, (ii) priority access, and (iii) general authorised access (GAA). Priority access and GAA tiers would be licensed for users, with automatic authorisation to deploy small-cell systems similar to installing Wi-Fi access points. SAS deploys a dynamic spectrum database to assign and monitor spectrum use and associated interference, thereby protecting higher-level users from the usage by lower-level users. A GAA tier would be assigned on an opportunistic and non-interfering basis within designated geographic areas. There have been proponents and opponents of the SAS in the CBRS band. A detailed review of the technical architecture of SAS is presented in Sohul et al. (2015). Sohul et al. (2015) also indicate the diverse interest groups in CBRS, including the Internet firms such as Google for SAS administration, the TISPs, the network equipment manufacturers, satellite communication firms, and standard development organisations such as the IEEE. A detailed review of stakeholder interests indicates that the cellular industry raised two important questions: whether or not the proposed framework provides sufficient certainty to attract investment and whether or not the existing technology can support the proposed framework. According to the cellular industry, the primary reason for

the uncertainty is the introduction of dynamic spectrum management (DSM) concepts and the inability of the existing technology to support such a dynamic approach. Even during the stakeholder consultation, it was evident that the SAS is technically complex and needs appropriate implementation.

The most recent Auction 110 in the C-band (3.45–3.55 GHz) was held in 2021, and close to 4,000 spectrum licences were given at an average winning price of USD 0.66 per MHz per PoP.

5.7 The Spectrum for Satellite Networks

As terrestrial 5G mobile networks are being rolled out across countries, there is renewed interest in integrating non-terrestrial networks (NTN), the primary one being the low earth orbit (LEO)) satellite networks (NGEO satellite systems) to complement terrestrial networks. Towards this, Starlink, operated by Musk-owned SpaceX and OneWeb, promoted by Bharti Global, has launched about 2,500 and 648 LEO satellites, respectively, at an altitude of about 1,200 km, to promote global broadband connectivity.

There are primarily three main use cases for integrating satellite networks (SatNets) with terrestrial 5G networks: (i) service continuity to provide seamless handover and roaming between terrestrial networks and SatNets, especially in the case of public safety and emergencies when terrestrial networks get disrupted due to natural catastrophes such as floods and earthquakes, thereby improving network resilience; (ii) service ubiquity to provide 5G services in unserved and underserved areas of the world, thereby bridging the digital divide; and (iii) service scalability that utilises the unique capabilities of SatNets in multitasking and broadcasting similar content over a large geographical area (Darwish et al., 2022). The SatNets can provide service not only to stationary but also to mobile users and devices. The FCC has recently authorised Starlink satellite Internet for vehicles in motion, including ships, trucks, and recreational vehicles.

In telecommunications, satellites and terrestrial networks have always been considered independent ecosystems, and their standardisation efforts have proceeded independently. Given the above advantages

of synergising terrestrial networks with SatNets, standard-setting organisations such as the 3GPP started to integrate SatNets into the standardisation process. As an extension to terrestrial networks, satellites were first mentioned in a deployment scenario of 5G in 3GPP Release 14. This was to provide 5G communication services for areas where terrestrial coverage was unavailable and support services that could be accessed more efficiently through satellite systems, such as broadcasting services and delay-tolerant services. Through Releases 15, 16, 17, and 18, 3GPP launched several standardisation activities to support the integration of SatNets and 5G terrestrial networks (Darwish et al., 2022).

Apart from providing access service directly to the users, SatNets can also be used as backhaul links (that connect different terrestrial points of presence). Interestingly, wireless communication through LEO satellites over long distances is 1.47 times faster than communication over the same distance through terrestrial optic fibre (Leyva-Mayorga et al., 2020). This advantage and global coverage provide a strong use case for SatNets as a backhaul to complement terrestrial optic-fibre networks, especially in rural and remote parts of the country, to enhance mobile broad band (eMBB).

There are still many issues yet to be resolved, including the frequencies to be allocated for satellite broadband; the methodology of allocation, whether it be administrative assignment or through auctions; the relatively higher cost of consumer equipment; and the placement and interconnections of SatNets with terrestrial public landline/mobile networks at the ground stations. While a variety of frequency bands can be used for providing satellite communication services, the widely used frequency bands are L-band (1–2 GHz), S-band (2–4 GHz), C-band (4–8 GHz), Ku-band (10–15 GHz), and Ka-band (17–31 GHz). The new-generation satellite communication systems have plans for deployment in higher bands, such as the lower part of V-band (37.5–52.4 GHz) for user links as well as gateway links and E-band (71–76 GHz/81–86 GHz) for gateway links (TRAI, 2024).

Starlink has the FCC approval for using both Ku- and Ka-bands, while approval is pending for using E-band (71–86 GHz). The OneWeb system uses the Ku-band to communicate between the user terminal and the satellite. In contrast, the Ka-band is used to communicate

between satellites and earth stations to connect to the Internet. As per the NFAP 2022 of India, most of these bands are reserved for fixed-satellite services (FSS) provided using geostationary satellites (GoI, 2022). The Ku- and Ka-bands are widely used for direct-to-home television broadcasting in most countries, including India. The Government of India announced the allocation of a 26 GHz spectrum band for terrestrial 5G communication, as in most countries, thereby paving the way for possible deployment of LEO systems in the 28 GHz band. These require close frequency coordination between the Departments of Telecommunications and Departments of Space and Information and Broadcasting to allocate the above standard frequency bands across terrestrial 5G networks, LEO SatNets, and satellite Television broadcasting. The TRAI released a consultation paper for determining spectrum bands to be allocated for satellite services, especially for mobile satellite services using NGEO satellites (TRAI, 2024). Table 5.9 provides an overview of spectrum bands used by different NGEO systems worldwide (TRAI, 2024).

Further, there are questions of allocating satellite spectrum through administrative means or auctions. Since satellite spectrum is used for

Table 5.9 Spectrum bands used by different satellite systems

Satellite system	Deployment frequency bands	Planned satellite numbers
SpaceX	Ku/Ka (first generation)	4,408
	Ku/Ka/E (2nd generation)	30,000
	V-band	7,518
Kuiper (Amazon)	Ka band	3,236
	Ku/V bands	7,774
Boeing	V band	5,921
Astra Space	V band	13,620
OneWeb	Ku/Ka (Phase 1)	648
	V (Phase 2)	6,372
O3B	Ka band	70
	V band	24
Telesat	Ka band	300
	V band	1,671

Source: Authors' own.

broadcasting, it is always used in a non-exclusive mode by appropriate coordination mechanisms. Even for mobile satellite systems, using orthogonal and left/right polarisation techniques, different satellite systems can use the same frequency bands with minimal interference. Hence, the satellite spectrum is being argued as an excludable, non-rival good, wherein the spectrum is assigned to each operator; however, using a spectrum band by one satellite operator does not diminish the value of others. In such cases of shared use, it is argued that satellite spectrum shall be assigned with administrative pricing and not through auctions. However, the satellite mobile service is very similar in the case of services provided. It may be considered a substitute for terrestrial mobile service, in which case it provides a level playing field by auctioning spectrum for satellite services much similar to terrestrial mobile services. In this context, the TRAI has released a consultation paper to discuss the modalities of spectrum assignment, especially for the NGEO satellite systems (TRAI, 2024).

The other major challenge in SatNets is the cost of the user terminal and access charges to the end users. Recent research analysing Starlink and OneWeb concludes that the standalone LEO systems have a distinct cost advantage only if the density is less than 0.1 person per square km compared to terrestrial broadband networks (Ogutu & Oughton, 2021). Hence, it is to the advantage of SatNet providers to integrate their networks with terrestrial 5G networks to improve the cost economies.

Despite these challenges, integrating LEO SatNets with terrestrial 5G networks and the associated standardisation activities and regulations will provide the much-needed resilient and ubiquitous future communication network systems.

5.8 New Approaches to Effective Spectrum Management

Given the evolution of 5G+ networks, country regulators worldwide have been revising their strategy and rules in response. We describe certain best practices that are being formulated by the regulators across the countries.

5.8.1 Light Licensing and Flexible Spectrum Regulation

Radio spectrum is a scarce resource and is needed for many devices and applications ranging from microwaves to aircraft to aerial missiles. There is competing demand for spectrum from utilities, railways, defence, space research, and broadcasting.

Hence, in recent years, some Organisation for Economic Co-operation and Development (OECD) countries have considered simplified licensing procedures to allow spectrum sharing among TISPs and possibly other spectrum users under light licensing. Table 5.10 details approaches countries use to promote sharing scarce spectrum resources. Australia's area-wide apparatus licence (AWL) in the 26 and 28 GHz bands is one example of the light licensing approach, which demonstrates a relatively light administrative burden and openness to a vast number of services and users, depending on the availability of spectrum in the requested area. The notable flexible-use spatial overlay spectrum auction was Auction 108 in 2022, wherein spectrum in the 2.5 GHz band (2,496–2,690 MHz) was put on auction in which close to 8,000 licences were issued by the FCC at a relatively higher price of USD 0.21 per MHz per PoP (NTIA, 2023).

5.8.2 Flexible Spectrum Management: From Static to Dynamic Approaches

Researchers and industry experts have criticised the current spectrum management regime using the 'command-and-control' approach for its inefficient use of scarce spectrum resources. Realising the need for efficient use of radio spectrum, countries are transitioning from the traditional command-and-control mode of spectrum management to flexible use. Country regulators and policymakers that define a stringent set of administrative rules for the assignment and usage of spectrum have started to adopt flexible use policies, including creating an active secondary spectrum market and deploying associated technologies. Some of the methods proposed towards forward-looking spectrum management and regulation include the following:

Table 5.10 Examples of light licensing sharing approaches

Sharing model	Country	Band	Services sharing spectrum
Light licensing model—simplified procedure	Australia	26 and 28 GHz	The area-wide apparatus licence (AWL) will share the spectrum with class licensees (unlicensed in the Australian framework) in the 24.7–25.1 GHz band and individual IMT licences in the 25.1–27 GHz band. AWL licences can be used for a range of services (including FWA, mobile wireless broadband, private networks, FSS, and support IoT).
Light licensing model—simplified procedure	New Zealand	2.575–2.620 MHz	Managed spectrum park (PSP) licences are intended to support local or regional communication services. MSP licences providing communication services must coordinate among themselves to avoid interference.
Light licensing model—simplified procedure	United Kingdom	Mobile brands covered under mobile trading regulations	Local access licence allows other users to access unused TISP spectrum and is envisaged to support other mobile use cases (e.g. private networks, mobile coverage (rural/indoor), foxed wireless access). However, the shared user does not have to employ the same technology as the incumbent licensee.
Light licensing model—simplified procedure	United Kingdom	1,800–2,390 MHz; 2,400 MHz, 3.87–4.2 GHz, and 26 GHz; 116–122 GHz, 185–190 GHz	Shared-access licence allows other users to access the spectrum in requested spectrum band and areas. It is dependent on interference assessments with existing users and is intended to support mobile use cases ((e.g. private networks, mobile coverage (rural/indoor), foxed wireless access).
Concurrent shared access ('club use')	Italy	26 GHz	Mobile services sharing between licensees
Concurrent shared access ('club use')	Slovenia	26 GHz	Mobile services sharing between licensees
Flexible use of geographic overlay licences	United States	2.5 GHz	Conducted in July–August 2022 in 2.5 GHz

Source: OECD (2022).

(1) perpetual licences with complete technical and service neutrality so that any spectrum can be used for any application without concerns about time constraints for recouping any investments (Freyens & Alexander, 2015),
(2) using leasing or shared access so that any unused spectrum can be exploited by others (Bhattarai et al., 2016),
(3) trading to provide fluidity of spectrum rights to allow the market to work efficiently in using spectrum (Freyens & Alexander, 2015).

Even though the DoT announced spectrum trading and sharing guidelines in 2015 (DoT, 2015), the sharing is limited to static sharing of spectrum under certain contractual conditions. As specified in the guidelines, there are also specific constraints in both trading and sharing. Also, leasing has been allowed only for CNPNs. Hence, there is a need for flexible spectrum management, including dynamic spectrum access (DSA) and sharing, as being practised in many countries (details of which are provided in Prasad & Sridhar, 2023).

A brief overview of international best practices in flexible spectrum management (OECD, 2022) follows:

(1) In its spectrum roadmap, Ofcom noted the potential of automated spectrum management tools. Another way to facilitate spectrum sharing may be through dynamic spectrum access (DSA) (Ofcom, 2021), combined with automation techniques that allow users to access the spectrum dynamically for a defined period or in a defined area. A more recent example of a dynamic approach can be seen in the Spectrum Access System (SAS) that facilitate coordination between and among the three tiers of users in the CBRS band (3.5 GHz) in the United States.
(2) A further dynamic approach is being implemented in Japan. The Ministry of Internal Affairs and Communications (MIC) has established a 'dynamic spectrum sharing management system' to be used to manage shared access to the 2.3 GHz (2,330–2,370 MHz) band between incumbent users (broadcasting and governmental use) and mobile services. Incumbent users input their spectrum use (e.g. frequency, location, day, time) into the sharing system, and mobile operators then apply for shared use. The system

decides whether or not the mobile operator can access the spectrum, depending on the request and availability. In May 2022, the MIC assigned KDDI Group a licence to use this 2.3 GHz band spectrum for five years.

(3) While the rules for access by unlicensed devices under the coordination of a TV white space (TVWS) geolocation database system were finalised several years ago by the United States, Canada, and other countries, the adoption of the technology has increased in recent years. The Airband initiative in the United States, led by Microsoft, and more recently, the designation of geolocation database administrator in Canada, is resulting in broader commercial use of the technology, primarily to support rural connectivity. Under Canada's framework, the white space database system coordinates spectrum access of white space devices by providing a list of available channels and the permitted power levels for each one to the devices. It also keeps track of the geolocation information it receives from the devices to manage the spectrum dynamically.

(4) Another dynamic approach to managing NR-U use can be seen in the United States, which established an AFC system to manage spectrum use by unlicensed, standard-power wireless access points in the 6 GHz band. The 6 GHz band has existing incumbent use in the fixed, mobile, and FSS, with fixed services being the largest user group. The AFC would determine exclusion zones and permit unlicensed access to the bands only at specific frequencies and locations outside of these zones to protect fixed services in particular (e.g. point-to-point stations) and radio astronomy sites.

5.8.2.1 Dynamic Spectrum Sharing

Along with flexible spectrum-sharing methods, several new licensing schemes have emerged from regulatory entities and from the industry to enable more efficient spectrum usage, such as opportunistic usage of TVWS (ECC, 2013), light licensing (ECC, 2009), LSA (ECC, 2014), and SAS (FCC, 2012). The need for associated regulatory governance and licensing mechanisms has also been stressed in Peha (2013) and Prasad & Sridhar (2014).

The EC released ECC Report 205 on LSA in February 2014. LSA is a complementary spectrum management tool that facilitates introducing new users in a frequency band while maintaining incumbents' existing services on the same band. LSA ensures a certain level of guarantee in terms of spectrum access and protection against harmful interference for both the incumbents and LSA licensees. In April 2013, Finland was the first country to trial the LSA on the 2.3 GHz band, where the incumbents—programme making special events (PMSE) licensees that use professional wireless camera links of the broadcasting and TV production companies, share their spectrum on a dynamic basis with the mobile operators. LSA is incorporated into the regular process of the Radio Communications Agency Netherlands. The PMSE sector must use the LSA booking system in the 2.3–2.4 GHz band. This obligation is incorporated into the licences of PMSE users in this band. Also, the national regulatory authorities (NRA) of Italy, France, Russia, and Portugal have piloted LSA. The spectrum sharing in these cases has either allowed the TISPs to increase their public network capacity or enterprises to deploy captive non-public 5G networks (Sridhar & Kokkinen, 2022).

Sharing of spectrum under appropriate regulatory structure between TISPs and other spectrum users is also possible in the unlicensed commons spectrum. One such example is the coexistence of the 4G LTE technology being deployed by mobile operators with Wi-Fi providers in the 5 GHz band. Additionally, TISPs may deploy dynamic spectrum sharing (DSS) within the public mobile networks to ensure gradual migration from 4G LTE to 5G.

However, Sridhar & Kokkinen (2022) point out that whatever the methodology we choose, an important regulatory initiative at this stage would be to set up a countrywide geospatial spectrum database that contains the spectrum in use across different areas by the various operators. Without this first step, the country's DSA methods will not take off.

5.8.3 Redesigning the LSAs

Spectrum licences are given as either national licences or regional licences. The spectrum is allotted nationwide in smaller European countries, while larger countries such as Australia, India, and the United States

have been allocating licences regionally. For example, in Australia, the 26 GHz spectrum was allotted in 2019 to the TISPs in twenty-nine defined areas. The defined areas reflect cities of more than 50,000 residents or towns with significant seasonal populations. However, the number of licence areas varies in Australia, depending on the spectrum bands in the auction. The first regional licence allocation was done in the United States in 1994 across thirty areas. As the spectrum allocation process matured, the FCC further refined the licence areas. Currently, there are five types of market area for the allocation of spectrum licensing in the United States. They are cellular market areas (CMAs), basic trading areas (BTAs), basic economic areas (BEAs), major trading areas (MTAs), and regional economic area groupings (REAs). A typical CMA covers only three to four counties, a BEA covers roughly fifteen counties, while an REA can cover hundreds of counties and can span several states. The country is divided into 734 CMAs, 176 BEAs, and 12 REAs. The FCC carefully balances geographic coverage associated with a licence and its allotted bandwidth to avoid market power concentration and to induce entry into high-cost, sparsely populated rural areas (Xiao & Yuan, 2018). In India, there are twenty-two LSAs currently.

However, as more and more high-frequency spectrums are being allocated to the TISPs, there is a need to change the definitions and boundaries of LSAs. The current LSAs, while suitable for the allocation of lower frequency bands, are not suitable. The high-frequency bands (especially the millimetre wave bands such as 26 GHz, 37 GHz, and 42 GHz) have very narrow propagation characteristics and hence will be deployed in select locations by the TISPs. Hence, there is a need to define much more granular LSAs for the allocation of high-frequency bands, much like what is being done in Australia and the United States. Though this increases the complexity of the spectrum allocation process, it shall be actively considered for high-frequency 5G and 6G spectrum bands.

5.9 Conclusion

In this chapter, we have reviewed the spectrum allocation process in India. While the enhanced SMRA is being used as a standard and well-proven auction methodology for the radio spectrum allocation, the

auction's outcome is determined by many configuration parameters, especially the reserve prices set at the initial clock round. The regulator shall consider fixing the reserve price for different bands in accordance with international prices and the market's specific requirements. It is essential to have a spectrum roadmap available in countries such as Australia so that the TISPs can plan for spectrum acquisition accordingly. While the C-band and millimetre wave bands are being deployed extensively by the TISPs in different parts of the world for 5G deployment, a large country such as India requires a different approach. The sub-GHz band will still be needed for the TISPs to cover the country's larger rural and remote areas. Hence, an active policy approach to release more 600 and 700 MHz bands is essential for rural connectivity. Further, most large countries, such as Australia and the United States, have been allocating spectrum in smaller geographical regions. This is required in the 5G spectrum, especially those in the 26 GHz band and higher. The LSAs in India are large geographical areas, so a micro region-based approach is required for the high-frequency spectrum allocation. Further, flexible approaches to spectrum management, including spectrum trading and sharing, shall be implemented for optimal and efficient spectrum use. To enable this, the government shall construct a geospatial spectrum database. The regulator shall also look at releasing NR-U in 6 and 60 GHz, which is also required to complement the licence spectrum allocation.

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6

From Net Neutrality to Digital Neutrality

In 5G+ Networks

6.1 Introduction

Ever since the controversial term 'net neutrality' (NN) was coined by Professor Tim Wu of Columbia Law School in 2003, most of the debates on NN revolved around the harmful consequences of TISPs that exercise control over data traffic in their networks.[1] The focus on TISPs in the NN debate stems from the unique position they have traditionally held in the Internet value chain. The value chain is conceptualised as a two-sided market with OTTs on the one side and end users on the other, with the TISP digitally bridging the two sets.

However, given recent technological and commercial developments, the classical view of NN no longer suffices to ensure fair competition on the Internet. A new conception of NN in a 5G world is proposed, and a broader definition of neutrality named 'digital neutrality' is defined to include large OTTs in the ambit of the NN regulation.

The chapter begins by outlining the classical approach to NN. Next, it lists the new drivers of competition in a 5G world that render the classical approach obsolete. Finally, it explores the appropriate definition of NN in a 5G world, starting with the current set of rules applicable in India.

[1] A version of this chapter first appeared in Prasad & Sridhar (2024).

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6.2 Classical NN and Its Variants

In classical discussions on NN, the TISPs that provide the required connection between OTTs and users tend to possess market power, hence the need for regulatory interventions to curb this. According to the 'end-to-end design principle' espoused by NN advocates, traffic on the Internet should be determined by the decisions of entities at the edges of the network and not the monopoly bottleneck TISP, which is in between.

There are good reasons for this classical view. Clearly, a dominant TISP can hinder competition in a downstream market in a number of ways, including by exercising pricing pressure by virtue of its monopoly position or by vertical arrangements (either formal or informal) with the OTTs. For instance, a TISP with its app marketplace can increase barriers to entry for other applications or players that are not part of the ecosystem with the TISP at its helm.

Unregulated TISPs may also extract all their revenues from OTTs, as opposed to extracting their revenues from end users. This possibility arises because OTTs have no choice but to connect with all TISPs to offer services to end users. This is referred to as 'multi-homing'. On the other hand, end users restrict themselves to one service provider through the subscriber identification module (SIM). This is referred to as 'single-homing'. Thus, TISPs have much greater pricing power over OTTs than over end users. This could lead to the OTTs bearing unsustainable costs.

Traffic management and pricing are the two pillars along which TISPs could use their market power. Traffic management techniques allow TISPs to manage traffic more extensively and to differentiate packet routing based on content, applications, and users. Traffic management allows for a wide range of operations, such as constructing fast lanes for certain types of data, providing guaranteed network capacity for certain types of users, preventing access to certain types of content, and selective authentication of users. These practices are contrary to the 'best-effort' paradigm under which traffic was managed in the early days of the Internet and which early advocates of NN championed as the best way forward. As for discriminatory pricing, NN advocates supported the pricing regime in which TISPs do not charge OTTs and obtain their revenues only from end users.

Table 6.1 Dimensions of NN

Traffic management	Price discrimination	
	Low	*High*
Low	Pure NN	Differential pricing
High	Differentiated traffic management	Pure non-net neutrality

Source: Adapted from Prasad and Sridhar (2014).

The different shades of NN can be divided into four categories: pure NN, differential pricing with no traffic management, differentiated traffic management without differential pricing, and pure non-net neutrality (see Table 6.1 from Prasad & Sridhar, 2014)

6.3 New Drivers of Competition

The classical conception of NN is becoming obsolete due to new technological and commercial developments. These include the proliferation of data and applications, new value chains, increased OTT power, and potential synergies from closer collaboration between OTTs and TISPs.

6.3.1 The Abundance of Data and Applications

The Internet connectivity market has grown from zero to multi-billion-dollar in fifteen years. The traffic communicated on networks has also been increasing exponentially. The number of mobile 5G subscriptions, currently at 1.6 billion, is expected to reach 5.3 billion by 2029 (Ericsson, 2023). This, in turn, will result in the average global mobile data consumption per smartphone reaching 56 GB per month at the end of 2029 (Ericsson, 2023). Further, 5G devices and connections will be over 10 per cent of global mobile devices and connections by 2023 (Cisco, 2023). It is estimated that the number of devices connected to the Internet will be more than three times the global population by 2023 and that there will be 3.6 networked devices per capita (Cisco, 2023). These developments will place a heavy load on the Internet. This increasing data requirement

means that OTTs, TISPs, other entities such as content delivery networks (CDNs), and cloud service providers must cooperate to handle the ever-increasing traffic load.

In terms of usage, most mobile data traffic is currently driven by video streaming. Up to 70 per cent of the data usage is via video content, primarily provided by the OTT video service providers. However, with the rapid deployment of 5G, new and diverse Internet applications with specific requirements are expected to emerge. For instance, the critical Internet of Things (IoT) is an emerging technology that demands data delivery within 50 milliseconds with 99.9 per cent certainty of availability and deliverability (Alriksson et al., 2020). In such an environment, classical principles of the NN doctrine are becoming increasingly obsolete.

As traffic increases, traffic management becomes necessary to optimally use the Internet highway. At some point, connectivity becomes a rivalrous good. At this point, discriminatory pricing becomes necessary to achieve efficient use. Thus, NN principles become obsolete. Though most NN regulations allow reasonable traffic management practices (RTMPs), which include temporary traffic prioritisation to alleviate network congestion, prioritising certain types of users or content for monetisation is viewed as violating NN principles (DoT, 2018).

6.3.2 The New Value Chain

The concept of NN was conceptualised under the assumption of a two-sided network. However, the Internet has evolved from its initial configuration. The current Internet value chain consists of many more entities, as Fig. 6.1 shows.

In the illustration, the TISPs provide the last-mile access connectivity to the end users while the OTTs provide the content. The OTT is typically connected to a CDN, through which the content provided by the OTT is routed to the TISP for distribution to the end users. The advertisers typically promote their advertisements in conjunction with the content provided by the OTT.

The commercial arrangements between different entities in the Internet ecosystem include contracts between OTTs and advertisers, OTTs and CDNs, CDNs and TISPs, OTTs and TISPs, OTTs and end

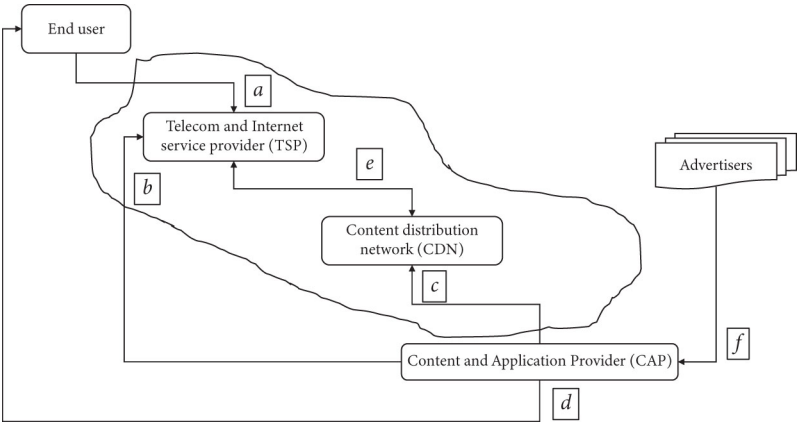


Fig. 6.1 The Internet value chain with associated charges
Source: Adapted from Sridhar (2019).

users, and TISPs and end users. The various charging mechanisms between the above-mentioned stakeholders are listed in Table 6.2.

The presence of more players and more commercial arrangements results in a situation where controlling the amount TISPs can charge OTTs through NN injunctions does not achieve the goal of low barriers to entry for OTTs, as a variety of other charges have to be incurred. New commercial and technical realities require the classical view of NN to be redefined.

Table 6.2 The type of charges possible in the Internet value chain

Charge	Purpose
a	Bandwidth charge paid by users to TISP
b	Charge paid by OTT to TISP for carrying their content to end users
c	Charge paid by OTT to CDN for routing their content to TISPs
d	Content charge paid by the end user for the content/application provided by the OTT
e	Charge paid by the TISP to the CDN provider for carrying the traffic to their network
f	Charge paid by the advertisers to OTT for carrying their in-content ads and paid search returns

Source: Adapted from Sridhar (2019).

6.3.3 The Increased Power of OTTs

Over the past decade, the Internet has evolved to a point where many OTT players also play gatekeeping roles and enjoy significant market power. For instance, Internet search engines have become the starting point for virtually everyone wishing to navigate the World Wide Web. By integrating searches across text, images, and video, the Google search engine has a fair amount of control over what content we access over the Internet and how we access it. The original premise of NN was that innovative OTTs needed to be protected from the market power of TISPs. Today, it is equally relevant to ask whether or not they must also be protected from their fellow OTTs who enjoy disproportionate market power.

The principle of static efficiency asserts that market distortions would be minimised when the TISP loads its tariffs onto the entity whose demand is less elastic to price changes. Typically, the OTTs exhibit relatively lower price sensitivity compared to end users. This is because OTTs would not change their market behaviour following a higher charge as much as an end user. Thus, the principle of static efficiency states that the TISP should collect a larger part of its revenues from OTTs. This contradicts the principle of NN that advocates charging the end user, not the OTT. The rationale for NN emanates from the mandate of dynamic efficiency that postulates the need to promote innovations in the Internet by minimising charges on the OTTs.

The implication that dynamic efficiency is best promulgated by protecting the OTTs assumes that all technological innovations occur within the OTTs and ignores the rapid developments that have radically transformed the provision of connectivity services. Further, it perpetuates the stereotype that all OTTs are garage start-ups needing protection, ignoring the immense and increasing market power commanded by powerful OTTs in today's world, such as the GAMMAs.

6.3.4 Closer Collaboration between OTTs and TISPs: An Example of Network Slicing

The benefits of classical NN must be assessed in light of the new technical possibilities thrown up by 5G+, which requires close integration

between TISPs and OTTs, most importantly in the paradigm of 'network slicing'.

Traditional mobile communication networks employ the one-size-fits-all approach to providing services to mobile devices, regardless of the communication requirements of vertical services. This design paradigm is not compatible with differentiated services. The concept of 'network slicing' has been proposed to address the diversified service requirements in 5G+ with the advent of technologies such as software-defined networking (SDN) and network function virtualisation (NFV). Network slicing is an end-to-end logical network service provisioned with a set of isolated virtual resources on infrastructure that is physically shared. These logical networks are provided as different services to fulfil the varying communication requirements of users. Network slicing provides a network-as-a-service (NaaS) model, flexibly allocating and reallocating resources according to dynamic demands. It can customise network slices for diverse and complex 5G communication scenarios and requirements (Li et al., 2017).

This network-slicing technology provides a compelling use case for constructing private networks. Private networks with associated QoS requirements can be provisioned by creating network slices of adequate capacity, reliability, and latency (Eswaran & Honnavalli, 2023) by the mobile network service provider. These slices can also be created at the network layer (of the open systems interconnection communication model) and procured by private enterprises for constructing their private networks. The complexity of managing the usage of network slices across different user requirements poses a challenge to the TISPs (Eswaran & Honnavalli, 2023). The requirements of private network users can be fulfilled by the TISPs using contractual agreements.

While NN promotes innovation by reducing barriers to entry for new OTTs, vertical arrangements between TISPs, CDNs, and OTTs also promote innovation via better integration between different elements of the value chain. These complementarities have led to 'walled gardens' comprising network operators, handset manufacturers, platform vendors, and content providers, who come together to provide the entire gamut of digital services and products.

Creating private networks for OTTs using network slicing and walled gardens can represent an example of 'specialised services' permissible

under the NN rules (DoT, 2018). However, as the list of exceptions increases, we must ask ourselves at what point we must regard ourselves as having moved away from the broad world views encompassed by the umbrella term 'net neutrality' and have entered a new reality.

The original conception of NN was appropriate only in the early days of the Internet. The outdated assumption that all innovation takes place within the OTTs and TISPs can only be 'dumb' pipes (hence not innovative) and the belief that only TISPs could misuse gatekeeper functions are two fundamental pillars on which the original formulation of NN rested. Both are in question today.

6.4 NN in 5G+

Given the changing realities, it is no surprise that NN, in practice, is vastly different from its original conception. In a network where best efforts have been taken, all end-user service requests demanding network capacity are treated equally, irrespective of the nature or content of such services. However, while best efforts are the stated intent on the Internet, traffic management techniques that allow connectivity providers to manage traffic more extensively, and to differentiate packet routing based on content, applications, and commercial agreements, have been increasingly used ever since the inception of the Internet.

Indeed, the current role of NN has come a long way from the original conception of Tim Berners-Lee, inventor of the World Wide Web and Massachusetts Institute of Technology (MIT) professor, who said (Wu, 2003),

> A neutral communications medium is essential to our society. It is the basis of a fair, competitive market economy. It is the basis of democracy, by which a community should decide what to do. It is the basis of science, by which humankind should decide what is true. Let us protect the neutrality of the net.

Before outlining the details of regulations concerning NN in a 5G world, let us first examine how NN is currently practised in India.

6.4.1 NN in India

India is seen as a global leader in mandating the neutrality of the Internet. It shot into prominence in 2016, when the Telecom Regulatory Authority of India (TRAI) shut down the 'zero-rating' scheme under which Internet service providers were planning to provide Internet access to a select set of applicants free of charge, in collaborative agreements with OTTs (Sridhar, 2019).

There have been several policy initiatives to define India's stance on NN. A committee established by the DoT submitted recommendations in May 2015 (DoT, 2015). The TRAI gave the DoT its recommendations on NN in November 2017 (TRAI, 2017). In 2018, the Government of India developed a regulatory framework for NN. It amended the terms of various licence agreements to incorporate NN principles along with appropriate exclusions and exceptions (DoT, 2018). The broad contours of the accepted regulatory understanding in India about NN are as follows (Prasad & Sridhar, 2015):

> A licensee providing Internet access services shall not engage in any discriminatory treatment of content including based on the sender or receiver, or the protocols being used for the user equipment. The licensee is prohibited from entering into any arrangement, agreement or contract, known by whatever name, with any person natural or legal, that has the effect of discriminatory treatment.

However, many caveats need to be considered.

6.4.1.1 RTMPs and Specialised Services

RTMPs are permissible under the NN regulation. According to the TRAI (2017, p. 23), in general, TISPs have incentives to ensure that their networks are managed in a manner that offers the best possible experience to a large number of users using different categories of content. However, the commercial considerations that prompt TISPs to use traffic management practices to improve network performance can also cause certain exclusionary or discriminatory practices. While this tendency needs to be regulated, the regulation should not affect the ability of TISPs to

manage their networks efficiently to optimise overall network performance and offer satisfactory QoS to the users, providing a diverse variety of content.

Further, the TISP is permitted to provide specialised services that are not usable or offered as a replacement for Internet access services and are not detrimental to the availability and overall QoS providing Internet access. Critical IoT services identified by the DoT that satisfy the definition of specialised services are also excluded from restrictions related to discriminatory treatment. However, the IoT as a class of services is not excluded. The CDNs are exempt from the restrictions on discriminatory treatment. While the potential of Internet platforms to violate neutrality is acknowledged, and the issue of search engine neutrality is highlighted, no decision has been taken about platforms or search engines to bring them under the NN directives.

The details of NN regulations in India clearly show that the industry has already evolved considerably from the classical conception of NN. It is time to acknowledge that a paradigm shift is underway and to develop a new formulation of NN.

6.4.2 The New Conception of NN

In a 5G+ world, the most important tasks for regulators regarding NN are providing connectivity to VNOs in a non-discriminatory manner, ensuring QoS in the public network, and facilitating competitive markets in the provision of network slicing.

As outlined in Chapter 4, given our recommended incentive structure, the telecommunications market could see a mix of vertically integrated TISPs combining infrastructure and services and VNOs that lease network capacity from network providers. NN implies that network providers need to provide connectivity on a non-discriminatory basis to all VNOs, whether they have business linkages with the VNO or not.

Further, the construction of network slices for private networks could affect the requirements of capacity and reliability of network capacity allocated for public networks. As a result, public users would be at a significant disadvantage if more slices were created through contracts between TISPs and OTTs. Further, the market for network slices could

be disadvantaged by the actions of influential OTTs. This needs to be prevented.

The following are the contours of the new approach to address these challenges.

(1) Enough capacity should be allocated for public networks so that the broadband requirements defined by the regulator are met. The current requirement in India is 2 Mbps downlink speed for an individual connection.
(2) A defined QoS should also be provided for wholesale connectivity provided by a network provider to a VNO, and the regulator should monitor its provision.

Concerning the monitoring of individual connectivity, the Body of European Regulators for Electronic Communications (BEREC) has developed an applicable regulatory assessment methodology in order to guide NRAs with the implementation of the NN regulatory assessment methodology regulation (BEREC, 2022). It is intended to help regulators monitor and supervise the NN provisions of the regulation based on various measurement tools to discern NN and a harmonised measurement methodology for QoS. According to the regulation, TISPs must describe the minimum, commonly available, maximum, and advertised download and upload speed in their fixed network contracts. TISPs must describe estimated maximum and advertised download and upload speeds for mobile network subscriptions.

One of the important uses of TISPs disclosing the advertised service parameters and their subsequent measurement is to detect unreasonable TMPs, including throttling and traffic shaping of specific applications or content. Apart from the requirement that the QoS parameters submitted by TISPs should meet all the requirements, third-party tools are also available for detecting traffic prioritisation (Sridhar, 2019). Such a methodology can be used to monitor the performance of the public Internet. Further, the contractual technical agreements for private network slices should be filed by the TISPs periodically with the regulator to ensure that the above-mentioned QoS for public network slices are possible. If any anomalies are detected, then the regulator can take remedial measures to address them. Since CDNs are not directly providing services to end

users, they should not be subject to NN rules, including for any traffic prioritisation at the behest of TISPs or OTTs. The space of specialised services should be broadened to include the various possibilities that emerge with 5G technologies.

While NN takes on new dimensions in a 5G world, regulators cannot restrict themselves to ensuring fair Internet access for OTTs and end users. As mentioned before, many OTTs have become essential gatekeepers of the Internet and have acquired significant market power. Hence, the spirit of NN has to be extended to the digital ecosystem as a whole.

6.5 Digital Neutrality

Digital neutrality is a new approach to achieving the objectives implicit in the NN doctrine. It focuses on creating fair competition in all parts of the digital ecosystem (including search engine usage, e-commerce, and social networking), not merely providing connectivity. In particular, it is concerned with the regulation of vertical mergers and other vertical commercial arrangements that could inhibit competition, at the same time recognising that such arrangements may lead to increased efficiencies.

Other arrangements whose benefits and harms need to be assessed are tie-ups between search engines and comparison-shopping services. Indeed, search neutrality is a central concern of the digital neutrality paradigm. This issue is discussed in Chapter 3 within the discussion of diagonal equity. App neutrality is yet another aspect of both digital neutrality and diagonal equity.

6.5.1 App Neutrality

The app stores from where one downloads the required application onto mobile phones/tablets are strictly guarded by the Big Techs such as Google and Apple for android and iOS applications, respectively. Both Google and Apple act as gatekeepers for the entry of an application in their app stores. Google Play Store, called initially Android Market, was launched on 22 October 2008 and was later rebranded as Google Play

Store in 2012. Similarly, Microsoft also has its own Windows App Store for all Windows-based applications. The Apple App Store was launched at the company's Worldwide Developers Conference (WWDC) on 9 June 2008, at the same time as that of Google. These app stores are two-sided platforms wherein the app developers post their applications on one side, to be downloaded and used by android and iOS users on the other side. As discussed in Chapter 2, the platforms charge fees from the app developers. Google charges users about USD 25 for app developers to register in the Play Store, while Apple charges USD 99 before the first app is submitted. Further, Apple charges up to 30 per cent of the in-app purchase revenue as commission. Similarly, Google charges 15–30 per cent of in-app purchase revenue. However, the platform firms exhibit stringent control over which applications get onto their respective app stores. The platforms check for the quality and security of the applications before accepting them in their app stores. Further, the gatekeepers can force the app developers to use their payment systems for in-app purchases or discriminate against using other payment systems. Hence, the app store firms exhibit tight monopoly control over the application ecosystem.

Side loading is a method by which one installs applications not from the respective official app store but from the package file distributed through email or file sharing. Side loading increased in popularity after the launch of the *Pokémon Go* application that was released in phases in 2016. Since this application was wildly popular and received extensive media coverage, many people around the globe wanted to install the application in advance of its official release date in a particular country. This led to people discovering the possibilities of side-loading applications onto their devices (Wahl, 2024). Both Google and Apple discouraged side loading of apps to avoid loss of control.

The Digital Markets Act (DMA) 2022 of the EU legitimised side loading as a means to control the monopoly power exhibited by these gatekeepers of the app stores. The app store firms quickly responded, indicating that they will not be held responsible and liable for any security loopholes arising due to side loading. The objective of this clause in the DMA is to ensure device and platform neutrality for the application ecosystem.

Similarly, the competition watchdog in India, namely the Competition Commission of India (CCI), in a recent case, noted that Google has been

dominant in India in both licensable operating systems and the App Store for android. In the case 'XYZ (the 'Informant') against Alphabet Inc.' on the bundling of the Google payment system with Google apps, the CCI ordered that Google should allow app developers to use any third-party billing/payment processing services, either for in-app purchases or for purchasing apps. In the order, it is also stated that Google shall not impose any condition (including price-related conditions) on app developers that is unfair, unreasonable, discriminatory, or disproportionate to the services provided to the app developers (CCI, 2020).

The above reiterates the monopoly power exhibited by the firms in the OTT ecosystem, which could potentially distort the neutrality of the digital ecosystem. Hence, there is a need for app neutrality within the overarching umbrella of digital neutrality. Such an approach would bring much-needed transparency, openness, and neutrality to the operations and business models of large Internet firms.

6.5.2 The Carriage Levy on OTT Non-Communications Providers

The traditional arguments favouring NN can no longer be used to excuse the commercial obligations of large OTTs. Nevertheless, we do not recommend commercial liabilities of large OTTs for their use of the public Internet. Instead, we propose that significant OTT communication service providers and OTT video services that are LTGs should pay carriage fees to the government, referred to as the broadband infrastructure levy (BIL), in proportion to their traffic on the public Internet. These fees will be used to build broadband infrastructure nationwide to meet the growing demand for network capacity.

As discussed in Chapter 4, such a levy is aligned with static efficiency considerations, as a levy on OTTs is less likely to distort behaviour because of the lower price elasticities of OTTs compared to end users. Such a levy also does not violate dynamic efficiency considerations, as it is imposed on entities that can better bear the costs than start-ups, whose innovation engine would be significantly impacted by levies. A direct commercial arrangement between TISPs and OTTs for the use of the

public Internet would be at cross purposes with the principle of NN. Hence, a government levy is recommended.

Timothy Wu, who coined the definition of NN, advocates the 'Separation principle', which creates salutatory distances between the many layers of the information economy (Wu, 2003). While separation should be examined on a case-by-case basis, the writing on the wall is clear: It is now time to conceive of neutrality afresh in the context of vastly transformed businesses and technological possibilities. We need neutrality in the digital economy, not just in providing connectivity services.

6.6 Conclusion

The original conception of NN is no longer sufficient to promote competition in the digital economy. As shown by developments in India, the application of NN principles has already gone beyond the classical tenets of NN. New technological and commercial developments in a 5G+ world will likely make the old conception even more obsolete. Hence, it is time to move to a new definition and conception that recognises that TISPs and influential OTTs must take joint responsibility for promoting competition and technological dynamism on the Internet. In today's world, the requirement is for digital neutrality, not just NN.

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7

Interconnection and Data Portability Regulation

7.1 Introduction

While benefiting from intrinsic direct network effects, telecom networks depend on interconnection and interoperability for scaling up. Interconnection augments the network effects through the indirect effects. When a network of size n_1 interconnects with another network of size n_2, the value for each network operator increases in proportion to $(n_1 + n_2)$. Hence, there is an incentive for networks to interconnect. At the same time, the negative spill-over cost that occurs when a new network takes subscribers and profits from existing firms inhibits the network operators from entering into interconnect agreements. This is true especially for more extensive networks, as they benefit little from connecting to a smaller network, hence the need for interconnection regulation.

In the absence of interconnection regulation obligation, virtually every telephone market in the United States and the rest of the world in the early twentieth century became a monopoly with a single largest network everyone needed to connect. The potential for specific industries, such as telecom, to move towards a monopoly structure in this manner illustrates the economic implications of interconnecting networks (Nuechterlein & Weiser, 2007).

In telephony, due to standardised technical interfaces of circuit-switched networks, carrier networks all over the world are interconnected. Within each country, the networks of different operators are interconnected so that one can seamlessly make calls from any part of the world to any other landline or mobile phone. However, due to the above reasons, there is little economic incentive for more extensive networks to interconnect with smaller networks. The interconnection usage charge

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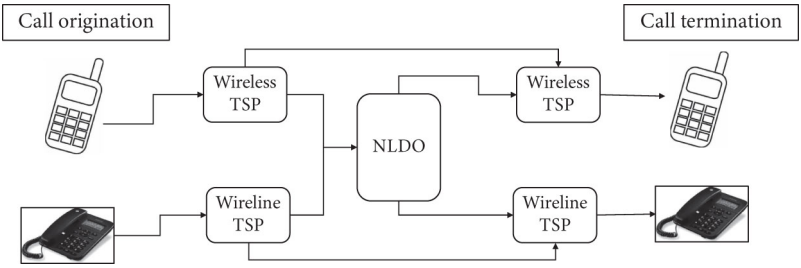


Fig. 7.1 The call flow across LSA within a country
Source: Adapted from Sridhar (2019).

is the charge payable by a network service provider to other network service providers or service providers for using the network elements to transit or terminate the calls (Sridhar, 2012).

The interconnection of networks can happen at various levels, as illustrated in Fig. 7.1.

In Fig. 7.1, calls across LSAs that originate from a landline or mobile after passing through the originating telecommunication service provider (TSP) are handed over to the national long-distance operator (NLDO) at the PoP. The NLDO carries the calls across the LSAs and hand them over to the terminating TSPs at the termination service areas, which terminate the call on a landline/mobile. In the case of calls within the LSA, the calls are handed over by the originating TSP to the terminating TSP directly. The IUCs are the charges paid by the originating TSP to the NLDO and terminating TSP for carrying the calls through their networks.

The origination of the termination of an international call is illustrated in Fig. 7.2.

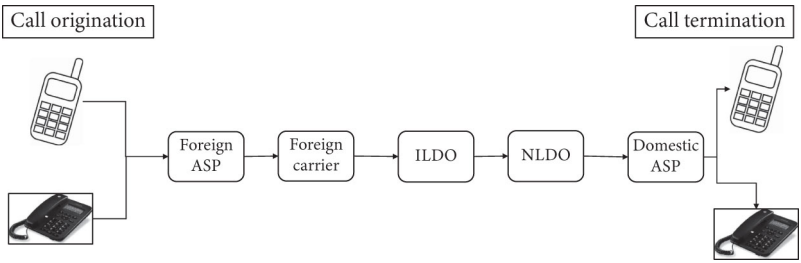


Fig. 7.2 The call flow of an international call
Source: Adapted from Sridhar (2019).

The flow of an international call is very similar to a domestic call except that it passes through a foreign carrier, who hands over the call to the international long-distance operator (ILDO), who then further hands over the call to NLDO towards termination. The compensation paid by the foreign carrier to the domestic TSP is referred to as the international settlement charge.

7.2 Termination Charges

Initially, the mobile operators had a receiving-party-pays (RPP) regime that was changed to the calling-party-pays (CPP) scheme in India in 1999.[1] Subsequently, the reference interconnect order of the TRAI in July 2002 specified interconnection charges to be mutually agreed upon between network operators (TRAI, 2002). However, most of the operators could not come to mutual agreement on network interconnection charges.

Given this impasse, there was a need for an interconnection regulation that facilitated a level playing field for all operators, provided equitable revenue-sharing terms, and allowed open interconnectivity so that subscribers could make any inter-network calls. In January 2003, the TRAI issued the interconnection regulation concerning cost-based IUCs for inter-network calls to address these issues and facilitate equitable interconnection terms. On 1 May 2003, the Telecommunication Interconnection Usage Charges (IUC) Regulation notified by the TRAI came into existence (TRAI, 2003).

Termination of calls assumes prominence when there are several TSPs. Call termination results in externalities—both positive and negative. Since the origination and termination of calls need not be on the same network, the termination service provider acts as a monopoly bottleneck facility for the originating call. While successful termination results in a positive network externality, denial of the same results in an adverse effect. The denial of termination could be due to technical or economic

[1] An RPP is a payment model for phone calls, and the person receiving it pays for it. On the contrary, a CPP is a payment model for phone calls in which the person making the call pays for it.

reasons. The negative externality in call termination has the effect of reducing competition and QoS. One way to circumvent this failure is through regulatory intervention (Sridhar, 2006).

In general, calls terminated within the caller's networks (referred to as on-net calls) are often charged less than off-net (i.e. terminating on a different operator's network) calls (Gabrielsen & Vagstad, 2008). The main reason is that the network infrastructure required for on-net calls is already in place with the operator, and no third party is involved in the call's handover. However, the termination charge must be paid to the receiver's network operator for off-net calls. The fixed termination charge, if set high, will increase the user charges and reduce the welfare of consumers who make off-net calls. High termination charges will also lead to originating service providers' reluctance to interconnect with other operators. If set low, operators will resort to practices of denial of call terminations originating from other networks (Sridhar, 2012). The cost associated with the termination of off-net calls is higher than that of on-net calls, as the originating service provider needs to provide enough bandwidth at the point of interconnect (PoI) to the terminating provider. This aspect is discussed in section 7.3.

Mobile service providers have contended that the termination charges in India are below cost and among the lowest in the world. Even the TRAI noted that mobile termination charges (MTCs) are between twelve and fourteen times lower than those prevailing in other countries (TRAI, 2006a). This leads to possible refusal to terminate calls or inadequate provisioning of interconnections with other networks for termination facilities. The research literature on termination rates indicates that mobile operators are incentivised to set termination charges that help them extract maximum surplus. On the contrary, low termination rates might even force the operators to increase prices and raise subscription charges, which is referred to as the 'water bed effect' (Genakos & Valletti, 2011). In general, larger operators propose higher termination charges, as the expected number of incoming calls from smaller networks is more than that of outgoing calls to such networks. For the same reason, the smaller entrants lobby for lower termination charges.

The revision in domestic and international termination charges (ITCs) over time (TRAI, 2018a) is indicated in Fig. 7.3. In its 2018 order, the TRAI reduced the MTC (the charges paid by the originating TSP to terminate mobile networks for domestic calls) to 6 paise/minute. The

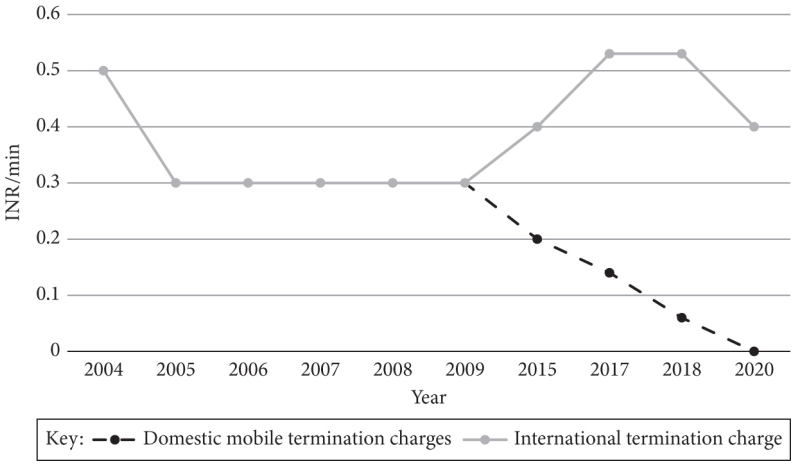


Fig. 7.3 Changes in MTC and ITC over time in India
Source: Adapted from Sridhar (2019).

MTC was reduced to zero for all domestic calls, effective as of January 2020 (TRAI, 2019). The ITCs for international incoming calls were revised to 0.40 paisa/minute (equivalent to USD 0.0055/minute). This is in line with the termination rates in the United Kingdom; however, they are deficient compared to the United States (USD 0.011–0.035) and Australia (USD 0.01–0.025).

Regulators tend to fix the floor charge for mobile termination at a level that covers the marginal cost. The argument for lowering the termination charges over time is the introduction of emerging technologies that have reduced the termination costs. Further, the marginal cost of termination on a wireline, in general, is very low due to higher capacities and associated fixed costs of wireline infrastructure. It is important to note that when there is a symmetry of call volumes between any two operators, then the MTC has no relevance.

7.3 Interconnect Congestion

The interconnection infrastructure to be deployed by the TSPs at the PoIs is associated with termination charges. If the termination charges

are kept too low, the terminating TSP, which is, in fact, the monopoly service provider for the call that needs to be terminated, may use its bottleneck termination facility to block or slow the termination (Sridhar, 2019). The insufficient provisioning of telecom circuit resources, depending on traffic requirements at the PoIs, leads to

(1) intra- and inter-network congestion at the PoIs,
(2) loss of calls,
(3) repeated call attempts by consumers,
(4) deterioration in QoS and resultant consumer dissatisfaction.

Hence, unless traffic symmetry is reached across the operators, the termination charges and associated PoI congestion continue to be a debatable regulatory issue (for details on the regulatory literature on IUCs with specific reference to India, refer to Kedia, 2018). While initially, the traffic symmetry between the telcos broadly justified the bill-and-keep regime, the recent emergence of pure-play Internet telephony players who are seeking to terminate their calls on mobile networks calls for a review of the current zero-termination-charges regime.

7.4 Interconnection Charges for Internet Protocol-Based Calls

While the IUCs regime applies PSTN/PLMN calls, traffic is shifting away from the PSTN/PLMN to packet-switched IP calls. One of the common forms of this type of call is Internet telephony calls made from OTT communication apps, such as Skype and WhatsApp. These are also referred to as 'number independent personal communication services' per the EU Digital Markets Act (DMA) 2022 (Council of the European Union, 2022), as these services operate over the Internet and do not require a numbering scheme. There are also cases of OTT communication service providers (Ott coms) taking an access service authorisation to offer Internet telephony calls. In this section, we discuss the applicability of the IUC (particularly the MTC) for such types of calls.

7.4.1 Internet Telephony Calls Terminating on the Carrier Network

The Internet telephony calls that terminate on the PLMN evoke special interest from regulators. The schematics of the Internet telephony calls terminating on the PSTN/PLMN is provided in Fig. 7.4. When the user makes this call, it is difficult to determine the exact location of the call's origination (e.g. the location of the Internet telephony app or the location of the gateway that translates the Internet telephony call to a PLMN call). Hence, Internet firms argue that bringing such calls under interconnection regulation is impossible. However, the mobile operators argue for termination charges, as they incur marginal costs in termination.

On 1 April 2002, India allowed a restricted form of Internet telephony in which the IP device-to-IP device communication was allowed. However, termination on the PSTN/PLMN was disallowed (Sridhar, 2012). One way the DoT enforced this restricted form was to ban the deployment of the media gateway switch that interconnects and translates packet-switched traffic to equivalent circuit-switched services within India. Ironically, permission for a call originating from an IP device to terminate in a PLMN/PSTN device outside India had to be granted, as the Indian government and regulator do not have jurisdiction over the

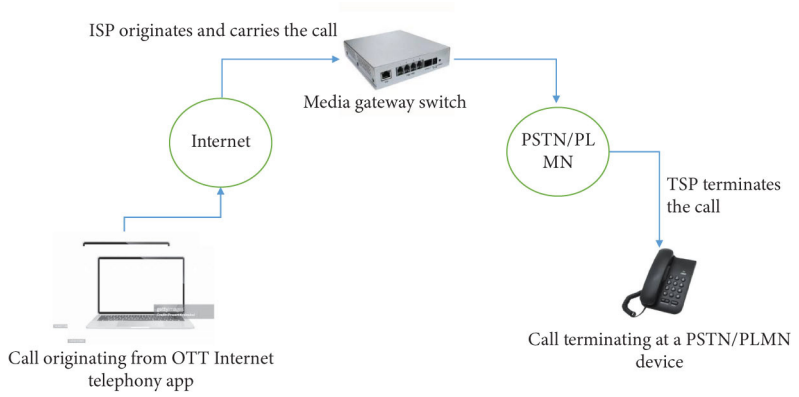


Fig. 7.4 Schematic diagram of IP device <–> PSTN/PLMN device call
Source: Adapted from Sridhar (2019).

installation of a media gateway switch that interconnects an IP call to a PSTN/PLMN call outside India.

In 2006, the TRAI recommended relaxing the restricted form, first for the licensed telcos. In response, the DoT modified the licence conditions for wireline and wireless access services providers. Subsequently, the following clause was retained in the unified licence with access service authorisation (DoT, 2013):

> While providing Internet Telephony service, the Licensee may interconnect Internet Telephony network with PSTN/PLMN/GMPCS [global mobile personal communication by satellite] network.

Subsequently, in 2016, the DoT issued modifications to the unified access service licensees as well as unified licensees with access service authorisation, allowing the deployment of the media gateway switch within India for interconnecting the Internet and the PSTN/PLMN for facilitating the flow of Internet telephony calls from within or outside India to the carrier network (DoT, 2016).

The clause in the unified licence with Internet service authorisation in Chapter IX reads as follows (DoT, 2013, p. 64):

> The Licensee (UL with Internet Service authorisation) may provide Internet Telephony through Public Internet by the use of Personal Computers (PC) or IP based Customer Premises Equipment (CPE) connecting only the following:
> a) PC to PC; within or outside India
> b) PC / a device / Adapter conforming to TEC or International Standard in India to PSTN/PLMN abroad.
> c) Any device/adapter conforming to TEC or International Standard connected to the ISP node with a static IP address similar to that of a similar device/adapter within or outside India.
>
> Explanation: Internet Telephony is a different service in its scope, nature and kind from real-time voice service as offered by other licensees like Basic Service Licensees, Cellular Mobile Telephone Service (CMTS) Licensees, Unified Access Service (UAS) Licensees, Unified Licensee (Access Service), Unified Licensee with authorisation for

access services. The Licensee can provide the Internet Telephony only as described in condition (ii) above. Voice communication to and from a telephone connected to PSTN/PLMN/GMPCS and use of E.164 numbering is prohibited.

The above clause rules out the provisioning of unrestricted Internet telephony by pure-play ISPs and any app-based providers, such as Skype or Hike, to connect Internet telephony calls to PSTN/PLMN networks.

7.4.2 International Internet Telephony Calls Terminating on the Local Carrier Network

The process of how an international call originating in an OTT Internet telephony app from a foreign country can be terminated in India on the PLMN/PSTN is shown in Fig. 7.5. The ISP must hand over the call to the ILDO, who, in turn, routes the call towards the destination. For a call to be terminated onto the PSTN/PLMN, the call will need to be delivered to the relevant carrier at its PoI using the requisite form. This means that the call will need to be converted

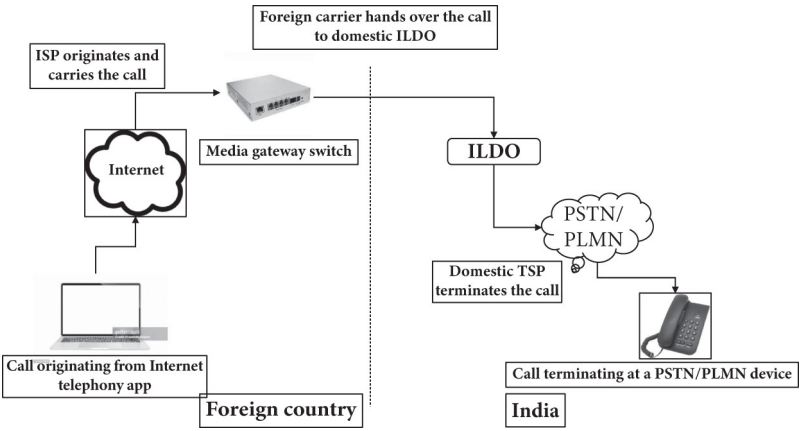


Fig. 7.5 Schematic diagram of international Internet telephony call flow
Source: Adapted from Sridhar (2019).

from a packet-switched Internet call to a standard circuit-switched call along with the appropriate signalling protocol before it is routed to the PoI of the mobile or fixed carrier. Further, the IP address of the origin and destination in the Internet telephony call must be translated into the corresponding E.164 international numbering format before termination. This is usually done by the media gateway switch using the enumeration (ENUM) translation scheme (refer to Sridhar, 2019, for detailed analysis).

One important question is, for the above type of Internet telephony calls that originate outside the country but terminate in a carrier network within India, should the termination charges be applicable as per the IUC?

Comprehending these issues, the TRAI, in its recommendation, has indicated the following (TRAI, 2017):

> The call termination charge for VoIP calls terminated onto a mobile or fixed line network would be the same as calls from traditional services.

Further, the DoT (2018a) states the following:

> Internet Telephony calls originated by International roamers from international locations should be handed over at the International gateway of licensed ILDOs, and International termination charges should be paid to the terminating access service provider.

Hence, the exact ITCs shall apply for international calls that terminate on the PSTN/PLMN.

However, despite these regulations, a grey market for international Internet telephony calls still exists. In this, the Internet telephony calls originating from outside the country masquerade as local calls and terminate on the local carrier network, thereby incurring zero (as of now) MTC compared to the higher MTC levied for international calls. The TRAI has been periodically alerting consumers of these calls and requesting consumers to inform them if the caller IDs for the incoming calls are not shown. Details of the grey market operation for evading ITCs are provided in Sridhar (2019).

7.5 The Interconnection between OTT Com Apps

While the regulators have mandated the interconnection of carrier networks, the interconnection between OTT com apps has evaded regulatory scrutiny. It must be noted that OTT com apps are increasingly becoming the most widely used communication medium. A recent report by Juniper Networks indicates that OTT business messaging traffic is expected to reach 375 billion messages in 2028, a substantial increase from the 100 billion messages recorded in 2023. This surge is attributed to the drop in the quality of SMS networks, prompting enterprises to seek alternative communication channels, including OTT messaging apps (Telecomlead, 2024). Given the diagonal equity principle outlined in Chapter 2 and the functional separation principle outlined in Chapter 4, interconnection regulation of various OTT apps should also actively be pursued so that messages from one app can be sent or received from another.

The OTT com app providers have leveraged network effects to amass massive subscriber bases. The large incumbent OTT coms have little incentive to interconnect with smaller apps. However, the new entrants in the OTT com space can survive only if they can interconnect with larger incumbents' apps. Hence, just as interconnection regulation mandates the interconnection of carrier networks, similar regulations should also apply to OTT coms.

Interconnection of OTT com apps is possible due to the incorporation of public application programme interfaces (APIs). Using APIs, it is possible to communicate across OTT apps (such as email communication across service providers) using the email addressing scheme and the Simple Mail Transfer Protocol (SMTP). Contrary to what the incumbents claim, the network effect and associated benefits will accrue to both the incumbents and new entrants. However, the incremental benefits are lower for more extensive networks.

7.5.1 Evolving Communication Technologies for Internetworking

The gold standard for interoperable messaging systems is the Extensible Messaging and Presence Protocol (XMPP)—a set of open technologies

for instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and routing of eXtensible Markup Language (XML) data (XMPP Standards Foundation, 2023). Initially developed by the Jabber open community, XMPP is the core protocol that powers today's OTT com apps, including WhatsApp and Google Chat. Several XMPP client apps are available, such as Dino and Swift.IM for desktops, blabber.im and Quicksy for android mobiles, and Monal and Siskin IM for iOS mobiles. Large OTT com apps such as WhatsApp have modified the XMPP considerably to improve performance and usability. However, these modified versions have also been converted into closed systems, preventing interoperability with similar XMPP-based apps. An indigenous app called 'Prav' is being developed by a group of Indian tech volunteers that is not vendor-locked and has all the richness offered by XMPP (Prav, 2023).

The Web Real-Time Communication (WebRTC) standard has been drafted by the World Wide Web Consortium (W3C) using the XMPP framework. The technology allows peer-to-peer (P2P) multimedia communication from one Internet user to another over simple Web browsers via simple 'non-proprietary' Javascript APIs or the open HTML 5. WebRTC enables users to initiate a voice/video call directly from their mobile/laptop Web browsers without needing any external native software application such as Skype or WhatsApp (Panda & Sridhar, 2016). WebRTC allows web application developers to write rich, real-time multimedia applications on the web without requiring plug-ins, downloads, or installs. Google initiated the WebRTC for inclusion in its Chrome browsers; however, after the adoption by the W3C, it has become a widely accepted standard for inclusion in all web browsers. The unique aspect of this communication technology is that it does not require any centralised service to connect the origin and destination in its purest P2P form. Thus, it enables communication without even a simple directory service provided by intermediaries. The technology consists of three major APIs, which can be called from various programming languages for accessing multimedia resources, initiating the P2P connection and enabling data sharing across the connected parties. Hence,

technologies such as WebRTC enable interconnection and interoperability between OTT apps and services.

7.5.2 Regulations on the Interoperability of OTT Coms

While technologies such as these continue to evolve, and hence provide options for Internetworking and interoperability, they are not adopted beyond small groups due to the lack of network effects of the insignificant OTT apps. Due to non-inter-networking and non-interoperability between these and significant OTT apps (also referred to as gatekeepers), the benefits of the open protocol do not reach the end users. As in a telecom network, the more extensive networks do not benefit from inter-networking. Hence, the significant OTT apps choose not to interconnect to preserve their monopoly power over their users. It is time that regulators intervened to promote the inter-networking of OTT apps for the benefit of users.

In the EU, Article 7(1) of the DMA 2022 specifies the following if the OTT com is a 'gatekeeper' (Council of the European Union, 2022):

> Where a gatekeeper provides number-independent interpersonal communications services that are listed in the designation decision under Article 3(9), it shall make the basic functionalities of its number-independent interpersonal communications services interoperable with the number-independent interpersonal communications services of another provider offering or intending to offer such services in the Union, by providing the necessary technical interfaces or similar solutions that facilitate interoperability, upon request, and free of charge.

In the above, a gatekeeper is a firm or a platform that wields considerable economic power over its consumers. By the same, Meta has published a 'WhatsApp Reference Offer' on the technical requirements to enable third-party providers to provide inter-operable services with WhatsApp (Meta, 2024). As the work on interoperability of OTT com

apps has already started, it is time to incorporate these classes into India's Telecommunications Act as well.

7.5.3 Regulation on the Interconnection of Internet Telephony with PSTN/PLMN Networks in India

In 2017, after extensive consultation on Internet telephony, the TRAI issued recommendations on various issues, including the numbering scheme to be used, ENUM implementation, enabling monitoring of calls by law enforcement officials, and so on (TRAI, 2017).

As per the DoT (2018a) amendment, the mobile numbering series is to be used to provide Internet telephony calls, and the service is to be untethered from the underlying access network. Realising this opportunity to interconnect with the PSTN/PLMN network, many VoIP communication service providers (such as Ring Central, Zoom, and Cisco Webex) applied for unified licence with access service authorisation (DoT, 2022) for providing enhanced VoIP services that connect to the PSTN/PLMN. The UL (VNO) licence also carried out a similar amendment.

In light of the modification of licence conditions regarding Internet telephony, and given the fact that the termination is on the PSTN/PLMN that has costs associated with last-mile termination, the current regime of zero termination charges requires a review, especially if there is significant asymmetry of traffic between the OTT apps and the PSTN/PLMN. Hence, a study needs to be conducted on the proportion of Internet telephony calls that terminate on the PSTN/PLMN networks for the possible revisions of termination charges.

The question often arises regarding how Internet telephony calls or OTT calls originating over the Internet untethered from the underlying carrier network can be subject to a termination charge. Once the Internet telephony calls interconnect with a carrier network, the underlying paradigm of 'untethered' does not hold, as the termination becomes carrier-dependent. Hence, the logic of non-applicability of termination charges does not hold.

7.6 Access to Emergency Services

The facility to call the nearest authority, such as the police, fire station, and hospital, in an emergency has been termed as access to emergency services. The legacy telephone network users can summon emergency services such as ambulance, fire, and police using a well-known emergency service number (e.g., 9-1-1 in North America and 1-1-2 in Europe). Location information routes emergency calls to the appropriate regional public safety answering point (PSAP) to serve the caller. The PSAP then dispatches local responders to the emergency site as per the requirements.

Accurate identification of the subscriber's geographical location is necessary when availing emergency services. The concept of emergency number calling has changed with the introduction of mobile services. It is envisaged that the caller's accurate location will also be available to the authority handling emergency situations along with emergency number calls. The TSPs use different technologies to provide location services, depending on whether the call originates on a fixed landline or mobile. VoIP services, especially in 4G long-term-evolution (LTE) networks, provide additional challenges for location and caller identification, as they do not use the numbering scheme used in the circuit-switched PSTN/PLMN.

7.6.1 Emergency Services of VoIP Providers

With the deployment of VoIP services, standardisation organisations, such as the Internet Engineering Task Force (IETF), the National Emergency Number Association (NENA), and the Third-Generation Partnership Project (3GPP), have developed architectures to enable emergency services for IP-based devices (Tschofenig et al., 2010).

Since 2005, the FCC in the United States has required providers of interconnected VoIP services to provide Enhanced 911 (E911) service to their customers. The interconnected VoIP providers must either (i) provide call-back and location information that a PSAP or other public

safety authority is capable of receiving and using to handle the call or (ii) in instances where the PSAP is not capable of receiving this information, must transmit all 911 calls to the appropriate PSAP via the wireline E911 network. The VoIP providers implement the technical details of obtaining location and user information for VoIP calls using automatic number identification to enable E911 services (FCC, 2013). Similarly, in its regulatory impact assessment conducted in 2007, Ofcom indicated the benefits of mandating that emergency calling services be enabled for VoIP calls (Ofcom, 2007).

Realising the need to migrate the emergency services based on circuit-switched technology to IP-based, the FCC released an order to migrate the US emergency service to Next Generation 911—NG911 (FCC, 2024). Though this regulation currently applies to wireline telecom providers, cellular mobile communication service providers, and interconnected VoIP service providers, the basic framework can be applied to OTT coms in the future. When using IP calls, the chances of caller ID masking and spoofing are possible security threats. However, end-to-end detection of caller ID spoofing attacks is being developed to mitigate security attacks of IP-based emergency calls (Mustafa et al., 2016).

In its consultation on Internet telephony regulation, the TRAI invited comments from various stakeholders on whether or not such an emergency calling service is possible in the case of Internet telephony service. Based on the responses, the TRAI recommended that the UL/UL (VNO) licensees that provide Internet telephony services may be encouraged to facilitate access to emergency number calls using location services; however, they may not be mandated to provide such services at present (TRAI, 2017). It also stated that subscribers may be informed about the limitations of unambiguously providing Internet telephony subscribers with access to emergency services. The same was included in the DoT UL amendments. However, the VNOs were mandated to provide emergency services through their parent TSP (DoT, 2018b).

In summary, Table 7.1 provides extant interconnection and emergency services regulations. It is to be noted that the MNOs and VNOs that provide VoIP services are required to provide emergency services. However, pure-play ISPs are exempt from providing the same. With the evolution of enhanced emergency service architecture such as NG911,

Table 7.1 Existing regulations on interconnection and emergency services

Licence type	Interconnection			Emergency services
	Across PSTN/ PLMN	*Between Internet telephony <–> PSTN/PLMN*	*Across Internet telephony*	
UL with access service authorisation	√	√	×	√ TRAI recommends Internet telephony/ VoIP providers to provide
UL (VNO) with access service authorisation	√	√	×	√ TRAI recommends Internet telephony/ VoIP providers to provide
UL (VNO) with Internet service authorisation	×	×	×	×
UL with Internet service authorisation	×	×	×	×

Source: Adapted from Prasad and Sridhar (2023).

future regulation should also mandate that significant OTT coms provide emergency service.

7.7 Number and Data Portability

7.7.1 Number Portability

In telecom markets with enough competition, it is important to provide subscribers with choice. Mobile number portability (MNP) allows the subscriber to retain their existing mobile number when they switch from one service provider to another or from one technology (GSM/CDMA) to another of the same service provider. Portability benefits subscribers and increases competition between service providers, rewarding operators with better customer service, network coverage, and service quality. Considering the growth of telecom services in India and the level of competition, the TRAI released its recommendations for MNP in 2006

to further enhance competition among service providers in the mobile sector and improve QoS and satisfaction of the mobile subscribers (TRAI, 2006b).

As per the recommendations, the MNP was initiated by the Indian government through a neutral third party that will establish a logically centralised database for implementing the MNP database (DoT, 2008). For MNP, the telecom service areas of the country were divided into two zones with eleven service areas, each with two metros in each area. Two third-party agencies were selected to provide the MNP service in the two zones. As per the MNP rules, in a multi-operator scenario, the last operator in the transmission shall be responsible for routing the call to ported numbers. The operators themselves will bear the up-gradation cost of their network. The recipient operator shall be permitted to charge a fee for successful porting directly to subscribers (for details on MNP, refer to Sridhar, 2012).

The numbering allotment in the case of the VNO is provided in DoT (2016). The parent network operator shall allocate the numbering plan to the VNO. The mobile services customers of the VNO can port their mobile numbers using the MNP facility to the service providers of their choice. These provisions shall be considered mandatory in the commercial agreement between the network provider and the VNO.

7.7.2 Data Portability

At this juncture, it is worth looking at developments in OTT communication that the regulators and policymakers have not addressed. The equivalent of a mobile number in OTT communication is the IP address and TCP/IP socket address in which the OTT apps operate. Both of these are dynamically allocated; hence, the number or address portability does not make sense in OTT communication. On the other hand, if an OTT communication subscriber intends to migrate from one app to another, there is a need to port all the contacts and related information about the subscriber from the current app to the new app. This constitutes the close equivalent to number portability.

Article 20 of the European Union General Data Protection Regulation (EU GDPR) endows the data subjects with rights to data portability

(Council of the European Union, 2016). As per the clause, the data subjects can enforce their rights to port data from the current data controller/data fiduciary to another data controller/data fiduciary without hindrance from the controller to which the personal data have been provided.

Further, the EU DMA 2022 states the following concerning a gatekeeper (Council of the European Union, 2022):

> The gatekeeper shall provide end users and third parties authorised by an end user, at their request and free of charge, with effective portability of data provided by the end-user or generated through the activity of the end user in the context of the use of the relevant core platform service, including by providing, free of charge, tools to facilitate the effective exercise of such data portability, and including by the provision of continuous and real-time access to such data.

Unfortunately, the Digital Personal Data Protection Act 2023 does not have this clause (MLJ, 2023). Hence, in the interest of consumers, the data portability across OTT coms should be enforced.

7.8 Containing SPAM Calls

Unsolicited commercial communication (UCC), often referred to as SPAM, is defined as 'any commercial communication that is neither as per the consent nor as per registered preference(s) of recipient' and regulated as per the Telecom Commercial Communication Customer Preference Regulation (TCCCPR) 2018 (TRAI, 2018b). After five years of enacting this regulation, the standard blockchain-based distributed ledger technology (DLT), as advocated by the TRAI, has been implemented by all the licensed TISPs to protect consumers from SPAM calls. Further, TRAI notified the severe penalties for sending SPAM calls that do not comply with the regulation, including blocking the sending entity for two years, on 13 August 2024 (TRAI, 2024). Through all the above initiatives, the ministry of communications data recently released indicates that the UCC calls have been decreasing over the telecom networks.

While the UCC regulations apply to the licensed TISPs, it does not apply to the OTT coms such as WhatsApp Business or Google's Rich Communication Service (RCS) for businesses that allow principal entities (PEs) such as businesses or banks, along with their telemarketers (TMs), to send chats and related messaging to consumers. The OTT communication service is provided over the public Internet, 'untethered' from the underlying physical network. Due to the above regulations on SPAM over telecom networks, the TMs have resorted to SPAM over OTT coms, such as WhatsApp. Hence, there is reason for TISPs to lobby for also bringing such OTT coms under the UCC regulations.

The TISPs provide interoperable services (both voice and SMS) as defined by the 3GPP and associated standards as enforced through telecom regulation. Hence, the DLT platform created by the TISPs provides interoperability and acts as a single framework to contain SPAM calls. Can the OTT messages be integrated into this common platform to contain SPAM over OTT communication?

The XMPP, initially developed by the Jabber open community, has been customised to a great extent by OTT coms such as WhatsApp and Google Chat. The RCS used by Google for business communication was started by the GSM Association, the largest professional body supported by mobile operators since 2008 to provide multimedia support to the SMS. Hence, it may be possible to integrate the OTT messages into the existing DLT platform by using appropriate interfaces. However, the OTT coms are not required to be interoperable as these are not regulated entities. Moreover, unlike the TISPs, whose operational jurisdiction is well bounded, OTTs provide their communication services across countries with varied regulations for containing UCC—hence the reluctance of the OTT providers to ensure compatibility with the DLT platform in India.

The other issue is 'message traceability'. To enhance message traceability for containing SPAM, on 20 August 2024, the TRAI issued directions that messages from all sending entities to the recipients must be traceable from 10 December 2024. However, the applicability of this to OTT coms is ambiguous. The Information Technology (IT) Act 2000 (2008), through section 79, provides immunity to all intermediaries such as OTT coms (MeITy, 2009). However, the IT (Guidelines for

Intermediaries and Digital Media Ethics Code) Rules 2021 has in its rule 4(2) that 'a significant social media intermediary providing services primarily like messaging shall enable the identification of the first originator of the information'. While the OTT coms contend that adhering to this rule will upend the end-to-end security of their messaging services, whether or not the same applies to security and privacy of business messages needs to be re-examined.

Considering all the above, can a telecom regulation such as the Telecom Commercial Communication Customer Preference Regulation (TCCPR) apply to unregulated OTT coms? If so, should they be brought into the regulatory ambit? The option that is always open to the OTT coms is to take proactive steps in containing SPAM messaging despite their business interest in promoting it. This shall be implemented using a robust consumer consent framework and maintaining a repository similar to the 'do-not-call registry' maintained by the TISPs. The regulators across the sectors have realised that the immunity of intermediaries for third-party messages is passé. It is time for the OTT coms to look at the interoperability of their messaging platforms to facilitate curbing spam calls so that uniform rules can be applied.

Based on the discussions above, we summarise the regulatory recommendations for a number of independent OTT coms in Table 7.2.

Table 7.2 Proposed regulation on the number of independent OTT communication services

Regulation	Act/regulation	Mandated or not
Interconnection with PSTN/PLMN	TRAI Interconnection Regulation	Yes
Emergency services	Government authorisation/ Licensing Regulation	Yes, for significant ones
Data portability among platforms	Rules under the DPDP Act	Yes
Interoperability amongst platforms	Digital Competition Act/Rules	Yes
Unsolicited commercial communication	The TCCPR	Yes, for significant ones

Source: Authors' own.

7.9 Conclusion

Interconnection, interoperability, and portability provide choices for the consumers and prevent the lock-in effect. The interconnection and interoperability through standardised interfaces exist for telecom networks. However, these are new areas for the regulation of OTT communication. A termination charge is one regulatory mechanism that ensures that calls which originate in one network are terminated seamlessly in another. While termination charges are often zero when the networks are symmetric, the asymmetric flow of calls or messages across networks can be corrected by levying a ceiling on termination charges. While this is a common practice in telecom, it is challenging for both domestic and international messages that originate from OTT Internet telephony apps that terminate on landline or mobile networks. The regulation in most countries is to treat such calls similarly to the existing termination charges regime as specified in the IUC regulation. Further, the existing regulations on emergency services applicable for TSPs and VNOs shall be mandated for OTT Internet telephony service providers who terminate their calls in landline/mobile networks. The first regulatory intervention on interoperability of OTT app-based number-independent communication services has already started in the EU with the pronouncement of the EU DMA 2022. In the United States, the next generation of emergency services using IP-based architecture is mandated for all telecom providers, including interconnected VoIP providers. Similarly, the EU DMA 2022 also enforces data portability based on user requests so that the users will not be locked into one platform. The interoperability and portability requirements will provide opportunities for improved competition, and even for some Indian start-ups, to enter the OTT communication space dominated thus far by the large Big Techs.

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8
Universal Service Policy

8.1 Introduction

Universal service refers to the provision of service—in this case, telephony and broadband—to all areas, including rural and remote areas, and to all demographics, including low-income households. The costs of such services are often partially compensated through a special corpus funded by carriers and the government.

A universal service policy is dynamic by its very nature. Shifts in technology, markets, and business constantly render extant policies obsolete. Traditionally, universal service (US) referred to basic telephony, but newer services started to be introduced with technological advances, especially after the advent of digitalisation (Jayakar & Sawhney, 2004). In India, mobile services were included within the ambit of the universal service obligation (USO) in 2006 and broadband in 2009 (Jain & Raghuram, 2010).

There are three important questions with regard to a US policy:

(1) How should this policy be funded?
(2) What services should be subsidised?
(3) What mechanism should be used for disbursement of funds?

8.2 The Universal Service Levy

Rural coverage and US provisioning are licensing requirements for basic fixed-line service providers in most countries. The Government of India (GoI), as part of the National Telecom Policy 1999, created the Universal Service Obligation Fund (USOF) by charging a universal service levy (USL) at a prescribed percentage of the revenue (5 per cent of the AGR)

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earned by the operators holding different type of licences (Sridhar, 2012). Consequently, the USO was removed from licence terms, although certain roll-out obligations were retained.

The USL reflects the belief that telecom licensees needed to give back to society for the privilege of being chosen to provide telecom services without being burdened with a USO in unviable areas. This approach implies that services in under-served areas are being subsidised by network operators and customers in viable markets.

8.3 Uses of the USL

Over time, the USOF, renamed Digital Bharat Nidhi, has grown in size, as illustrated in Fig. 8.1 (DBN, 2024):

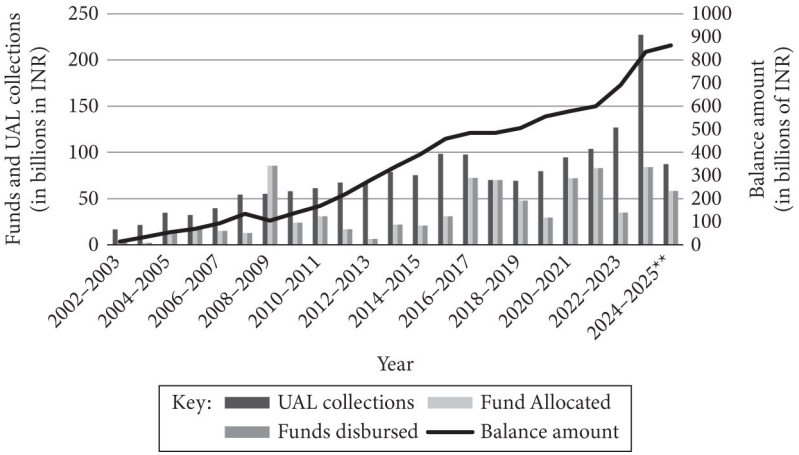


Fig. 8.1 The growth of USOF in India over the years (fund status in Rs. Cr.)
Note: **Until December 2024.
Source: DBN (2024).

As can be seen, the balance amount in the USOF is about INR 863 billion (about USD 10 billion).

A brief review indicates the following trends:

(1) The share of the USOF distributed for village public telephones has decreased considerably, indicating the decreasing role of

shared telecom services and the increasing trend of personalised communication services such as household and mobile telephony.

(2) A substantial portion of the USOF is distributed for the creation of general telecom infrastructure in rural and remote areas of the country.

(3) A significant portion of the USOF is also allotted for new telecom initiatives such as green telecom.

An explanation is in order, since a large amount of the USOF is being distributed for general telecom infrastructure. The GoI initiated a nationwide optic-fibre network christened 'BharatNet' with the objective of connecting all the 250,000 village panchayats in the country through an optic-fibre backbone. The project, implemented in phases, uses a combination of fibre-optic cables, satellite connectivity, and wireless technologies to extend the Internet to rural areas. The initiative is part of the 'Digital India' programme and is managed by Bharat Broadband Network Limited (BBNL), a special-purpose vehicle under the Department of Telecommunications (DoT). On average, about INR 40 billion (USD 0.5 billion) per year and a total of INR 160 billion (USD 2 billion) over the past four years have been spent by the USOF on building out the BharatNet Project.

The salient features of the BharatNet Project are as follows (DBN, 2024):

(1) High-speed broadband for rural India—this provides 100 Mbps broadband connectivity to all 2.64 lakh Gram Panchayats (GPs) across India.

(2) Non-discriminatory access to the network—the network is open for all TSPs to use the infrastructure to offer broadband and mobile services. It ensures fair and equal access for mobile operators, ISPs, Cable TV operators, and content providers who can leverage BharatNet's backhaul to expand their services in villages, thus making high-speed Internet more widely accessible.

(3) Digital services in rural areas—this provides infrastructure for essential digital services, including E-health (telemedicine, remote

consultations), E-education (online learning, digital classrooms), E-governance (citizen services, Aadhar authentication, rural banking), and e-commerce and digital payments (unified payment interfaces (UPI), rural fintech solutions).

(4) Infrastructure for private and government operators—BharatNet serves as a backhaul network for mobile operators (4G, 5G expansion in villages); ISPs for last-mile connectivity; and state governments for broadband in schools, hospitals, and police stations.

(5) BharatNet, implemented in three phases—

- Phase I (completed—December 2017): 1.20 lakh GPs connected; 3.12 lakh km of optical fibre laid. Implementation is done through Bharat Sanchar Nigam Ltd (BSNL) (70 per cent of the work), Power Grid Corporation of India Ltd (PGCIL), and RailTel (15 per cent each).
- Phase II (ongoing): an additional 1.25 lakh GPs will be connected. A mix of underground fibre, aerial fibre, radio, and satellite is used for implementation using multiple agency-led models, that is state-led, private-led, and central public-sector undertakings (CPSU)-led models. Eight states are implementing their own networks, whereas implementation is done entirely by private companies in Punjab and Bihar. The CPSU-led model was implemented by BSNL, RailTel, and the PGCIL in Uttar Pradesh (UP), Madhya Pradesh (MP), and Sikkim. Over 5,000 remote/hilly GPs are to be connected via satellite.
- Phase III (approved in August 2023): existing networks will be upgraded and connectivity will be extended to remaining villages. Under the amended programme, an estimated 2.65 lakh GPs are proposed to be connected in a ring network to improve reliability (BBNL, 2024). Last-mile connectivity will be implemented via BharatNet udyamis (BNUs), that is village entrepreneurs, ISPs, and self-help groups (SHGs). The plan is to provide 1.5 crore rural home fibre connections in the next five years using BNUs. BSNL, appointed as the project management agency, will provide Internet-leased lines to over 7,000 blocks with sufficient bandwidth to ensure a minimum 25 Mbps download speed to every home fibre subscriber.

(6) Current status (as of December 2024): the optical fibre laid is around 6.92 lakh km, and around 81 per cent of target GPs (2.14 lakh) are service-ready. Over 1.04 lakh public Wi-Fi hotspots have been set up in villages, and 12.21 lakh homes now have fibre-to-the-home (FTTH) connections. As of December 2023, over 95 per cent of the allocated budget (Rs 39,825 Cr) had been disbursed.
(7) Network monitoring and maintenance: centralised network operations centres (NOCs) in Delhi and Bengaluru will monitor performance. BSNL, RailTel, and the PGCIL will manage operations and maintenance (O&M). Measures have been taken to prevent fibre cuts, theft, and power supply disruptions.
(8) Economic growth and digital inclusion: providing high-speed Internet for businesses and start-ups encourages rural entrepreneurship and reduces migration to cities by improving local employment opportunities. It also supports Digital India, and other Make in India initiatives.
(9) Future plans: these include enhancing connectivity to non-GP villages and remote regions, strengthening BharatNet Udyam and leveraging artificial intelligence (AI) and advanced technology to improve monitoring and performance.

As we design a US scheme for 5G and beyond, we need to revisit the fundamental principles behind the concept of US.

8.4 Theoretical Issues: What to Build

There is growing literature on theoretical frameworks for choosing the services included in USO schemes.[1] In line with the canonical literature on the state's role in economic theory, Gasmi and Recuero Virto (2005) discuss the role of the USO in terms of the 'market efficiency gap' and

[1] In addition to the choice of services, one must also decide the level at which a service will be provided. The concepts of universal service (US) and universal access (UA) to telecommunications and information and communication technology are distinct. US refers to service at the individual or household level, for example a telephone in each home. UA refers to a publicly shared level of service, for example through public payphones or Internet telecentres. However, they are also intrinsically linked to each other, as UA is the precursor for US.

the 'viability gap'. The market efficiency gap refers to bottlenecks in the free working of the market mechanism that, once removed, would enable a particular service to be provided without further intervention by the USO organisation. Examples include high usage charges on spectrum, high interconnection charges, and discriminatory access to the local loop. A viability gap, on the other hand, refers to a situation where the provision of a service is beyond the ability of the market, even when allowed to function in the most optimal way.

A market efficiency gap requires the easing of bottlenecks in the working of markets and does not call for a US policy. Even a viability gap in itself is not a sufficient condition for the utilisation of USO funds. Sawhney (2003) introduces two further criteria: first, a new communication technology should be provided universally once it becomes a 'consumption norm', since citizens cannot function effectively without it. Second, universalisation of a service becomes a necessity if the lack thereof creates impediments and roadblocks at a systemic level.

The notion of a consumption norm goes back to the work of Adam Smith and refers to the bare essentials required by the poorest citizens to function in society. The philosopher John Rawls refers to these as 'primary goods' (Rawls, 1971). Reflecting the spirit of the consumption norm, the EU Universal Service Directive of 2002 (European Parliament, 2002) identifies the following necessary condition for a service to be included within the ambit of US: 'in the light of social, economic and technological developments, has the ability to use the service become critical for social inclusion?'

Some governments have tried to operationalise the notion by setting a trigger mechanism in the form of a minimum number of users that would need to be crossed before the provision of subsidies for its universalisation is considered. As cited by Sawhney (2003), the Californian Assembly Bill 3643, which became law on 1 January 1995, set the threshold at 65 per cent penetration of the residential market (California Public Utilities Commission, 1996). In line with this approach, in the same year, the EU decided not to expand the definition of USO to broadband, citing the low levels of uptake in the society at large.

The second criterion identified by Sawhney is related to the system-centric forces that necessitate the inclusion of a particular service. For example, the development of factory production accelerated the movement for universal education in the nineteenth century, as factory owners needed educated workers (Sawhney, 2003). Similarly, accelerated globalisation and the attendant cross-border travel led to a standardisation of the training of aeroplane pilots in the early 1990s. In telecommunications, the need for nationwide systems for governance, service delivery, and commerce is creating pressure to develop digital infrastructure in rural areas.

Prasad (2013) introduces 'temporality' as a third criterion for choosing services. Temporality refers to the time it takes to build an ICT network. If an ICT network takes time to build, starting the process before the service becomes a consumption norm or system requirement makes sense.

Based on these criteria, we identify a two-pronged strategy for services to be funded by a USL:

(1) 4G for all and
(2) fibrisation of towers for 5G in urban and semi-urban areas.

8.4.1 Good 4G: A Consumption Norm

The country's current Internet penetration was about 52.4 per cent at the start of 2024 (Datareportal, 2024). Hence, broadband service does not qualify as a consumption norm that needs to be guaranteed through government support. From a systemic point of view, however, the usefulness of broadband cannot be denied. Even if it has to be weighed against the usefulness of other systemic inputs such as education and health, we must recall that broadband can enable universal health and education through remote education and health services. Hence, from a systemic point of view, rural areas need public networks on a par with urban areas, that is at 5G level. However, this mandate depends on the ability to provide complementary inputs for remote education and health services. Until such inputs are available, the mantra should be good-quality 4G.

8.4.2 Fixed-Line Infrastructure for 5G in Urban and Semi-Urban Areas: A System Requirement

Wireless connectivity has powered the telecom revolution in India. By the end of November 2024, wireless subscriptions, at 1148.65 million, accounted for 96.76 per cent of total telephone subscriptions, whereas wireline subscriptions, at 38.5 million, accounted for only 3.24 per cent (TRAI, 2025).Similarly, 903.79 million wireless broadband subscribers accounted for 95.66 per cent of total broadband subscribers (data as of 31 November 2024). Mobile broadband users alone accounted for 95.11 per cent of subscriptions in November 2024, while wired broadband subscribers stayed at 40.97 million, accounting for only 4.34 per cent (TRAI, 2025). Fixed wireless subscribers were 0.55 per cent at 5.16 million. Wireless connectivity is a large part of not only the access network but also the backhaul network. For instance, the share of microwave spectrum in backhaul is estimated to be around 70–80 per cent (Ericsson, 2022).

However, the lack of adequate fibrisation will become a significant bottleneck for the roll-out of 5G. 5G technology uses a high-frequency spectrum and operates in small cells, which need fixed-line backhaul connectivity due to the quantity and speed of data involved. Given the potential of 5G to transform the economy, this amounts to a system requirement of the kind that education had in the early years of the Industrial Revolution.

The need to deploy US funds to build out fixed-line backhaul/fibre to the tower also stems from 'temporality' (i.e. the time taken for the build out), which makes it incumbent to start immediately even in advance of the same being part of a consumption norm or a system requirement.

India's per capita fibre coverage is around 0.09 km, way below its global counterparts (China's per capita fibre coverage is 0.87 km, while that of the United States and Japan is approximately 1.7 km) (Tele.net, 2020). Approximately 35.11 per cent of telecom towers/base transceiver stations (BTSs) were fibrised as of June 2022. The National Telecom Policy 2025 (NTP-25) aims to increase fiberisation to 80% of telecom towers by 2030 (DoT, 2025). The fiberisation is expected to improve backhaul speeds and will enable the advancements in access technologies to be effectively used. A focused approach to fibrising existing towers and scaling

up fibre-connected towers from 35 to 80 per cent in two years would be preferred, as it would yield immediate and quantifiable benefits in 5G and beyond.

8.5 Theoretical Issues: Who to Charge

As of now, telecom operators can be said to inherit the government's obligation to provide universal access (UA) to communication services, which flows from the government's exclusive privilege to provide communication services.

However, currently, this obligation is divided into two parts:

(1) a levy that finances the activities involved in the obligation, and
(2) the actual build out of the network, which is carried out through a separate process of tendering.

The current structure of US was formulated in an environment where it could be said that 'the network is the service' in the sense that voice telephony comprised the major service element. The availability of the network at affordable prices was all that was necessary to ensure that the service reached the end users. However, this is not the case today. In a 5G world, a network is only the launching pad on which a thousand services can bloom. Hence, the ecosystem for US needs to evolve.

The government cannot be said to have an exclusive privilege to provide the many services available today. This absence of an exclusive privilege implies that the entities in the services layer cannot be said to have a roll-out services obligation, which translates into a USL that they are liable to pay to fund the roll-out being done by the network providers. Therefore, the universal levy should only be charged to the network providers, as they are responsible for the physical roll-out of the infrastructure service providers, and the service providers should be absolved of the levy.

However, we have argued in Chapters 4 and 6 that entities riding on the network—VNOs, significant OTT coms, and OTT video service providers—pay a BIL to finance the build out of the public network. This recommendation aligns with the goal of static efficiency (minimising the

effect of levies in distorting unfettered market activity) without overtly compromising the objective of dynamic efficiency (incentivising technological dynamism). It also aligns with the principles of classical net neutrality.

Given these considerations, our design for US is described in section 8.6.

8.6 The Twin Engines of Digital India: Infrastructure Supply and Demand

We propose the USOF be renamed as the Broadband Infrastructure Fund (BIF), financed by a BIL on the VNOs, significant OTT coms, and significant OTT video service providers that simultaneously serves two purposes—it finances the build out of the telecom infrastructure and also ensures those making most use of the network contribute to its development.

Hence, we recommend the following:

(1) The USL, as it exists today at 5 per cent of AGR, will be charged to the network providers to contribute towards the USOF.
(2) A new BIL of 3 per cent of the AGR will be charged to all VNOs, significant OTT coms, and significant OTT video service providers on their revenues from their Indian operations net of the revenue involving specialised contracts into which they may have entered with network operators.

The revenue models of the old and new proposals are referred to in Chapter 4 on Licensing.

8.7 Conclusion

Realising that 5G+ networks and services are very different from the earlier technologies, and to ensure that 4G+ networks reach every netizen in the country, we propose reconsidering the way the USL is collected and the USOF is disbursed. Since backhaul fibrisation with adequate

capacity is needed to support the 5G+ access networks, we recommend the speedy upgrade of tower and backhaul fibrisation using the BIF. We propose a BIL to be applied at the current rates (i.e. 3 per cent of AGR) to VNOs, significant OTT coms, and significant OTT video service providers to contribute to the BIF. The applicable revenue should be net of the revenue earned via specialised contracts between service providers and the network operator. This exclusion will encourage the build out of unique network slices to 5G+ networks to provide superior-quality services. The USL remains at the government-mandated current rate (i.e. 5 per cent of AGR) and is applicable only to network providers.

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9
The Future of Telecom Regulation

9.1 Introduction

Over the past fifty years, the digital ecosystem has developed globally with few impediments arising from national sovereignty, geopolitical tensions, or market barriers. However, while immense technological possibilities continue to open up, a similar development trajectory cannot be expected over the next few decades. Technology is becoming an arena of great power rivalry rather than a sphere of market competition (Kennedy & Lim, 2018). Nation states are reasserting their power vis-à-vis technology giants located in the private sector (Sheng, 2022). Concerns about privacy and infringement of human autonomy are dampening optimism about the potential of technology to bring about positive change, even as the role of technology in national security creates a counterforce overriding these concerns (Bradford, 2023). The rise of electoral autocracies also portends a future in which the possibility of technology being used as an instrument of control is as high as its use as a tool for liberation (Matovski, 2021). In the face of these developments, to what extent can the regulatory framework we propose balance the different forces at play to enable rapid, inclusive, and environmentally responsible technological development?

Expecting our framework to be sufficiently comprehensive to address all the complex challenges would be asking too much. However, our proposal already includes a set of solutions for some future developments.

9.2 Impact of Regulatory Interventions

The key pillars of our regulatory recommendations are functional separation of the infrastructure and services layer, diagonal equity between

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TISPs and OTT coms, and digital neutrality. These recommendations enable the following developments, which are of relevance to the important debates of the day:

(1) Enhanced capability of national governments to regulate OTT coms: as part of our recommendations, significant OTT coms will be included in the purview of the government's authorisation regime. They will also be subject to taxation in the same manner as traditional communication service providers. This inclusion recalibrates the balance of power between governments and technology companies in the right direction, at the same time putting in place guardrails against overreach by the state machinery. Further, we recommend the registration of cloud storage providers. Hence, our framework is capable of addressing concerns related to data nationalism, wherein governments are keen that data about their citizens and organisations be stored within their territorial jurisdiction.
(2) Heightened competition in the services layer: our recommendations can bring about greater competition and innovation in the services layer through the functional separation of services and infrastructure and the non-discriminatory access to infrastructure. Competition can play a role in ameliorating cyber security, privacy, autonomy, and climate change concerns. Innovative service providers that promise higher levels of data protection, accountability for using private data, transparency about using algorithms for behaviour modification, and a focus on energy-efficient solutions may emerge. However, a note of caution must be struck about the capability of competition to address all possible harms arising from the unfettered working of the market mechanism.
(3) Generation of a higher level of resources for infrastructure expansion: we recommend a Broadband Infrastructure Levy (BIL) applicable to large traffic generators among OTT coms to finance infrastructure build out for 5G and beyond. Bringing the network's intensive users into the ambit of the universal services levy is a game changer that could dramatically enhance resource mobilisation for future technologies.

Nevertheless, governments will continue to exercise a significant role in the digital ecosystems within their countries. We expect four main models to emerge:

(1) the US model of market-led innovation;
(2) the Chinese model of state-directed innovation;
(3) the European model of innovation, which is subject to a rights framework; and
(4) the model of emerging economies that balance growth, sovereignty, and individual rights.

The US model is currently based on unfettered technological innovation. In future, while there will be forces in society calling for safeguarding privacy, autonomy, and climate change issues, these will be overwhelmed by the imperative to preserve the leadership position in global technology development. We do not expect functional separation, diagonal equity, or digital neutrality to emerge as strong organising principles. Instead, TISPs and OTTs will attempt to become platform captains of their walled gardens.

The Chinese model involves asserting state power over the economic muscle of technology giants and subjugating technology to serve the interests of the Chinese state. In the process, individual freedom and privacy are compromised. While the US and Chinese models appear to be opposites, they share a common purpose of using technology developments for national security and geopolitical competition. As in the US model, we do not expect functional separation, diagonal equity, or digital neutrality to emerge as strong organising principles.

The European model is based on a more thoughtful assessment of technology's impact on society, the environment, private freedoms, and the public good. The introduction of various regulations such as the General Data Protection Regulation (EU) 2016/679 (GDPR), the Digital Markets Act, and Digital Services Act has proved this. These regulations constitute the voice of reason in the current digital landscape. Consequently, we expect functional separation, diagonal equity, and digital neutrality to emerge as strong organising principles. However, given the circumscribed role of Europe as a technological powerhouse in today's world, it may be a voice crying out in the wilderness.

The emerging economies will attempt to play catch-up in the technology sweepstakes. They will attempt to leapfrog to the frontier of advanced technology through AI and leverage high technology to supply the basic needs of their populations. Governments may use technology to increase their control over their populations and restrict the space of civil liberties. Alternatively, some leaders of emerging economies will align with Europe to call for more responsible use of emerging technologies such as 6G and AI. Whether governments attempt to use technology to increase their own power or that of the citizens, the power of technology companies is likely to be circumscribed. Hence, functional separation, diagonal equity, and digital neutrality may emerge as organising principles for regulation.

Beyond the broad contours presented above lie important details about the precise nature of 6G technologies. We now turn to examine these.

9.3 Recent Developments in 6G Networks

The ITU aims to finalise the standardisation of IMT-2030 6G by the end of 2030, concurrent with the 3GPP, completing their Release-23 6G standardisation. The ITU established a workgroup in July 2018 to research 6G systems. While there is currently limited information about 6G standards, international standardisation bodies are anticipated to define them by 2030. Recognising the growing demand for IoT-related products in the future, both industry players and policymakers acknowledge the necessity of developing the next generation of wireless networks. Research and development for 6G are underway, with network availability expected by 2030. Experts stress the importance of a unified global standard for 6G, considering it a cornerstone of industry digitalisation. Achieving a global consensus on the technical specifications for 6G technology is deemed crucial.

Organisations such as the Next G Alliance in North America, FutureForum in China, 6G-IA in Europe, 6G Forum in Korea, and the Beyond 5G Promotion Consortium in Japan are at the forefront of the research phase for future 6G systems. As 6G is expected to enable new use cases and support emerging technologies such as augmented and

virtual reality, autonomous vehicles, and the IoT, collaboratively developed standards will enable the sharing of knowledge, expertise, and resources, which leads to the development of new and innovative technologies. By developing standards collaboratively, stakeholders can identify and address potential issues early in the process, leading to enhanced safety and security. As 6G networks will digitise more legacy, industrial, and critical real-world functions, there is an increased vulnerability to disruptions caused by security-associated cyber-attacks on 6G networks and systems. The hardware supply chains essential for 6G adoption and operations will be crucial for advancement and potential attack targets, becoming a competitive battleground.

The policy engagement with 6G standards has been primarily driven by national security concerns, which have limited their focus to specific areas. Increasing tensions in the US–China relationship are starting to bleed into telecommunication advancements—right from the point of standards creation. However, this narrow approach makes it challenging to address economic issues through international rule setting. Moreover, the standards ecosystem is complex and requires attention to ground-level challenges, such as managing consensus across different bodies, engaging industry stakeholders in a lengthy consultation process, and ensuring quality standards outcomes. Quality research and development are essential for producing robust standards proposals requiring funding and resources. With growing geopolitical tension, these challenges stand to be exacerbated. While increased attention to standards is a good sign, it should lead to a deeper understanding of their importance and value in emerging technology rule setting and their role in facilitating digital trade (CUTS, 2024).

The ITU Radiocommunication Assembly (RA) has established a strategic agenda to drive the development of IMT-2030 for 6G and ensure the sustainable use of spectrum and orbital resources. A resolution was adopted during RA-23, outlining the framework for developing standards and radio interface technologies for the sixth generation of mobile systems (IMT-2030). Additionally, RA-23 embraced a resolution on gender equality, aiming to enhance, expedite, and broaden women's active participation in the work of the ITU radiocommunication sector (ITU-R).

9.3.1 Neutral Hosts

The construction of private networks to suit users' varying demands will become more important when MNOs deploy 6G networks and services. These networks must guarantee super-high-speed connectivity with very low delay tolerance to support applications in tactile Internet, 3D holographic telepresence, and human-body communication. In this context, the NH technologies and NH operators assume importance in the communication ecosystem, as explained in Chapter 1.

Earlier forms of NHs were tower companies, such as the American Tower Corporation or Indus Towers, which leased their passive tower infrastructure to multiple MNOs. However, in 5G, the sharing of the network elements by the NHs to MNOs can range from passive infrastructure to network slicing and even spectrum sharing. The MNOs, on the other hand, also benefit without substantial sunk costs in infrastructure deployment in local areas.

Apart from NHs providing CNPNs, 5G Public–Private Partnership Projects (5GPPP) and European Commission Horizon 2020 (H2020) initiatives have also embraced the 5G-enabled NH framework for real-world deployments in three European cities: Barcelona in Spain, Bristol in the United Kingdom, and Lucca in Italy (Fernández-Fernández et al., 2021). The study by Fernández-Fernández et al. (2021) indicates the benefits of using the NH model for deploying, provisioning, and managing vertical services over a virtualised and shared infrastructure. In a neutral host pilot (NHP) project, the city of Espoo considers an alternative approach to the traditional uncoordinated jungle of mobile operator antennae. Instead of telcos constructing 5G small cells and smart 5G light poles along streets, the city is planning on a model to deploy shared 5G base stations operated by an NH operator. This NH, having its local spectrum licence (e.g. 26 GHz), provides the 5G facility for national telcos, who run their services as virtual operators and compete on top of the NH platform. This trend likely affects the national mobile ecosystem and speeds up local IoT connectivity innovation. Apart from shared 5G connectivity platforms, the project also envisions a shared data platform wherein the data collected by IoT devices and sensors are collated and shared using a standard interface for the development of applications by local ecosystem partners (Sridhar & Hammainen, 2020). The trend of

NH being part of the value chain is likely to continue as 6G networks are deployed.

Some countries, including India, have limited the CNPNs solely for captive use and hence do not allow them to be interconnected with any PLMN/PSTN or the Internet. Investing in 5G networks is optimal if the captive network can connect to the PSTN/PLMN. This can be done by an NH operating the CNPN and extending the connectivity to PSTN/PLMN. By restricting CNPNs from being interconnected with the public networks, the economic viability of CNPNs is questionable. The regulatory guidelines should be augmented to incorporate NHs in the equation. NHs bring in new dimensions of competition in the telecom sector, at the same time benefiting both the business and retail customers (Sridhar & Prasad, 2022). Depending on the type of NH, an appropriate licensing/authorisation regime may be applied.

9.4 Emerging Regulations in the 6G World

When 6G technologies and service deployment evolve, the specific characteristics of 6G networks cause concern beyond the core areas of communication. In this context, we explore the applicability of appropriate regulations when 6G comes into being in 2030.

9.4.1 Spectrum Regulation

The appropriate allocation of the millimetre wave and Terra Hertz spectrum is critical for successfully deploying 6G. The millimetre waves and THz spectrum bands used in 6G networks differ from conventional radiocommunication bands, including limited propagation, high directivity, and high path losses (Boccardi et al., 2014). The above characteristics require standards to be developed for licensed bands by 3GPP and unlicensed bands by the IEEE. THz communications are still nascent, so its standardisation efforts are just beginning. The IEEE 802.15.3d–2017 was proposed in 2017, the first standard proposed for THz fixed point-to-point links operating at carrier frequencies between 252 and 321 GHz. For developing nano-network standards at THz

frequencies, IEEE P1906.1/Draft 1.0 discusses recommended practices for nano-scale and molecular communication frameworks (Elayan et al., 2020). However, international cooperation in frequency assignments for 6G THz communication is important to provide interoperable networks and systems worldwide.

Further, 6G network deployment includes very small microcells to provide the required coverage and high capacity. This requires shared access to public infrastructure, such as street furniture and municipal facilities, for installing THz antennae. The Directive (EU) 2018/1972 of the European Parliament and Council of 11 December 2018 established the European Electronic Communications Code (EECC) as the overall framework of guidelines governing digital communications in the EU (European Parliament and Council of the European Union, 2018). Chapter II Article 43 deals with RoW. It stipulates that, in granting rights to communications network providers to install facilities over and under public/private property, member states should use simple, efficient, transparent, and publicly available procedures, applied without discrimination or delay and follow the principles of transparency and non-discrimination in attaching conditions to such rights (Mitra et al., 2023). In its recommendation on 'Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed', the TRAI indicated the setting up of a national RoW policy and a council to implement the same. Appropriate RoW policies for using shared public spaces and an expedited approval process are required for deploying 6G microcells. Accordingly, telecommunications RoW rules were proposed in 2024 by the DoT (DoT, 2024).

While these would enhance 6G access, as explained in the previous chapters, strengthening the backhaul through extensive fibrisation is also required to support 6G access network speeds.

9.4.2 The Ethics of AI

AI will be deeply engrained in 6G network architecture, playing a critical role in designing, deploying, and optimising network services. However, this increased reliance on AI has also sparked ethical concerns, particularly privacy, trust, and accountability. As we move towards a future

powered by 6G networks, addressing these ethical considerations will ensure responsible and equitable deployment of AI-driven 6G technologies. The large amount of data collected at the intelligent edges and used by AI/ML algorithms can be misused, causing information leakage or tampering. With AI systems becoming more autonomous in decision-making in 6G, there is a growing concern about their safety, transparency, and accountability, especially regarding their potential impact on living beings. This may pose serious concerns to the integrity of every individual, institution, organisation, and even the country at large. Further, ethical issues can arise at the individual and societal level. Individual ethical concerns include the protection of privacy, security, safety, and dignity and harms due to misuse, tampering, or the non-transparent black-box-based approach used in AI/ML algorithms (Alakwe, 2023). At the societal level, the issues include fairness and justice, transparency, surveillance, democracy, and civil rights, which are caused by bias in the algorithms. Such ethical issues in 6G networks deployed in health-care settings are presented in Srivatsava et al. (2021).

Further, fully automated AI-based 6G networks will operate with minimal human intervention in network operations. While AI systems' behaviour is based on their training, they may struggle to navigate exceptional situations in the same way as humans. This becomes particularly critical in safety-critical systems, such as driverless cars or medical diagnosis systems, where decisions directly impact physical safety. Without transparency and explainability, users may find it challenging to comprehend the systems with which they interact, including their associated consequences, making it challenging to hold involved stakeholders accountable. Hence, in 6G-powered systems, trust becomes paramount. Continuously monitoring an AI tool for decision-making would demand considerable time and resources, making the use of it impractical. However, a lack of supervision could pose significant risks to our safety, security, and societal values (Wu, 2022).

Although efforts to regulate AI usage are underway or already in place, the swift progression of AI technology raises scepticism about whether or not policy measures alone can adequately address ethically dubious AI applications. To address these challenges, the 'ethics-by-design' approach, based on the conviction that technology is not neutral and that values can, to some extent, be embedded into the design

process, is advocated in 6G network design and development. This proactive approach can be valuable in developing intelligent network systems that respect human values. Implementing guidelines, laws, and regulations is crucial for addressing data ethics and ownership in 6G, ensuring a balance between risk and benefit. This comprehensive approach aims to mitigate ethical concerns and promote responsible use of AI in 6G networks. Further, effective AI development demands significant investment. As automation and intelligent machines increasingly influence government processes, lower-income countries may lag, particularly those in the Global South. Policymakers need to take proactive measures to prevent AI from exacerbating global inequalities. This may entail initiatives such as data sharing and collaborative approaches. Moreover, institutionalised mechanisms are needed to enforce ethical norms such as fairness, transparency, and accountability across all networks and sectors. The EU has taken the first step in releasing guidelines on trustworthy AI systems and has released the Artificial Intelligence Act 2024 (EU, 2024). Other countries worldwide must also come together to provide global guidelines for building ethical AI systems. Standards on AI ethics, such as the IEEE 7000 series, are still evolving, and global effort is needed to enable the standard development process towards a trustworthy AI system in the context of 6G networks (CUTS, 2024).

9.4.3 Cybersecurity and Privacy

The localisation accuracy in 6G provides several benefits, including determining precise indoor locations, thereby enabling services such as emergency health care and disaster prevention. The NextG alliance has identified many use cases, including sensing and monitoring of humans in local 6G networks to provide services such as monitoring a patient's health condition through in-body sensors and sensing human activities in hospitals of the elderly, to name a few (Ahokangas et al., 2024). However, if not used properly, these 6G local networks and services also have the adverse effect of surveillance and psychological manipulation, jeopardising individuals' rights to privacy. Cyber warfare, in which adversaries hack and turn off national critical infrastructure (CI), poses enormous

challenges to national security for countries worldwide. Nation states, with their well-funded operations, have been establishing themselves as the perpetrators of cyber warfare, posing considerable threats to the global society (CUTS, 2024). Given the ramifications of data breaches and cyber-attacks, it is pointed out that the existing regulations, such as the EU GDPR, will have to be revised, taking into account the intelligent processing of personal data in 6G networks (Porambage et al., 2021). India enacted the Digital Privacy Data Protection (DPDP) Act in 2023; subsequent rules were released in 2025 (MeITy, 2023). The Act is enforced by the Ministry of Information Technology (MeITy). Apart from the Privacy Act, the Information Technology Act 2000 (amended 2008), which deals with computer and computer-related offences, is undergoing major revisions in the form of the Digital India Act (MeITy, 2009). Some aspects of privacy as related to telephony have also been captured in the Telecom Act 2023 (DoT, 2023). All these three laws must be synchronised to handle cybersecurity-related offences and intrusions when 6G gets deployed.

9.4.4 Net Neutrality

As discussed in Chapter 6, we argue for moving from net neutrality to digital neutrality to consider the market power of OTT coms apart from that of TISPs. We also argued that with technologies such as 'network slicing', there is a fine line of distinction between reasonable traffic management practices and net neutrality violations.

The question gains more importance, especially in 6G networks, where fine-tuning network parameters (including traffic prioritisation) is possible with intelligence at the network edges. While prior generations were marketed primarily to consumers, 5G+ networks are also targeted at business enterprises. Network slicing, which enables sharing network resources across many customer segments, allows for more efficient utilisation than if each resource were dedicated to a single user or use case. This trend is likely to continue in 6G networks as well. Researchers have argued that strict regulation on net neutrality will impede the development of customised services in 5G and beyond networks (Koenig & Veidt, 2023).

Challenges for the net neutrality regime will continue when 6G use cases such as tactile Internet and human-body communication requiring very low delay tolerance are deployed in 6G networks. This requires careful observation of different possibilities in 6G while considering the possibility of content and user discrimination. In the 6G world, the most important tasks for net neutrality advocates are to ensure a defined quality of service in the public network and encourage competitive markets to provide network services.

9.4.5 Towards Green 6G

Earlier mobile technologies aimed to provide reliable connectivity and ubiquitous coverage. Hence, the energy and environmental concerns were not prioritised during deployment. Due to this, the world has witnessed a proliferation of mobile towers, especially in urban areas. As per the current statistics, the United States leads the world in several cell sites, totalling 7.5 million, followed by Germany and India (Opencellid, 2024). However, over time, both the 4G and 5G technologies embraced the concept of green communications, focusing on optimising resource and energy usage. Hence, it is anticipated that environmental sustainability principles must be firmly applied in the ongoing development of 6G (Nayak & Patgiri, 2020).

Along with challenges related to battery life, energy efficiency is a significant factor that will determine the design of ultra-fast next-generation networks. The software-isation of the communication network modules in 5G and beyond networks increases energy consumption. In 6G, every device, including smart devices and applications, will utilise advanced signal-processing mechanisms. Additionally, they will need to handle Big Data, necessitating significant processing power and high-energy consumption. Since 6G is still in its initial development phase, its long-term effects on the environment are uncertain. However, there are already concerns that immersive technologies might compound the existing adverse effects on the environment due to the need for a multi-fold increase in power consumption. Researchers have been developing advanced signal-processing techniques to support zero-energy devices and even harvest energy in some cases (Hu et al., 2021).

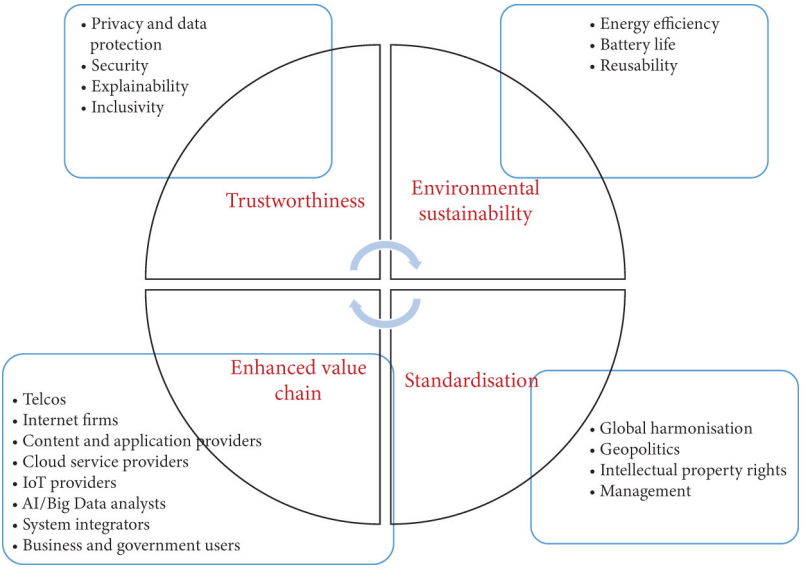


Fig. 9.1 Regulatory challenges in 6G
Source: Authors' own.

A summary of the regulatory challenges in the era of 6G is given in Fig. 9.1.

9.5 Conclusion

As carriers worldwide deploy 5G networks, research on 6G networks has started. The standardisation process for 6G is expected to be completed by 2030. However, apart from superior speeds and connectivity, the 6G networks are expected to provide an immersive experience, connecting humans and things seamlessly. New technologies such as THz communication and molecular communication enhanced by the extensive use of AI/ML algorithms are expected to enhance user experience to a heightened level. Tactile Internet, holographic 3D imaging, human-body communication and the Internet of Everything are expected to revolutionise varied sectors such as transportation, health care, entertainment, and manufacturing, to name only a few. NHs are expected

to play an important role in 6G networks to augment the carriers' infrastructure and optimise the spectrum's use for superior connectivity and experience. However, extensive use of AI/ML and Big Data poses serious concerns in data security, surveillance, algorithmic bias, explainability and other related areas. Hence, telecom regulation, as we witness it today, will need a drastic transformation, covering areas other than communication. We will also witness a complex value chain consisting of telecom companies, Internet firms, cloud service providers, IoT users, data analysts, and system integrators with overlapping areas of operations.

In this book, we recognise the changing landscape of telecom regulation and provide the first drastic overhaul of the existing regulatory landscape. Though our recommendations are specific to India, the principles we espouse are equally applicable in other countries. This evolution will continue when we migrate our networks and services to 6G. We hope the new framework we have provided in this book is a stepping stone into the future of communications regulation worldwide.

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Index

For the benefit of digital users, indexed terms that span two pages (e.g., 52–53) may, on occasion, appear on only one of those pages.

Tables and figures are indicated by an italic *t* and *f* following the page number.

26 GHz 118–19, 118*f*, 123, 130–31, 134*t*, 137–39, 200–1
3.3 GHz 85
3GPP 2, 8–9, 10–11, 15–16, 16*f*, 24–25, 103, 109, 110, 129–30, 173, 178, 198, 201–2
6 GHz 15, 28*t*, 103, 104*f*, 105, 107, 108*t*, 108–9, 110, 130–31, 136
60 GHz 16*f*, 105, 109–10, 110*t*, 138–39

accounting separation 76
acquisition 106, 116, 118–19, 138–39
Adani 124*t*
adoption 46–47, 136, 170–71, 198–99
adversaries 127, 161–62, 204–5, 206
advertisements 41–42, 43*f*, 44, 48–49, 50, 65, 146–47, 147*f*, 147*t*
Adwords 41–42
Africa 108*t*
Aho 4, 27
Ahokangas 204–5
Aircel 124*t*
aircraft 127, 133
Airtel 87, 124*t*
Akhtar 8, 28
Alakwe 202–3
Alexander 135
Alibaba 49–50
Alphabet 50, 65, 155–56, 157
Alqahtani 27
Alriksson 146, 157
altimeters 127, 128 *see also* aircraft
Amazon 38*t*, 41, 42–43, 46, 49–50, 131*t* *see also* Amazon Prime
Amazon Prime 38*t*, 41–42, 87
Andaman 114*t*
Andhra Pradesh 114*t*, 118*f*, 123*t*
Android 66, 154–56, 169–70
anticompetitive 64
antitrust 65, 99*t*
AOL 41
API 10–11, 19, 169, 170–71
app neutrality 66, 154–56
Argentina 108*t*, 120
Argyres 9–10, 28
ARPANET 36
ASCII 10–11
ASP 160*f*
Assam 114*t*, 118*f*, 123*t*
auction 111, 112, 113–15, 116, 119, 120–21, 131–32
Australia 82–83, 108*t*, 109–10, 110*t*, 133, 134*t*, 137–39, 162–63
Austria 109–10
authorities 128, 137
autocracies 195
automation 3*f*, 22, 135, 203–4
autonomous 4, 21*f*, 24–25, 27, 198–99, 202–3
autonomy 49, 50–51, 195, 196, 197

backbone 17, 36, 69, 70, 185
Baidu 49–50, 65
Balaji 87
Barcelona 200–1
Barry 61
BATX 49–50
Baumol 68
BBNL 185, 186
beamforming 27

Belgium 109–10
Bengal 114*t*, 118*f*, 123*t*
Bengaluru 187
BEREC 37, 153, 157
Berkeley 36
BharatNet 185, 186, 187
Bhat 27
Bianchi 65
Bigelow 9–10, 28
Bihar 114*t*, 118*f*, 123*t*, 186
BIL 88, 92, 93, 94*t*, 95, 96, 97, 98*t*, 98, 99*t*, 156, 191–93, 196
Blabber 169–70
blockchain 177
Boccardi 201–2
Boeing 131*t*
Bohlin 82–83
Bosch 22
Boström 157
Bradford 195
Brandenburger 61
Brazil 65, 107, 108*t*, 120
Brinton 47
Briscoe 46–47
Bristol 200–1
Broadband Infrastructure Levy 67, 70, 88, 156 *see also* BIL
browser 65, 170–71
BSNL 124*t*, 186, 187
BTS 103, 105, 190–91
Buchi 16–17
bundling 18, 39, 49, 75, 114, 155–56

C-band 104*f*
California 36, 188
Canada 12, 108*t*, 110*t*, 120, 136
capitalism 47–50, 47*t*
Carterfone 10
catastrophes 129
Cave 76, 83, 99*t*, 111
CBRS 128–29, 135
CCA 114
CCI 155–56, 157
CCS 167–68
CDMA 1–2, 10–11
CDN 43*f*, 44, 91, 145–47, 147*f*, 147*t*, 149, 152, 153–54
Chennai 75, 114*t*
Chiang 47
Chile 107, 108*t*
China 12, 19, 21, 42, 49–50, 65, 109–10, 190–91, 198–99
Chowdhury 26
Chrome 65, 170–71
Cisco 145–46, 157, 172
CLECs 34
CMTS 75, 78*f*, 166–67
CNPN 22, 23–24, 105, 127, 135, 200–1
codification 10–11
cognition 26, 113–14
Colombia 108*t*
Columbia 143
combinatorial auction 113–14
Communications Convergence Bill 73–101
communities 44
compatibility 10–12, 149, 178
conceptual 63, 81, 96, 143, 146
Condoluci 7
confidentiality 61
Congedo 82–83, 99*t*
congestion 23, 42, 146, 163–64
consortium 170–71, 198–99
Content Delivery Networks 44, 89*f*, 91, 145–46 *see also* Content Distribution Networks
Content Distribution Networks 63
COTS 7
Coursera 42–43, 88
COVID 42
CPE 166
CPSU 186
Cramton 111
CUG 79*f*
Curwen 82–83, 99*t*
Cybersecurity 204–5

DailyHunt 42–43
Darwish 129–30
data portability 64, 67–68, 159–82, 163*f*, 179*t*
data protection 38*t*, 49, 51, 93, 176–77, 196, 197, 204–5
Datafication 6–7

Delhi 114*t*, 118*f*, 120–21, 123*t*, 187
delicensed 107, 108*t*, 109–10
Deloitte 190–91
densification 5–6
deregulation 83
diagonal equity 51, 55–72, 59*t*, 85, 95, 154, 169, 195–96, 197, 198
diffusion 67
digital neutrality 51, 66, 143–58, 195–96, 197, 198, 205
digitalisation 183, 198
Dino 169–70
Disney 41, 87
divestiture 65
Docomo 59–60
DoD 36
DOI 1–2, 99*t*, 195
DOJ 65
Dounoukos 83–84
DPDP 179*t*, 204–5 *see also* data protection
Dresden 22
DSL 34, 36, 38, 39*f*
duopoly 84, 85, 114
dynamic spectrum sharing 51, 135, 136–37
dynamism 157, 191–92

Economides 45–46
EdTech 38*t*, 88
Edward 99*t*
Eisenmann 45
elasticity 58, 65, 87–88, 156–57
Elayan 201–2
Elgar 99*t*
eMBB 2, 3*f*, 21*f*, 26, 130
empirical 57–58, 66
entrepreneurs 19–20, 186, 187
ENUM 167–68, 172
enumeration 167–68
environmental 15, 107, 110, 195, 206, 207*f*
equality 62–63, 199
equitable 32, 62–63, 66, 67, 161, 202–3
Ericsson 34–35, 145–46, 157, 190
Espoo 200–1
Esselaar 37
Eswaran 149
ethical 92, 178–79, 202–4
exchequer 95, 111, 114–15, 120–21
explainability 203, 207*f*, 207–8
externality 45, 46–47, 64, 67, 68, 161–62

Facebook 38*t*, 41, 42–43, 60, 109
fairness 202–4
Farrell 9
Faulhaber 64
FCC 10, 106, 108*t*, 109–10, 110*t*, 114, 128–29, 130–31, 133, 136, 137–38, 173–74
federated 9
Feigenbaum 87
femtocells 5–6
Fernández 200–1
fibrisation 6, 70, 189, 190–91, 192–93, 202
fiduciary 176–77
Finland 6, 12, 22, 120, 137
fintech 185
Flanagan 74
Flipkart 38*t*, 42–43
forbearance 45
foreclosure 99*t*
Forzati 11
Freyens 135
FTTH 187
functional separation 51, 66–67, 73–101, 99*t*, 169, 195–96, 197, 198
FWA 34–35, 134*t*

GAA 128–29
Gabrielsen 162
Gallion 28
GAMMA 49–50, 148
Garcia 12
Gasmi 69, 187–88
gatekeeper 64, 66, 148, 150, 154–55, 171–72, 177
Gavrilovska 8, 56–57
GDP 3, 18
GDPR 49, 176–77, 197, 204–5
Genakos 162
geolocation 136
geopolitical 12, 50–51, 195, 197, 199, 207*f*

geospatial 137, 138–39
geostationary 105, 130–31
Gharaei 28
Gigabit 3*f*, 109
Gilbert 83
globalisation 189
GMPCS 79*f*, 166–67
GOI 82, 90, 92, 106–7, 130–31, 183–84, 185
GoogleFi 20
GPRS 1–2, 35
granularity 93, 96
GSM 1–2, 10, 75, 175–76, 178
guardrails 196
Guatemala 107
Gujarat 114*t*, 118*f*, 123*t*

Hammainen 200–1
HAP 59–60, 60*f*
haptic 27
harmonisation 2, 153, 207*f*
Haryana 114*t*, 118*f*, 123*t*
Hazlett 58, 59–60
HealthTech 88
Henderson 83–84
Herfindahl 74–75, 84
heterogeneity 2, 5–6, 69–70, 76–77, 93, 96
HetNets 5–6
HHI 84, 85*t*, 123–24 *see also* Herfindahl
Himachal 114*t*, 118*f*, 123*t*
holographic 24–25, 27, 200, 207–8
Honduras 108*t*
Honnavalli 149
hotspots 16, 18, 19–20, 187 *see also* Wi-Fi
Hotstar 38*t*, 42, 87
HSPA 2
HTML 170–71
Hu 206
Huang 6–7
Huawei 49–50
Hulu 41, 42
Hybridisation 13, 28, 55, 56–57, 58, 61

IBM 9
ICANN 37
IEEE 13, 14, 14*t*, 15–16, 16*f*, 28, 104–5, 106, 107, 109, 110, 128–29, 201–2, 203–4
IETF 37, 173
ILD 79*f*, 160*f*, 161, 167–68, 167*f*
immersive 206, 207–8
IMT 2, 107, 128, 134*t*, 198, 199
incumbents 38, 85, 137, 169
indigenous 169–70
inefficiency 21, 33, 69, 85, 87–88, 133
inequality 203–4
infringement 195
injunction 46, 69–70, 147
INSAT 79*f*
Intel 9
intellectual 59–61, 207*f*
interconnection charges 67, 159–61, 164–68, 187–88
interference 13, 15, 109–10, 127, 128–29, 131–32, 134*t*, 137
Intermediary 43, 44, 45, 92, 170–71, 178–79
internationalisation 49–50
Internetworking 171
Interoperability 2, 10–12, 19, 59*t*, 159, 169–72, 178, 179, 179*t*, 180
interoperable 11–12, 19–20, 169–70, 171, 178, 201–2
interworking 10–11
IoE 26
IoNT 27
iOS 66, 154–55, 169–70
IoT 26, 120, 134*t*, 146, 152, 157, 198–99, 200–1, 207*f*, 207–8
IPL 87
IPLC 79*f*
Ireland 82–83
ISM 13
Israel 12
ITA 119*f*
Italy 57–58, 82–83, 120, 134*t*, 137, 200–1
ITC 162–63, 163*f*, 168
ITU 2, 37, 103–4, 198, 199
iTunes 40
IUC 77–78, 160, 161, 164, 168, 180 *see also* interconnection charges

Jain 183
Jammu 114*t*, 118*f*, 123*t*
Japan 12, 59–60, 65, 108*t*, 110*t*, 124*t*, 135, 190–91, 198–99
Javascript 170–71
Jayakar 183
Jio 87, 123–24, 124*t*
jitter 16–17, 40
Joskow 84
Jung 28
Juniper 169
jurisdiction 73–74, 77, 103–4, 165–66, 178, 196
justice 65, 202–3

Ka-band 104*f*, 105, 130–31, 131*t*
Karnataka 114*t*, 118*f*, 123*t*
Kashmir 114*t*, 118*f*, 123*t*
Katz 18
KDDI 59–60, 135
Kedia 164
Kennedy 195
Kerala 114*t*, 118*f*, 123*t*
Khorov 15
Kim 12
Koenig 205
Kokkinen 137
Kolkata 114*t*, 118*f*, 120–21, 123*t*
Korea 12, 15, 42, 87, 88, 107, 108*t*, 109–10, 198–99
Krämer 11, 66
Ku-band 104*f*, 105, 130–31, 131*t*
Kuiper 131*t*
Kumar 108–9

Large Traffic Generators 42, 70, 196
Latipulhayat 73
Latva 4, 27
leapfrog 198
Lee 150
legislation 61
LEO 129, 130–31, 132
Leppänen 4, 27
Leyva 130
Li 136, 149
liberalisation 34
Licensed Service Area 35
light licensing 109–10, 133, 134*t*, 136
Lim 195
litigation 46, 87, 88
Liv 87
LLU 24
lobby 106, 109–10, 162, 178
localisation 204–5
LTE 10–11, 16*f*, 137, 173
LTG 42, 51, 87, 88, 94*t*, 156 *see also* Large Traffic Generators
Lucca 200–1
Lufthansa 22

Madhya Pradesh 114*t*, 118*f*, 123*t*, 186
Maharashtra 114*t*, 118*f*, 123*t*
Mahmoodi 7
Malayalam 87
Malaysia 109–10
Mariscal 83, 99*t*
marketplace 43, 44, 46, 49, 144
masking 174
masquerade 168
Massachusetts 150
Matovski 195
Mayorga 130
McAfee 111
MCI 33–34
McKinsey 95
MeiTY 178–79, 204–5
merger 4, 50, 62–64, 154
messenger 38*t*, 57–58, 68
Meta 20, 49–50, 60, 105, 171–72
Metcalf 46–47
Mexico 83, 108*t*
microcells 5–6, 22, 202
Microsoft 9, 41, 49–50, 136, 154–55
middleware 10, 169–70
Milgrom 111
MIMO 15
MIT 150
Mitra 202
Mitta 87
mMTC 3*f*, 20
MNO 17, 22, 23, 24, 111, 116, 174–75, 200
MNP 175–76

Mobile Termination Charges 162, 163*f*
see also MTC
Modigliani 47–48
modularisation 8–13, 24–25, 28, 57, 96
monolithic 8–9, 56–57
monopoly 10, 32, 33–34, 35, 45–46, 65, 83, 84, 144, 154–55, 156, 159, 161–62, 163–64, 171

MSP 134*t*
MTAs 137–38
MTC 162–63, 163*f*, 164, 168 *see also* Mobile Termination Charges
MTNL 124*t*
multimedia 170–71, 178
multiplexing 14, 106
Mumbai 114*t*, 118*f*, 120–21, 123*t*
Musgrave 63
Musk 129
Mustafa 174
MVNO 24

Naik 110
Nalebuff 61
narrowband 34
Nayak 206
NDCP 190–91
Nelson 87
NEMs 8–9, 11–12, 20, 22, 24–25
net neutrality 39–40, 45, 51, 60, 64–66, 67, 70, 80*t*, 88, 90, 93, 94*t*, 96, 143–58, 191–92, 205–6
Netflix 38*t*, 40, 41–42, 87
Netherlands 137
netizen 192–93
Network Function Virtualisation 24, 149
network slicing 20–22, 21*f*, 24–25, 148–50, 152, 200, 205
Neumann 86–87
neutrality 23–24, 64, 65, 66, 73–74, 81, 88, 135, 143, 145*t*, 145, 150, 151, 152, 154, 155, 156, 157
NFV 149
NGEO 105, 129, 130–32
Ngongang 17
Nicholls 111
Nicobar 114*t*
Nidhi 184
NLDO 79*f*, 160, 160*f*, 160*f*, 161
NOC 187
Nokia 7–8, 22
Noll 84
NPRM 128–29
NTIA 133
Nuechterlein 10, 32, 159
number portability 68, 175–76 *see also* MNP

Odisha 118, 118*f*, 123*t*
OECD 133, 134*t*, 135
OfCom 57–58, 108*t*, 109–10, 110*t*, 135, 173–74
OFDMA 15, 107
Ogutu 132
Ola 42–43
oligopoly 8–9, 35, 36–37
Oman 108*t*
OneWeb 129, 130–31, 131*t*, 132
openness 9, 10, 11–12, 133, 156
opportunistic 128–29, 136
orbit 129, 199
Orissa 114*t*
OSI 9, 37
OTT com 38*t*, 39*f*, 39–40, 55, 57, 78, 89*f*, 92, 94*t*, 156, 164, 169–72, 176, 178, 179*t*, 180
OTT video 38*t*, 39*f*, 40–42, 44*f*, 70, 86–89, 92, 94*t*, 97, 146, 156, 191–93
Oughton 15, 108–9, 132
Owen 66
Oxford 1–2, 195

panchayat 185
pandemic 42
Parker 42–43
Parliament 81, 89, 92, 188, 202
Pasquale 66
Patriciello 110

PDOs 19–20
peering 36
Peha 136
Pekeč 113–14
Peltonen 6–7
Perez 12
Peru 108*t*
PGCIL 186, 187
phenomena 13, 42, 58, 59–60
philosopher 188
picocells 5–6
PLMN 1–2, 24, 38*t*, 39, 59*t*, 79*f*, 164, 165–68, 165*f*, 167*f*, 172, 173, 175*t*, 179*t*, 201
PMWANI 19 *see also* PDOs
Pokémon 155
Poland 82–83, 109–10
polarisation 131–32
policies 13, 18, 83, 133, 176, 183, 198, 202, 203–4
Porambage 204–5
portability 68, 94*t*, 175–76, 177, 180 *see also* MNP
Portugal 137
POTS 32, 36
Practo 38*t*
Prasad 1–2, 18, 35, 59*t*, 63, 64, 69, 73, 75, 78*f*, 79*f*, 81, 94*t*, 97*t*, 98*t*, 103, 105, 107, 108*t*, 114–15, 116, 119, 121, 125–26, 135, 136, 143, 145*t*, 145, 151, 175*t*, 189, 195, 201
privacy 38*t*, 49, 61, 93, 178–79, 195, 196, 197, 202–3, 204–5, 207*f*
privatisation 33, 73
promulgated 66, 148
pronouncement 180
propensity 17
proprietary 8–9, 11–12, 170–71
protocol 8–9, 12, 16–17, 19, 24, 36, 37, 39*f*, 57–58, 87, 109, 151, 164–68, 169–70, 171
PSTN 32, 38*t*, 39, 59*t*, 164, 165–68, 165*f*, 167*f*, 172, 173, 175*t*, 179*t*, 201 *see also* PLMN
Punjab 114*t*, 118*f*, 123*t*, 186
Qatar 108*t*
QoS 15, 17, 20, 22, 23, 24–25, 42, 59*t*, 80*t*, 92, 93, 94*t*, 96, 108–9, 149, 151–52, 153–54, 161–62, 164, 175–76
Qualcomm 1–2
Quicksy 169–70

radar 127, 128
radiocommunication 107, 199, 201–2
Raghuram 183
RailTel 186, 187
railways 133
Rajasthan 114*t*, 118*f*, 123*t*
RAN 11–13, 24–25
RCS 178
Reed 46–47
Reliance 60, 123–24, 124*t*, 202–3
resilience 12, 129, 132
reusability 15, 107, 207*f*
RIA 109–10
rival 49, 59–60, 131–32, 146
RLAN 108*t*
roaming 2, 39, 129, 168
robotic 3, 3*f*, 4, 25, 27
Rochet 45
Rohit 1–2, 195 *see also* Prasad
Rothkopf 113–14
RTA 15
Russia 137

Sachs 157
Saha 110
Samsung 65
Sandvine 42
Sarnoff 46–47
satcom 105 *see also* SatNet
SatNet 129–31, 132
Saudi 108*t*
Sawhney 69, 183, 188, 189
scalable 12, 19–20, 129
scarce 23, 103, 111, 115, 133
Schnurr 11, 66
SDN 149
semiconductor 9–10

Sheldon 36
Sheng 195
Sherman 65
SHGs 186
Shin 28
Shy 88–89
Sikkim 186
SIM 16–17, 144
Simplilearn 88
Simultaneous Multiple Round Ascending Auction 111
Singapore 12, 110*t*
Skype 38*t*, 164, 167, 170–71
slice 5, 20, 21*f*, 21, 116, 149, 152–54, 192–93
Slovakia 109–10
Slovenia 134*t*
Smith 188
SMRA 111, 114–15, 127, 138–39 *see also* Simultaneous Multiple Round Ascending Auction
SMS 4*f*, 56*t*, 57–58, 59*t*, 89–90, 169, 178
SMTP 169
Sohul 128–29
Sony 87
sovereignty 33, 47*t*, 48, 49–50, 195, 197
SpaceX 129, 131*t*
Spain 109–10, 200–1
SPAM 177–79
spatial 15, 107, 133
spectral 2, 4, 25, 26, 28*t*
spectrum leasing 22
spectrum sharing 51, 133, 135, 136–37, 200
spectrum trading 135, 138–39
spoofing 174
Sridhar 1–2, 16–17, 18, 19, 24, 32, 33, 35, 37, 42, 59*t*, 60, 63, 64, 69, 75–76, 81, 103, 105, 107, 108*t*, 109, 114–15, 116, 119, 121, 125–26, 127, 128, 135, 136, 137, 143, 145*t*, 145, 147*f*, 147*t*, 151, 153–54, 159–60, 160*f*, 160*f*, 161–62, 163*f*, 163–64, 165–66, 165*f*, 167–68, 167*f*, 170–71, 175*t*, 176, 183–84, 195, 200–1
Srivatsava 202–3
SSA 77, 79*f*, 80*t*
Stallings 36
standards 2, 8–12, 13, 15–16, 16*f*, 17, 19, 24–25, 37, 49–50, 68, 103, 104–5, 109, 129–30, 132, 159–60, 169–70, 173, 178, 180, 189, 198–99, 201–2, 203–4, 207*f*, 207–8
Starbucks 16, 19
Starlink 129, 130–31, 132
stationary 105, 129
Statista 41, 86–87, 97, 98
Stork 37
substitutability 15, 37, 39, 51, 55, 56, 57–58, 59*t*, 61, 63–64, 67, 89–90, 106–10, 111, 131–32
SUC 76–77, 93, 95, 97
surveillance 202–3, 204–5, 207–8
sustainability 206
Sweden 82–83
Switzerland 120

tactile 24–25, 27, 200, 206, 207–8
Taiwan 12, 120
Tamil Nadu 75, 114*t*, 118*f*, 123*t*
Tanenbaum 9, 32
Tanzania 120
taxation 196
taxonomy 38*t*, 103, 104*f*, 159–61
TCCPR 179, 179*t*
TEC 166
Telcos 12, 20, 22, 23, 24–25, 34, 36, 37, 39–40, 42, 89, 109–10, 164, 166, 200–1, 207*f*
Telegram 39
telemarketers 178
telemedicine 88, 185
telepresence 27, 200
telesurgery 27
Tencent 49–50
Teppayayon 82–83
Terahertz 5–6, 26, 28*t*, 103, 104*f*
Thailand 108*t*
theoretical 1–2, 27, 43–44, 68, 187–92

throttling 153–54
throughput 15, 107, 108–9
THz 26, 27, 103, 201–2, 207–8 *see also* Terahertz
Tirole 45
traceability 178–79
trustworthiness 203–4, 207*f*
Tudou 42
TVWS 136

UAL 157, 184*f*
UASL 75–78, 80*t*
UAVs 27
Uber 38*t*, 42–43
ubiquitous 4, 24–25, 41, 127, 129, 132, 206
UCC 177, 178
UDP 39*f*
UK 57–58, 109–10
UN 92, 119*f*, 120*f*
unbunding 19, 24, 33, 78*f*, 81–82, 84, 86, 91, 95
Unicode 10–11
unicorn 48
Unified License 99*t*
Universal Service 33, 51, 64, 69–70, 80*t*, 91, 93, 94*t*, 95, 183–94 *see also* USL
unlicensed 5, 13, 14, 18, 26, 58, 104*f*, 104–5, 106–7, 108*t*, 109–10, 110*t*, 134*t*, 136, 137, 201–2
unmanageable 86
unmanned 27
unnecessarily 33
unnecessary 39–40, 66
unprecedented 4
unreasonable 153–54, 155–56
unregulated 144, 179
unsolicited 177, 179*t see also* UCC
untethered 38, 91, 96, 172, 178
upGrad 38*t*, 42–43, 88
UPI 185
upload 153
URLLC 3, 3*f*, 20, 21*f*
Uruguay 120
USL 97, 97*t*, 98*t*, 98, 99*t*, 183–87, 189, 191, 192–93
USO 183–84, 187–88
USOF 183–84, 184*f*, 185, 192–93

Vagstad 162
Valletti 162
Veidt 205
Venkatesh 35
Viacom 87
Virtual Network Operator 79*f see also* MVNO
virtualisation 7–8, 13, 24, 149
Visa 43
VoD 40, 41
Vodafone 123–24, 124*t*
Volkswagen 22
VOLTE 35
VoWiFi 17
VR 110
Vriendt 1–2
VSAT 75–76, 79*f*, 105

Wahl 155
Wang 157
WANI 19–20 *see also* PMWANI
warfare 204–5
watchdog 155–56
wearable 110
WebRTC 170–71
Weforum 4
Weiser 9, 10, 32, 159
Wellman 57–58
Wetherall 9, 32
Whalley 82–83, 99*t*
Wi-Fi 14*t*, 16*f*, 18, 19, 104*f*, 109
Wilson 111
Windows 9, 154–55
winner 47, 111, 113–15
WLAN 13, 14, 17 *see also* Wi-Fi
WPC 103–4
WRC 107
Wu 143, 150, 157, 203

Xiao 137–38
Xiaomi 49–50
XML 169–70
XMPP 169–71, 178

Yahoo 41
Yang 46–47
Youku 42
YouTube 7–8, 40, 41–42
Yuan 137–38

Zaidi 157
Zhang 5–6
Zipf 46–47