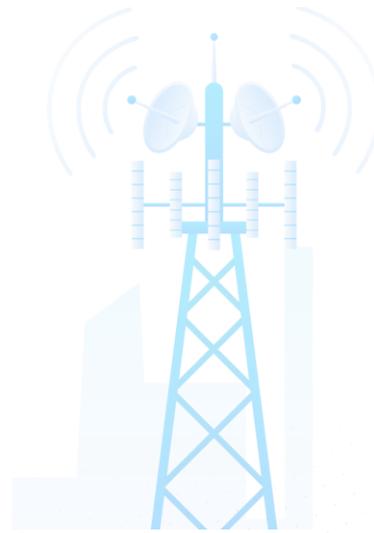




Bharat 6G Alliance Whitepaper



Spectrum Roadmap for 6G in India

OCTOBER 2025
VERSION 2.0



Executive Summary

India has seen massive rollouts of 5G network in the last three years, with world-leading advancement in mobile speeds and widespread coverage across the country. Today, India remains among the leading mobile markets with the most affordable mobile broadband access. The timely availability of adequate mid-band spectrum was a key factor behind these rapid deployments.

To secure a leadership position for India as cellular technologies evolve towards 6G, the Honourable Prime Minister Shri Narendra Modi launched the Bharat 6G Vision in March 2023. The primary goal of this vision is to design, develop and deploy 6G network technologies that provide ubiquitous, intelligent and secure connectivity for a high-quality living experience for the world. From an India-centric perspective, the 6G vision emphasizes three pillars - ubiquity, affordability and sustainability.

The Bharat 6G Vision led to the formation of the Bharat 6G Alliance (B6GA), comprising operators, government, academia, industry and R&D organizations. The Spectrum Working group within B6GA focuses on global spectrum trends for 5G Advanced and 6G, including WRC-23 and WRC-27 considerations for IMT 2030.

The whitepaper is an update to the 2024 Spectrum WG report and reflects the current state of 5G technology and spectrum use in India. It provides recommendations for a 6G spectrum roadmap and enabling policy framework to support India's leadership ambitions.

The scope of the document includes the following –

- Assessment of spectrum available to TSPs for IMT mobile services and gap analysis based on data traffic growth;
- Evaluation of future IMT requirements and how networks and services are likely to evolve in the coming years;
- Review of emerging wireless technologies such as HAPS, HIBS, NTN, satellite direct-to-device, drones, V2X and Ambient IoT;
- Formulation of a national spectrum strategy to support 5G expansion, 5G Advanced adoption, and early 6G trials;
- Identification of potential bands under discussion in global forums for IMT and non-terrestrial applications;
- Recommendation for a structured five-year plan through 2030, covering different implementation phases and associated internal and external engagements;
- Suggested policy initiatives for regulatory sandboxes, experimentation and early trials to accelerate innovation.

This updated version provides refined recommendations for India's spectrum roadmap across short-term (2025), medium-term (2027) and long-term (2030 and beyond) horizons.

It serves as a strategic guide for researchers, industry participants, and policymakers as India transitions from 5G to 6G.

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1. Introduction

India’s digital transformation vision aims to leverage technology to drive economic growth, improve governance and enhance citizens’ quality of life. This vision encompasses initiatives to expand digital access and services to various segments of society, promote innovation and bridge the digital divide. Within this vision, 5G was launched by Hon’ble PM Modi in India on Oct, 2022. In a short span starting from Oct 2022, more than 457K sites have been deployed¹, making India #2 market in the world. Network speeds have significantly improved. Starting with an average download speed of 20 Mbps in Nov 2022, India has reached a median download speed of 107 Mbps in May 2024. In the global speed benchmarking, its ranking has been rising from 108th position in Sep,2022 to 12th position in Jun 2024 on the SpeedTest Global Index™². Today India is global leader with cheapest / affordable broadband access.

Noteworthy, that one of the decisive factors behind these rapid deployments has been the timely provision and assignment of mid-band spectrum for 5G deployments in India. To secure a leadership position for India as the cellular technologies evolve towards 6G, the Prime Minister Honourable Shri Narendra Modi launched the Bharat 6G Vision in March 2023. The primary goals of this vision include “Design, develop and deploy 6G network technologies that provide ubiquitous intelligent and secure connectivity for high quality living experience for the world”. From an India-centric perspective, the 6G emphasis is on three pillars of ubiquitous coverage, affordability and sustainability. The Bharat 6G Vision led to the formation of the Bharat 6G Alliance (B6GA) involving Operators, Government, Academia, Industry and R&D organizations. The Spectrum Working group within B6GA is focusing on the global trends in terms of spectrum for 5G Advanced and 6G including WRC 23 and WRC 27 considerations for IMT 2030. This report is an update on the 6G Taskforce Report on Spectrum published in March 2023 and reflects the current state of the 5G technology within India, the current spectrum situation and the recommendations for a Spectrum Roadmap for India as cellular technologies evolve to 5G Advanced and 6G. Efficient spectrum utilization, along with additional new spectrum is essential to providing end consumers with more services, capacity, and data speed in every generation of cellular communications.

1.1 ITU-R Cycle for IMT-2030 (commonly called as 6G)

ITU-R holds standardization responsibility of radio interface systems used in International Mobile Telecom networks and the “collective” name applied to such systems/technologies in ITU-R is “IMT.” Following table highlights the various generations of IMT technologies and their name in common language.

IMT-2000	3G	Rec. ITU-R M.1457
IMT-Advanced	4G	Rec. ITU-R M.2012
IMT-2020	5G	Rec. ITU-R M.2150
IMT-2030	6G	To be developed

Table 1-A : ITU name for IMT Technologies

[ITU-R WP 5D](#) has developed a new ITU-R Report ([ITU-R M.2516](#)) on “Future Technology Trends”. This Report provides a broad view of future technical aspects of terrestrial IMT systems considering

¹ <https://dot.gov.in/5g-bts-deployed>

² <https://www.speedtest.net/global-index>

the timeframe up to 2030 and beyond, characterized with respect to key emerging services, applications trends and relevant driving factors and is applicable to radio interfaces, mobile terminals, and radio access networks by considering the timeframe up to 2030 and beyond (Figure 1-A)³

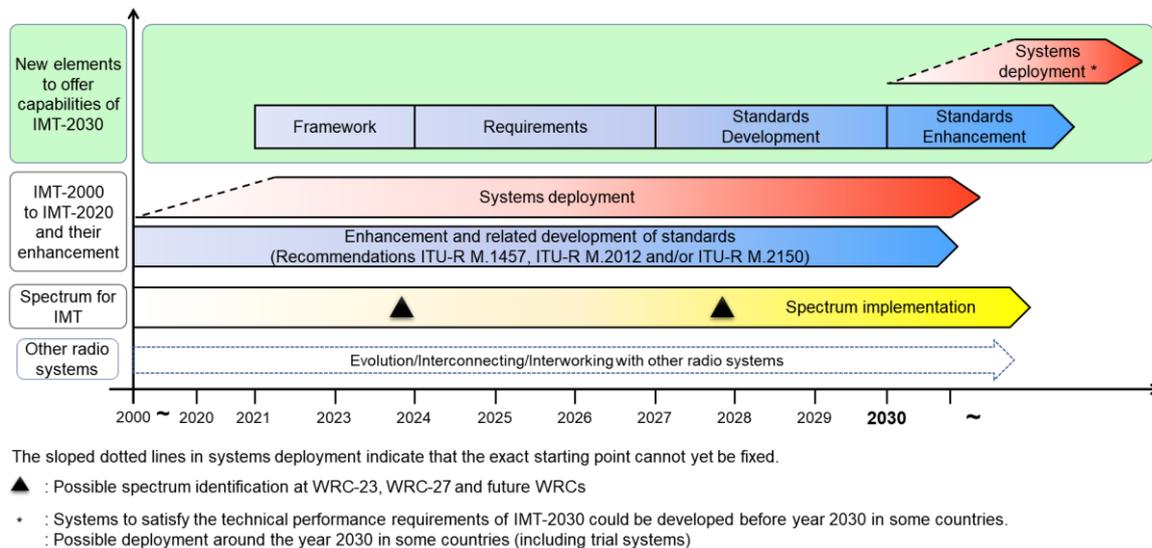


Figure 1-A : Timeline of 6G Technology & relationship with spectrum aspects

1.2 The Role of a National Spectrum Strategy in Enabling 5G & 6G

To continue to success story of mobile revolution in India, it is highly important to identify the trends of services and applications increasing the data traffic demands and develop a structured roadmap for spectrum in India. This is also important to ensure seamless transition and expansion of 5G networks across India. At the same time, it owes importance to allocate sufficient spectrum for 5G Advanced in 2027-28 timeframe and initial trials for 6G technologies. The success of affordable and accessible connectivity is founded in global harmonization of spectrum and technology, including a conducive set of regulatory conditions. The following provides a broad list of aspects of spectrum management

- Spectrum is limited natural resource hence competitive allocation is inevitable
- Global harmonization is paramount to ensure economy of scale and timely ecosystem
- Under the ITU-R Radio Regulations (RR), spectrum allocation involves various services, including Mobile Service (MS). International Mobile Telecommunications (IMT) framework stands out as the key technology for mobile broadband within various MS Applications. IMT is an unique MS application as it requires formal identification and global harmonization, ensuring worldwide compatibility and efficiency.
- To achieve this, candidate frequency bands for IMT undergo extensive study over the four-year World Radiocommunication Conference (WRC) cycle for potential identification. This process enables long-term spectrum planning, ensuring that mobile communications evolve effectively in step with global needs.
- 6G represents the next commercial step in this evolution, with IMT-2030 technology at its core, positioning itself as the future of mobile communication standards

³ [ITU-R M.2516](#)

- Commercialization of new bands is time consuming process hence a comprehensive long-term roadmap of spectrum is highly important. This roadmap is expected to account for needs of new and emerging IMT technologies and various use cases while allowing for growth of existing networks and services in a harmonious manner.
- Spectrum roadmap need to factor in network topology and deployment scenario of the spectrum in conjunction with technological advancements to deliver the expected performance of 6G without needing to add new cell sites. This is critical for sustainability of telecom network while ensuring affordability of service.
- Increasing demand for spectrum owing to need of increased coverage, capacity connectivity at an affordable cost

Therefore, a structured and clearly laid out spectrum roadmap is essential to manage the diverse and competing demands from various radio services. The purpose of this document is to develop clear recommendations for a comprehensive spectrum roadmap and a National Spectrum Pipeline.

2 IMT spectrum at ITU World Radiocommunication Conference (WRC)

In terms of spectrum, the ITU Radio Regulations (RR) establishes the allocation of specific frequency bands for each radio service (41 services in total), including the mobile terrestrial service (the service involved, in the case of IMT).

In the Radio Regulations, for the allocation of frequencies, the world has been divided into three Regions as shown on the following map (Figure 2-A) and described in RR Nos. 5.3 to 5.9

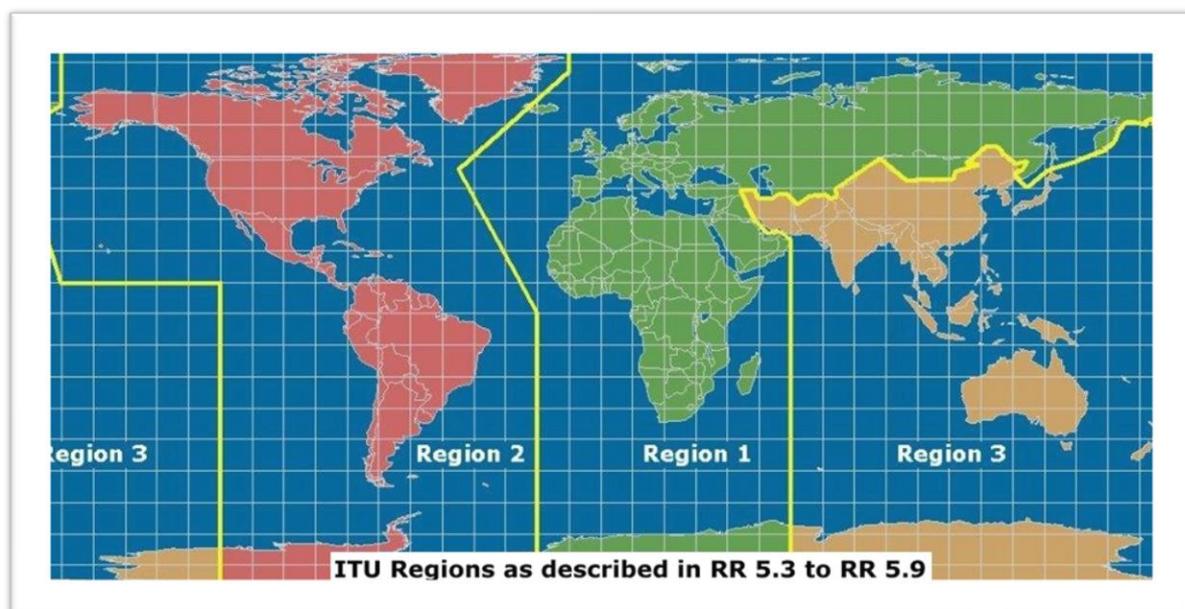


Figure 2-A : ITU-R Regions

2.1 Historical IMT identification

Successive World Radiocommunication Conferences (WRCs), held at a frequency of 4 years have identified specific frequency bands for the deployment of IMT systems in general (which includes IMT-2000, IMT- Advanced and IMT-2020). This identification does not preclude the use of any of these bands by any application of the services to which they are allocated and does not establish priority in the Radio Regulations. In effect, it is up to each country to determine whether and which bands will be made available for IMT in each country/region depending on national/regional requirements.

In the mid-1980's work began by ITU for defining the next "generation" of mobile radio standards/mobile networks on a global basis, which led to the allocations of the new globally available frequency bands. The World Administrative Radiocommunications Conference (WARC)-1992 identified 1885-2025 MHz and 2110-2200 MHz in addition to previously identified 800, 900 MHz frequency Bands.

At the WRC-2000, all the major existing cellular bands were added, increasing the potential IMT-2000 spectrum availability by approximately three times and also identified the frequency

bands namely 806-960 MHz, 1710-1885 MHz and 2500-2690 MHz. The earmarking of these frequency bands led to the completion of ITU standards for the third generation (3G) in the year 2000. Additionally, the frequency bands (i) 450–470 MHz, (ii) 790–960 MHz, (iii) 1710–2025 MHz, (iv) 2110–2200 MHz, (v) 2300-2400 MHz, (vi) 2500-2690 MHz, and (vii) 3400-3600 MHz allocated for IMT application.

A Joint Task Group (JTG) 4-5-6-7 was established in WRC-12 for additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions. The Joint Task Group 4-5-6-7 recommended more than 20 additional frequency bands for IMT applications.

The WRC-15 considered the recommendations of JTG. After detailed deliberations, WRC-15 identified frequency bands 470-694/698 MHz, 1427-1518 MHz, 1885-2025 MHz, 2110-2200 MHz and 3300-3400 MHz or portions thereof for IMT applications.

WRC-19 had identified additional radio-frequency bands 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71 GHz for the deployment of 5G networks. While identifying the frequency bands, WRC-19 also took measures to ensure an appropriate protection of the Earth Exploration Satellite Services, including meteorological and other passive services in adjacent bands. A total, 17.25 GHz of spectrum was identified for IMT in WRC 19, in comparison with 1.9 GHz of bandwidth available before WRC-19. Out of this, 14.75 GHz of spectrum has been harmonized worldwide, reaching 85% of global harmonization.

WRC-23 identified frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz to add more spectrum in mid band for IMT.

Efforts are being made to get more spectrum in lower and mid bands. Accordingly, frequency bands 4400-4800 MHz, 7 125-8400 MHz (or parts thereof) and 14.8-15.35 GHz are under consideration for WRC-27.

In terms of historical perspective, past WRCs have identified the following bands in different regions for IMT (Table 2-A : IMT Identifications in various WRC

Frequency Bands identified for IMT (MHz)	Footnotes identifying the band for IMT in the Radio Regulations			Available Bandwidth (MHz)	Timing
	Region 1	Region 2	Region 3		
450-470	5.286AA			20	WRC-07
470-698	5.307A**	5.295** 5.308A**	5.296A**	228	WRC-15/23
694/698-960	5.317A	5.317A	5.313A** 5.317A	262	WRC-07/2000
1 427-1 518	5.341A 5.346**	5.341B	5.341C, 5.346A	91	WRC-15
1 710-2 025	5.384A 5.388			315	WARC-92, WRC-2000
2 110-2 200	5.388			90	WARC-92
2 300-2 400	5.384A			100	WRC-07
2 500-2 690	5.384A			190	WRC-2000

Frequency Bands identified for IMT (MHz)	Footnotes identifying the band for IMT in the Radio Regulations			Available Bandwidth (MHz)	Timing
	Region 1	Region 2	Region 3		
3 300-3 400	5.429B**	5.429D	5.429F**	100	WRC-15/23
3 400-3 600	5.430A	5.431B	5.432A** 5.432B** 5.433A**	200	WRC-07
3 600-3 700	5.433B** 5.434B**	5.434	-	100	WRC-15/23
3 700-3 800*	5.434B**	5.435B**	-	100	WRC-23
4 800-4 990	5.441B	5.441A** 5.441B**	5.441B**	190	WRC-15
6 425-7 025 *	5.457E	5.457F**	5.457D**	600	WRC-23
7 025-7 125 *			5.457E	100	WRC-23
10 000-10 500 *	-	5.480A**	-	500	WRC-23
24 250-27 500	5.532AB			3250	WRC-19
37 000-43 500	5.550B			6500	WRC-19
45 500-47 000	5.553A**			1500	WRC-19
47 200-48 200	5.553B**			1000	WRC-19
66 000-71 000	5.559AA			5000	WRC-19
Note:					
Reference Documents: Recommendation ITU-R M.1036, RR edition 2024 and WRC-23 Final Acts					
* this band is identified for IMT from 01.01.2025 (Not for Region 3)					
** this band is identified in some countries of the Region					

Table 2-A : IMT Identifications in various WRC

Further, to bridge the digital divide in remote and rural areas and maintain connectivity during disasters, frequency bands 700 MHz, 900 MHz, 2 GHz and 2.6 GHz bands have been identified in WRC-23 for high-altitude platform stations as IMT base stations (HIBS) - a new application of mobile service to provide mobile broadband with minimal infrastructure using the same frequencies and devices as IMT mobile networks.

2.2 India's leadership on 6G Spectrum in APAC and WRC

India took the early lead for APT common position on WRC-23 AI 10 towards studying various frequency bands in 7.125 – 24 GHz and 92 – 275 GHz towards 6G spectrum⁴. India coordinated with several other countries (like Korea, Laos, Vietnam, Japan, among others) that had like-minded views on 6G spectrum resulting in a APT view (a Preliminary APT common proposal⁵ towards WRC-23 Agenda Item 10) that was submitted⁶ for information of the WRC-23 in

⁴ APG23-5/INP-31: India's input to APG23-5 on IMT in portion(s) of the frequency ranges 7.125-24 GHz and 92-275 GHz including possible additional allocations to the mobile service on a primary basis

⁵ APG23-6/INP-21: India's input to APG23-6 on IMT for a PACP

⁶ CPM23.2/103: APT input to CPM23 on AI 10 as Preliminary APT view

Section 2 of the CPM 23 Report. Similar views from multiple countries (Korea, Laos, Viet⁷
⁸on AI 10 were also added to Section 2 of the CPM 23 Report aligned with India's efforts.

This demonstrated India's crucial lead in 6G Spectrum through active engagements in global platforms as well as at national level with incumbent users and stakeholders. India was one of the driving forces towards the new WRC-27 AI 1.7.

2.2.1 WRC-27 Agenda Item 1.7 for new IMT spectrum

Resolution 256 (WRC-23) decided to conduct sharing and compatibility studies for terrestrial component of IMT in the following frequency bands:

- 4 400-4 800 MHz, or parts thereof, in Region 1 and Region 3;
- 7 125-8 400 MHz, or parts thereof, in Region 2 and Region 3;
- 7 125-7 250 MHz and 7 750-8 400 MHz, or parts thereof, in Region 1;
- 14.8-15.35 GHz

For Region 3 including India, all the above bands are under consideration in AI 1.7

2.2.2 WRC-27 Agenda Item 1.13: Potential Mobile-Satellite Service (MSS) Bands

In addition to possible new IMT bands, the WRC-27 agenda will consider studies on other radio services, including direct connectivity between satellites and mobile devices to complement terrestrial network coverage. Direct-to-Device (D2D) technologies allow satellites to have direct connectivity to standard mobile phones. D2D is a new and highly complex issue, and the ITU work on spectrum is only a small part of the new regulatory and technical activity which will be required. On top of D2D in mobile bands, WRC-27 will also study new mobile satellite bands, which may provide a similar service in either bespoke or tailored mobile handsets⁹.

These topic in the agenda will have to study various aspects regarding its feasibility, including sharing and compatibility with other services and technical and operational measures to avoid interference especially to existing Terrestrial IMT Networks. But it also faces challenges regarding cross-border spectrum management, roaming and national licensing. In India there is already high degree of Terrestrial Coverage of IMT networks, hence protection of these existing networks is very important consideration in these agenda items.

A summary of the WRC-27 agenda items related to non-terrestrial applications using IMT bands is listed in the table below:

⁷ CPM23.2/221: Multi-country input from Korea / Laos / Viet Nam on AI 10

⁸ CPM23.2/213: GSMA views on AI 10

⁹ GSMA : Spectrum Policy Trends 2024

WRC-27 AI 1.12	WRC-27 AI 1.13	WRC-27 AI 1.14
MSS allocation for Low-data-rate NGSO mobile satellite system	MSS allocation in IMT bands for direct connectivity to complement the terrestrial IMT network coverage	Additional allocation to mobile satellite system
Frequency bands: <ul style="list-style-type: none"> 1 427-1 432 MHz (s-to-E), 1 645.5-1 646.5 MHz (s-to-E) (E-to-s), 1 880-1 920 MHz (s-to-E) (E-to-s), 2 010-2 025 MHz (s-to-E) (E-to-s) 	Frequency bands: the frequency bands between 694/698 MHz to 2700 MHz range with terrestrial IMT deployment in M.1036	Frequency bands: <ul style="list-style-type: none"> 2 010-2 025 MHz (E-to-s) in R1&R3 2 160-2 170 MHz (s-to-E) in R1&R3 2 120-2 160 MHz (s-to-E)
Potential Technology: 3GPP IoT NTN Proprietary	Potential Technology: 3GPP LTE, 5G NR 3GPP LTE NTN, NR NTN	Potential Technology: 3GPP NR NTN Proprietary

Table 2B : WRC-27 Agenda items for MSS and D2D

2.3 Summary: WRC-23 as a platform for 5G Advance and 6G

WRC-23 has set the agenda for the new cycle, WRC-27, thereby setting out the likely roadmap for spectrum bands to support 5G-Advanced and 6G. WRC-23 has been the platform to shape the present and guarantee the future of evolution of mobile telecommunication. The below figure¹⁰ shows an important relation between standards development, ITU-R activities and national activities.

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031
3GPP Release	REL-18 (RAN)	REL-19 (RAN)	REL-20 (RAN)		REL-21 (RAN)	REL-22 (RAN)		REL-23 (RAN)	
					First implementable 6G specification				
ITU-R activities	WRC-23: Discussions on agenda items for IMT identification at WRC-27	ITU-R shares studies towards a potential IMT identification decision at WRC-27			Decision on IMT identification of specific bands at WRC-27	National regulators decide which frequencies to release, and begin licensing process (pre- or post-WRC-27). Early deployments on new frequencies are expected around 2030			

Above: Timeline for defining spectrum for 6G and the first 3GPP 6G standard.

¹⁰ <https://www.ericsson.com/en/6g/spectrum>

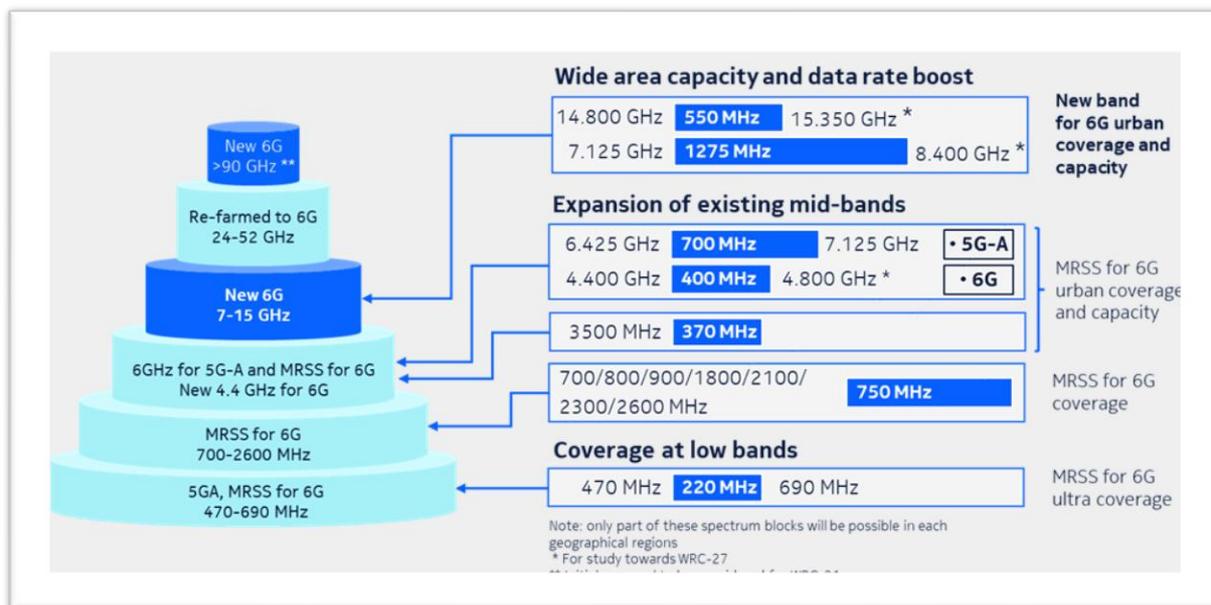


Figure 2-B : WRC-23 - Foundation Platform for 5G-A and 6G

2.4 WRC-31 Preliminary Agenda Item 2.6 on Sub-THz /THz

The sub-THz range (90–300 GHz) holds good promise for the future, providing extremely high data rates for niche applications like holographic communications, indoor immersive experiences, and data centre connectivity. However, there are significant challenges to overcome, such as signal attenuation and limited propagation distances as detailed in section 3.

Resolution 255 (WRC-23), proposes few potential Sub-THz bands for IMT as a preliminary agenda item 2.6 for WRC-31. Since the discussions are very early in nature, the WRC-23 recognized that the bands as part of the agenda item (102-109.5 GHz, 151.5-164 GHz, 167-174.8 GHz, 209-226 GHz and 252-275 GHz) would need further discussions.

ITU-R also published a report¹¹ on Technical Feasibility of IMT in the bands above 100 GHz; that includes various aspects like propagation models, technology enablers, antenna techniques, deployment architectures and several test and measurements results from early R&D activities in various external organizations. Sub-THz spectrum is can be considered to be used future applications beyond 6G, though not considered as a key band for Day-0 applications of 6G targeted to be released in 2030.

¹¹ ITU-R M.2541: ITU-R Report on Technical Feasibility of IMT in bands above 100 GHz

3 Spectrum Related Wireless Technologies Trends

As IMT technologies like 5G and 6G continue to evolve to deliver new applications, these applications also leverage capabilities of other wireless technologies to complement and/or supplement by the use of spectrum bands and wireless network infrastructure. The emerging wireless technologies listed below are poised to play a significant role in and around the IMT ecosystem:

3.1 High Altitude Platform Stations (HAPS) and High Altitude Platform for IMT Base Stations (HIBS):

High Altitude Platform Stations (HAPS) and High Altitude Platform Systems (HIBS) are innovative technologies designed to provide wireless communication services from the stratosphere. These platforms typically operate at altitudes between 20 km and 50 km above the Earth's surface, offering a unique combination of satellite and terrestrial communication capabilities.

Extended Coverage: HAPS and HIBS can cover a large geographical area, making them ideal for providing connectivity in remote and underserved regions.

These platforms can support high data rates and large numbers of users, making them suitable for both urban and rural deployments; under circumstances where rapid deployment is needed for meeting emergency situations and challenged geographies.

Technology trials¹² have also been conducted by some countries.

Spectrum Aspects:

During the WRC-19 identified several frequency bands for HAPS, including 31-31.3 GHz, 38-39.5 GHz, and 47.2-47.5 GHz / 47.9-48.2 GHz. These bands are intended to support the deployment of HAPS for broadband connectivity and other applications. Ongoing trials and regulatory developments are crucial for realizing the full potential of these platforms. A comprehensive national spectrum strategy should consider the integration of HAPS and HIBS to address future connectivity needs and support the evolution of wireless networks. Harmonized spectrum bands are essential to support these services, ensuring seamless integration with terrestrial networks.

¹² HAPSMobile by SoftBank conducted successful test flights of its solar-powered HAWK30 aircraft in the United States to demonstrate the feasibility of using solar-powered HAPS for long-duration flights and continuous connectivity.

Stratobus by Thales Alenia Space, developed a stratospheric airship for telecommunications, surveillance, and environmental monitoring and disaster response <https://developingtelecoms.com/telecom-technology/satellite-communications-networks/19082-softbank-tests-new-haps-5g-payload-in-japan.html>

3.2 Ambient IoT & Wireless Power Transfer (WPT)

The 5G Ambient IoT concept, currently under development within 3GPP, envisions a future where massive numbers of IoT devices are deployed in the environment to perform low-power, long-lasting sensing and communication tasks. A complementary technology advancement in Wireless power transmission (WPT) technologies is poised to become integral to powering electronic devices and electric vehicles wirelessly, without physical connectors.

Key use cases of Ambient IoT and WPT include:

1. **Smart Cities and Infrastructure Monitoring:** WPT can power Ambient IoT sensors deployed across city infrastructure (e.g., bridges, roads, traffic lights) to monitor structural integrity, pollution levels, and energy consumption. These sensors, when wirelessly charged, can operate indefinitely, reducing the need for maintenance and battery replacement.
2. **Supply Chain and Logistics:** In warehouse environments or along supply chains, small IoT devices can track goods, monitor temperatures, and log shipment conditions. Using WPT, these devices can stay powered for long periods without the need for manual intervention, ensuring uninterrupted data collection and real-time updates.
3. **Agriculture and Environmental Sensing:** In precision agriculture, WPT-enabled IoT devices can monitor soil moisture, crop health, and weather conditions. By harnessing WPT, farmers can eliminate the logistical challenge of changing batteries in remote fields, allowing continuous data flow for optimized decision-making.
4. **Wearables and Healthcare Devices:** For Ambient IoT in healthcare, WPT can support low-power devices like health trackers, smartwatches, or implants. These devices can communicate continuously with 5G networks for real-time health monitoring while being wirelessly recharged without the need for user intervention.

In these use cases, WPT complements 5G Ambient IoT by extending the operational lifespan of devices, enabling seamless data transmission, and reducing the logistical burden of battery maintenance, further driving the adoption of 5G-enabled IoT ecosystems.

In the ITU-report SM.2392-1 (2021) provides a comprehensive overview of frequency bands considered for the harmonized use of WPT. The key bands explored include:

- **19-25 kHz:** Primarily used for industrial and consumer WPT systems.
- **79-90 kHz:** Applied in wireless charging for electric vehicles.
- **6.78 MHz:** A globally recognized band for low-power WPT applications.
- **13.56 MHz:** Common for medium-power WPT, including consumer electronics.
- **915 MHz and 2.4 GHz ISM bands:** Ideal for higher-power WPT systems, including industrial and robotics applications.

The report underscores the importance of harmonizing these frequency bands across regions to ensure the seamless deployment of WPT systems globally.

In addition to spectrum allocation, safety is a critical consideration for WPT systems. The ITU-R SM.2505 report presents an analysis of the safety implications of beamformed WPT systems, which focus electromagnetic energy precisely toward the target device. The study concluded that beamformed WPT, when designed and regulated properly, is safe for use. This finding is based on assessments of power density, human exposure limits, and compliance with international electromagnetic field (EMF) safety standards

3.3 Wireless connectivity in Transportation

Wireless technologies are playing a pivotal role in modernizing public transportation systems, enhancing safety, efficiency, and user experience. As emerging trends in wireless communication integrate into public transport infrastructure, governments and international regulatory bodies are increasingly focused on developing a comprehensive spectrum strategy to support these innovations.

The ITU-R M.2445 report highlights the growing use of wireless communication technologies in public transportation systems worldwide. The report emphasizes wireless technologies' role in improving road safety, reducing railway accidents, and enhancing transportation efficiency through intelligent transportation systems (ITS), vehicle-to-everything (V2X) communication, and automation.

According to a recent article published by 3GPP¹³. 3GPP and ETSI's group railway have been working together to support many essential features in 3GPP 4G (for e.g., MCPTT, ProSe).

Intelligent Transport Systems

In addition to rail-safety, there has been growing demand and focus on leveraging wireless technology in vehicles and associated infrastructure to improve the safety and meet the target to halve the road traffic accidents by 2030. This involves enabling various technological components in the vehicles. This includes – V2V, V2I and V2N communications, radar, visual, rf sensing technologies.

For e.g., in U.S.A., there are initiatives¹⁴ to evolve towards fully automated safety features in the cars; to have the potential to improve equity, air pollution, and traffic congestion.

Enabling ITS, requires harmonized allocation of frequency band in 5.9 GHz as well as standard (3GPP V2X) for V2X communications in all the vehicles. There is also a need to have allocation of spectrum for Radars for vehicle safety and autonomous driving.

- Short-range radar (24 GHz) is commonly used for parking assistance, blind-spot detection, and lane-changing safety, while
- Long-range radar (76-81 GHz) enables adaptive cruise control, collision warning, and emergency braking systems.

These radar systems require dedicated frequency bands and spectrum allocations to ensure seamless operation. Having ubiquitous 5G coverage to provide connectivity to vehicles is also an important component for a successful ITS system of the future.

3.4 Non-Terrestrial Networks

Non-Terrestrial Networks (NTN) are still in their early stages of adoption and are gaining popularity too, as they hold significant promise for bridging the digital divide and bringing broadband to areas, lacking terrestrial connectivity.

As the demand for ubiquitous connectivity surges, Non-Terrestrial Networks (NTNs) are emerging as a critical solution to bridge the gap in areas underserved by traditional terrestrial infrastructure. 3GPP defines NTN broadly as "networks providing radio access via non-terrestrial platforms" – essentially encompassing satellite networks, high-altitude platforms

¹³ <https://www.3gpp.org/technologies/railways1>

¹⁴ <https://www.nhtsa.gov/vehicle-safety/automated-vehicles-safety>

(HAPS), and even future aerial drone networks. The 3GPP based NTN solutions offer access to the device ecosystem of the 3GPP network and infrastructure to connect to other terrestrial users. Currently, the 3GPP based NTN is also the only (candidate) for the ITU-R's satellite component of IMT-2020¹⁵. The current 3GPP NTN operates in (S-band, L-band) in FR1.

REL	WI	NR band	Uplink (UL) operating band Satellite Access Node receive / UE transmit F _{UL,low} – F _{UL,high}	Downlink (DL) operating band Satellite Access Node transmit / UE receive F _{DL,low} – F _{DL,high}	Remarks
REL-17	NR NTN solutions	n256	1980 – 2010 MHz	2170 – 2200 MHz	FR1, FDD, S-band
REL-17	NR NTN solutions	n255	1626.5 – 1660.5MHz	1525 – 1559 MHz	FR1, FDD L-band
REL-18	NR NTN LSband	n254	1610 – 1626.5MHz	2483.5 – 2500MHz	FR1, FDD, LS-band
REL-18	NR NTN enh	n512*, n511*, n510*	27.5 – 30.0GHz 28.35 – 30.0GHz 27.5 – 28.35GHz	17.3-20.2GHz 17.3-20.2GHz 17.3-20.2GHz	FR2, FDD, Ka-band

In addition to these bands, WRC-23 is also studying the feasibility and technical conditions to allow Direct to *Device communication* in the existing IMT identified bands. This will allow terrestrial operators to provide connectivity to their subscribers even outside their terrestrial network coverage through a satellite provider (who would be licensed to use the operator's licensed spectrum) without any modifications to the devices.

Additionally, there are satellites launched to provide satellite-based connectivity for IoT and low data-rate applications in remote areas like dessert, over sea etc., (See WRC-27 Agenda Items 1.12, 1.13, 1.14 in Section 2.2.2)

Many countries envisage that IMT systems towards 2030 and beyond will enable ubiquitous connectivity to regions beyond today's terrestrial networks. This would require suitable mechanisms to interwork, integration and co-exist in frequency bands to be used by satellite as well as terrestrial network.

3.5 Enabling Sub THz Communication

The sub-terahertz (sub-THz) spectrum, ranging from 90 GHz to 300 GHz, presents significant opportunities for next-generation mobile networks. It offers massive bandwidth potential, with some bands providing several tens of GHz, which is essential for supporting ultra-high data rates and increased network capacities.

Traditionally, frequencies above 90 GHz have been allocated for scientific purposes, such as astronomy, earth observation, and meteorology. However, they have seen limited use in wireless communication. Despite this, international radio regulations have already allocated over 100 GHz of sub-THz spectrum to fixed and mobile services, laying the groundwork for future 6G networks.

The Radio Regulations (RR), established in 2000, designate specific bands between 90 and 275 GHz for mobile and fixed services, amounting to a total of 105.1 GHz. ITU-R has also published a report¹⁶ on the technical feasibility of IMT in bands above 100 GHz discussing propagation models, technology enablers, antenna techniques, deployment architectures and several test and measurements from early R&D activities. However, many of these active bands

¹⁵ [M.2514](#) Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020

¹⁶ ITU-R M.2541: ITU-R Report on Technical Feasibility of IMT in bands above 100 GHz

are adjacent to passive frequency bands, protected by footnote RR 5.340, which prohibits any emissions in these ranges to prevent interference with scientific and environmental monitoring activities (Figure 3-A)

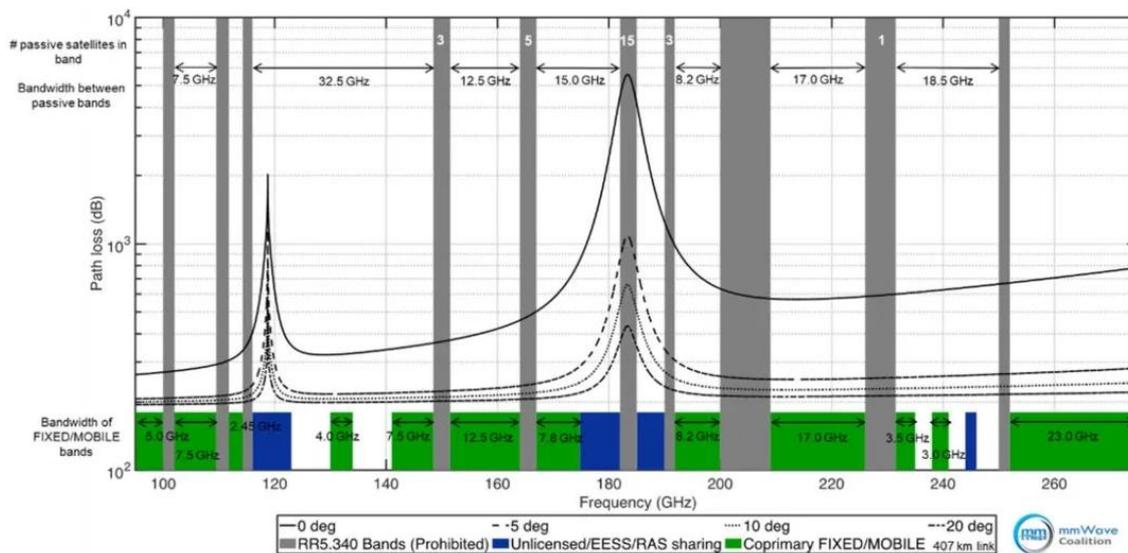


Figure 3-A : Sub-THz Spectrum Characteristics¹⁷

Key Research and Development Challenges in Sub-THz spectrum:

- **Propagation Losses:** The higher the frequency, the greater the atmospheric attenuation, limiting effective transmission distances. Research into materials, antennas, and waveform design is critical to mitigate these losses.
- **Device and Component Development:** Creating reliable, efficient components like power amplifiers, mixers, and detectors is a major challenge in the sub-THz bands, as they require materials capable of operating efficiently at such high frequencies.
- **Spectrum Sharing:** Since many of these bands are already occupied by scientific and satellite services, developing spectrum-sharing techniques will be vital to ensuring co-existence with these services, especially for sub-THz communication systems.
- **Advanced Antenna Technologies:** Research into massive MIMO, beamforming, and adaptive antenna systems is essential to ensure directional communication and maximize signal efficiency in these high-frequency bands

The W-band (75–110 GHz) offers around 15 GHz of usable spectrum, while the D-band (110–170 GHz) provides over 30 GHz. These bands, along with other sub-THz frequencies, could form the backbone of future high-speed communication systems. Industry looks at D & W bands as promising bands for backhaul applications. Based upon technological advances the availability of D band is expected to be ahead of other ranges in this spectrum.

3.6 AI integration and Sensing in 5G Advanced and 6G

In order to realize the intelligence of Radio Network, the new functions of sensing and AI need to be supported. In 6G, Communications and sensing will be coordinated and collaborated in all possible dimensions including spectrum, hardware, signalling, protocol, networking and others, achieving mutual promotion and benefits. Sensing can also be regarded as a ‘new

¹⁷ <https://mmwavecoalition.org/>

channel' that link the physical world to the digital world. Thus, real-time sensing combined with AI technologies can also be essential to realize the digital twin.

The end-to-end collection, processing and storage of network data can be realized through the data sensing function. AI function can use these data on demand to support different application scenarios. In this way, the utilization and support of AI capabilities can be realized more efficiently. The integration of AI and sensing in 6G will enable create an efficient, and adaptive network that meets end consumer demands in response to environmental conditions. AI-native wireless communication will enable the modelling of non-linear functions efficiently, complement real-time real time rescheduling decisions and adaptation to new waveforms.

3.7 Fixed Wireless Access

FWA (Fixed Wireless Access) has emerged as an important use case in 5G and is rapidly growing technology that offers high-speed internet connectivity to homes and businesses. It uses 5G technology to provide broadband speeds without the need for physical cables. This is especially beneficial in In India and other developing countries as well as regions where fiber-optic infrastructure is limited or non-existent. Some of the key benefits it offers are:

Bridging Digital divide: Can be deployed in both urban and rural areas, providing internet access to a wider population. Offers download speeds of up to 1 Gbps, enabling faster downloads, streaming, and online gaming in unserved areas.

Flexible deployment: Easy to install and can be quickly deployed in areas with high demand.

Cost-effective: Can be a more cost-effective alternative to traditional fiber-optic connections, especially in remote areas

However, FWA puts high stress on network capacity and planning and has its own requirement on spectrum usage patterns as per the deployment topologies.

3.8 Wireless LAN

There are emerging using cases of AR/VR/XR and innovative use cases in the areas of education, healthcare leading to high data growth. Since the higher frequencies of high band of IMT (FR2) do not penetrate well into buildings, hence these need to be complemented with Indoor Wi-Fi coverage within the buildings to reach the signal with the apps to the user, also commonly known as Personal Area Network. Wi-Fi also is used by operators to provide indoor connectivity to the user premises through FWA CPEs.

3.9 Technologies to efficiently utilize spectrum

3.9.1 Spectrum Sharing

Spectrum sharing refers to when two or more radio systems operate in the same frequency band. Two forms of spectrum sharing are currently present:

- Spectrum sharing between systems with the same level of access rights to the spectrum; and
- Spectrum sharing between systems with different levels of access rights to the spectrum.

These methods of spectrum sharing are not mutually exclusive. Existing IMT systems involve various combinations of spectrum sharing through different techniques for interference mitigation. The same is expected in IMT towards 2030 and beyond. One of the key aspects in advancing spectrum sharing is to natively develop IMT technologies capable of making use of databases, spectrum sensing, software defined radios, and reconfigurable radio networks, among others. These aspects are expected to play important roles in addressing the demand for next generation wireless services while enabling the broadband connectivity and digital inclusion in underserved areas.

Improving receiver susceptibility to interference would be a key enabler for spectrum sharing, especially between different radio systems, and spectrum utilisation efficiency improvements. It is desired that IMT systems for 2030 and beyond would enable a smooth transition from previous IMT technologies, while maintaining optimum use of spectrum resources. IMT towards 2030 and beyond should facilitate co-existence with the current IMT technologies to enable the same spectrum to be used by different IMT technologies, while balancing the bandwidth used for each technology based on user demand.

3.9.2 Technologies for broader frequency spectrum

To achieve extreme high data rate and high-capacity communication, IMT 2030 may require wider channel bandwidth compared to IMT-2020. This requires need for large contiguous chunks of spectrum for 6G.

Spectrum utilization can be further enhanced by efficiently managing resources through different technologies such as advanced carrier aggregation (CA) and distributed cell deployments, as well as spectrum sharing technologies and technologies for broader frequency spectrum

Further, the radio access technologies for different bands for IMT systems from the low to the very high bands present common technical issues related to coverage and power efficiency. Single-carrier signal waveforms are preferred over orthogonal frequency division multiplexing (OFDM) signal in higher frequency bands as a radio technology owing to their power efficiency. When applying radio technologies, including integrated access and backhaul, to a wider range of areas, the significance of power-efficient radio technology like single carrier is likely to increase.

From semiconductor viewpoint, though complementary metal oxide semiconductor processes are promising for use in certain frequency bands from around 100 GHz, other alternatives can be considered because operation in these bands will require careful conditioning of the output power, phase noise, I/Q imbalance, and noise figure along with the semiconductor process reliability and Rep. It is noteworthy that operating from around 100 GHz could require up to an order-of magnitude more elements relative to arrays deployed in millimetre waves, which could pose design challenges.

3.9.3 Use of Extreme MIMO

Extreme MIMO (E-MIMO) would be deployed with new types of antenna arrays, much larger-scale antenna arrays, a distributed mechanism, and AI assistance. This is expected to achieve better spectrum efficiency, larger network coverage, more accurate positioning, more accurate sensing, higher energy efficiency, etc.

The size of the antenna element is relative to the wavelength which is inversely proportional to the transmission frequency. When the operating frequency grows from 3.5 GHz to 7 GHz, it is possible to have four times more antenna elements in the same area. The benefit of more antenna elements is higher antenna gain which translates into better coverage, and more accurate beamforming which translates into higher capacity.

Advanced antenna technologies and extreme massive Multiple Input Multiple Output (mMIMO) antenna are expected to be the key radio technology for the new 7 – 8 GHz bands in boosting the antenna gain and enabling the reuse of the existing base station sites.¹⁸

¹⁸ 5G Americas Paper: The 6G Upgrade in the 7-8 GHz Spectrum Range

4 Mobile Broadband Growth in India

4.1 Subscriber Growth Projections 2024-2030 (Till 6G launch)

Globally 5G subscriptions are forecast to reach 6.3 billion by 2030, and will be 2/3 of all mobile subscriptions. With India¹⁹ to grow to 1310 million by 2030. The projections shows that 5G subscriptions will overtake the 4G subscriptions.

-96% of users in India, access to the internet is primarily using the mobile broadband, making India as Mobile First Broadband Country. The penetration of 5G devices has significantly improved close to 32% (in 2025). It has been observed that 5G users are consuming, on the average, more data than 4G. The 5G's share of mobile traffic has reached 35% by end of 2024 and is forecast to grow 80% in 2030.

Mobile subscriptions

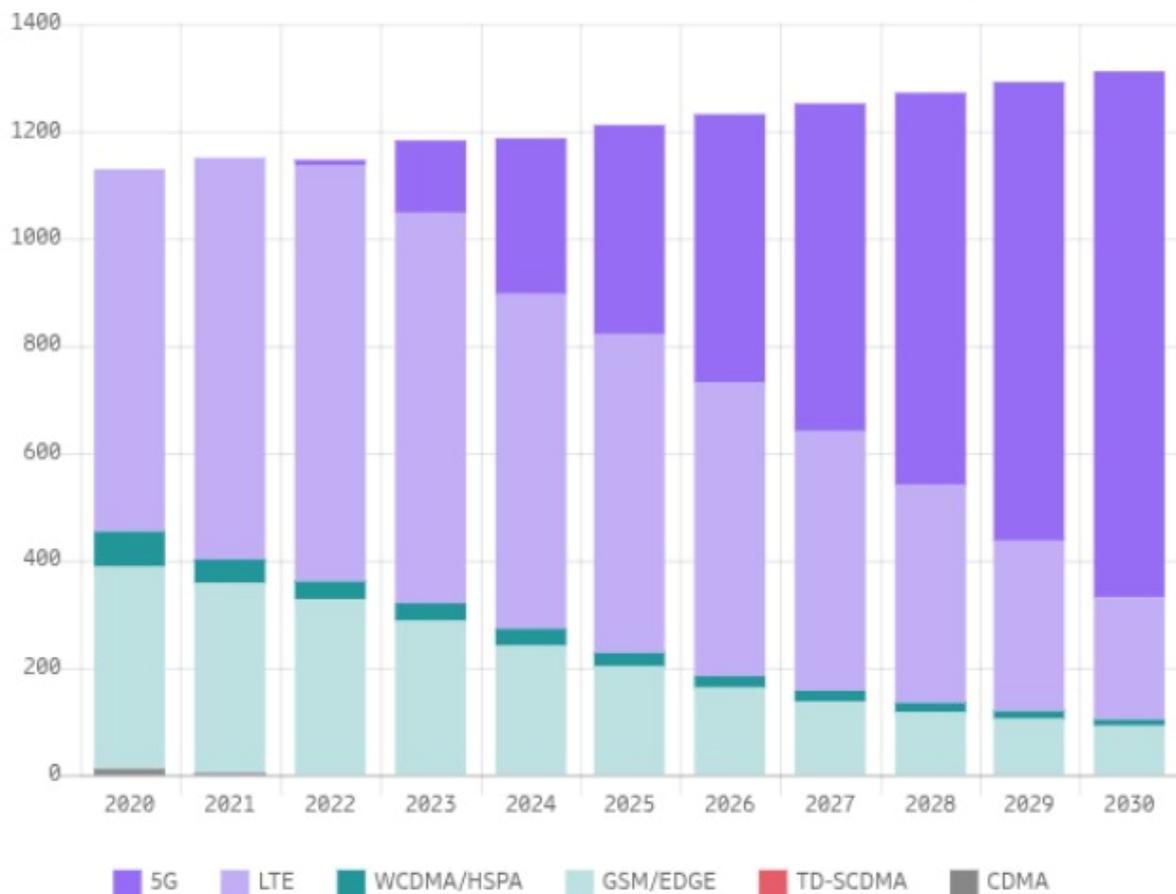
Unit: Million

5G | LTE | WCDMA/HSPA | GSM/EDGE | TD-SCDMA | CDMA

All devices

Year: 2020 - 2030

Source: EMR June 2025



¹⁹ <https://www.ericsson.com/en/reports-and-papers/mobility-report/key-figures> (India, Nepal and Bhutan combined)

4.2 Data traffic Projections 2024-2030 (Till 6G launch)

The data consumption is expected to grow from 31 GB/mo per subscriber in 2024 to 50 GB/mo in 2027 and finally reaching a value of 75 GB/mo in 2030. In a short span, the capacity utilization of 5G has reached to 18%, and will rapidly increase. The 5G subscriptions will rise from a base of 170 million in 2024 to 675 million in 2027 to finally reach 816 million in 2030 before launch of 6G.

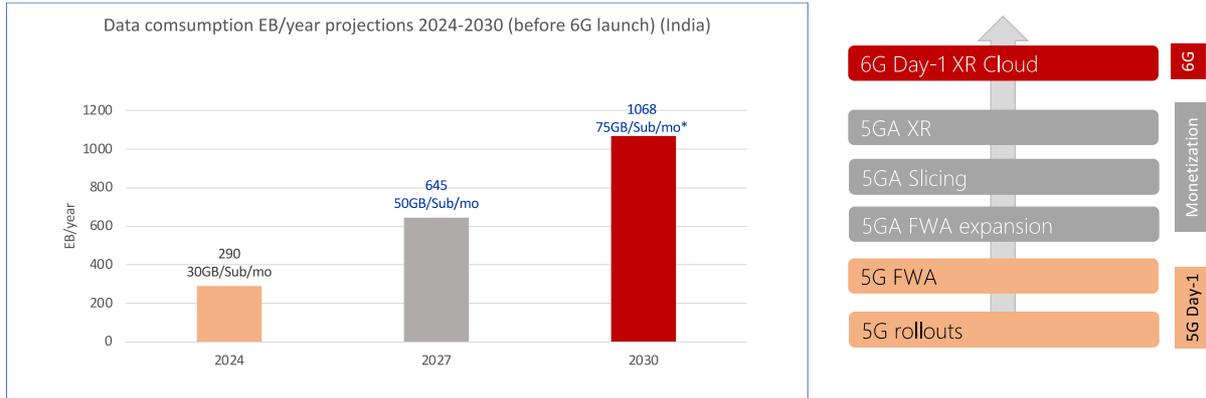


Figure 4-B : India MBB Traffic Forecast (Source : Industry Reports, B6GA member's analysis)

Figure 4-B above, provides a view to the total mobile data traffic demands in India during 2024-30, pointing to a ~3X data traffic growth, i.e. from 340 EB/year in 2024 to 645 in 2027, reaching to 1068 EB/year in 2030.

ITU-R Report M.2370²¹ anticipated that for the years 2020-to-2030, global IMT traffic will grow in the range of 10-100 times over this period. The report further noted that the overall mobile data traffic volume will exceed 5 ZBytes per month by the end of 2030.

1.1 Data Traffic versus equipped radio capacity - gap analysis for India

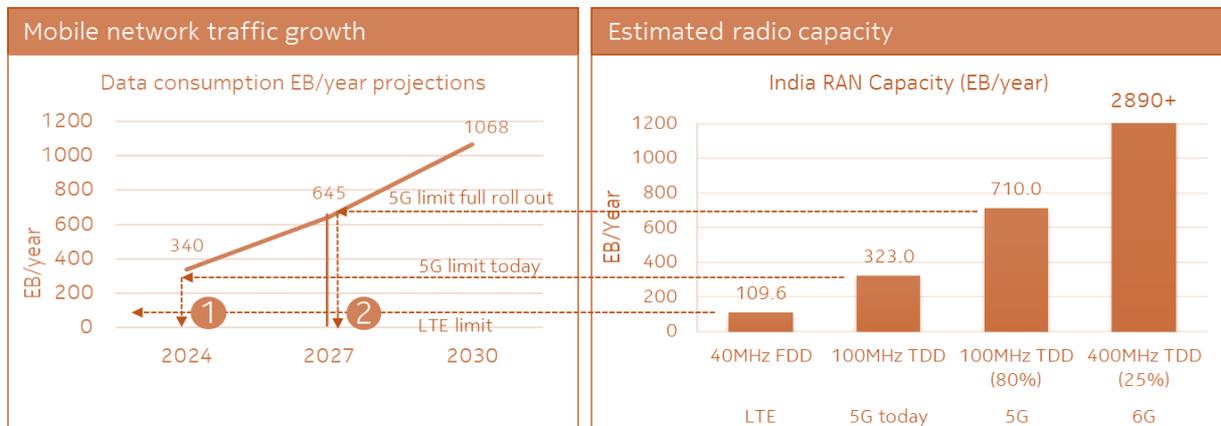
Figure 4-C provides a comparison of mobile network data traffic growth during 2024 to 2030 and validates it with the equipped RAN capacity.

This validation indicates that current capacity from 40MHz LTE TDD and 100 MHz FDD 5G/NR is just about able to manage the demand whereas after 2027, as 5G device penetration grows in the network and the traffic demands rise to 646 EB/year, the equipped capacity will significantly fall short of the demand. Therefore, India needs to continue 5G rollouts and post 2027 there will be a demand for significant additional spectrum to meet the increasing demand. Part of this could be managed through spectrum refarming and the balance would come from additional spectrum.

²⁰ Ericsson-mobility-report-India-edition 2024

²¹ ITU-R Report M.2370: IMT traffic estimates for the years 2020 to 2030

Post 2028, in addition to spectrum addition, it would demand densification followed by radio technology enhancement with 6G in 2030, providing 400 MHz channels. An assessment of additional spectrum requirement for the shortfall is done in subsequent section.



- ① = Continue more 5G rollouts
- ② = More spectrum and enhanced radio required by 2028-30

Figure 4-C :Traffic Forecast and Estimated Capacity Gap (B6GA members' analysis)

5 Spectrum demands for 5G-Advanced and 6G

5.1 Mobile Broadband - Foundation of Digital Economy in India

Digitalisation has fundamentally transformed the global economy, reshaping economic growth, employment, consumer welfare and living standards. In the adoption of digital technologies, the internationally recognised India Stack, a growing FinTech ecosystem and a burgeoning digitally inclined population, combined with expanding internet and mobile connectivity, are driving India to become the fastest-growing digital economy.

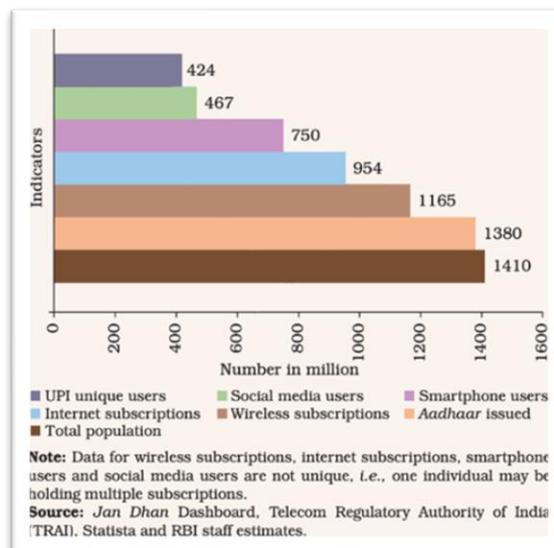


Figure 5-A : RBI Report on Digital Connectivity Indicator for India²²

²² RBI 2024 Report on Currency and Finance

<https://rbi.org.in/Scripts/AnnualPublications.aspx?head=Report%20on%20Currency%20and%20Finance>

India has one of the largest digitally connected population worldwide as per RBI’s 2024 Report on Currency and Finance (Figure 5-A). JAM trinity of Jandhan – Adhaar – Mobile has enabled the fast pace growth of Digital Economy of India.

In the adoption of digital technologies, the internationally recognised “India Stack”, a growing FinTech ecosystem and a burgeoning digitally-inclined population, combined with expanding and Affordable Mobile Connectivity Infrastructure, are driving India to become the fastest-growing digital economy (Figure 5-B). One of the fundamental drivers of this wave of digitalisation has been near ubiquitous connectivity through mobile, internet-connected devices and communication networks. India is home to the second largest telecom subscriber base (TRAI, 2023) and internet user base globally (ICRIER, 2024). The growth in digital enablers has been powered by competitive offerings by telecom operators, advent of global tech giants and among the cheapest data prices in the world. India is expected to be the second largest smartphone manufacturer in the next five years (Deloitte, 2022).

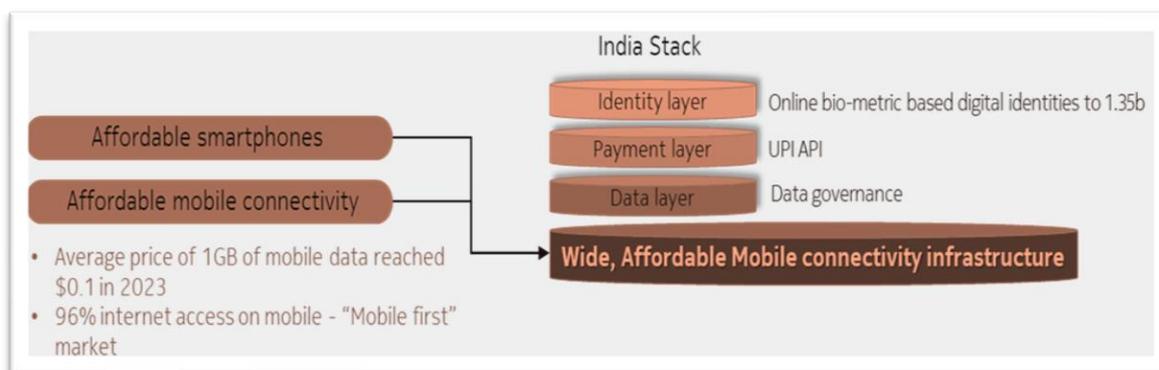
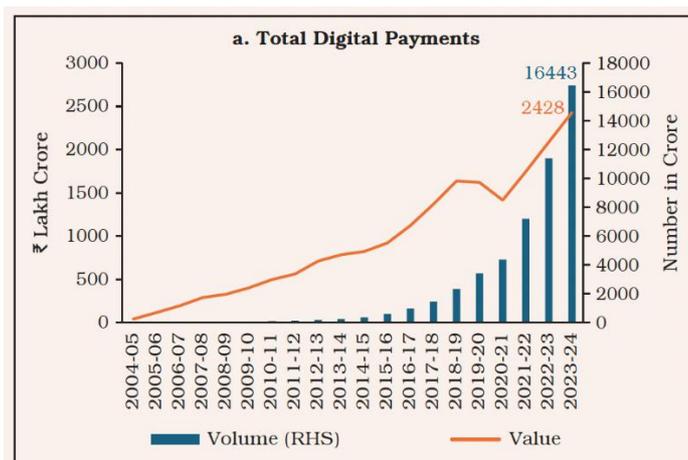


Figure 5-B : India Stack for Digital Economy in India

The heavily tech-based startup ecosystem includes various sectors like FinTech platforms, viz., insurance and payments, gaming, software as a service (SaaS)-based tools, logistics, healthcare services, education technology, e-commerce and online markets. With India on course to reap late mover advantages to become the fastest growing digital economy in the world with a digital ecosystem set to cross US\$ 1 trillion by 2025 (MeitY, 2019). Since 2014, there have been over 116 billion Aadhaar-based authentications and 20 billion electronic-know your customer (e-KYC) authentications. Number of Digital Payments in India crossed 16443 Crore in FY 2023-24 (Figure 5-C) and these are projected to continue to grow exponentially over next 3-5 years as number of UPI user grow to match up with smartphone user growth. (Figure 5-A)

This will add to the pressures / enormous / excessive demands on networks going forward. India is a cost sensitive society, and it is imperative to manage the traffic growth cost effectively. Additionally serious efforts are needed to expand the value of mobile connectivity to richer applications with a potential for wide scale out, to ensure the returns on investments.



Source: RBI; NSO; UN World Population Prospects; and RBI staff estimates.

Figure 5-C : Growth of Digital Payments in India (Source: RBI Report)²³

5.2 Emerging applications

The initial deployment of 5G have been made in India in both NSA and SA mode. Currently MBB is the mainstay of data consumption. FWA has offered an interesting element which has raised the data consumption and improved the penetration of broadband access to retail and enterprises. This is still in initial phases and would grow sharply going forward.

In addition, the commercial implementation of network slicing for enterprises has stated in initial stage with possible bundling of AR/VR with slicing, and with 5GA deployments in 2027-28 timeframe, it will assume widescale deployments. With the advent of commercial XR devices in 2026-27 timeframe immersive services will be find good uptake in India and globally.

With the deployment of 5GA in 2027-28 timeframe the additional applications that would pick momentum are –

- a. **Differentiated connectivity services** 5G networks will be able to offer differentiated connectivity services to end-consumers/applications and enterprises using the the public 5G network
- b. **Critical communication** in enterprise, utility and Strategic Sectors
- c. **Event based XR services** for concerts and sports
- d. **Programmable networks** which would allow users to adapt network to suit their needs in terms of coverage, QoS and experience in autonomous manner. Programmable networks transform themselves from Networks to Platforms with open APIs to avail this capability. This capability will be the essential building block for upcoming applications like Digital twins and Metaverse at large scale
- e. **Integration of Communication with Compute** is another key element which will augment the key value of networks in near future. Edge compute is an integral part of

²³ RBI 2024 Report on Currency and Finance

<https://rbi.org.in/Scripts/AnnualPublications.aspx?head=Report%20on%20Currency%20and%20Finance>

mobile network architecture and will integrate the applications with mobile networks through Edge compute APIs. These capabilities will be inevitable for latency critical remote computing that TSPs can offer, and for Digital twins and Metaverse applications which essentially demand distributed placement of Application workloads at network Edges with autonomous discovery and LCM.

- f. **NTN communication:** New ways of tighter coordination of non-terrestrial networks with terrestrial networks of communication are emerging and under study as we evolve to 6G with ubiquitous coverage.

Further, 6G is positioned to bring about two critical evolutions –

- a. Physical- Digital fusion (DTs, Metaverse) which means a dynamic, network-connected representation of real-world things in the digital world. This would allow the physical world to be replicated, simulated and automated with the digital world – opening the doors to a wealth of new possibilities benefitting humanity
- b. Human (capabilities) augmentation which means extensions that will enable humans to interact with digital and within digital world \
- c. Cognitive intelligence- The networks will become AI native to achieve and act like lining being by self-detecting, self-healing and self-optimization. It will help in achieving the efficiency in the network by real time decision-making in dynamic and complex environments

To achieve these ends, 6G will enable integration of communication and sensing (ICAS) and integration of Communication and AI. AI will be natively built in the 6G architecture. There will be enormous amount of AI traffic from captive AI traffic as well as the external AI traffic from Applications.

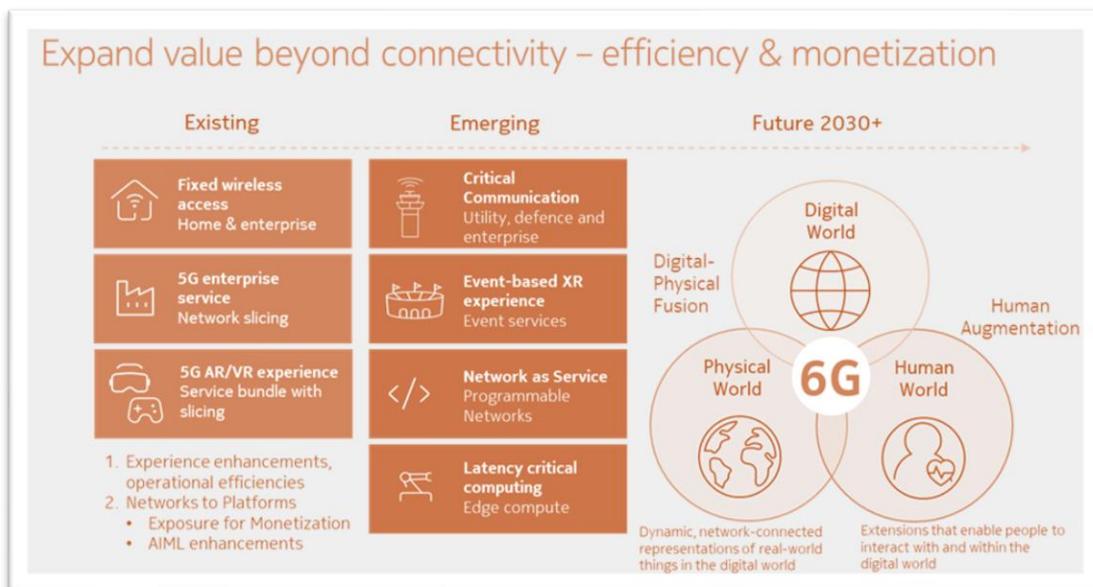


Figure 5-D : Expanding value beyond connectivity in 6G (B6GA member contribution)

5.3 Current Spectrum Landscape for Mobile Broadband in India

From telecom licensing and spectrum allocation, India is divided into 22 regions called as Licensed Service Areas (LSA)²⁴.

Further, to classify across different band ranges (sub 1 GHz, Mid Band and High Band) the total IMT spectrum available in India is summarized as the table below (Table 5-A).

Spectrum Band	Band range (MHz)*	Spectrum for IMT	Total Spectrum
600 MHz	663-703 [612-652]	40+40 MHz	Sub 1 GHz 105+105 MHz Total: 210 MHz
700 MHz	723-748 [778-803]	20+20 MHz	
800 MHz	824 – 844[869 – 889]	20+20 MHz	
900 MHz	890 – 915 [935 – 960]	25+25 MHz	
1800 MHz	1710-1755[1805-1860]	55+55 MHz**	Mid Band 95+95 MHz & 490 MHz Total: 680 MHz
2100 MHz	1939-1979 [2129-2169]	40+40 MHz	
2300 MHz	2300-2380	80 MHz	
2500 MHz	2535-2655	40 MHz	
3300 MHz	3300-3670	370 MHz	
26 GHz	24250-27500	3250 MHz	High Band 3250 MHz
		Total for IMT	4140 MHz
<p>Note: * For paired (FDD) bands, the uplink frequencies are shown in brackets **Besides above, additional spectrum of 15 +15 MHz in Kerala and Orissa service areas and 10+10 MHz spectrum in Haryana, Mumbai and Kolkata service areas in 1800 MHz is available for telecom services.</p>			

Table 5-A : Current IMT allocation in India

India has adopted progressive policies of technology neutral licensing of spectrum. All spectrum assigned through auctions are technology neutral. However, the spectrum assigned administratively prior to 2012, in the 800 MHz, 900 MHz and 1800 MHz bands for GSM/CDMA services were not technology neutral. The operators having administratively assigned spectrum have an option to liberalise (convert to technology neutral) by paying market determined price on a pro-rata basis.

Following Table (Table 5-B) highlights the comparison of allocation of IMT spectrum in as compared to Global Allocations

²⁴ <https://dot.gov.in/lsa>

Global allocation of IMT bands	India's allocation of IMT bands
<ul style="list-style-type: none"> • A total 19686 MHz spectrum has been identified for IMT implementation, out of which bandwidths of 510 MHz, 2136 MHz, and 15250 MHz fall in the low-band, mid-band, and high-band, respectively. • This addition of bands is without considering the IMT band identification via regional or country-specific footnotes. 	<ul style="list-style-type: none"> • A total 4140 MHz spectrum is available for IMT with bandwidths of 210 MHz, 680 MHz, and 3250 MHz falling in the low-band, mid-band, and high-band, respectively. • In India, IMT allocation is lower than the global allocation. • In the crucial low band and mid-band, IMT allocation is considerably less than the global allocation • Similarly high band allocation is also lower than Global allocation, however IMT deployment in these bands is currently infancy stage in most markets.

Table 5-B : Comparison of IMT spectrum allocation in India with Global Scenario (Source: WPC Analysis)

5.4 Additional Spectrum Requirements

5.4.1 5G Advanced

The networks have evolved from 4G cycle with roughly 40MHz TDD spectrum in 2300 MHz band and 20 MHz TDD spectrum in 2500 MHz band along with FDD bands in lower mid-bands like 1800 and 2100 MHz bands. With 5G, it has evolved in to 100 MHz channel size in 3.5 GHz (n77) C-band.

The Figure below explains the need for midband spectrum that provides a careful balance of coverage and capacity.

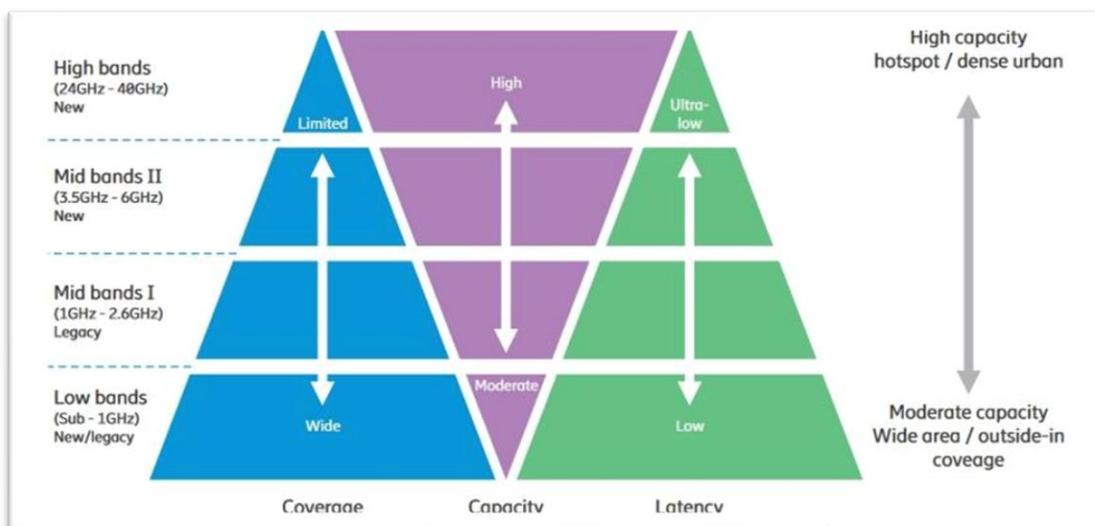


Figure 5-E : Spectrum Trade-Offs (Source - IEEE Comsec Blog, Broadband Library)²⁵

²⁵ <https://broadbandlibrary.com/5g-low-latency-requirements/>

NDCP-2028 has envisioned a target of 50 Mbps everywhere for 2022, and subsequently Bharat 6G Vision has laid out an ambitious target of providing 100 Mbps data experience anywhere and everywhere by 2030.

GSMA has published a widely read report “Mid-band spectrum Vision 2030” in 2021 with a detailed case study of major cities in the world. Mumbai in India was also part of this research. The report concluded that a minimum of 2 GHz mid-band spectrum will be needed in order to provide IMT-2020 experience of 100 Mbps download and 50 Mbps uplink speeds anywhere. In particular for Mumbai, it concluded a mid-band spectrum need of 2600 MHz for this target data rate.

Research has been carried out by industry for Delhi, to validate the results of GSMA study²⁶. The assessment indicates a requirement of additional 1.5 GHz mid-and spectrum in Delhi for the true 100 Mbps downlink experience everywhere. The analysis has followed the valid assumptions to develop the assessment based on population density and calculating traffic demand vs supply per sqKM. Based on the gap in capacity, it calculated the additional 2.2 GHz mid-band spectrum that would be needed to manage this data rate.

In addition, there should be effort to offer larger blocks of contiguous spectrum which provides better spectral efficiency and energy efficiency performance.

Bands	Assigned Spectrum	Macro Av. SE LTE (bps/Hz) DL	Macro Av. SE LTE (bps/Hz) UL	Activity factor	High-band offload factor	#Macro Sectors /BS	Macro Cell radius (m)	Small cell SE (bps/Hz) DL	Small cell SE (bps/Hz) UL	Small cell per Macro
700	10x2	1.8	1.8	25%	25%	3	130	3.7	3.2	
800	10x2	1.8	1.8	25%	25%	3	130	3.7	3.2	
900	10x2	1.8	1.8	25%	25%	3	130	3.7	3.2	
1800	20x2	2.5	2.2	25%	25%	3	130	3.7	3.2	
2100	10x2	2.5	2.2	25%	25%	3	130	3.7	3.2	
2300	80	2.5	2.2	25%	25%	3	130	3.7	3.2	3
2500	30	2.5	2.2	25%	25%	3	130	3.7	3.2	3
3500	370	6.0	4.1	25%	25%	3	130	3.7	3.2	3

²⁶ <https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2021/07/Estimating-Mid-Band-Spectrum-Needs.pdf>

Area (sqkm)	1484
Pop. density	10000
#macro sites	27965

Capacity delivered Mb/s per sqkm	50003
Capacity demand Mb/s per sqkm	2,50,000
Offload to high bands @25%	62,500.00
Capacity gap Mb/s per sqkm	1,37,496
Capacity gap Mb/s per cell site	2.92E+04
Spectrum gap GHz per cell site	1.53 GHz

Table 5-C : Spectrum Gap Analysis (B6GA members' analysis)

As the demand for connectivity grows and emerging technologies like Industrial IoT (IIoT), smart cities, and autonomous systems gain traction, the need for new spectrum allocations becomes evident. The current IMT spectrum assignments in sub-GHz, mid-band, and high-band ranges provide adequate capacity for existing 4G and 5G services. However, the future of 5G advances and 6G services requires additional spectrum sources to handle emerging technologies, higher data rates, and new use cases.

Overall IMT network need additional 200 MHz of spectrum per operator network in next 3-4 years for 5G Advance and further 500-750 MHz per operator network by 2030 for 6G services (Figure 5-F) as shown below.

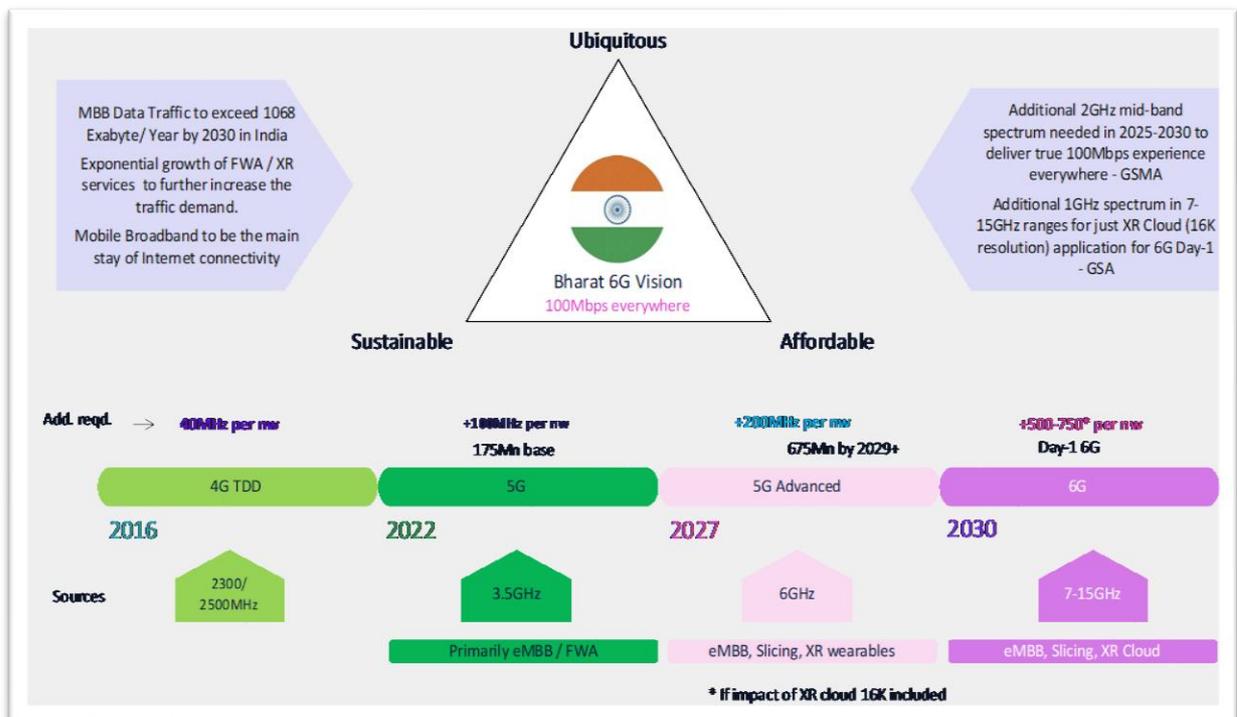


Figure 5-F : Spectrum need per Operator in India (Source: B6GA Member's analysis)

6 Potential Sources for Additional Spectrum for 5G & 6G in India

As IMT networks in India evolve towards 5G Advance leading upto 6G, expanding the availability of radio spectrum is critical to meet the growing demands of next-generation mobile communications. Both optimizing existing allocations and exploring new frequency bands are necessary steps to ensure India's leadership in global mobile technology development.

It should be noted that the 5G Advance and 6G use cases applicable for each band are unique and depend upon the propagation characteristics of the band. Hence the role of each band- Low, Mid & High- is critical, indispensable in this journey. Following Figure 6-A captures the applicability of each spectrum range for respective IMT deployment scenarios.

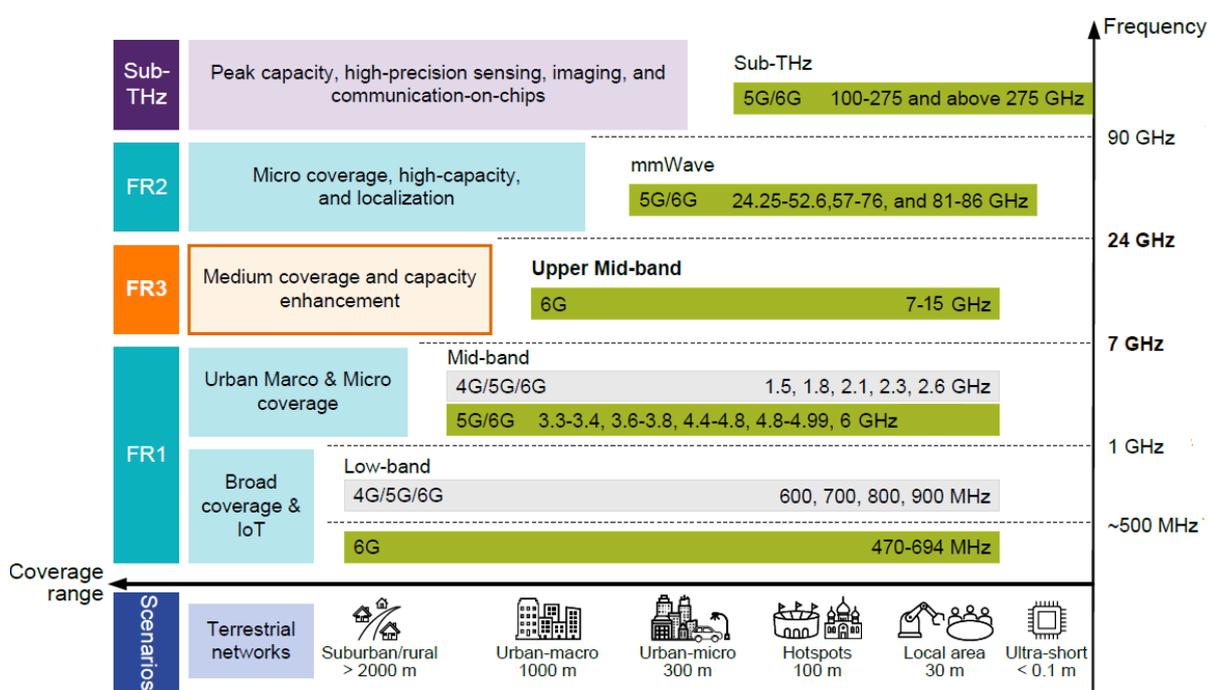


Figure 6-A : Overview of potential spectrum bands for various IMT scenarios

Categorization of Potential IMT spectrum candidate bands:

The following sections explore the potential sources of additional spectrum needed to support the country's future IMT deployments, including the reassignment of existing allocated bands and exploration of new spectrum from international agreements. These sections capture the details of spectrum ranges suitable for IMT assignments and the technical, and regulatory considerations pertaining to each of them.

Based upon the varying Radio regulation status the new sources of IMT spectrum could broadly be categorised as follows:

6.1 Existing Potentials

These are the bands which have already been identified for IMT in Indian NFAP. But are partially unassigned for commercial use in India due to other usage by other services.

These include:

- **600 MHz, 700 MHz, 1800 MHz, 2100 MHz Bands:** Certain portions of these bands remain administratively assigned to government agencies. A detailed audit of current usage is required to release spectrum for IMT services, potentially enhancing mobile broadband and rural connectivity. These are also important from coverage aspects of IMT networks.
- **2600 MHz Band (n41):** Studies on expanding the n41 band (2600 MHz) for IMT should be considered to meet growing data demand and support advanced 5G services.
- **37–43.5 GHz and 47.2–48.2 GHz:** These bands offer significant bandwidth for advanced 6G applications, including AR/VR, holographic communication, and high-speed data access in urban and industrial settings. Indian telecom regulator TRAI released a consultation paper on Auction of Frequency Spectrum in 37-37.5 GHz, 37.5-40 GHz, and 42.5-43.5 GHz bands Identified for IMT²⁷ in April 2024 seeking inputs from the stakeholders.
- **66–71 GHz:** With a focus on ultra-high-speed data for city hotspots, this band is useful for applications such as autonomous vehicle connectivity and smart city use cases. It should be noted that TRAI also released a Consultation Paper on Consultation Paper on Assignment of Spectrum in E&V Bands, and Spectrum for Microwave Access (MWA) & Microwave Backbone (MWB)²⁸ seeking industry inputs. It may be noted that this band has been identified in WRC-19 as a candidate IMT access band.

6.2 Hidden Gems:

Following Bands represent hidden opportunities for India specific IMT assignments, These include:

- **L-Band (1427–1518 MHz):** This band has been identified for IMT in WRC-15, nevertheless the assignment of this band is still pending in India. Recently, the Government has identified 67 MHz spectrum (out of 91 MHz spectrum) in this band for IMT services, which will be made available by December 2026.
- **Extended C-band (3670–4200 MHz):**
 - Currently spectrum from 3 300 to 3 670 MHz has been assigned for 5G in India. While there is IMT identification till 3800 in WRC-23 in various regions, it is restricted in India till 3670 currently. The adjacent 3.7 – 4.2 GHz spectrum is currently assigned to FSS (s to E) applications. This spectrum is FDD paired with FSS (E to s) assignments in lower 6 GHz band as shown in Figure 6-B . With the potential availability of parts of 6 GHz band for IMT in future, the corresponding FSS downlink part may also be considered for IMT applications subject to the required technical study towards the same.

²⁷ [Consultation Paper No. 4/ 2024](#), TRAI

²⁸ [Consultation Paper No. 22/ 2023](#), TRAI

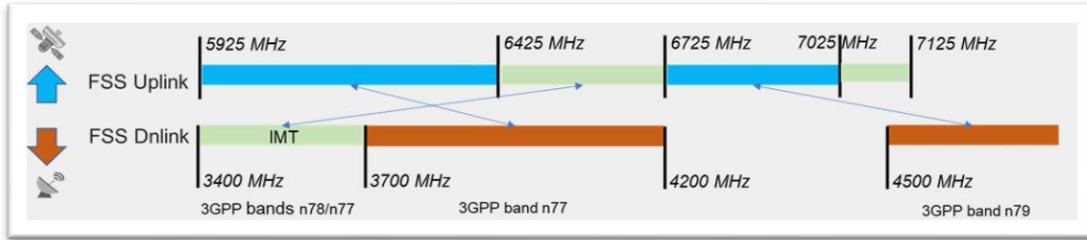


Figure 6-B : FSS and IMT Band Plans

- There is important coexisting aspects related to performance characteristics of Radio Altimeters used in Aviation. While their assigned frequency range is 4200 - 4400 MHz, many of the older generation Radio Altimeter have poor filtering characteristics resulting in certain restrictions of IMT deployment in C-band. Retrofitting of Radio Altimeters is expected to get completed in next few years, opening the possibility of IMT in extended C-band.
- It is worth noting that even though current IMT identification in WRC-23 is till 3800, IMT is deployed/planned to be deployed in extended C-band spectrum upto 4000 MHz in many countries. Further expansion of IMT from 3670 to 4200 MHz range could provide growth spectrum for 6G.²⁹

6.3 Emerging spectrum for 5G Advanced and 6G:

This spectrum consists of new bands identified from IMT WRC-23 & the ones being projected for IMT identification in WRC-27 as well as potential candidate for IMT in India. These include:

- **4.4–4.8 GHz:** This band is one of the candidate bands for 6G, under WRC-27 Agenda Item 1.7. However, the proximity to the aviation altimeter band (4.2–4.4 GHz) needs to be studied to avoid interference with aircraft altimeters. Technical assessments will be essential to ensure compatibility with existing services, while exploring this band's potential for future IMT services.
- **6 GHz (5925–7125 MHz):**

The 6 GHz band has gained traction as a candidate for future IMT use, particularly because of its large contiguous bandwidth. It supports enhanced coverage and capacity for urban and suburban environments, and its ability to balance mobility and data requirements makes it a promising 6G candidate.

This band is assigned to Fixed satellite services (FSS) Earth to space links operation in India. The 6 GHz band can be sub-divided into three ranges.

- **5925-6425 MHz:** Generally referred to as lower 6 GHz band. There is no precedence of IMT identification under ITU-R RR in this band. It has been decided to de-license the lower 6 GHz band i.e. 5925-6425 MHz for low power applications to improve Wi-Fi speed and for enabling upcoming high-bandwidth applications,

²⁹<https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2023/05/5G-and-Aviation-Altimeters.pdf>

including augmented and virtual reality gear, wearable displays, and advanced gaming consoles. Therefore, this band is not available for IMT service.

- **6425-7025 MHz:** Generally referred to as Upper 6GHz band. This band was identified for IMT in Region 1, whereas some administrations from Region 2 & 3 respectively signed Country footnote towards IMT identification of this band in their geography. This upper 6 GHz band has been identified for IMT service as part of a phased plan for the wider 6 GHz band. The first part of this band i.e. 6425-6725 MHz will be available immediately and the second part 6725-7025 MHz will be made available by 2030.
- **7025-7125 MHz:** WRC-23 saw a global consensus for IMT identification in this band during WRC-23. India has also allocated this band for IMT, available immediately.
- **7.125–8.4 GHz:** This band is one of the candidate bands for 6G, under WRC-27 Agenda Item 1.7. This band offers promising capabilities for mid-range communication, providing an ideal blend of bandwidth and coverage.
 - As per India's NFAP 2022³⁰, frequency band 7125 – 8400 MHz has been allocated to FIXED and MOBILE (except aeronautical for some portions) service. Also, **portions of the band** have been allocated for FIXED-SATELLITE (space-to-Earth, Earth-to-space), EARTH EXPLORATION-SATELLITE (Earth-to-space, space-to-Earth), MARITIME MOBILE SATELLITE (space-to-Earth), METEOROLOGICAL SATELLITE (Earth-to-space, space-to-Earth), SPACE RESEARCH (Earth-to-space). Further, the SRS (E-to-s), EESS (E-to-s), MMSS (s-to-E) in some of the portions cannot claim protection from further development of fixed and mobile services as per RR 5.460, 5.560A and 5.461AB.
 - They could be critical for future 6G deployments, particularly in urban areas where capacity demands are high. Further, this band offers extension to the 6 GHz band identified for IMT in India with possibility of larger contiguous spectrum enabling 6G use-cases.
- **14.8-15.35 GHz:** This band is one of the candidate bands for 6G, under WRC-27 Agenda Item 1.7. This band provides promising mid-band capabilities for a blend of coverage and capacity.
 - As per India's NFAP 2022, frequency band 14.8 -15.35 GHz has been allocated for FIXED & MOBILE as Primary and SRS as secondary services and has wide deployment of backhauls links
- **Overall 7–15 GHz:** Some ranges in this spectrum are being explored globally for 6G applications outside ITU-R process, including IIoT and broadband services, where wider bandwidth is crucial for future immersive communication and virtual experiences. In May

³⁰[https://dot.gov.in/sites/default/files/NFAP%202022%20Document%20for%20erelease.pdf?download=](https://dot.gov.in/sites/default/files/NFAP%202022%20Document%20for%20erelease.pdf?download=1)

2023 the FCC proposed policies which would position the 12.7-13.25 GHz band to support flexible terrestrial wireless use, including 6G wireless services³¹

- After the deliberations in WRC-23 and the final outcome, the new WRC-27 agenda item 1.7 includes the bands 7.125 – 8.4 GHz and 14.8-15.35 (in addition to 4.4-4.8 GHz) for study in Region 3. The stakeholders in India should assess the possibility of creating more opportunity for IMT in this band. This band is emerging as the high potential for 6G in many parts of the world & India can take leadership in this band.

6.4 Sub THz

Indian Regulator, TRAI has provided following recommendations on the Tera Hertz Spectrum

- The Government should introduce a new experimental authorisation for the spectrum in the 95 GHz to 3 THz range termed as ‘Tera Hertz Experimental Authorisation’ (in short, THEA).
- the purpose of THEA should be to promote Research & Development (R&D), indoor and outdoor testing, technology trial, experimentation, and demonstration in the 95 GHz to 3 THz range.
- Authorisation and assignment-exempt operations should be permitted in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in India.

Sub-THz spectrum is likely to be considered in WRC-31 cycle for 6G Advance deployments, it is unlikely to be used in Day-0 services of 6G.

6.5 Golden Band for 6G in India: Mid-Band spectrum

Mid-band frequencies, typically between 1–6 GHz, offer an ideal balance between capacity and coverage, making them critical for 6G and 5G networks. These bands support high data rates and relatively wide coverage, catering to eMBB, IIoT, and smart city applications.

As per GSMA report there is a shortfall of about 200 MHz mid-band spectrum per operator than the requirements for 5G Advanced. Further As per GSA studies, 500-750 MHz additional spectrum per network, with potential channel bandwidth of 400- 500 MHz may be needed for 6G use cases. The number of options to fulfil this gap are very limited

The ability to reuse existing cell sites to deliver high quality service is a very important consideration in selecting spectrum bands for 6G. It is very important factor for sustainability of telecom networks, reducing carbon footprint and ensuring affordability of telecom services to end users. Sustainability and Affordability are two important corner stone of Bharat 6G Vision.

Given that 3.5 GHz band is the main 5G deployments band in India, the spectrum bands for 6G also need to be as close to these frequencies as possible as propagation characteristics in higher frequency bands of FR2 are not ideally suitable for wide area deployments. The higher the frequency is compared to 3.5 GHz, the more challenging it is to reuse the grid due to inherent propagation characteristics of spectrum bands. Technological advancements like

³¹ FCC 23-36, “Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband or Other Expanded Use”

Extreme MIMO along with higher EIRP can help to mitigate this to an extent, However, EIRP increase may not be limited due to EMF radiation safety concerns.

6 GHz to 8.4 GHz represent “Golden Band” of opportunity for 6G in India. Unlike many other countries, India is still evaluating the potential usage of 6GHz spectrum. Detailed studies need to be undertaken regarding what features can enable capacity and coverage in this spectrum range comparable to such characteristics in 3.5 GHz range. This “Golden Band” together with Extended C-band (upto 4200 MHz) and 4.4 GHz to 4.8 GHz represent the two large chunks of spectrum opportunity for 5G-Advance and 6G in India

Figure 6-C outlines potential mid-band spectrum options which could be evaluated for IMT assignment in India.

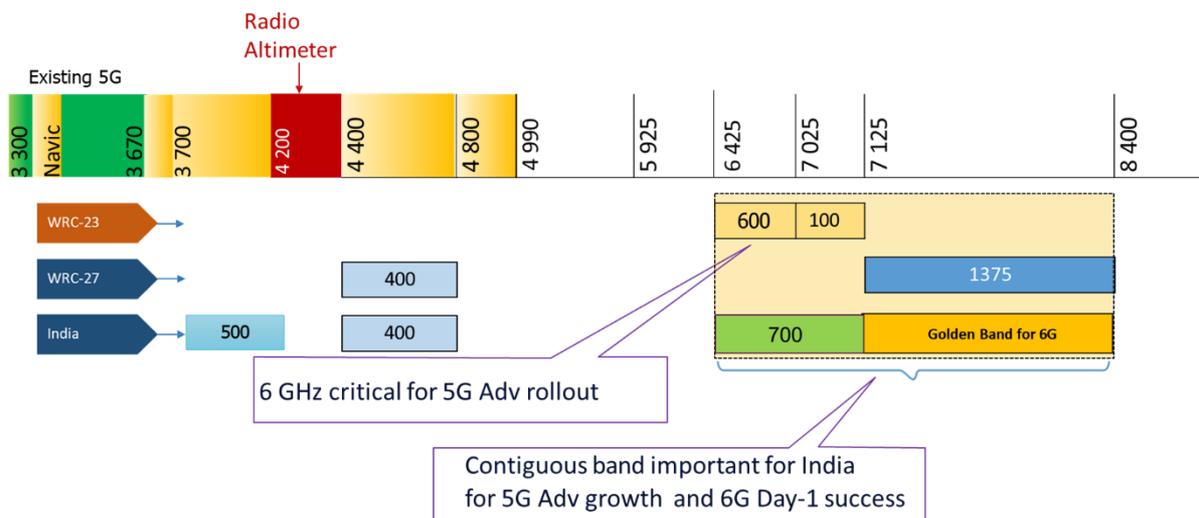


Figure 6-C : Potential sources of large chunks of mid-band spectrum for 5G-A and 6G in India

7 Global update on strategies around potential 6G spectrum

The potential spectrum under discussion globally is heavily utilized by various entities, including commercial, public sector, and government organizations, for applications such as radio astronomy and satellite communications. Each region faces unique challenges, prompting the adoption of tailored strategies and best practices for effective spectrum management as we transition to 6G.

Relocating many users, particularly those involved in government or satellite operations, presents significant challenges. Even if regulators worldwide agree on spectrum availability and proceed with licensing, the most substantial technical hurdle will be effectively sharing this spectrum without disrupting existing services. Balancing licensed, license-exempt, and shared spectrum is essential³².

Examples of Regional Strategies:

1. United States:

- The FCC is exploring shared licensing approaches through three specific models: nationwide licensing, site-level licensing, and technology-based licensing. A research report from the Next G Alliance on "Spectrum Access Mechanisms" highlights the U.S. National Spectrum Strategy's introduction of dynamic spectrum sharing into policy and regulatory frameworks. This approach acknowledges the ongoing importance of licensing to enhance spectrum availability across various sectors, beyond just public telecommunications networks. The report emphasizes that policies vary significantly among nations, and it is crucial to understand the implications of these differences on economic and regulatory considerations.
- In a multi-country joint statement by the White House³³, the emphasis is on the spectrum policy and manufacturing principles that prioritize 6G technologies. These technologies are designed for efficient spectrum use and include built-in mechanisms for spectrum sharing, allowing them to coexist with existing service providers. The initiative also aims to foster a globally competitive market throughout the information and communications technology value chain, promoting diversity among software and hardware suppliers across all areas of computing and connectivity. Efforts are underway to investigate the coexistence of licensed and unlicensed devices within this band, aiming to maintain operational integrity.
- The National Spectrum Strategy Implementation Plan³⁴ released in March 2024, Strategic Objective 2.1 states to prioritize several spectrum bands for study. The Strategy identified the following spectrum bands for near-term, in-depth study to determine whether they may be repurposed for non-Federal or shared Federal and non-Federal use: (1) 3.1-3.45 GHz; (2) 5030-5091 MHz; (3) 7.125-8.4 GHz; (4) 18.1-18.6 GHz; and (5) 37.0-37.6 GHz. The study plans will be developed jointly by NTIA and the affected Federal agencies. The studies will consider various typically employed spectrum management mechanisms to assess fully the possibilities for expanded or

³²<https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2024/02/Spectrum-Policy-Trends-2024.pdf>

³³<https://www.whitehouse.gov/briefing-room/statements-releases/2024/02/26/joint-statement-endorsing-principles-for-6g-secure-open-and-resilient-by-design/>

³⁴<https://www.ntia.gov/report/2024/national-spectrum-strategy-implementation-plan>

more efficient uses of the spectrum. The study plans will be mutually agreed to between NTIA and affected Federal agencies. The Appendix provides the approach to band studies and details on adoption of study plans. It also lists the top-line schedule for completing studies of these spectrum bands.

- Recently USA also indicated making available additional 800 MHz of IMT spectrum as part of One Big Beautiful Bill Act³⁵.

2. Considerations in Europe:

- The Electronic Communications Committee (ECC) is working on initiatives to enhance receiver resilience, which will help future-proof the coexistence of various users and improve spectrum efficiency. European Strategy Development: A report from the European Telecommunications Network Operators' Association (ETNO)¹ advocates for a coordinated effort to identify and harmonize spectrum that meets anticipated 6G demands. Ensuring sufficient spectrum for outdoor and macro deployments at fair prices is vital. Additionally, collaboration between the European Commission, Member States, and industry stakeholders is recommended to create a comprehensive 6G strategy, focusing on use cases, traffic growth, and spectrum needs.

3. UAE Views³⁶:

- The UAE's Telecommunications and Digital Government Regulatory Authority (TDRA) emphasizes the critical role of AI in future spectrum governance. The TDRA advocates for enhanced data collection on spectrum usage, asserting that AI can improve policymaking and cost efficiency. Future management regimes are expected to be more agile, with increased automation and autonomy.

4. US-Sweden Joint Statement³⁷:

- A recent statement from the United States and Sweden highlights the importance of exploring long-term research collaborations related to 6G. This includes efficient use of communication resources, addressing spectrum issues, and developing test beds and open architectures.

³⁵ <https://www.congress.gov/bill/119th-congress/house-bill/1/text>

³⁶ <https://developingtelecoms.com/telecom-business/telecom-regulation/16609-uae-regulator-tdra-releases-its-6g-roadmap-to-2030.html>

³⁷ <https://www.state.gov/joint-statement-of-the-united-states-of-america-and-the-kingdom-of-sweden-on-cooperation-in-advanced-wireless-technologies/>

8 Recommendations on Strategy & Policy initiatives for 5GA & 6G Spectrum

A well-defined national spectrum strategy roadmap is a cornerstone for India's digital transformation by unlocking the full potential of emerging technologies, fuelling economic growth. This section highlights the key recommendations and policy initiatives on spectrum in the short, mid and long term.

8.1 Short-Term (by Dec-2025):

- **Comprehensive Spectrum Review:**
 - A thorough analysis of existing spectrum allocation and usage is crucial to identify gaps, inefficiencies, and opportunities for optimization.
 - This review should encompass both licensed and unlicensed bands, considering current demands and future projections for 5G and beyond.
- **National Spectrum Pipeline**, and possible target bands for 5GA and 6G with the following objectives:
 - Define clear pathways for 200 MHz mid band spectrum per operator for 5G advanced
 - 6 GHz – 8.4 GHz spectrum is foreseen as “Golden Band” of opportunity for 6G success in India. The entire frequency range should be studied for use by mobile operators. Detailed consultation with stakeholders to arrive at a most prudent and realistic assessment of spectrum requirements in the 6GHz spectrum band between Wi-Fi services, the new proposed IMT services and incumbent FSS and FS users in this band. Use of this frequency range for IMT will be pivotal in reaching the total spectrum requirement of 1.5-2 GHz needed for successful deployment of 6G. Technological advancements including extreme MIMO in 6G are likely to deliver the expected performance of 6G without needing to add new cell sites. This will be important facilitator in meeting key fulcrum of Sustainability and Affordability in Bharat 6G vision
 - Accelerate the commercialization of 600 MHz band and expedite APT 600 band plan (n105)
 - Consultation on usage of 526 – 582 MHz band in India with view of possible IMT allocation as it is highly suitable for wider coverage area.
 - The extended C band (3700-4200 MHz) is a potential candidate band, it has to be carefully studied as to how the incumbent Satellite based Broadcasting and any other incumbent user can either coexist or be migrated (with right techno commercial analysis. This may include action like Acceleration of the retrofitting of TVRO filters and RA for expansion of IMT services beyond 3 670 till 4 200 MHz, and possible offloading of teleporting and VSAT traffic to IMT 5G networks.
 - Consultation paper and discussions with the multiple industry stakeholders on the 5G and 6G coexistence, along with the other technologies coexistence in the spectrum of interest.
 - Explore possible utilization of 4 800 – 4 990 MHz for IMT without compromise on transmission power / EIRP as per resolves 5 of Resolution 223 (Rev.WRC-23).

- Assignment plan for L-Band and band plan decision
- **Global Engagement on IMT-2030/6G:**
 - Participate actively with in international forums and collaborate with like-minded global/regional organizations on spectrum harmonization aspects.
 - India must actively participate in international forums like WRC-27 and 3GPP to shape global standards for 6G as well as secure a feasible sharing through identification of spectrum for IMT through sharing studies.
 - This proactive engagement will ensure that India's interests are represented and that its expertise contributes to the development of future wireless technologies.
- India already has a progressive experimental licensing regime coupled with “regulatory Sandbox Policy”. There should be a **Call for Proposal** for Prototypes and Field Demonstrations in spectrum bands of interest by R&D institute, Academia and Industry.
 - Initiating pilot projects and trials for cutting-edge wireless technologies in designated bands will provide valuable real-world data and insights.
 - This hands-on experience will be crucial for shaping future spectrum allocation strategies and fostering a vibrant ecosystem of innovation.
- Develop detailed guidelines and procedures for spectrum sharing and access mechanisms.
- Audit of govt allocated spectrum in the globally harmonized bands and identified for IMT, to enable their potential release for commercial usage in India.

8.2 Mid-Term (by Dec-2027):

In the mid-term, one of the key objectives should be to finalize the position development for WRC-27 and establish a strong basis for spectrum planning in India.

- Sharing and Compatibility studies for the WRC-27 agenda items for 6G spectrum for India
 - For all the bands under consideration under AI 1.7 (4 400 – 4 800 MHz, 7 125 – 8 400 MHz, 14.8 – 15.35 GHz)
 - To ensure protection of terrestrial IMT deployments while studying the new agenda item AI 1.13
 - Study the results from pilot projects and trials for emerging wireless technologies in selected bands.
 - Accelerate the prototyping and initial technology development in potential 6G candidate bands.
- Establish a national platform for industry collaboration and knowledge sharing on spectrum planning.
- Study the regulatory framework for cybersecurity and privacy in wireless connectivity.

- Auction of identified spectrum bands as per the national spectrum pipeline to enable upto 200 MHz mid-band spectrum per operator as per National Spectrum Pipeline
- Potential assignment for IMT in sub-GHz bands, e.g., 526 – 582 MHz.

8.3 Long-Term (Post WRC-27):

As the WRC-27 developments and outcomes regarding IMT-2030/6G become clear (around 2027) and the 3GPP specifications around 2029, India must initiate a comprehensive review and planning process for 6G spectrum requirements. This will involve identifying national allocation, technological trials, and developing a long-term roadmap for allocating and managing 6G spectrum resources.

- Considering the WRC-27 developments and outcomes, finalize spectrum for initial 6G deployments in India
 - o Consider development of IMT-2030/6G at 3GPP (around 2029) with policy recommendation related to spectrum allocations for successful 6G launch in India with Global Perspective
 - o Identify and assign the full range of bands from outcome of WRC-27 in the national frequency allocation plan keeping in mind the 500-750 MHz per operator for 6G use-cases.
 - o The national spectrum pipeline to be updated for all the potential bands from WRC-27 agenda item 1.7.
- Large scale Field trials for 6G in the newly identified 6G spectrum bands.
- Assessment of THz spectrum technology and potential inputs to WRC-31
- Continuously monitor global spectrum trends and integrate them into the national strategy toward technology trials
- Develop mechanisms, sandbox environments, and policies for spectrum allocation, coordination and sharing with incumbent users (both private and govt.)
- Foster research and development of innovative spectrum technologies for future wireless generations through experimental licenses for wireless applications, facilitate import and development of measurement equipment, electronics radio components, antennas

8.4 Other Policy Recommendations for Fostering 6G Research in India (New mid bands)

Potential policy announcements to guide the Government of India's support for academic research and research organizations on 6G technologies, specifically focusing on the mid band spectrum for 6G:

- I. Funding & Incentives:
 - a. Dedicated 6G Research Fund: Establish a dedicated fund with substantial annual allocation specifically for 6G research in India. This fund should support academic institutions and research organizations working on various aspects of 6G, including the exploration of the full mid band spectrum for 6G.

- b. **Matching Grants:** Implement a matching grant program where the government matches private sector investments in 6G research projects, encouraging industry participation and collaboration with academia.
- c. **Tax Incentives:** Offer tax breaks or credits for companies and institutions investing in 6G research and development, particularly focusing on the utilization of the 7.125-8.4 GHz band.

II. Spectrum Allocation & Access:

- a. **Limited Experimental Licenses:** Grant limited-time experimental licenses in the 7.125-8.4 GHz band and other spectrum bands of academic and research interests to research institutions and universities for conducting research and developing prototypes. This will allow for hands-on experimentation and real-world testing within this critical spectrum.
- b. **Call For Proposal for Prototypes and Field Demonstrations** in spectrum bands of interest by R&D institute, Academia and Industry.
- c. **Spectrum Sharing Framework:** Develop a flexible framework for spectrum sharing between existing users and future 6G deployments in mid band. This should prioritize research access while ensuring minimal disruption to existing services.

III. Infrastructure & Collaboration:

- a. **National 6G Research Network:** Establish a national network of interconnected research labs equipped with advanced testing facilities and resources specifically dedicated to 6G research, including the exploration of the 7.125-8.4 GHz band and other suitable bands .
- b. **Interdisciplinary Research Centres:** Encourage the creation of interdisciplinary research centres focused on 6G technologies, bringing together experts from diverse fields such as telecommunications, computer science, materials science, and electrical engineering.

IV. Human Capital Development:

- a. **Scholarships & Fellowships:** Offer scholarships and fellowships for students pursuing graduate studies and research in areas related to 6G technology, particularly focusing on the 7.125-8.5 GHz band and other suitable bands .
- b. **Training Programs:** Organize specialized training programs and workshops for researchers and engineers on cutting-edge 6G technologies and applications within this specific frequency range.
- c. **Public Awareness & Engagement: Knowledge Dissemination Platforms:** Create online platforms and resources to disseminate information about 6G research, its potential benefits, and the challenges associated with developing technologies.
- d. **Public Outreach Events:** Organize public events and webinars to raise awareness about 6G technology and encourage public engagement in this crucial area of development.

These policy recommendations together with other steps outlined in this section are expected to effectively foster a thriving ecosystem for 6G research in the country, paving the way for innovation and leadership in this transformative technology, particularly within the critical mid band.

9 Appendix

9.1 Key References

- a) Bhart 6G Vision Document: Source: <https://dot.gov.in/>
- b) India's NFAP 2022
- c) [Recommendation ITU-R M. 2160](#)
- d) RBI 2024 Report on Currency and Finance
- e) Ericsson Mobility Report 2024
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- g) GSMA Report : Spectrum Policy Trends 2024
- h) GSMA Report : Vision 2030: Mid-band Spectrum Needs
- i) India's Position papers for WRC-23
- j) TRAI Consultation Paper on Auction of Frequency Spectrum in 37-37.5 GHz, 37.5-40 GHz, and 42.5-43.5 GHz bands Identified for IMT
- k) TRAI Recommendations on the Tera Hertz Spectrum
- l) TRAI Recommendations on Encouraging Innovative Technologies, Services, Use Cases, and Business Models through Regulatory Sandbox in Digital Communication Sector
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- q) <https://www.state.gov/joint-statement-of-the-united-states-of-america-and-the-kingdom-of-sweden-on-cooperation-in-advanced-wireless-technologies/>

9.2 Acronyms

3GPP	3 rd Generation Partnership Project
5GA	5G Advanced
AI	Artificial Intelligence
APAC	Asia Pacific
API	Application Programming Interface
APT	Asia Pacific Telecommunity
AR	Augmented Reality
CA	Carrier Aggregation
CDMA	Code Division Multiple Access
D2D	Direct to Device
ECC	Electronic Communications Committee
EIRP	Effective Isotropic Radiated Power
e-KYC	Electronic-know your customer
eMBB	enhanced Mobile Broadband
EMF	Electo Magnetic Field
ETNO	European Telecommunications Network Operators' Association (ETNO)
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Multiplexing
FR	Frequency Range
FSS	Fixed Satellite Systems
FWA	Fixed Wireless Access
GSA	Global Mobile Supplier Association
GSM	Global System for Mobile Communications
GSM4	GSM Association
HAPS	High Altitude Platform Stations
HIBS	High Altitude Platform for IMT Base Stations
ICAS	Integration of communication and sensing
ICRIER	Indian Council for Research on International Economic Relations
IIoT	Industrial Internet of Things
IMT	International Mobile Telecommunications
IoT	Internet of Things
ISM	International Safety Management
ITS	Intelligent transportation systems
ITU	International Telecommunication Union
JAM	Jandhan – Adhaar – Mobile
LSA	Licensed Service Area
M2M	Machine to Machine
MBB	Mobile Broadband
MCPTT	Mission-Critical-Push-To-Talk
MIMO	Multiple Input Multiple Output
mMIMO	massive Multiple Input Multiple Output
MS	Mobile Subscriber
MSS	Mobile-Satellite Service
MWA	Microwave Access
MWB	Microwave Backbone
NDCP	National Digital Communications Policy
NFAP	National Frequency Allocation Plan
NGSO	Non-Geostationary Orbit

NR	New Radio
NSA	Non StandAlone
NTN	Non Terrestrial Network
OFDM	Orthogonal frequency division multiplexing
QoS	Quality of Service
R&D	Research & Development
RR	Radio Regulations
SA	StandAlone
TDD	Time Division Duplex
TDRA	Telecommunications and Digital Government Regulatory Authority (TDRA)
THEA	Tera Hertz Experimental Authorisation' (in short, THEA
THz	Tera Hertz
TRAI	Telecom Regulatory Authority of India
TSP	Telecom Service Provider
TVRO	Television receive-only
UPI	Unified Payments Interface
V2I	Vehicle to Infrastructure
V2N	Vehicle to Network
V2V	Vehicle to Vehicle
V2X	Vehicle-to-everything (V2X)
VR	Virtual Reality
VSAT	Very Small Aperture Terminal
WARC	World Administrative Radiocommunications Conference
WPT	Wireless Power Transfer
WRC	World radiocommunication conferences
XR	Extended Reality

9.3 Terms of Reference for the B6GA Spectrum Working Group

1. Background

6G, like its fifth generation predecessor, will further revolutionize the way we interact with technology. To harness its true potential, effective management of radio spectrum is crucial. The B6GA Spectrum Working Group is established to

- Develop recommendations to enable access to relevant spectrum for Wireless technology expansion beyond 5G leading to 6G technology, identification and allocation of sufficient spectrum network expansion towards 6G time-frame in India, and
- Ensure B6GA recommendations on spectrum issues meet the current and future social, economic and technological requirements/expectations/needs of the country, including harmonization of the spectrum globally or regionally to make technology affordable for deployment, consumers and enterprises adoption.

2. Objectives

- Develop roadmap of spectrum access towards network expansion towards 6G
- Recommend ease-of-access for experimentation and research to the new spectrum bands considered under by 3GPP and ITU-R for 6G
- Develop plan towards potential sharing and compatibility of the Identified spectrum for WRC-27 agenda on priority for 6G.
- Develop roadmap for developing and promoting sufficient harmonized spectrum bands with other countries in various regional preparatory groups. [and evaluate potential frequency bands for 6G, considering global harmonization and the needs of Industry.]
- Recommend policies for the allocation and licensing of spectrum to support innovative 6G services while ensuring efficient and fair use.
- Develop strategies for the deployment of IMT services with existing incumbent and future systems.
- Foster collaboration between government, industry, and academia to drive research and development in 6G spectrum.

3. Responsibilities

Members are responsible for:

- Contributing expertise and insights to inform the group's deliberations and outputs.
- Participating actively in meetings and collaborative activities.
- Developing and reviewing materials, such as reports, policy proposals, and technical and spectrum-need analyses.
- Liaising with their respective organizations to ensure alignment and gather additional input.

4. Reporting and Output

The working group will report to B6GA, and its output would include:

- A comprehensive report on potential frequency bands for 6G and strategies for their allocation.
- Policy recommendations on spectrum licensing and management.
- Technical guidelines for spectrum sharing and interference management.
- Regular updates on the group's progress to stakeholders

9.4 Spectrum Working Group Members

S. No	Name of Member	Organisation	Role
1	Prof David Koil Pillai	IIT Madras	Chair
2	A.K. Tiwari	Reliance Jio	Vice Chair
3	Mr. Nirmesh Yadav	Bharti Airtel Limited	Vice Chair
4	Ravi Lakhota	Vodafone Idea	Vice Chair
5	Mr. Dileep Lakhera	Bharti Airtel Limited	Member
6	Shri Debashish Bhattacharya	Broadband India Forum	Member
7	Mr. Dilip Krishnaswamy	C-DOT	Member
8	Mr. Prakash R	C-DOT	Member
9	Mr. Golla Srinikhil	C-DOT	Member
10	Mr. Abhijeet Abhimanyu Masal	CEWiT	Member
11	Mr. Art King	Cohere Technologies	Member
12	Dr. Brajesh Mishra	DoT	Member
13	Ms. Neha Upadhyay	DoT	Member
14	Mr. Pankaj Pakhare	DoT	Member
15	Shri Ram Babu	DoT	Member
16	Dr. P. S. M. Tripathi	DoT, WPC	Member
17	Ms. Radhika Kollu	DoT, WPC	Member
18	Dr. Sendil Devar	Ericsson	Member
19	Dr. Sonali Garg	HFCL Limited	Member
20	Prof Jyotsna Bapat	IIIT Bangalore	Member
21	Prof. Vivek Ashok Bohara	IIIT Delhi	Member
22	Prof. Shamik Sarkar	IIIT Delhi	Member
23	Prof K. J. Vinoy	IISc, Bengaluru	Member
24	Prof. Debarati Sen	IIT Kharagpur	Member
25	Prof. Suvra Sekhar Das	IIT Kharagpur	Member
26	Prof. Anil Kumar Yerrapragada	IIT Madras	Member
27	Dr. Radha Krishna Ganti	IIT Madras	Member
28	Prof. Preetam Kumar	IIT Patna	Member
29	Dr. Sarvendranath Rimalapudi	IIT Tirupati	Member
30	Dr. Chandra Prakash	ISRO	Member
31	Mr. Mombasawala Mohmedsaeed	Keysight Technologies India Pvt Ltd	Member
32	Mr. Jaydeep Roy	Logic Fruit Technologies	Member
33	Mr. Vinay Shrivastava	Nokia	Member
34	Dr. Punit Rathod	Qualcomm	Member
35	Mr. Nishant Gupta	Qualcomm	Member
36	Dr. Vinosh James	Qualcomm	Member
37	Shri Jitendra Singh	Qualcomm	Member
38	Mr. Vivek Kumar	Railway Board	Member
39	Mr. Radhey Sarda	Reliance Jio Infocomm Limited	Member

40	Ms. Chanchal Pathak	TCIL	Member
41	Mr. Saurabh Mittal	TCS	Member
42	Ms. Bhoomika Gaur	TEC	Member
43	Mr. Sandeep Sharma	Tech Mahindra	Member
44	Mr. Rajat Agarwal	Tech Mahindra	Member
45	Shri Om Prakash Mishra	TCIL	Member
46	Prof. Suresh M N	Thiagarajar College of Engg., Madurai	Member
47	Mr. Abdul Kayum	TRAI	Member
48	Mr. Abhay Kumar Tripathi	Vodafone Idea Limited	Member

9.5 Drafting Committee

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- R. David Koipillai, IIT Madras

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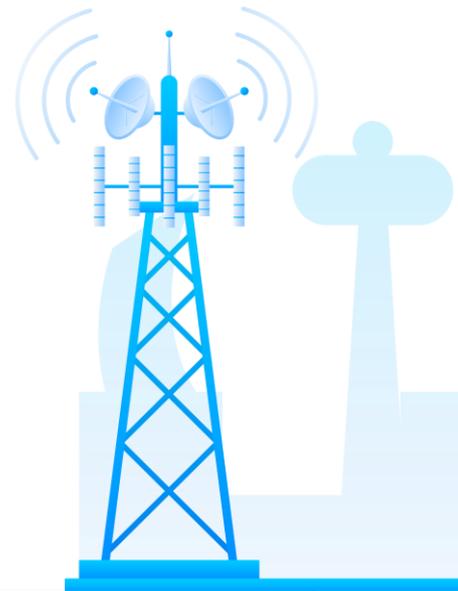
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