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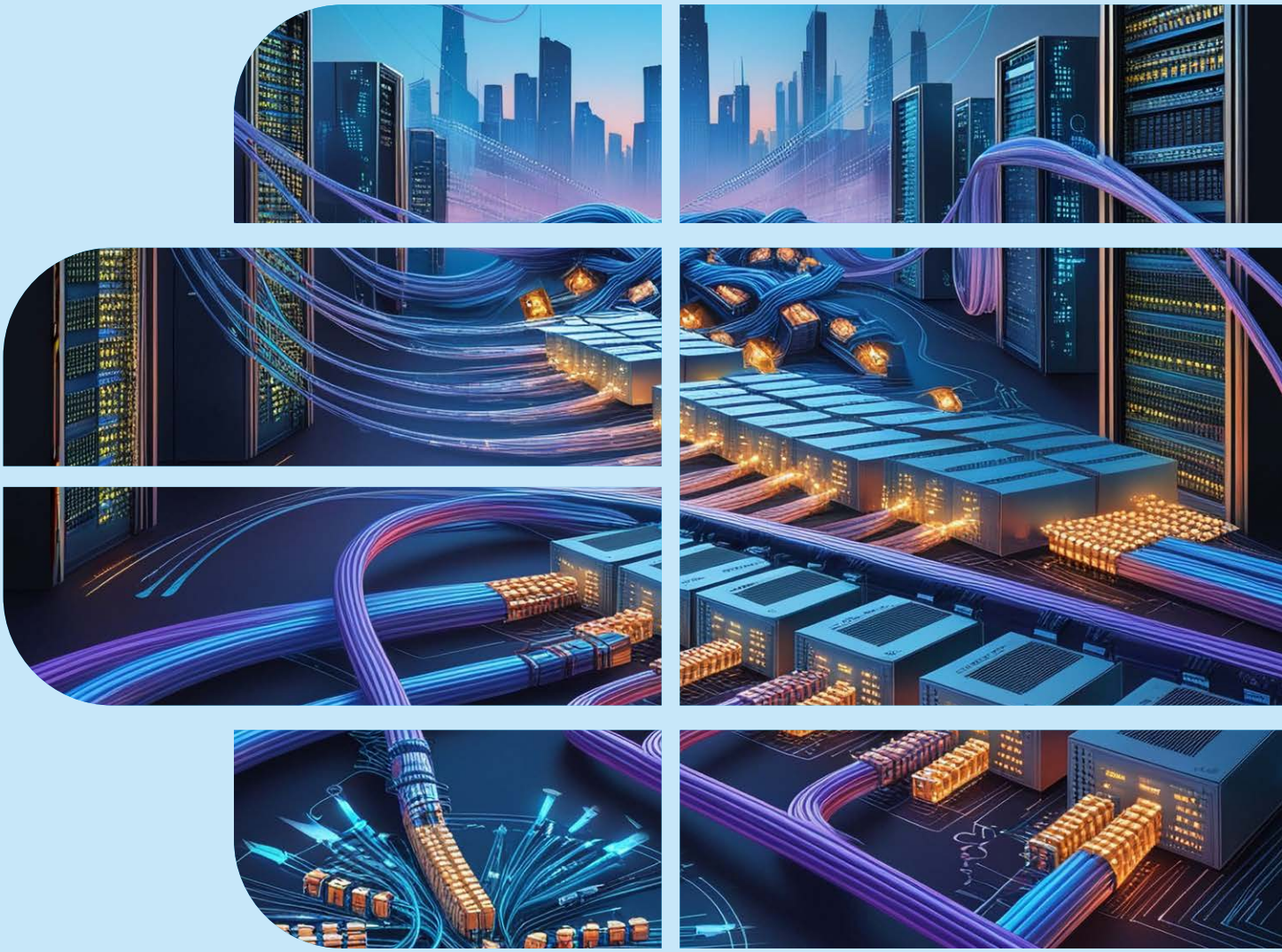

DIGITAL INFRASTRUCTURE

INVESTING IN THE FUTURE FOR A VIKSIT BHARAT

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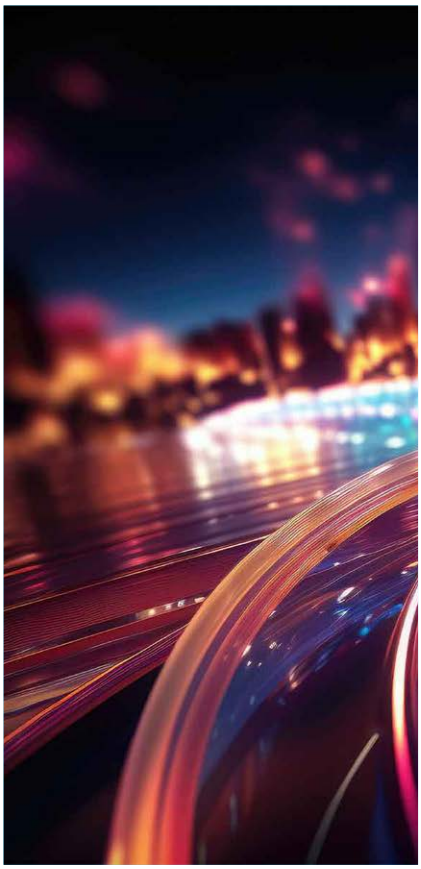
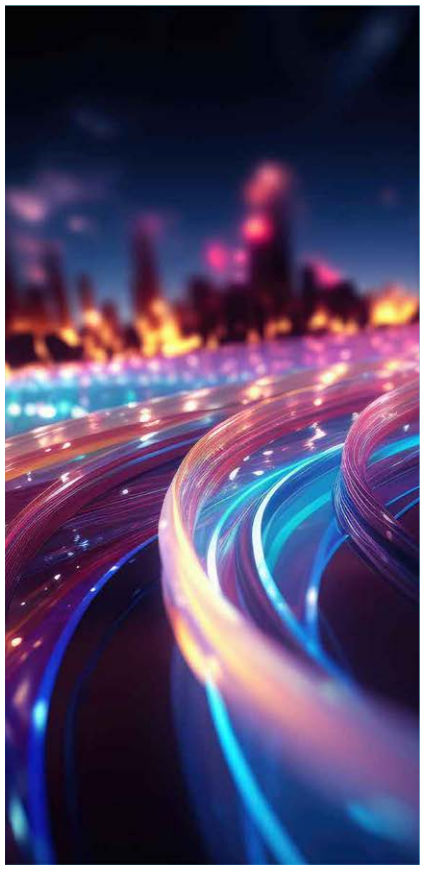
EXECUTIVE SUMMARY

The expansion of digital infrastructure has reshaped India's economic and social landscape, with broadband internet at the core of this transformation. Initiatives like the Digital India Mission have spurred economic growth by expanding financial inclusion and opening new pathways to prosperity. Yet, significant challenges remain in delivering reliable, affordable, high-speed broadband, particularly in bridging the urban-rural divide and ensuring access for all socioeconomic groups. This paper underscores the critical role of resilient digital infrastructure in fostering widespread, reliable, and sustainable internet access, essential for inclusive digital growth in India. It outlines the necessity of building a resilient digital infrastructure that encompasses three interconnected components: the backbone (high-capacity fiber-optic cables), the middle mile (data centers, Content Deliver Networks (CDN), and Internet Exchange Points (IXP), and the last mile (wireless mobile data, satellite internet, and public Wi-Fi). Strengthening these elements is vital for achieving universal connectivity, improving user experience, and supporting India's aspirations of a USD 1 trillion digital economy by 2027 and "Viksit Bharat" status by 2047.

Despite tremendous progress in internet proliferation over the past decade, India is still faced with challenges, especially in fixed broadband proliferation. India's digital growth remains mobile-first, with 95.6% of users relying on mobile internet compared to only 4.3% using wireline broadband, highlighting a significant infrastructure gap. In this context, the paper calls for a comprehensive strategy to strengthen this infrastructure, drawing from successful models both domestically and internationally.


A holistic broadband infrastructure is crucial for a resilient, high-quality, high-speed network. According to the International Telecommunication Union (ITU), such infrastructure includes fiber optic cables, mobile towers, modern Wireless Fidelity (Wi-Fi) and satellite technologies, Light Fidelity (LiFi), Free Space Optical Communiation (FSOC), Mesh Wi-Fi, data centers, internet exchanges, content delivery networks, and under-sea cables with standalone Cable Landing Stations (CLS). An equitable blend of these technologies is essential to deliver the "ubiquitous, resilient, high-speed, and low-latency" connectivity defined in the ITU's IMT-2030 framework, supporting a vast array of human and machine interactions. Furthermore, strengthening critical infrastructure such as CDNs, data centers, submarine cables, and IXPs is key to addressing the rising demand for high speed, robust, and resilient broadband, reducing latency, and improving internet access, especially in underserved areas. Promoting open access to submarine CLS and formalising TRAI's recommendations for incentives can accelerate this growth.

Fiberisation challenges can be overcome by way of streamlined state-level implementation of Right of Way (RoW) rules, leveraging BharatNet and Smart Cities for fiberisation and fostering Public-Private Partnership (PPP). The ₹78,000 crore from the Digital Bharat Nidhi should target rural areas, while the Telecom Technology Development Fund drives local innovation. Expanding submarine cable capacity with multiple landing points will further enhance network resilience. Moreover, India can foster a competitive digital landscape through comprehensive non-discriminatory active and passive infrastructure sharing across authorisations including non-licensed entities.

The paper elaborates that while policies such as the National Digital Communications Policy (NDCP), National Broadband Mission (NBM), Telecom Reforms 1.0 and 2.0, and the Telecommunications Act 2023 reflect the government's commitment to a thriving digital economy, additional measures—such as increased public-private investment, streamlined regulatory policies, and an emphasis on ease of doing business—are essential to achieving national broadband priorities.

It is also important to remember that a large section of the Indian population, especially in rural areas, still remains unconnected while intrinsic needs of customers is growing for high speed internet with low latency at affordable prices. Key recommendations are:

1) Supporting last-mile connectivity through initiatives like the Prime Minister's Wi-Fi Access Network Interface (PM-WANI) by lowering internet bandwidth costs for Public Data Offices (PDOs).

2) Backing satellite-based broadband in rural areas.

3) Empowering Local cable operators (LCOs) by decoupling broadcasting revenues from license fee calculations and encouraging revenue-sharing agreements between Telecom Service Providers (TSP) and LCOs, as demonstrated by Kerala Vision's success, fostering fiber connectivity.

4) Incentivising Tier-2 and Tier-3 Internet Service Providers (ISP) for rural expansion and offering tax breaks to those showing significant subscriber growth can also stimulate rapid expansion in underserved regions.

5) Digital connectivity to be prioritised much like electricity and water in building codes, with strict enforcement of the Model Building By-Laws (MBBL) and Bureau of Indian Standards (BIS) standards.

6) Creating a Digital Readiness Index to provide policymakers with standardized metrics to evaluate infrastructure gaps and monitor progress, guiding evidence-based decisions to advance the goals of Digital India.

7) Meeting demand side constraints
   - » Focus on services like telemedicine, education, and commerce.
   - » Incentivising local content creation in regional languages and supporting sectors like gaming and education.

METHODOLOGY

This paper is the culmination of a two-pronged study that included secondary and desk-based research alongside stakeholder consultations.

The secondary research involved a systematic review of policy documents, government reports, consultation papers, parliamentary discussions, industry reports, academic literature, international best practices and economic data published by multilateral institutions as well as foreign governments. The research also includes insights from academicians, commentaries by industry experts and analysis by members of civil society. In addition, press releases and news articles from relevant industry bodies and regulatory authorities were analysed to contextualise the study. This initial research helped identify gaps in knowledge, challenges, and potential solutions for India's infrastructural and regulatory challenges.

As the next step to secondary research, a multi-stakeholder conference[1] was organized to consolidate insights from the desk research, explore the factors influencing fixed broadband adoption, and discuss potential strategies to address the challenges surrounding India's fixed broadband penetration and the broader digital infrastructure landscape. Key takeaways from the insightful discussions between stakeholders - government officials, industry executives, telecom experts, and organizational leaders - involved in India's digital infrastructure development helped shape the recommendations put forth in the paper.

1 https://www.communicationstoday.co.in/a-robust-digital-infrastructure-for-bharat-the-path-to-achieving-multi-gigabit-to-every-household-by-2030/?__cf_chl_tk=zx57rYzZ37wBsp5tb4GQIlhWFlQDelSLXLzeW0GCY_4-1729149729-1.0.1.1-AirEo_hLSWw7nryB.P3HGq73HK4XKbcYVRHsRL3x5tc

INTRODUCTION

The proliferation of digital technologies has driven transformative economic changes globally, with India exemplifying this shift. Embracing digital solutions has boosted efficiency, expanded financial inclusion, and opened new economic avenues.[2] A key driver is internet adoption, with India reaching 969.6 million connections as of June 2024, according to Telecom Regulatory Authority's (TRAI) 2024 report.[3]

Government policies, starting with 1990s reforms focused on liberalization, privatization, and globalization,[4] have fostered competition and investment in telecom, while initiatives like the Digital India Mission accelerated broadband adoption.[5] Broadband's societal impact spans multiple sectors: it creates jobs[6], enhances e-governance through data-driven policymaking[7], expands telehealth by improving access to remote healthcare[8], and enables e-education for inclusive learning.[9] Additionally, broadband fuels the entertainment sector, with India's gaming market expected to grow from $2.6 billion in 2022 to $8.6 billion by 2027, as global gaming revenues surpass $208 billion.[10]

The COVID-19 pandemic underscored the need for high-speed internet due to the shift to remote work. As life and education move online, internet demand is surging, thereby making 20 GB of mobile data per month insufficient for an individual. Though mobile internet has fuelled India's adoption surge,[11] wireline broadband with optical fiber offers superior reliability, limitless bandwidth, and uninterrupted connectivity, ideal for remote work, online education, and High Definition (HD) streaming.[12] Wireline plans also provide higher data limits (150 GB to 1 TB per month), further enhancing their utility.[13]

However, India faces a stark disparity: 95.6% of the 969.6 million internet subscribers rely on wireless connections, while only 4.3% use wireline broadband.[14]

Further, the urban-rural gap in net-density, i.e., internet subscriptions per 100 population, has remained around 68 percentage points, on average. This puts into perspective the magnitude of the problem of urban-rural digital divide, with rural India lagging far behind urban areas when it comes to internet access.

2 https://dea.gov.in/sites/default/files/The%20Indian%20Economy-A%20Review_Jan%202024.pdf

3 https://www.trai.gov.in/sites/default/files/QPIR_09102024_0.pdf

4 https://ideas.repec.org/p/ags/uitcoe/15859.html

5 https://www.investindia.gov.in/team-india-blogs/digital-india-revolutionising-tech-landscape

6 https://itif.org/publications/2023/08/14/enabling-equity-why-universal-broadband-access-rates-matter/

7 https://itif.org/publications/2023/08/14/enabling-equity-why-universal-broadband-access-rates-matter/

8 https://itif.org/publications/2023/08/14/enabling-equity-why-universal-broadband-access-rates-matter/

9 https://www.excitel.com/blogs/the-role-of-high-speed-internet-in-e-learning/

10 https://www.thehindu.com/sci-tech/technology/indias-gaming-market-quadruple-by-2027/article66095714.ece

11 https://www.trai.gov.in/sites/default/files/Cons_P_14092023.pdf

12 https://www.cnet.com/home/internet/fiber-optic-versus-5g-why-the-wired-connection-still-reigns/

13 https://www.airtel.in/blog/broadband/6-reasons-why-broadband-is-more-advantageous-than-mobile-hotspot/

14 https://www.trai.gov.in/sites/default/files/QPIR_09102024_0.pdf

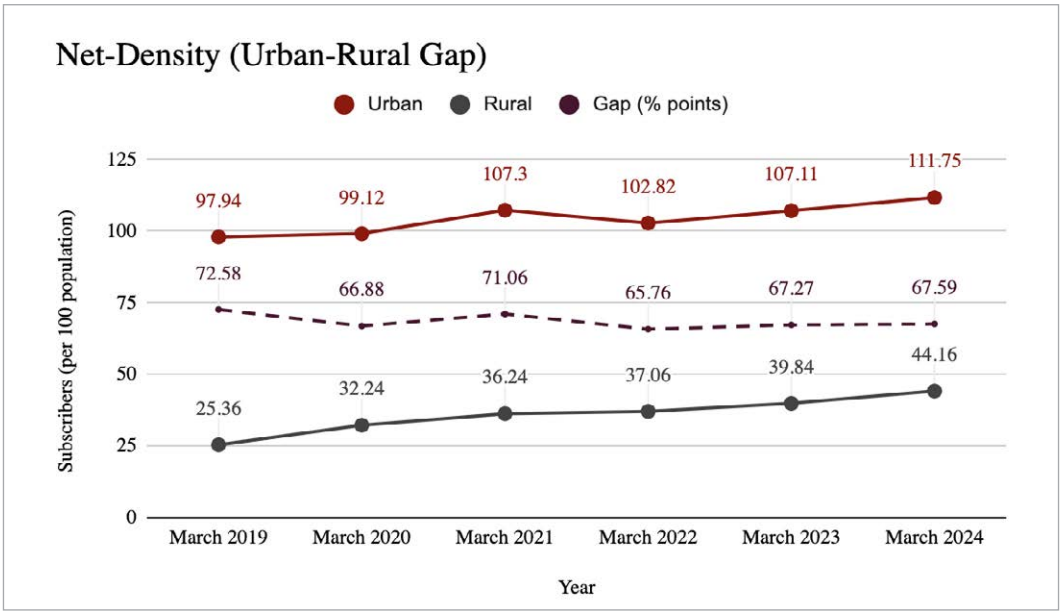


Fig 1: Net-density in India (March 2019 - March 2024) based on TRAI data [15,16,17,18,19,20]

Such digital inequality limits access to essential online services, including digital financial tools, hindering financial inclusion. As job searches move online, internet access and digital literacy are crucial for staying competitive in the job market.[21] The International Telecommunications Union (ITU) highlights four key contributors to global digital disconnection - infrastructure gaps, affordability, lack of digital skills, and perceived lack of awareness regarding the internet's benefit. Thus, prioritizing affordable and widespread telecom infrastructure along with strategic investments and supportive policies will enable high-speed connectivity nationwide.[22]

The Government of India's initiatives, including the National Digital Communications Policy 2018 (NDCP),[23] National Broadband Mission 2019 (NBM),[24] and Telecom Reforms 1.0 and 2.0, have significantly advanced India's digital infrastructure. However, with many citizens still unconnected, scaling infrastructure is essential to ensure meaningful connectivity for every household. As per studies on growth dividends from mobile penetration in India, a 10% increase in internet subscribers leads to a 3.2% increase in the rate of growth of per capita GDP, underscoring the importance of universal and secure internet access.[25] India must, therefore, cultivate an inclusive internet ecosystem that emphasizes "*meaningful ubiquitous connectivity*,"[26] going beyond basic access to ensure reliable and affordable connections.

15 https://www.trai.gov.in/sites/default/files/QPIR_04072024_0.pdf

16 https://www.trai.gov.in/sites/default/files/QPIR_21082023_0.pdf

17 https://www.trai.gov.in/sites/default/files/QPIR_26072022_0.pdf

18 https://www.trai.gov.in/sites/default/files/QPIR_27082021.pdf

19 https://www.trai.gov.in/sites/default/files/PIR_17092020_0.pdf

20 https://www.trai.gov.in/sites/default/files/PIR_10072019.pdf

21 https://inc42.com/resources/bridging-the-urban-rural-digital-divide-in-india/

22 https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-ra-cii-broadband-report-telecom-convergence-summit.pdf

23 https://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf

24 https://dot.gov.in/sites/default/files/National%20Broadband%20Mission%20-%20Booklet_0.pdf?download=1

25 https://icrier.org/pdf/Digital_Communications.pdf

26 https://www.itu.int/itu-d/sites/projectumc/home/aboutumc/

BUILDING AND STRENGTHENING DIGITAL INFRASTRUCTURE IN INDIA

Broadband refers to reliable, high-speed internet that is "always on," characterized by bandwidth, speed, and low latency.[27] At its core, affordable and resilient high-speed broadband connectivity forms the backbone of a knowledge-driven economy.

Given the importance of broadband, India must now establish a "resilient internet connection" that provides consistent service even during disruptions. Internet resilience depends heavily on robust infrastructure. Although India ranks sixth in South Asia for internet resilience, it lags behind peer nations in infrastructure.[28] Thus, efforts to achieve universal connectivity and digital growth must also prioritize expanding and strengthening India's infrastructure.

This infrastructure and how they facilitate access to the internet is illustrated below [29]

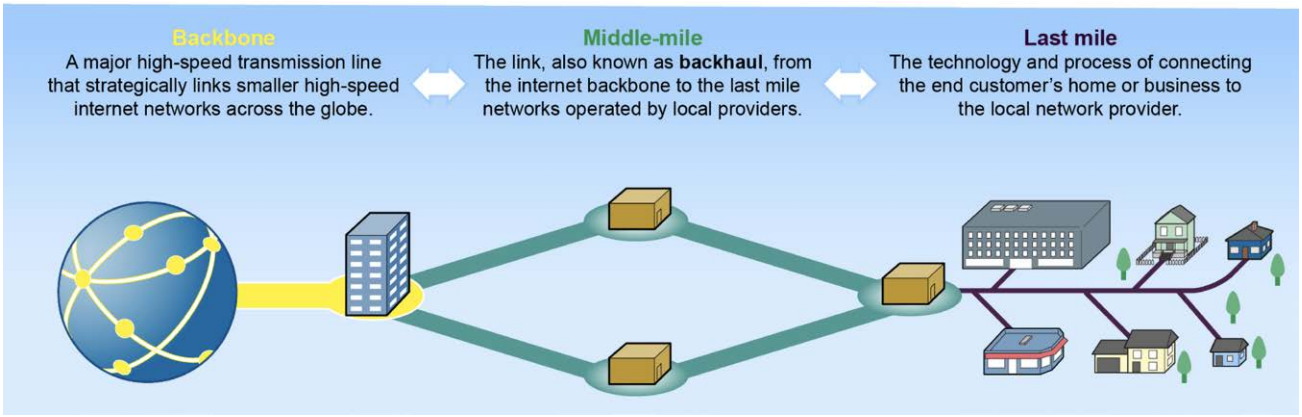


Fig 2: Components of internet infrastructure[30]

27 https://www.pewresearch.org/internet/2021/09/01/the-internet-and-the-pandemic/

28 https://pulse.internetsociety.org/resilience

29 https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2023/08/broadband-basics-how-it-works-why-its-important-and-what-comes-next

30 https://www.gao.gov/assets/870/862535.pdf

The Three Pillars of Connectivity

India's journey towards a thriving digital economy relies on a robust, resilient internet infrastructure, which can be categorized into three essential components: the backbone, the middle mile, and the last mile. Each plays a unique yet interconnected role in ensuring seamless internet access.

The Backbone: Foundation for High-Speed Data Flow: The backbone consists of high-capacity terrestrial and submarine fiber-optic cables, which serve as information highways connecting India to the global network. Fiber-optic technology enables speeds up to 10 Gbps with low latency, essential for applications like video conferencing, cloud computing, and e-commerce.[31] Submarine cables, responsible for over 99% of intercontinental traffic, connect at CLS supporting India's data centers, e-commerce, and software services.[32] With 17 submarine cables, India is a key hub, enabling high-speed, cost-effective global data exchange.[33]

ISPs maintain this backbone, operating across three tiers:

- **Tier 1 ISPs**: Large global providers managing substantial backbone infrastructure.
- **Tier 2 ISPs**: Regional providers relying on Tier 1 networks, extending services geographically.
- **Tier 3 ISPs**: Local providers focused on last-mile delivery to end-users.

The Middle Mile: Facilitating Efficient Data Distribution: The middle mile connects the backbone to the last mile and includes key elements such as:

- **Data Centers**: Secure facilities housing massive computer systems to store, process, and manage data, crucial for business operations.[34]
- **Content Delivery Networks (CDNs)**: Geographically distributed servers that cache frequently accessed content, reducing loading times and enhancing user experience.[35]
- **Internet Exchange Points (IXPs)**: Virtual marketplaces where ISPs interconnect, facilitating faster and more efficient data exchange. A 1% increase in IXPs per 10 million inhabitants can raise broadband speeds by 0.8%.[36]

The Last Mile: Delivering Connectivity to Every User: The last mile is the final segment that connects individual users and devices to the internet, relying mainly on two key technologies:

- **Wireless Mobile Data**: Mobile network operators have driven internet adoption in India through 3G, 4G, and 5G technologies, crucial for remote areas. Telecommunication towers ensure coverage and manage data traffic. By January 2024, India had around 0.78

31 https://www.eurofiber.com/en-be/lifeline/best-quality-network/fiber-optic-speed-and-technology-behind-it

32 https://www.communicationstoday.co.in/india-secures-its-burgeoning-submarine-cables-industry/

33 https://www.thehindubusinessline.com/info-tech/indian-undersea-cable-landing-stations-increase-their-capacity-by-nine-times-between-2016-2021-trai-report/article66353161.ece

34 https://www.cisco.com/c/en/us/solutions/data-center-virtualization/what-is-a-data-center.html

35 https://www.trai.gov.in/sites/default/files/CP_16122021_0.pdf

36 https://www.unescap.org/sites/default/d8files/2022-03/APSDJ%20NO.2-2_25%2003%202022_0.pdf

million towers[37] with another 1.2 million estimated to be needed in the financial year 2023-2024.[38] To meet the increasing demand, 65% of the towers need to be fiberized as compared to the existing 36% fiberization.[39]

- **Satellite Internet**: For isolated regions where traditional infrastructure is difficult to deploy, satellite internet offers a reliable alternative. Although it may not match fiber-optic speeds, satellite technology can deliver high-speed connectivity to even the most remote areas in a cost-effective manner.[40]
- **Public Wi-Fi**: Known as "open Wi-Fi," public Wi-Fi provides internet access in public spaces like airports, shopping malls, and bus stops. Available in coffee shops, hotels, and other venues, it offers convenient and affordable connectivity, allowing users to save on mobile data expenses and stay connected outside their home networks.[41]

In addition to these core components, emerging telecom technologies offer fiber-like bandwidth through modern wireless solutions, especially in areas where fiber installation is challenging or economically unviable:

- **Unlicensed E & V Band Radios**: The V band supports multi-gigabit wireless backhaul for small cells and short haul point to multipoint connectivity, where wired connections aren't feasible.[42] E-band (71-76 GHz/81-86 GHz) offers data transmission up to 60 Gbps, while the lower V band (57-66 GHz) is ideal for short-range, high capacity and high-speed applications like WiGig (IEEE Certified Standard based on 802.11ad and 802.11ay) and Mesh Wi-Fi. The upper V band (66-71 GHz), unaffected by oxygen absorption characteristics, is better suited for cellular backhaul.[43]
- **Free Space Optics (FSOC)**: This technology uses invisible light beams for high-speed data transmission, offering easy deployment, low power consumption, and cost advantages over fiber optics, though precise positioning is essential.[44]
- **Light Fidelity (Li-Fi)**: Li-Fi provides speeds up to 100 times faster than Wi-Fi by using visible light, making it ideal for smart cities, homes, and IoT applications.[45]
- **Mesh Wi-Fi**: Extends wireless coverage effectively by using multiple nodes to ensure seamless connectivity, even in challenging environments.[46]

37 https://tele.net.in/telecom-statistics-telecom-towers-btss-and-5g-btss-in-india/#:~:text=The%20telecom%20tower%20count%20in,million%20during%20the%20same%20period.

38 https://telecom.economictimes.indiatimes.com/news/65-telecom-towers-need-fiberisation-12l-towers-to-be-deployed-to-make-india-5g-ready/98612401

39 https://telecom.economictimes.indiatimes.com/news/65-telecom-towers-need-fiberisation-12l-towers-to-be-deployed-to-make-india-5g-ready/98612401

40 https://www.ey.com/en_in/technology/how-satellite-internet-can-transform-digital-connectivity-in-india

41 https://www.proofpoint.com/us/threat-reference/wifi#:~:text=Public%20Wi%2DFi%2C%20also%20known,security%20costs%20can%20be%20high.

42 https://www.ksics.com/ubr/

43 https://www.analog.com/en/resources/technical-articles/e-band-wireless-radio-links.html

44 https://www.business-standard.com/content/specials/optical-wireless-technology-lifi-fsoc-will-be-a-game-changer-technology-for-5g-rollout-in-india-122052600962_1.html

45 https://telecom.economictimes.indiatimes.com/news/fsoc-tech-may-see-increased-adoption-in-india-as-5g-roll-outs-pick-up-pace/96695817

46 https://stl.tech/blog/what-is-mesh-wi-fi/#How_does_mesh_Wi-Fi_work

- **Advanced Wi-Fi Technologies**: Wi-Fi has evolved significantly, with current and upcoming standards like Wi-Fi 6E, Wi-Fi 7, and eventually Wi-Fi 8 enhancing speed and performance.
    - » **Wi-Fi 6E**: Launched in 2021, it delivers up to 9.6 Gbit/s, mitigating congestion and enhancing outdoor coverage.[47]
    - » **Wi-Fi 7**: Expected to reach speeds of around 40 Gbit/s, Wi-Fi 7 will offer lower latency and better performance in crowded areas, paving the way for future wireless connectivity.[48]

India's internet landscape is rapidly evolving, driven by infrastructure development and technological advances. Expanding digital infrastructure is crucial for bridging the digital divide and improving accessibility. Rising data consumption, fuelled by affordable data, handsets, availability of data centers, and e-commerce pose capacity challenges.[49] The post-COVID shift to remote work, Over-The-Top (OTT) entertainment, and e-education highlights the urgent need for a robust, nationwide high-speed internet infrastructure to meet growing demand.[50]

Strengthening internet infrastructure requires equal emphasis on both access and content infrastructure. This means prioritising and liberalising subsea and inland fibre along with cable landing stations, as well as data centres, CDNs, and IXPs. Beyond connectivity and accessibility, internet connection quality, too, is paramount.[51] Stable connections and minimal latency ensure seamless continuity for demanding use cases like live video streaming, virtual reality, big data, and the Internet of Things. Data centres and IXPs work in tandem to bolster reliable and high speed internet accessibility and optimise data flow.

However, India lags in the proliferation of IXPs and data centres, with only 8% of cities having IXPs and 3 data centres per 10 million people.[52] Additionally, India is falling behind in terms of infrastructure, with only 17 submarine cables and 14 CLS, despite its strategic location connecting Southeast Asia to Europe and the US.[53] In contrast, the US is linked to the global internet via around 88 submarine cables[54] and the European Union (EU) has around 166 submarine cables.[55] China has invested in or built more than 65 subsea cables.[56] This highlights the urgency of strengthening all components of India's digital infrastructure.

The interconnectedness of infrastructure components underscores their synergistic role in accelerating internet access. India's robust and resilient internet infrastructure is fundamental for achieving universal access. Continued strengthening and expansion of this infrastructure will ensure India matches global standards for internet connectivity and broadband penetration.

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47 https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/

48 https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/

49 https://timesofindia.indiatimes.com/business/india-business/62gb-per-month-indians-to-top-data-use-in-5-years/articleshow/101175695.cms

50 https://telecom.economictimes.indiatimes.com/news/telecom-equipment/in-depth-is-indias-undersea-cable-system-in-for-a-shake-up/102738088

51 https://www.smartdc.net/data-centers-ensure-connectivity-in-our-digital-society/

52 https://pulse.internetsociety.org/resilience

53 https://timesofindia.indiatimes.com/business/india-business/big-boost-for-indias-internet-quality-three-large-undersea-cable-projects-to-expand-capacity-by-more-than-four-times/articleshow/112672969.cms

54 https://www.usni.org/magazines/proceedings/2023/may/information-warfare-depths-analysis-global-undersea-cable-networks

55 https://dgap.org/en/research/publications/protecting-eus-submarine-cable-infrastructure

56 https://asia.nikkei.com/Spotlight/The-Big-Story/China-s-undersea-cable-drive-defies-U.S.-sanctions

GLOBAL BEST PRACTICES FOR INFRASTRUCTURE DEVELOPMENT

Globally, various nations are implementing strategies to foster universal connectivity through robust digital infrastructure development.

Thailand: With its "Thailand 4.0" initiative,[57] Thailand prioritises nationwide digital infrastructure expansion, digital workforce development, and the digitization of government services. This includes strategic investments in data centres, cloud computing, and international digital gateways.

USA: The United States' Connect America Fund–II (CAF-II) aims to enhance broadband infrastructure, even in areas with existing fibre networks. Annual investments in this initiative reach $70-75 billion.[58]

Singapore: Singapore's OpenNet consortium, backed by government grants, separates infrastructure development and service provision to drive broadband growth. Singapore's broadband network offers 1Gbps speeds to over 85% of households, with a penetration rate of 91.8% by 2023.[59] Further goals of digitisation are supported by the new SG$100 million investment aimed to upgrade speeds to 10Gbps.[60] Details of Singapore's infrastructure success are elaborated in **Annexure-I.**

Malaysia: Malaysia's impressive 70% internet penetration is attributed to successful public-private partnerships (PPPs) for broadband infrastructure deployment.[61]

Netherlands: The Netherlands has robust connectivity and ensures rural-urban balance.[62] Government commitment ensures widespread 1 Gbps broadband access. Their national broadband strategy aimed at enabling broadband access to all households has also led to extensive fibre-optic networks.[63] AMS-IX (Amsterdam Internet Exchange) improves broadband performance by reducing latency,[64] while tier-1 data centres strengthen digital infrastructure.[65] Details of Netherland's infrastructure success are elaborated in **Annexure-I.**

57 https://www.industry.go.th/web-upload/1xff0d34e409a13ef56eea54c52a291126/m_magazine/12668/373/file_download/b29e16008a87c72b354efe-bef853a428.pdf

58 https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-tmt-broadband-infrastructure-for-trans-forming-india-noexp.pdf

59 https://www.zdnet.com/home-and-office/networking/singapore-is-boosting-its-broadband-for-ai-and-autonomous-vehicles/#google_vignette

60 https://www.zdnet.com/home-and-office/networking/singapore-is-boosting-its-broadband-for-ai-and-autonomous-vehicles/#google_vignette

61 https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-tmt-broadband-infrastructure-for-trans-forming-india-noexp.pdf

62 https://omdia.tech.informa.com/om030124/netherlands-country-regulation-overview--2023

63 https://digital-strategy.ec.europa.eu/en/policies/broadband-netherlands#:~:text=Main%20aims%20for%20broadband%20development&text=In%20this%20plan%2C%20the%20Dutch,of%201%20Gbps%20by%202023.

64 https://www.juniper.net/us/en/customers/ams-ix-case-study.html

65 https://www.stackscale.com/data-centers/amsterdam/

South Korea: In 2017, South Korea was ranked second out of 176 countries in the ITU's ICT Development Index. 100% of its urban and rural populations are covered by a 4G mobile network. South Korea's "government-driven, infrastructure-first" approach, centred on top-down policies, has been key in developing robust telecommunications and broadband networks.[66]

China: China has developed the world's largest optical fiber and 4G networks and achieved over 70% internet penetration. Between 2015 and 2020, fixed broadband household penetration increased from 52.6% to 96%, while mobile broadband user penetration rose from 57.4% to 108%.[67] China's growing digital infrastructure can be attributed to increased government investment which is comparable to developed economies as well as light regulation that drew innovation in the sector.[68]

Germany: Germany is nearing complete 5G coverage for households, with 98.1% of the population already covered by the 5G network. The impressive 5G coverage was made possible through a multi-pronged government-led effort which included a dedicated 5G Strategy in 2016 to support network expansion through investment friendly frameworks and regulatory support.[69] Given Germany's relatively slow growth in establishing a fiber optic network,[70] the 2021 coalition agreement prioritized digital infrastructure, targeting full fiber optic and 5G coverage by 2025. [71]

66 https://www.global-solutions-initiative.org/wp-content/uploads/2023/11/Yoon-Hyun-Kang.pdf

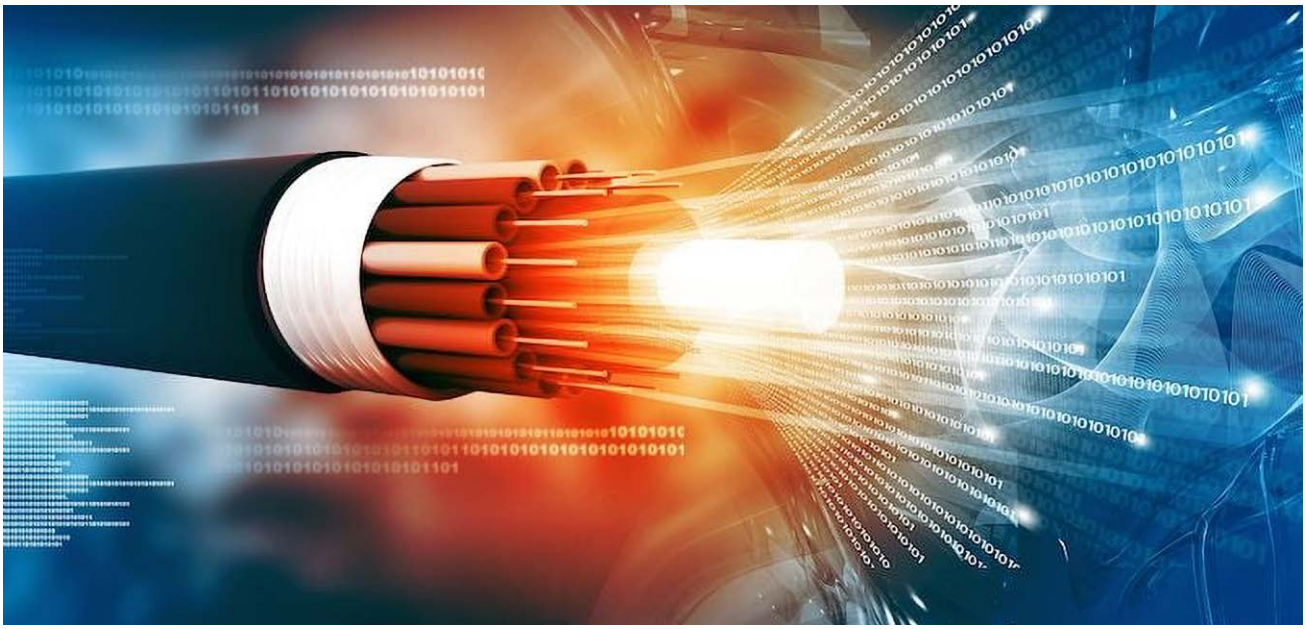
67 https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021/#:~:text=The%20%E2%80%9C14th%20Five%2DYear%20Plan%E2%80%9D%20period%20is%20an%20important,of%20industry%20chains%2C%20promote%20the

68 https://www.elibrary.imf.org/view/journals/001/2019/016/article-A001-en.xml#:~:text=Reflecting%20continued%20government%20investment%2C%20the,services%20to%20millions%20of%20users

69 https://bmdv.bund.de/SharedDocs/EN/publications/5g-strategy-for-germany.pdf?__blob=publicationFile

70 Germany ranks second to last in the EU for fiber optic coverage, with 29.8% of households connected compared to the EU average of 64%. https://digital-strategy.ec.europa.eu/en/factpages/germany-2024-digital-decade-country-report

71 https://digital-strategy.ec.europa.eu/en/policies/broadband-germany#:~:text=Summary%20of%20broadband%20development%20in,of%20all%20areas%20by%202030.



EU: The region has achieved an overall 5G coverage of 89% with a total fiber optic coverage of 64%.[72] EU's Digital Decade policy serves as the main tool for coordinating regulatory[73] and non-regulatory to create an enabling governance framework. Moreover, a total of EUR 205.5 billion was dedicated to the digital transition between 2021 and 2023, accounting for nearly 17.4% of the overall EU budget.[74]

In essence, the backbone, middle mile, and last mile function in synergy to create a robust internet infrastructure. By strengthening each component, India can unlock the transformative potential of the digital revolution for its citizens, businesses, and the overall economy.

CHALLENGES

India's journey towards building a world-class digital infrastructure is ongoing. Despite Significant progress, challenges remain within the policy and regulatory environment. If unaddressed, these hurdles could hinder the growth of resilient and inclusive digital transformation. It is essential to identify solutions to ensure continued and equitable progress.

a) Achieving Widespread Fiberisation and Infrastructure Deployment

Despite significant progress in mobile technology, India's fixed line fiberisation lags behind developed nations. A World Bank study also emphasises the significant impact of broadband penetration on a country's GDP growth, with every 10 percentage point increase contributing an additional 1.38 percentage points.[75]

72 https://ec.europa.eu/newsroom/dae/redirection/document/106687

73 The European Digital Infrastructure Consortium (EDIC) is a legal framework aiding Member States to set up and implement multi-country projects. https://digital-strategy.ec.europa.eu/en/policies/edic

74 https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/horizontal-priorities/digital-tracking_en

75 https://documents1.worldbank.org/curated/en/645821468337815208/pdf/487910PUB0EPI1101Official0Use0Only1.pdf

As of July 2024, India has achieved 44% fiberisation of Telecom Towers[76]. This leaves India well behind, compared to over 70% fiberisation achieved in most developed nations.[77] India must significantly accelerate fibre deployment to meet the demands of 5G and 6G and double-up fibre deployments from the current 20 million kilometres per year aiming to reach nearly 110 million homes with quality broadband delivering speeds of at least 1Gbps.[78]

PARAMETER	INDIA	CHINA	SOUTH KOREA	JAPAN	USA
Fibre kilometre (fkm) per capita	0.09[79]	1.3[80]		1.35[81]	1.34[82]
Fiberisation	33%	80% - 90%[83]	65-70%	80%-90%[84]	80%-90% [85]

While India is mobile-first, wireless data's limitations necessitate a robust network infrastructure that combines fibre optics, Wi-Fi, and satellite communication, mirroring the 80-85% Fiberisation rate achieved by the US, China and Japan.[86]

However, the massive investment required for fiberisation, estimated at around ₹2.2 lakh crore, and the regulatory landscape is challenging for telecom operators[87] adds to the complexity of the issue. Moreover, achieving rapid deployment, particularly to connect every village with optical fibre cable within 1,000 days as per the government's vision, presents logistical challenges.[88]

Though the government has been investing in infrastructure creation via initiatives like Bharatnet and the Network for Defence Services, to name a few, it hasn't been sufficient to overcome the issue.

Moreover, India also lacks domestic submarine cables due to high costs, though such cables could improve connectivity by linking coastal cities as well as help connect international CLS to domestic CLS-Point of Presence (PoP) and state capitals. In India there is a concentration of sub-sea cables in about 14 cable landing stations which poses a single point of failure risk.[89] Hyperscalers, aware of this risk, sometimes choose dedicated cable stations.

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76 https://www.communicationstoday.co.in/telecom-towers-fiberisation-the-master-key-for-faster-5g-rollout/

77 https://indianinfrastructure.com/2023/08/21/data-explodes-the-big-shifts-in-indian-telecom/

78 https://economictimes.indiatimes.com/industry/telecom/telecom-news/india-must-close-gap-with-china-on-fibre-deployment-sterlite-tech-exec/articleshow/109568238.cms?from=mdr

79 https://www.ey.com/content/dam/ey-unified-site/ey-com/en-in/insights/telecommunications/documents/ey-dipa-repoert-gati-shakti-paving-the-way-for-accelerated-digital-infrastructure-rollout-in-india.pdf

80 https://aabsys.com/fiberization-of-telecom-towers-for-effective-5g-rollout-in-india/#:~:text=A%20country%20needs%201.3%20km,1.34%20and%20China's%20is%201.3.

81 https://telecom.economictimes.indiatimes.com/news/5g-to-drive-fiber-market-but-growth-in-rural-broadband-a-distant-dream/94290191

82 https://telecom.economictimes.indiatimes.com/news/5g-to-drive-fiber-market-but-growth-in-rural-broadband-a-distant-dream/94290191

83 https://economictimes.indiatimes.com/industry/telecom/telecom-news/fibre-rollout-pace-jumps-6-fold-since-5g-launch-still-trails-target-global-markets/articleshow/103235037.cms?from=mdr

84 https://economictimes.indiatimes.com/industry/telecom/telecom-news/fibre-rollout-pace-jumps-6-fold-since-5g-launch-still-trails-target-global-markets/articleshow/103235037.cms?from=mdr

85 https://economictimes.indiatimes.com/industry/telecom/telecom-news/fibre-rollout-pace-jumps-6-fold-since-5g-launch-still-trails-target-global-markets/articleshow/103235037.cms?from=mdr

86 https://telecom.economictimes.indiatimes.com/news/low-fiberisation-leads-to-a-5g-success-story-roadblock-telcos-infra-providers/90975203

87 https://www.thehindu.com/sci-tech/technology/fiberisation-for-5g-deployment/article65677914.ece

88 https://www.thehindu.com/sci-tech/technology/fiberisation-for-5g-deployment/article65677914.ece

89 https://timesofindia.indiatimes.com/business/india-business/big-boost-for-indias-internet-quality-three-large-undersea-cable-projects-to-expand-capacity-by-more-than-four-times/articleshow/112672969.cms

To build a CLS requires an International Long Distance (ILD) license and landing service provider status. The entity must join the cable consortium and provide landing services, with infrastructure costs around $5 million or more. Only those able to make this investment and wait 5-8 years for returns can establish a cable station.[90] While data centers drive demand, it is crucial to diversify CLS locations to promote the growth of data centers in cities beyond Chennai and Mumbai.

Despite the private sector's significant role in India's telecom infrastructure development, to fully realise the nation's digital economy ambitions, "an estimated $15 to $20 billion annually" (~₹1.25-1.67 lakh crore) in additional investment is necessary.[91] This highlights the need for clear, certain and consistent regulatory reforms to create a more attractive investment environment.

b) Expanding Broadband Access in Rural India

India's rural-urban digital divide is highlighted by the stark contrast in internet density—45.12% in rural areas compared to 112.48% in urban areas.[92] It stems from early efforts by the government and private sector focusing on mobile broadband to meet basic connectivity needs[93], leaving wireline infrastructure underdeveloped and more so in rural areas. Several factors amplified this gap:

i) PM-WANI Challenges: While the PM-WANI scheme holds the potential to transform rural connectivity, high leased line costs, infrastructure limitations, and lack of awareness hinder its widespread adoption.[94]

ii) Challenges for LCOs: Recognising the potential of LCOs to drive last-mile connectivity and broadband proliferation, the Indian government amended the Cable Television Network Rules in 2023.[95] However, challenges like Capex requirements, long payback periods, operational delays, limited bargaining power, and disincentives caused by the inclusion of broadcasting revenue in licence fee calculations impede their progress.[96]

iii) Limited Incentives for ISPs: Rural areas often present lower profitability for ISPs due to factors like lower population density, dispersed settlements, and potential lower income levels of customers. This reduces the commercial attractiveness of investing in rural connectivity.[97] TRAI's Recommendations on "Roadmap to promote Broadband Connectivity and enhanced Broadband Speed" made in August 2021[98], should be approved and adopted for expeditious implementation.

90 Based on input from industry stakeholders

91 https://telecom.economictimes.indiatimes.com/news/industry/etdigitaltelcosummit2023-indias-telecom-industry-has-invested-rs-3-lakh-crore-in-in-fra-to-date-akhil-gupta/102824139

92 https://www.trai.gov.in/sites/default/files/QPIR_09102024_0.pd

93 https://trai.gov.in/sites/default/files/PIR_12032024_0.pdf

94 https://telecom.economictimes.indiatimes.com/news/industry/in-depth-what-ails-indias-growth-in-public-wi-fi/102295753

95 https://economictimes.indiatimes.com/industry/telecom/telecom-news/government-introduces-key-amendments-to-cable-tv-network-rules/article-show/104010879.cms?from=mdr

96 http://aidcf.com/pdf/Accelerating_Cable_Broadband_with_Regulatory_Impetus.pdf

97 https://documents1.worldbank.org/curated/en/099230004062228270/pdf/P1723000e5e0d20908c790a5ffdda147f1.pdf

98 https://trai.gov.in/sites/default/files/PR_No.41of2021.pdf

c) India's Rigorous Telecom Licensing Framework

India's telecom licensing system, with its multiple licenses and permits, poses challenges for smaller or newer companies by increasing costs, delays, and complexity. This can discourage investment in critical digital infrastructure, stifle innovation, and restrict market entry, thereby limiting the development of new technologies and hindering the growth of the country's digital economy.

As deliberated in the Parliament, the legislative intent of the Telecom Act (2023) is to transition from the current complex licensing system to a simplified authorization process. As the then Hon'ble Minister of Communications, Shri Ashwini Vaishnaw had stated that the Act will replace the 100 types of licenses that currently exist with a straightforward authorization structure. This change aims to foster innovation and competition by reducing administrative burdens, removing entry barriers, and enhancing the affordability and accessibility of telecom infrastructure and digital services.

However, TRAI's recent recommendations on service authorization[99] mainly reorganizes the current licensing regime without making any substantial reforms, as was envisaged, under the Telecommunications Act, 2023. They have introduced some additional complexities by categorizing service authorizations into three types: main, auxiliary, and captive. The recommendations seem to be somewhat misaligned with the Act's aim to simplify processes and reduce regulatory burdens by retaining geographic constraints which include spectrum assignments at the Telecom Circle or Metro level and proposing fragmented sub-circle authorizations for internet services.

d) Simplifying Infrastructure Sharing in India

Infrastructure sharing includes the sharing of active infrastructure (like lit fibre, access node switches, and broadband remote access servers) and passive infrastructure (like dark fiber, physical sites, poles and ducts and also power supplies). The reduced costs for service providers as a result of such sharing could also translate into reduced costs for consumers.

In 2007, TRAI recommended limited active infrastructure sharing among licensed TSPs following which, DoT issued guidelines on infrastructure sharing in 2008. Subsequently, after several amendments to the Unified License (UL), DoT issued amendments in April 2021 to the UL, Unified Access Service License (UASL), and ISP licences, allowing for infrastructure sharing related to Wi-Fi equipment such as Wi-Fi router, access point, and backhaul,[100] amongst licensed service providers.

Currently, in India, the UL regime has several provisions pertaining to infrastructure sharing. While passive infrastructure is allowed in India to some extent, it is not allowed uniformly across all licences as some of the service licences and authorizations under UL do not contain specific provisions relating to the permission for passive infrastructure sharing.[101] Provisions on passive infrastructure sharing, viz, building, tower, dark fibre, duct space, right of way etc. are covered in chapters on access service, internet service, national long-distance service,

99 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2056267#:~:text=In%20total%2C%20there%20are%2014,an%20agreement%20with%20the%20entity.

100 https://www.trai.gov.in/sites/default/files/CP_INF_13012023.pdf

101 https://trai.gov.in/sites/default/files/Recommendation_24042024_0.pdf

international long-distance service, and machine to machine (M2M) with Infrastructure Provider (IP-I) registered companies specifically permitted to lease/rent out/sell dark fibre, Right of Way, duct space, towers to licensed TSPs.

However, the 2024 TRAI recommendations on infrastructure sharing propose that all telecommunication service licensees should be allowed to share both passive and active infrastructure.[102] As per the said recommendations, active infrastructure that covers elements directly related to service delivery, can be shared with all types of telecom licensees, provided the sharing aligns with the scope of their respective licenses.

The exclusion of infrastructure providers (IP-I) and Digital Connectivity Infrastructure Provider (DCIP) from these recommendations is concerning as their exclusions incomplete framework for Service Authorisations. In case a separate consultation is to be done, then it should be conducted in a manner that it is synchronised with the remaining service authorisation framework to ensure holistic rules governing both infrastructure providers and service providers.

Infrastructure sharing models have been developed and implemented both in developed and emerging markets to ensure efficiency and sustainability. Details on infrastructure sharing models in each of these jurisdictions are elaborated in **Annexure-II**:

EUROPEAN UNION (EU)	USA	INDONESIA
Allows[103] co-location and sharing of network elements and associated facilities for providers of electronic communications networks	Allows both co-location and infrastructure sharing	Allows sharing and transfer of spectrum and infrastructure sharing
Similar framework applies for sharing of passive or active infrastructure.[104]	Allows both active and passive infrastructure sharing without any evident exclusion	Sharing of passive infrastructure is mandatory for telecommunications operators
To address market failures related to Significant Market Power (SMP), operators designated as SMP (as defined under the statute) may be obliged to provide access to their active or passive infrastructure.[105]	Law requires local exchange carriers to share infrastructure with qualifying carriers[106] to enable such recipients to provide telecommunication services	By enabling the joint utilisation of both active and passive infrastructure among licensed and unlicensed entities, operators can reduce their cost burdens

Subsequent to the TRAI's consultation paper on Telecommunication Infrastructure Sharing, Spectrum Sharing, and Spectrum Leasing[107] and an open house discussion held in 2023,[108] the Authority made many positive recommendations in April 2024.[109] TRAI recommended that telecom licensees be allowed to share passive infrastructure with all telecom service providers and share active infrastructure elements, excluding core networks, to ensure each licensee maintains at least two independent core

102 https://trai.gov.in/sites/default/files/Recommendation_24042024.pdf

103 By way of Article 44 of European Electronic Communications Code (EECC)

104 Article 47 of EECC

105 Article 68 of EECC

106 Defined as a telecom carrier that lacks economies of scale or scope as determined as per regulations as well as those that offer telephone exchange service, exchange access, and any other service that is included in universal service, to all consumers without preference throughout the service area

107 https://www.trai.gov.in/sites/default/files/CP_INF_13012023.pdf

108 https://www.trai.gov.in/events/open-house-discussion/ohd-consultation-paper-telecommunication-infrastructure-sharing

109 https://www.business-standard.com/industry/news/trai-moots-passive-infrastructure-sharing-among-telecom-service-licensees-124042401229_1.html

networks. Additionally, TRAI advised the DoT to review stand-alone telecom licenses and consider a provision similar to clause 33.3 of the UL, allowing active and passive infrastructure sharing across services under any telecom license. However, there was no specific recommendation to permit sharing with license exempt entities. Current Indian law restricts license exempt entities from accessing passive infrastructure, limiting their ability to build and manage networks. While these recommendations are meaningful, enabling passive infrastructure sharing for license exempt operators could further enhance competitiveness.

e) Limitations in Measuring India's Digital Readiness

India's pursuit of its ambitious Digital India goals necessitates the creation of robust indices to measure aspects related to digital connectivity across states and union territories. This will ensure consistent progress monitoring and identify areas for improvement. Existing global indices like the Network Readiness Index (NRI)[110] and the ICT Development Index (IDI)[111] provide valuable insights but may have limitations when applied to the specific context of a developing economy like India. They primarily focus on access metrics without fully considering the quality, reliability, and affordability of broadband services.[112]

The Broadband Readiness Index (BRI), introduced under the National Digital Communication Policy (NDCP) 2018, was designed to evaluate and improve digital communications infrastructure across India's states and union territories. By fostering collaboration among government bodies, private enterprises, and local stakeholders, the BRI sought to address issues like RoW challenges and attract investments. Its main goal was to assess the state of digital infrastructure, providing insights to guide strategic decision-making and investment in ICT programs.

Its two distinct segments, part I scrutinised infrastructure development across nine key parameters, including the availability of state policies on RoW and Towers, fibre connectivity, and the extent of public institutions integrated into the digital network; while part II delved into demand-side indicators such as household internet usage, smartphone penetration, and digital literacy rates. However, the BRI has not been implemented due to operational challenges, thereby calling for the recalibration of such indices in driving digital inclusion and development initiatives.[113]

110 https://portulansinstitute.org/the-value-and-uses-of-the-network-readiness-index/

111 https://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2015/methodology.aspx

112 https://icrier.org/pdf/State_of_India_Digital_Economy_Report_2024.pdf

113 https://icrier.org/pdf/2-March-2020/BRI.pdf

RECOMMENDATIONS

To unlock India's full digital potential and foster a thriving digital economy, a multifaceted strategy is required. Targeted policy interventions aimed at simplifying regulations, efficient fund utilisation and proactive policy support will create a more conducive environment. A few interventions are suggested here:

a) Strengthening Digital Infrastructure:

CDNs, Data Centers, Submarine Cables, and IXPs: Expanding CDNs, data centers, and IXPs is crucial to meet rising broadband demand, reducing latency and improving internet access, especially in remote areas. Light-touch regulations, infrastructure sharing and appropriate incentives can accelerate this growth. Open access to submarine CLS and promoting domestic cables will prevent monopolies and strengthen connectivity. Collaborative investments and diversified landing points can reduce failure risks.

b) Overcoming Obstacles to Fiberisation:

To address challenges related to increasing fiberisation and accelerate India's digital infrastructure progress, the following strategies are crucial:

1. Streamline Regulation: New RoW rules do create uniform approval processes but awareness creation at the state level to expedite fibre deployment.
2. Increase Government Support: Leverage programs like BharatNet and Smart Cities for full tower Fiberisation.
3. Promote Collaborative Partnerships: Actively foster PPPs between telecom operators, infrastructure providers, and government agencies.
4. Support R&D and Local Innovation: Continue to support domestic innovation through the Telecom Technology Development Fund (TTDF), prioritising the development of solutions tailored for rural connectivity to ensure inclusive digital growth.
5. Enhancing domestic submarine cable capacity: Encourage collaboration between multiple providers and hyperscalers, allowing them to pool resources for large-scale investments. Promoting the establishment of multiple landing points would prevent single points of failure, ensuring a resilient and reliable subsea cable network.

c) Strategies for Last Mile Connectivity:

To overcome challenges related to last mile connectivity and bridge the rural-urban divide, India can implement the following:

- **Support PM-WANI:** Regulatory measures should be implemented to lower internet bandwidth costs, making Wi-Fi services more affordable for PDOs. Some recent steps taken by DoT with PM-WANI amendments issued on September 16th and TRAI's draft Telecom Tariff Order (TTO) which permits PDOs to operate with retail internet bandwidth are welcome moves in this regard. Widespread awareness campaigns are essential to educate the public and businesses about PM-WANI's benefits. Continued

government support, including policy backing and funding along with prioritizing satellite-based broadband in rural areas will ensure uninterrupted high-speed internet access during emergencies.

- **Empower Local Cable Operators:**[114] Broadcasting revenues should be decoupled from license fee calculations to incentivize their transition into ISPs, fostering spread of broadband and increasing competition. Encouraging revenue-sharing agreements between TSPs and LCOs, alongside regulatory support and investment in technology integration, will further enhance collaboration. Additionally, raising awareness of broadband benefits and the role of LCOs is essential for community engagement.

  One of the most promising examples of expanding fixed broadband access via local cable operators comes from Kerala where Kerala Vision, a leading ISP, partnered with over 8,000 LCOs to achieve extensive optic fiber connectivity in Kerala, outpacing larger telecom players. It supported LCOs by simplifying regulatory processes and upgrading their technology while enhancing backhaul capacity through its Multi-Protocol Label Switching (MPLS) network. A sustainable revenue-sharing model ensured the financial viability of LCOs, creating a mutually beneficial ecosystem. This approach can serve as a blueprint for other regions in India.

- **Incentivize Tier-2 & Tier-3 ISPs for Rural Expansion:** Reward ISPs for exceeding a minimum of 20% year-over-year rural subscriber growth within their licence area and incentivize rapid rural expansion through higher tiers based on achieved growth percentages.[115] Additionally, tax breaks for ISPs that consistently demonstrate significant growth in rural subscribers is recommended.

- **Addressing Gaps in Rural Connectivity through Local Entrepreneurs and Enhancing Common Service Centres:** Rural India has a strong demand for digital infrastructure, but current efforts are insufficient. Connectivity alone is not enough; it must translate into "meaningful connectivity". Policy solutions on the lines of TRAI recommendations of 2021 (referred earlier) should focus on providing services like telemedicine, education, and commerce through broadband in such regions along with efforts to enhance digital literacy.

114 https://www.trai.gov.in/sites/default/files/Recommendations_31082021_0.pdf

115 https://www.trai.gov.in/sites/default/files/Recommendations_31082021_0.pdf

- **Leveraging local content creation to drive demand**: State governments should offer incentives for local entertainment content production, and similar incentives could be extended to the gaming and education sectors. Local content in regional languages can boost rural demand for digital connectivity.

- **Home Broadband as a Utility:** Digital connectivity is essential and should be prioritized like electricity and water in buildings. Authorities should not approve any building without verified digital infrastructure compliant with the amended MBBL and BIS standards. While the Central government has amended building by-laws to include digital connectivity, some states have yet to adopt the same.

d) Ease of Doing Business: TRAI's 2023 recommendations for 'Ease of Doing Business in Telecom and Broadcasting Sector,'[116] aiming to create a process-oriented approach for periodic reviews and reforms, including a user-friendly, transparent digital single window system to streamline inter-departmental online processes, should be looked at in this regard. Moreover, a light touch regulatory approach within the telecom sector is much needed. These reforms should focus on reducing compliance burden; **restricting licensing to only services that utilize scarce resources or pose a threat to public health** and introducing a swift online registration system to replace cumbersome licensing processes.

An important development in this regard is the enactment of the Telecom Act, 2023. The TRAI recommendations on the Framework of Service Authorisations encourage active and passive infrastructure sharing is encouraged between authorised entities, however, IP-I and DCIP are excluded from the framework, awaiting further consultations. Synchronisation of the consultations and respective Rules is necessary for a comprehensive and cohesive framework.

e) Enabling Comprehensive Infrastructure Sharing

India can foster a competitive and efficient digital infrastructure landscape through these measures:

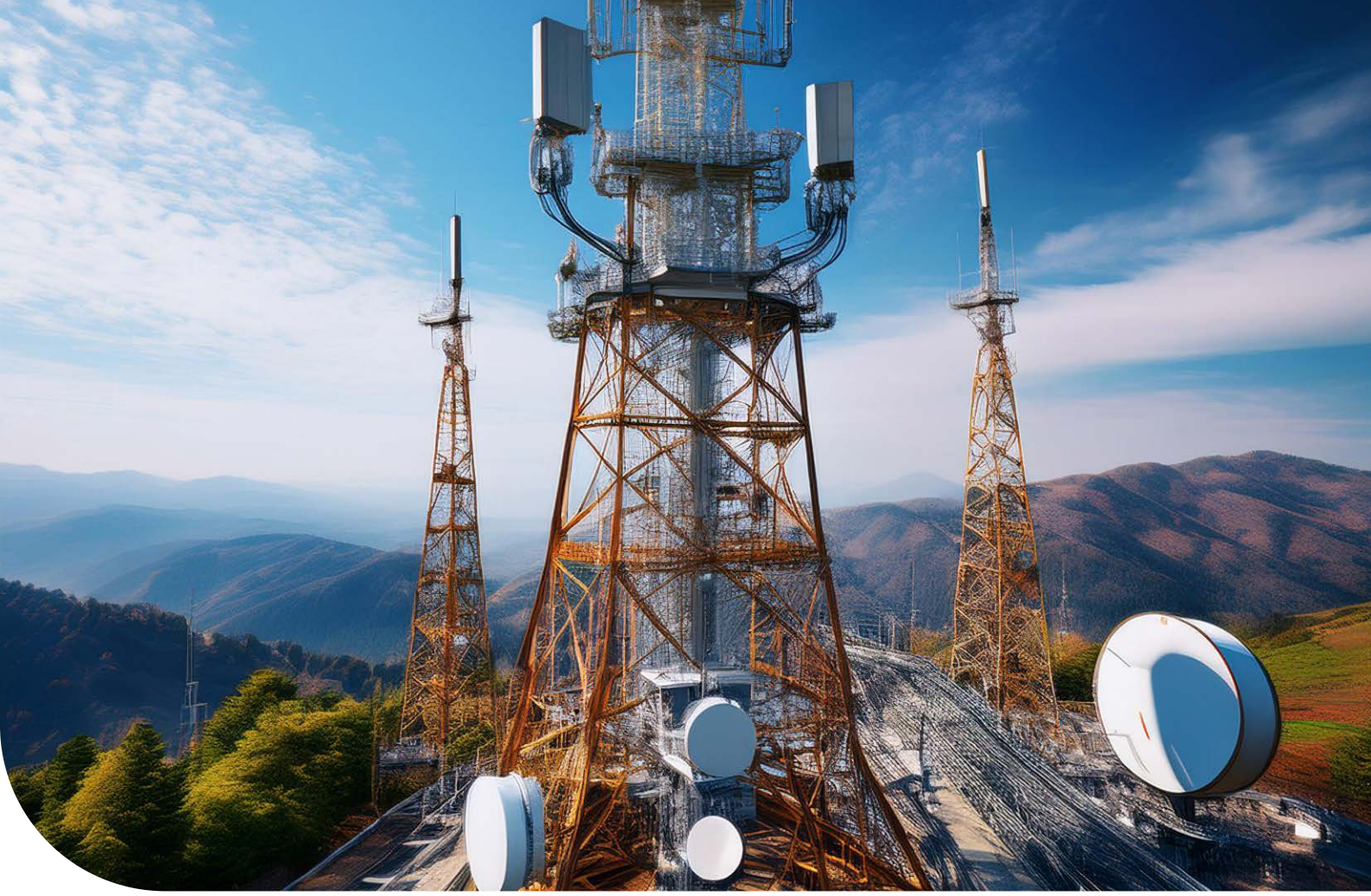
1. Allow Active and Passive Sharing: Introduce a clear non-discriminatory regulatory framework that allows the sharing of both active infrastructure and passive infrastructure uniformly across categories of service authorizations under section 3(1) (a) and 3(1) (b) of Telecom Act, 2023. This has also been acknowledged and recommended by TRAI in its recent recommendations on '**Telecommunication Infrastructure Sharing, Spectrum Sharing, and Spectrum Leasing**'.[117] Additionally, passive infrastructure sharing ought to be allowed to license exempt entities to enable them to set up their own 'dark fibres' for captive use.

2. Draw from International Best Practices: Draw insights from successful infrastructure sharing models implemented in both developed and emerging markets, adapting them to the unique context of India. For instance,[118] mandatory passive sharing in Indonesia; clear provisions for both active and passive sharing in EU and USA and regulatory frameworks promoting access under fair terms in EU.

116 https://www.trai.gov.in/sites/default/files/Recommendations_02052023_0.pdf

117 https://trai.gov.in/sites/default/files/Recommendation_24042024_0.pdf

118 Annexure II



A successful illustration of infrastructure sharing emerges from tower sharing arrangements in India.[119] Transparent and non-discriminate basis sharing of towers along with initiatives like Mobile Operators Shared Towers (MOST) benefited consumers and service providers alike, resulting in marked reductions in capital and operational expenditures, enhanced capital efficiency, and improved energy usage in national telecom asset creation.[120]

f) **Creating a Digital Readiness Index for India's Broadband Landscape:** Indices provide standardized metrics to assess socio-economic phenomena, guiding policymakers and stakeholders in monitoring progress and making informed decisions. India needs a Digital Readiness Index (DRI) to evaluate policy implementation, infrastructure availability, and digital connectivity, as the existing BRI is stalled due to operational challenges. Detailed metric for DRI is given in Annexure-III. This will offer policymakers insights into India's digital readiness, enabling realistic goals aligned with international standards. A state-wise or Licensed Service Area (LSA)-wise index will support evidence-based decisions, efficient resource allocation, and help bridge infrastructure gaps, advancing Digital India's goals.

119 https://www.itu.int/net/wsis/c2/docs/2008-May-19/mdocs/C6-session3-Gupta.pdf

120 https://trai.gov.in/sites/default/files/presentations_&_cv/Day2_24Aug2017/Session4_Infra%20Sharing/Infrastructure%20Sharing_TR%20Dua.pdf

CONCLUSION

Building resilient, inclusive digital infrastructure is essential for India to achieve its full potential in the digital era. It fuels economic progress, promotes innovation, and connects communities, ultimately improving the lives of citizens across the nation. Government's ambitious Digital India initiative has spurred remarkable digital transformation. However, ensuring ubiquitous and equitable access to high-speed internet remains a challenge, especially in bridging the digital divide between rural and urban areas. To truly realise the goals of Digital India, several key priorities must be addressed:

1. Expanding Wireline Infrastructure: While mobile internet has seen significant growth, concerted efforts are needed to accelerate Fiberisation and expand wireline infrastructure to complement mobile networks.

2. Targeted Policy Interventions: Need for proactive government policies to address remaining hurdles such as streamlining regulatory processes, clarifying complex levies, and incentivizing investment.

3. Leverage Technology for Last Mile Connectivity: Harness the power of technology to bridge the gap in last-mile connectivity by capitalising on innovations like Satellite Communication (Satcom) and Public Wi-Fi networks based on the PM-WANI framework

4. Global Models and Collaboration: Drawing insights from successful infrastructure development models worldwide, combined with strong public-private partnerships, will accelerate the deployment of robust broadband networks nationwide.

By prioritising these strategic actions, India will solidify its digital foundation. This will propel economic growth, foster inclusivity, drive innovation, and ensure that all citizens reap the benefits of the digital age.

ANNEXURE-I

Global Best Practices for Infrastructure Development

Globally, various nations are implementing strategies to foster universal connectivity through robust digital infrastructure development.

- **Singapore**: Singapore's OpenNet consortium, backed by government grants, separates infrastructure development and service provision to drive broadband growth. Singapore's broadband network offers 1Gbps speeds to over 85% of households, with a penetration rate of 91.8% by 2023.[121] Further goals of digitisation are supported by the new SG$100 million investment aimed to upgrade speeds to 10Gbps.[122] This upgrade marks a next step in Singapore's Nationwide Broadband Network, commercially launched in 2010 with a $1 billion investment from the Government. The network, which can already support speeds of 10Gbps, reached more than 95% of homes and businesses in Singapore in 2013 becoming a first in the world.[123]

  Building on previous plans, Singapore launched the Digital Connectivity Blueprint in 2023 with an aim to enable Singapore's entire "digital infrastructure stack".[124] Two of the Blueprint's five strategic priorities relate specifically to connectivity positioning Singapore as a global leader in digital infrastructure.

  One priority aims to double submarine cable landings within the next 10 years to further expand and diversify Singapore's submarine cable network. Another priority sets a goal of 10 Gbps domestic connectivity within the next five years. Singapore plans to support this second priority through actions such as facilitating a tenfold increase in the NBN's bandwidth and allocating spectrum to support faster Wi-Fi networks and 5G Standalone (SA) networks. Resilience, security and sustainability of Singapore's digital infrastructure are also included in the Blueprint's strategic priorities.[125]

  Adding to this, recently, the country also launched new standards for data centres to support the growth of compute capacity while ensuring environmental sustainability and it will also help operators determine the best operating temperature to optimise energy efficiency, whilst safeguarding operational reliability.[126] Boasting an impressive network of 100 data centres, 1,195 cloud service providers, and 22 network fabrics, Singapore's digital infrastructure is formidable. With a robust network supported by 24 submarine cables, the city-state has emerged as a global cloud connectivity leader.[127]

121 https://www.zdnet.com/home-and-office/networking/singapore-is-boosting-its-broadband-for-ai-and-autonomous-vehicles/#google_vignette

122 https://www.zdnet.com/home-and-office/networking/singapore-is-boosting-its-broadband-for-ai-and-autonomous-vehicles/#google_vignette

123 https://www.straitstimes.com/tech/s-pore-to-invest-up-to-100m-to-upgrade-national-broadband-network-to-10gbps

124 https://www.imda.gov.sg/-/media/imda/files/programme/digital-connectivity-blueprint/digital-connectivity-blueprint-report.pdf

125 https://www.oecd-ilibrary.org/sites/281399b4-en/index.html?itemId=/content/component/281399b4-en

126 https://w.media/singapore-unveils-ambitious-project-to-transform-internet-infrastructure-expand-connectivity/

127 https://www.aseanbriefing.com/news/singapores-data-center-sector-regulations-incentives-and-investment-prospects/

- **Netherlands**: The Netherlands is one of the most advanced telecom markets in Europe and is one of the top performers in the EU in terms of providing connectivity and bridging the gap between urban and rural areas.[128] The Netherlands has achieved impressive broadband penetration due to several key factors. First and foremost, the Dutch government has shown proactive commitment to promoting digitalization and high-speed internet access. Their national broadband strategy was formulated and close to ensuring that all households have access to broadband networks of at least 100 Mbps, with a vast majority enjoying speeds of 1 Gbps by 2023.[129] This commitment has led to extensive fibre-optic networks covering a significant portion of the country, with fixed broadband reaching 100% of households in 2018. As of 2021, more than half of Dutch households have access to fibre optic networks, and it's projected that nearly 85% will have access by 2025.[130]

  A crucial aspect of the Netherlands' approach is its market-based infrastructure rollout. Private operators play a significant role in deploying broadband networks independently, supported by coordination efforts from local and regional actors. This strategy aims to remove barriers and facilitate information exchange among stakeholders, ensuring efficient deployment and widespread access.[131] The Netherlands also stands out for its low latency rates in the EU.[132] Additionally, the Amsterdam Internet Exchange (AMS-IX) also plays a significant role in the Netherlands' impressive broadband penetration. AMS-IX is one of the largest Internet Exchanges globally in terms of the number of connected peering networks.[133] This, combined with the Amsterdam region being part of a leading group of tier-1 data centres alongside London, Frankfurt, and Paris, further enhances the country's digital infrastructure.[134] Notably, the region has shown the highest increase in square metres among these key data centre hubs.[135] These factors collectively underline Netherlands' position as a leader in high-speed internet access and digital connectivity within Europe, driven by its commitment to digital infrastructure, strong public-private collaboration, and robust fibre networks.

128 https://omdia.tech.informa.com/om030124/netherlands-country-regulation-overview--2023

129 https://digital-strategy.ec.europa.eu/en/policies/broadband-netherlands#:~:text=Main%20aims%20for%20broadband%20development&text=In%20this%20plan%2C%20the%20Dutch,of%201%20Gbps%20by%202023.

130 https://dutchreview.com/expat/fibre-optics-in-the-netherlands/

131 https://ec.europa.eu/newsroom/document.cfm?doc_id=44325

132 https://investinholland.com/why-invest/infrastructure/digital/

133 https://www.juniper.net/us/en/customers/ams-ix-case-study.html

134 https://www.stackscale.com/data-centers/amsterdam/

135 https://nlnet.nl/project/digitalmainport/TheThirdMainport.pdf

ANNEXURE-II

- **European Union:** The European Union (EU) allows[136] co-location and sharing of network elements and associated facilities for providers of electronic communications networks. As per this provision, an operator[137] may be required to co-locate and share the network elements and associated facilities installed on, over or under public or private property in order to protect the environment, public health, public security or to meet town- and country-planning objectives subject to mutual agreement. Similar framework applies for sharing of passive or active infrastructure.[138] Further, to address market failures related to Significant Market Power (SMP), operators designated as SMP (as defined under the statute) may be obliged to provide access to their active or passive infrastructure.[139]

  Additionally, to make high-speed broadband quickly available, the EU established a set of harmonised measures to lower the cost of rolling out broadband, through the Broadband Cost Reduction Directive.[140] One of the ways laid down to reduce cost is providing access to existing physical infrastructure. by network operators to electronic communication network operators intending to roll out high-speed broadband networks under fair and reasonable terms and conditions, including price.

- **USA:** Telecommunications Act 1996, contains requirements for both co-location and infrastructure sharing under different provisions of the said Act. There is a separate provision[141] on Infrastructure Sharing which requires local exchange carriers to share infrastructure with qualifying carriers[142] to enable such recipients to provide telecommunication services, etc. Another provision requires telecommunication carriers to provide access to poles, ducts, conduits and rights-of-way to competing carriers.[143] Thus, the USA allows both active and passive infrastructure sharing without any evident exclusion.

- **Indonesia:** In 2020, the Omnibus Law (Law No. 11 of 2020 on Job Creation) was adopted in Indonesia. Amongst other laws, it contains the amendments to Law No. 36 of 1999 on Telecommunications ("Telecommunications Law") and Law No. 32 of 2002 on Broadcasting ("Broadcasting Law"). Sharing and transfer of spectrum and infrastructure sharing are some of the key points of the said Law. Prior to the Omnibus Law, telecommunications operators were encouraged to share passive infrastructure with other telecommunications operators. Under the Omnibus Law, sharing of passive infrastructure is mandatory for telecommunications operators.[144] By enabling the joint utilisation of both active and passive infrastructure among licensed and unlicensed entities, operators can reduce their cost burdens. This facilitates the entry of new players, fostering greater competition.

136 By way of Article 44 of European Electronic Communications Code (EECC)

137 Defined under 2(29) as 'an undertaking providing or authorised to provide a public electronic communications network or an associated facility'

138 Article 47 of EECC

139 Article 68 of EECC

140 https://digital-strategy.ec.europa.eu/en/policies/eu-rules-reduce-cost-high-speed-broadband-deployment

141 Section 259

142 Defined as a telecom carrier that lacks economies of scale or scope as determined as per regulations as well as those that offer telephone exchange service, exchange access, and any other service that is included in universal service, to all consumers without preference throughout the service area

143 Section 251

144 https://www.mondaq.com/telecoms-mobile-cable-communications/1017870/sharing-is-the-new-normal-for-the-telecommunications-sector

ANNEXURE-III

Detailed metric of DRI: To develop a tailored index for India, it's essential to consider the following metrics:

- Fibre Connectivity: Measure the extent of fibre optic network coverage via [145]
  - » Fibre kilometres per capita
  - » Proportion of towers fiberized
  - » Number of fiberized households vs total households
  - » Ratio of fibre as a public utility compared to other utilities
  - » Total fibre network vs the total road network (considered as an aspect)
- Network Speed:
  - » Average and peak broadband speeds available to consumers
  - » Speed of data being made available to subscribers
- Reliability:
  - » Network uptime
  - » Downtime incidents
  - » Responsiveness of network maintenance services
- Affordability:
  - » Cost of broadband relative to income levels
  - » Pricing comparisons with other countries
  - » Per GB cost of data
- Accessibility:
  - » Availability of public Wi-Fi hotspots, especially in rural and underserved areas
- Efficiency:
  - » Average network congestion
  - » Internet Exchange Point (IXP) throughput
  - » Content Delivery Network (CDN) penetration
  - » Domain Name System (DNS) resolution time
- Quality of Service (QoS):
  - » Latency
  - » Jitter
  - » Packet loss
- Deployment and Subscriber Base:
  - » Increase in telecom towers/points of presence
  - » Number of approvals in government deployments
  - » Internet subscriber base and penetration
  - » Fixed subscriber base and penetration
  - » Broadband subscriber base: number of people connected vs available

145 https://www.icra.in/Rating/DownloadResearchSpecialCommentReport/2365