Bharat 6G VISION

सत्यमेव जयते

Government of India
Ministry of Communications
Department of Telecommunications
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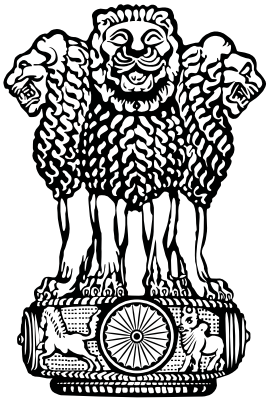
Bharat
6G Vision Statement



सत्यमेव जयते

Design, develop and deploy 6G network technologies that provide ubiquitous intelligent and secure connectivity for high quality living experience for the world

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1 Executive Summary

Every decade, the world bears witness to yet another, highly improved, generation of wireless cellular technology that changes the way the future of communication is perceived. Each new generation provides an almost disruptive impetus to the state of technological advancement, spearheads societal change, and leaves the world wondering if we have truly understood how limitless communication technology can be.

During the last decade, more than 700 million Indians, representing 75% of both rural and urban adult population, became users of mobile and fixed broadband services. Broadband connectivity has transformed lives and livelihoods, particularly of the poor. During the last five years, India has also ramped up telecom equipment manufacturing and exports in a decisive move towards an Atmanirbhar Bharat. During this period, India has also made important contributions to global telecom standards to ensure that its dispersed rural population clusters are as well served as its urban population. The Low Mobility Large Cell rural use case proposed by India is now a mandatory requirement to be met by mobile communication technologies adopted as International Telecommunications Union (ITU) standards.

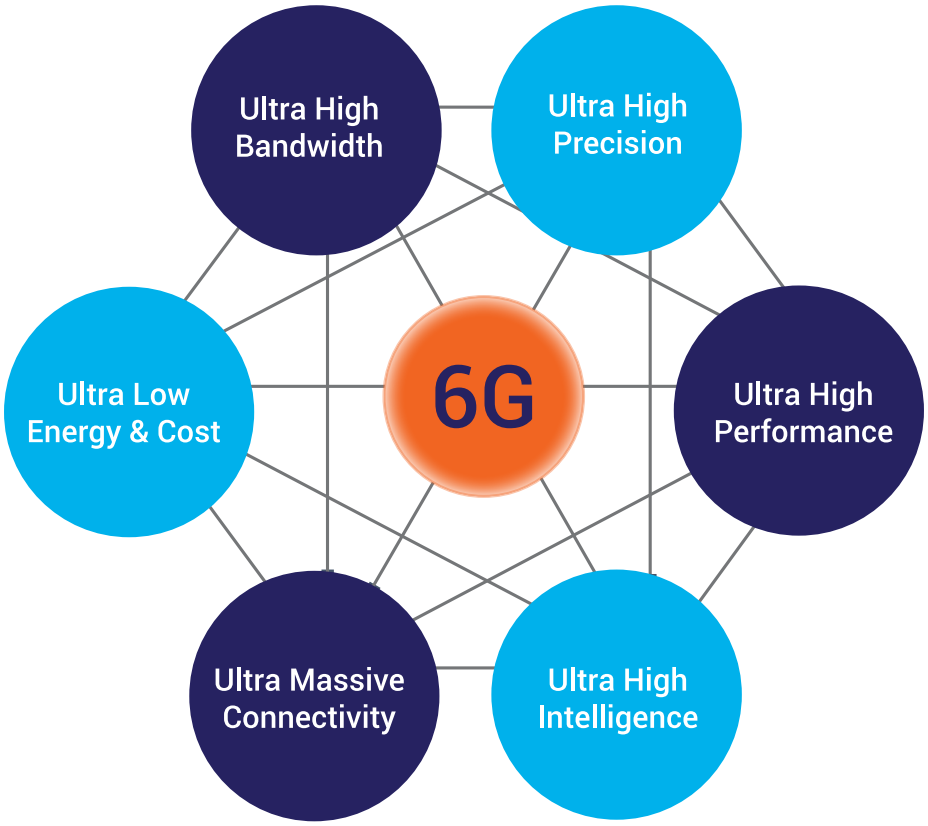
Communication technology is ever evolving, from the early

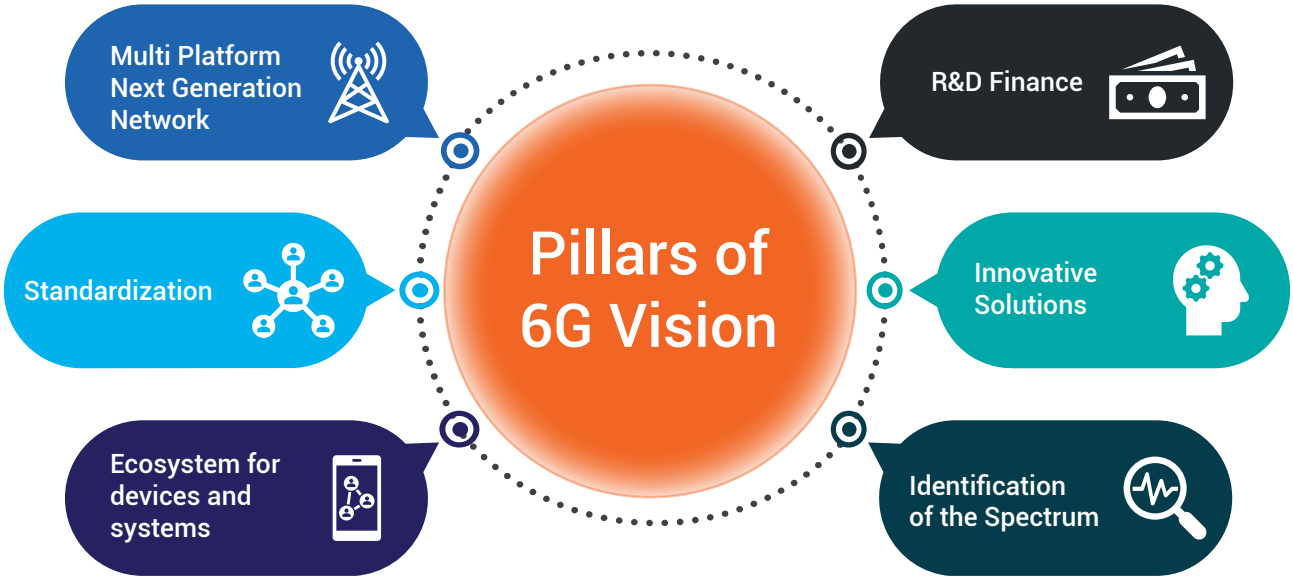
days of fourth generation (4G), when the newfound gaming graphics bowled the world over, to the recent promise that 5G brings to us in terms of heightened connectivity. Today, as India embarks upon its own unique 5G journey, the global telecom sector has already initiated strides towards creating 6G or sixth-generation communication technology as the next big thing on the communication horizon. Despite being at a concept stage, 6G is already making waves with its promise of unified human-machine and machine-machine connectivity and offers a glimpse of what lies in store for the world as the next decade draws closer.

6G will build upon 5G technology and provide more reliable, ultra-low latency and affordable solutions with speeds almost 100 times faster than 5G to enhance and drive new communication applications. These technological advances will impact not just user experience but also transform economies and lives everywhere. It will very likely include intelligent network management and control, and integrated wireless sensing and communication while balancing the potential consequent carbon footprint with reduced energy consumption and a myriad of sustainable and eco-friendly initiatives.

With a Vision of 6G as of today, we need to take stock of where we are with the resources at our disposal and where we ought to be to ensure achievement of Mission 6G. Accordingly, India must focus on aligning its research on technologies in the coming decade that would bolster and propel the implementation of 6G in India in a highly customized manner. Hyper-connectivity and advanced user experience delivered by 6G will improve and enable access to required information, resources (both virtual and physical), and social services without constraints of time and physical location. The advent of 6G will significantly reduce differences in regional and social infrastructure and availability of economic opportunities and will thereby provide alternatives to rural exodus, mass urbanization, and its related problems.

To further explore the impact of 6G in India and to investigate how India can realise its Mission of becoming a global leader in this space, the Technology Innovations Group set up six task forces in India to explore the major pillars of the 6G Vision.



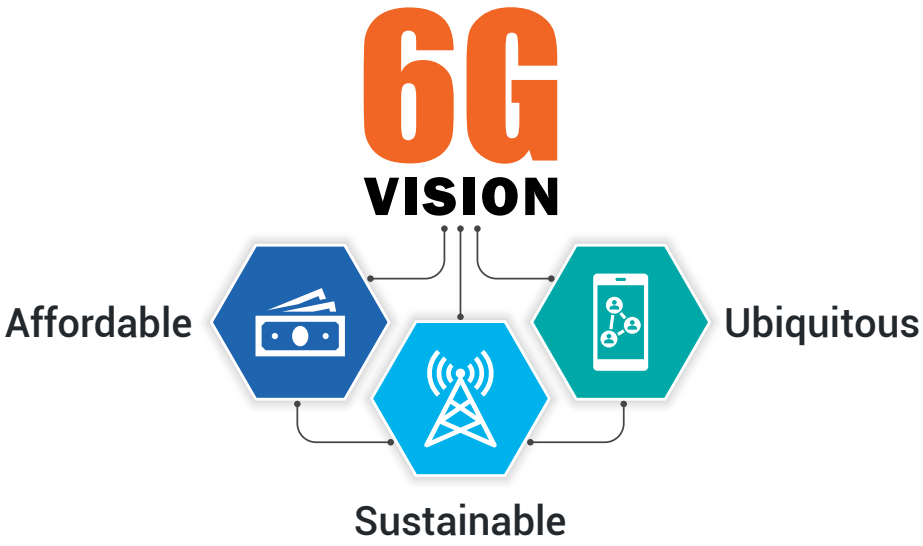


Six task forces formed under the Technology Innovations Group

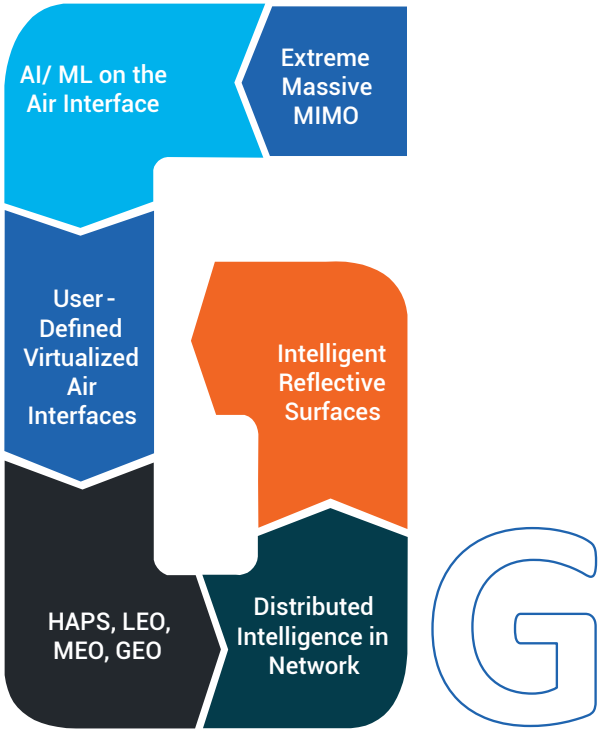
Technology Innovations Group, based on their deliberations on the complete 6G ecosystem, have recommended extensive research in mmWave and Terahertz communications, fiber-broadband, Tactile Internet and Remote Operations, multi-sensor man-machine interfaces and devices leveraging edge cloud computing resources. Well-placed headways into AI, Space-Terrestrial Integration, combined communication and sensing in (Sub) Terahertz bands, SoCs, and innovative solutions emanating from CoEs can further be accentuated by participation in and contribution to global standards forums and leveraging of the start-ups of today. All this and more can be achieved with a robust and much-needed Research & Development (R&D) funding mechanism.

India will identify priority areas for research by involving all stakeholders including industry, academia, and service providers, spanning theoretical and simulation studies, proof-of-concept prototypes and demonstrations, and early market interventions through start-ups, to take the lead. To accomplish the end-state of smart traffic management, virtual reality (VR)/ virtual navigation, smart and highly accurate environmental monitoring, and other fantastical promises of 6G, India will launch a 6G Mission that holistically combines all associated technologies, supported by an adequate financial backup. The Mission can be divided into two phases – the first being the ideation phase to understand the inherent potential and risk associated with the pathways ahead and test proof-of-concept implementations, while the second phase will be dedicated to conceptualizing and delivering potential technology solutions to serve India and the global community. While the basic objective for India will be a customised 6G implementation plan, acceptance and support from the global community can fast forward our commercialization drive and pave the way for further newer technologies.

India has the necessary wherewithal to drive the 6G wave globally and leverage this powerful force multiplier to transform itself into a leading global supplier of advanced, relevant, and affordable telecom systems and solutions. Our primary focus must be on multi-platform next-generation networks like Dense optical networks, AI/ML on the air interface and for network optimization, tactile Internet, Intelligent network operation, Intelligent Reflective Surfaces, Efficient Low Earth Orbit satellites, High-altitude platform systems (HAPS), User-defined virtualized air interfaces, and the like. Further, initiatives into investigating and implementing methods to standardize such technology and devices can provide additional structure and foresight to our 6G roadmap and assist us in efficiently allocating resources to ensure that India becomes a key role player in 6G technology implementation and adoption.



In conclusion, we expect that 6G will play an important role in filling the gap in the provisioning of e-services for urban and rural populations, help in the achievement of the United Nations (UN) Sustainable Development Goals (SDGs), and contribute tremendously towards improving the quality and opportunities of life. These will embody innovations that specifically address the country's needs and improve the productivity of its people, particularly of those in rural areas for whom telecommunications is critical to overcoming the tyranny of distance. These technologies will also provide immense opportunities for India's entrepreneurs to innovate and develop new products based on their Intellectual Property (IP) not just for the Indian market but also for the entire world, transforming India into a global leader providing life- and livelihood-transforming solutions.



2

India and the Telecom Revolution

Mobile wireless telecommunications have, without a doubt, transformed the lives of people and the global economy over the last three decades. Wireless technology harnessed the power of the Internet to morph the daily lives of people and intertwined them into a digital world. From the first generation of analogue technology to the fifth generation of wireless broadband technology, the advancement of seamless Internet has made accessibility and affordability well within the reach of the common people. The results can be seen in India too, which went from a country with less than 20 million landline connections (in 1998) to more than a billion mobile telephone subscribers today with 75% of subscribers always having broadband connectivity irrespective of their location.

At present, the total annual purchase of smartphones is greater than 16 crore smartphones for about 30 crore Indian households. This means that every household today is buying smartphones at an average of one phone every 2 years. A similar amount is being spent annually on two-wheelers, while the annual spend on other household appliances is a lot less. It is interesting to note that an average Indian finds a personal smartphone as valuable as a personal vehicle. Smartphones have evolved from being a means for calling, entertainment, snapping pictures and videos, payments, e-commerce, navigation, etc., to aiding the enhancement of livelihoods.

Affordable telecom technology has enabled Indian citizens to develop their lives and livelihoods at a speed unseen in previous generations. Now, with the imminent deployment of 5G technology bringing in advanced broadband services, higher data rates, better video quality, etc., the experiences of the citizens are only going to improve further. The new machine-type communication capabilities in 5G driving the Mission of Industry 4.0 will impact livelihoods significantly. Many Indians are self-employed or run small enterprises. Their ability to support their customers better through online tracking of their products/ sales, or to monitor critical business activities even as they are on the move, will improve greatly. With the assured low-latency data transfer capability offered for the first time in 5G, professionals can even perform some tasks remotely through tactile Internet.

As India progresses into the centenary of its independence, the next two decades are a critical growth phase that will determine the country's future. It is crucial to seize this opportunity of the latest generation in wireless technology even as the technology is still fresh "from the oven". As the world's second-largest telecom market, India must evolve to become a net technology provider and manufacturer to the world. This means that we must actively participate in defining the contours of the next sixth generation (6G) and drive the innovations such that we address the pressing needs not only for India but for every other country with similar requirements. We must pivot to the position of a leading global provider of technology and solutions for the greater good.

3

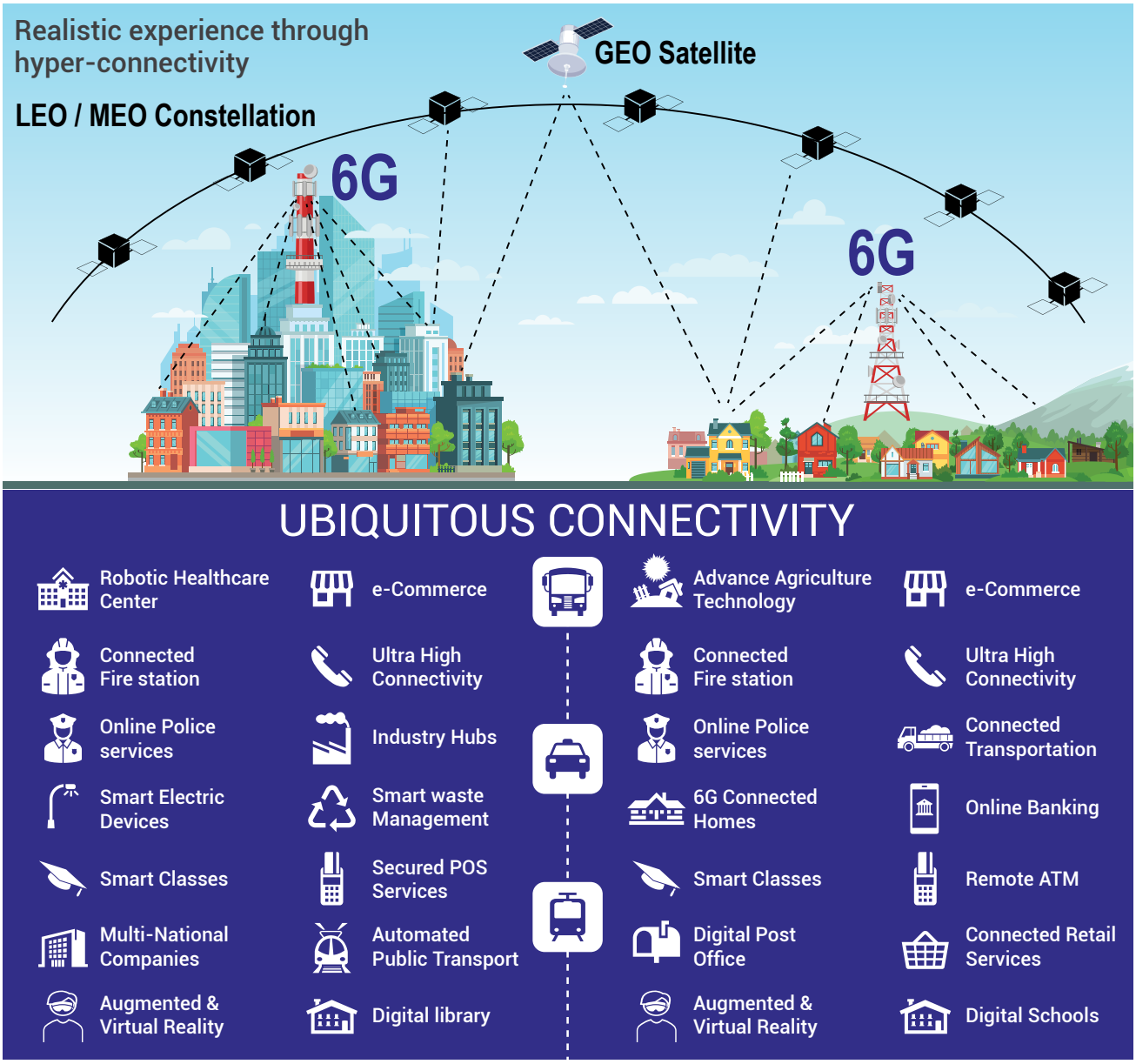
The 6G Promise

As India recently concluded the highly anticipated spectrum auctions, the implementation of 5G mobile services has finally been set in motion in the country. While the full potential of 5G will take shape over time, we already have a clear understanding of how it can impact and change the Indian and global telecommunication landscape for the better. 6G will build extensively on this enhanced state of technology. The global community has already begun exploring its potential in a bid to push the frontiers and stay abreast of the high-paced technological advancements that symbolise the telecom sector.

Although technically 6G does not exist today, it is already conceived as a much superior successor to the widely anticipated 5G. It promises a world of unimaginable speeds, connective intelligence and a highly mature IoT model that will enable and empower automated cars and smart home networks and will heighten the already existing interplay between everyday life and the internet. The global vision is to further transform connectivity to make big data analytics and holographic displays a norm when 6G technology is finally implemented in the 2030s.

The current cell-phone technology is the ubiquitous 4G which supports our current way of life by providing us with seamless streaming and gaming experiences. The new 5G technology promises a speed range of 40 – 1,100 Mbps with the potential to hit maximum speeds of 10,000 Mbps through technologies such as millimeter-wave spectrum and beamforming. While 5G itself seems very futuristic as of now, 6G will offer ultra-low latency with speeds up to 1 Tbps that will amp up the machine-to-machine and human-to-machine interactions to unprecedented heights and transform the development and use of virtual and augmented reality (VR/AR), mobile edge computing, Artificial Intelligence (AI), etc. 6G use cases will include remote-controlled factories, constantly communicating self-driven cars and smart wearables taking inputs directly from human senses. While 6G promises growth, it will simultaneously have to be balanced with sustainability since most 6G supporting communication devices will be battery-powered and can have a significant carbon footprint.

This report further elaborates on India's 6G Mission which aims to provide all these high-speed and ultra-low latency solutions at affordable prices to urban and rural areas alike, irrespective of external factors such as terrains, weather, and environmental conditions.



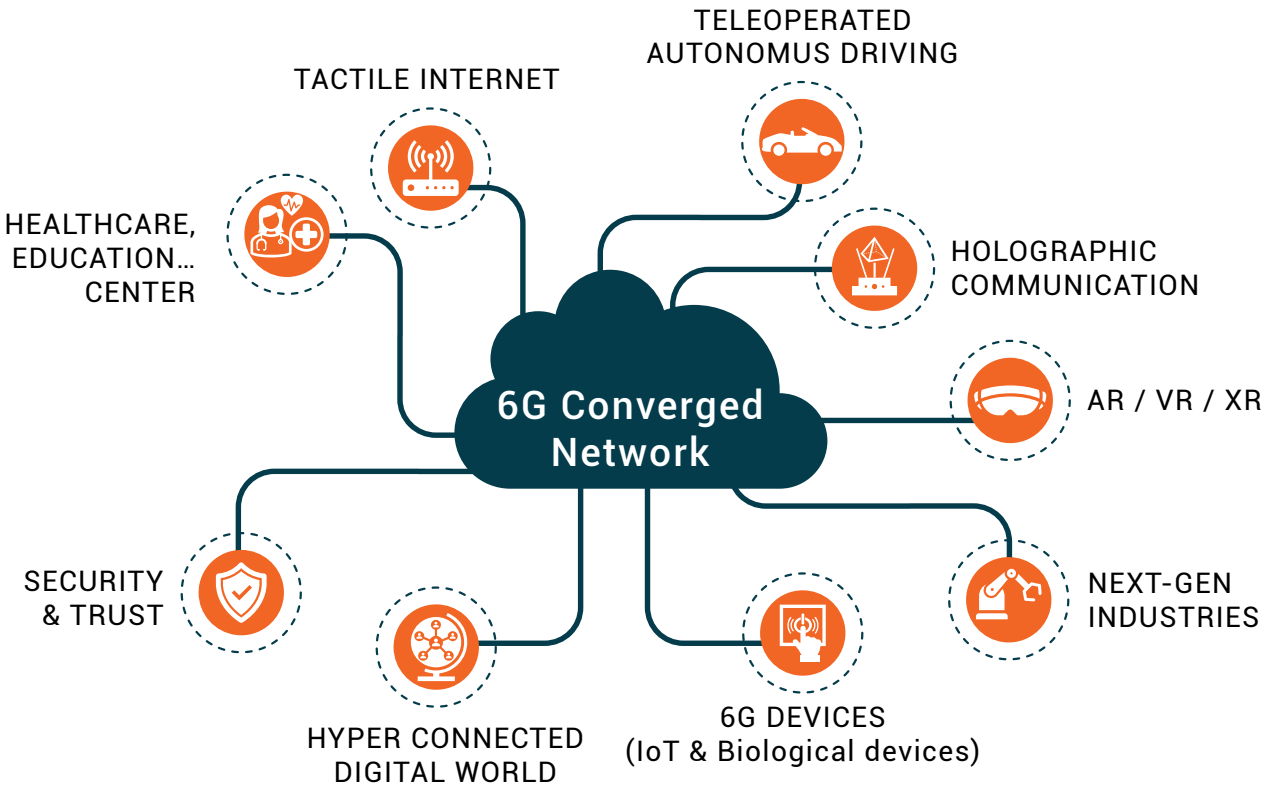
4

The 6G Roadmap

4.1 Global 6G Scenario

The lifestyle of modern society made a drastic shift when broadband access became ubiquitous with smartphones that were powered by the fourth generation (4G) of wireless technology. People were able to connect with their peers 24x7 instantaneously and at high speed with the tap of one's fingers. The need for physical presence in business settings is reduced enabling a boost in efficiency and productivity in all sectors of society.

As we come to grips with the wave of changes that 4G has wrought, the fifth generation (5G) of wireless technology is being rolled out from 2020 onwards. The Internet of Everything is enabling an explosion in remote human-machine and machine-machine interaction. Technology that could only be imagined during the 4G era is being manifested during the 5G wave. And yet every day, we keep discovering, creating, and developing technologies that are of much higher capability than 4G technology. Vehicles can communicate with each other and with us to enable a safer and better transportation experience, machines in factories are interacting with the smart controller as well as with each other to improve productivity, urban and rural utilities are becoming smarter in fulfilling their functions, and so on.



Now that 5G is rolling out, the question for the next decade is what the sixth generation (6G) of wireless technology will look like and how can we convert our vision into reality. What can we expect to become feasible and available in the next decade? Given the impact it will have on lives, livelihoods, and productivity, it is important for everyone across the world, particularly those in growing economies, to ponder over what they would like 6G to deliver and how they can shape it to suit their needs. Many countries and consortiums are actively addressing this question through research efforts and realizing their Vision for 6G. The following discussion summarizes the major efforts that are being pursued worldwide in 6G.

A major effort in North America has been launched by the Next G Alliance[1] of stakeholders who range from service providers and vendors to universities and start-ups. The main drivers of their Vision are classified into four foundational impact areas – Everyday Living, Experience, Critical Roles, and Societal Goals. They include four categories of use cases: Network-Enabled Robotics and Autonomous Systems, Multisensory Extended Reality, Distributed Sensing and Communications, and Personalized User Experiences. Based on this classification, the alliance has identified high-level functional and performance requirements based on both audacious and incremental objectives. These goals cover trust, security and resilience, an enhanced digital world experience, affordable solutions that span all aspects of the network, distributed cloud and an AI-native network, and sustainability concerning energy efficiency and life cycle costs. Due to these requirements, nearly fifty technological areas have been identified within the domains of system components, radio technologies, network architecture, Operations, Administration, and Maintenance (OA&M) and provisioning, security, reliability, privacy, and resilience.

1. https://nextgalliance.org/

B

South Korea has outlined a 6G R&D Plan with Rs. 1200 CR investment in the first phase running till 2025, for attaining global leadership, developing key original technologies, making significant contributions to international standards and patents, and building a strong foundation for 6G research and industry.[2] Six focus areas have been identified for attention: terabit speeds, operation in 100-300 GHz band, 3D-coverage integrating LEO satellites with a terrestrial network extending up to 10 km airspace for drones, 10% of the latency in 5G, ubiquitous AI, and security designed into every element of the network. Several key technologies are being pursued to achieve the desired goals: Terabit wireless and Terabit optical communications, RF components and spectrum studies in the THz band, mobile communications in space, ultra-precision networking, intelligent wireless access and network, and real-time network monitoring. A total of 14 LEO satellites are proposed to be launched before the end of the decade. Three 6G research centres have been established in universities in 2021, and 6G capabilities of working-level researchers are being enhanced by scaling up joint R&D by small and medium enterprises, universities, and research centres in Korea. Working together with Korean Intellectual Property Office, R&D funding, a strategy for the key fields of space networking and intelligent high-precision networks having high potential for obtaining pre-emptive standard-essential patents are being put in place. To create global collaborative networks, South Korea is also promoting joint studies on core 6G technologies and 6G spectrum with foreign countries that are carrying out government-led research on 6G technologies.

C

Europe has been in the vanguard of telecom research since the era of 2G. The European 6G Vision[3] identifies key features of 6G including intelligent network management and control, integrated wireless sensing and communication, reduction of energy consumed, trustworthy networks, scalability, and affordability. The 6G architecture is envisaged as a flexible and efficient network of networks including non-terrestrial networks, encompassing novel AI-powered enablers to enhance network performance and provide AI-as-a-Service using a distributed cloud. AI and Machine Learning are expected to play a key role in human-digital-physical interaction to automate certain levels of decision-making. Network capacity is expected to expand to approach and even exceed Shannon and Moore's limits. Smart optical transport is being pursued to ensure an intrinsically secure, green, and scalable network. Photonics integration is being pursued to integrate optical, radio and digital electronic functions. Quantum technologies are being explored to understand their potential for unprecedented performance in quantum sensing, communication, security, and computing. The overarching Vision is to ensure leadership in strategic areas and establish secure and trusted access to key technologies making Europe a sovereign, independent, and reliable source for 6G public and private network solutions and services. A parallel objective is to foster entrepreneurship with private and public participation, complemented with tax policies for start-ups to avoid the relocation of promising businesses. Sovereignty and security requirements are being identified and enforced.

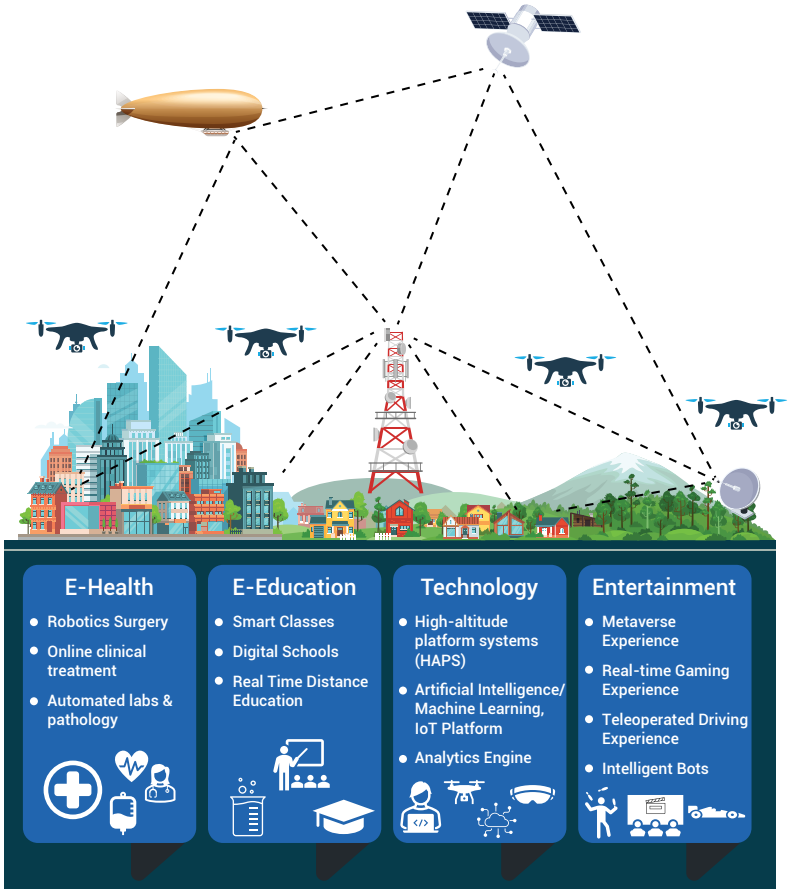
In the first explorative phase (Hexa-X The European 6G flagship project[4] of research), running from 2021 till 2023, the critical technology enablers for 6G being studied are: sub-THz transceiver technologies, accurate stand-alone positioning and radio-based imaging, improved radio performance, artificial intelligence (AI) / machine learning (ML) inspired radio access network (RAN) technologies, future network architectures, and special purpose solutions including future ultra-reliable low-latency communication (URLLC) schemes.

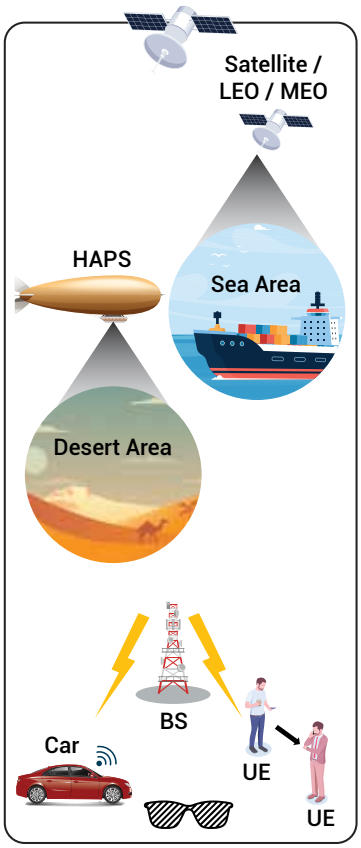
2. https://www.msit.go.kr/eng/bbs/view
3. https://www.researchgate.net/publication/352226800_European_Vision_for_the_6G_Network_Ecosystem
4. https://ieeexplore.ieee.org/document/9482430)

D

In Japan, the Integrated Optical and Wireless Network (IOWN) Forum[5] published its Vision 2030[6] white paper, which laid out key technology directions for infrastructure evolution in four dimensions: cognitive capacity, responsiveness, scalability, and energy efficiency. Phase 1 work was started to identify use cases and technical requirements. Cyber-Physical Systems and AI Integrated Communications Use Cases have been spelled out. Functional architectures have been defined for an Open All Photonics Network (APN), a Data-Centric Infrastructure, (DCI), a Data Hub, and fibre sensing for the APN. Requirements and proposed solutions for the transport backbones to support the 6G wireless network and a reference end-to-end implementation model have been developed. Open APN, DCI, and Data Hub will evolve with the progress in optical/radio communication and photonic-electronic technologies. IOWN proposes to build liaison relationships with other 6G fora and SDOs to complement their efforts.

The following 6G technology areas have been highlighted[7] for research in Japan: high-density distributed antennas, spectrum sharing and integration with non-terrestrial networks, THz band propagation studies, THz band devices, THz radio technologies, Extreme Massive MIMO, Next generation of HAPS communications with improved reliability and lower latency, integrated wireless sensing and communication, use of AI across the telecom network, flexible and intelligent networks, RAN-Core convergence, integrated multi-technology networks, advanced security and distributed cloud.





5. https://iowngf.org/
6. Vision 2030
7. https://www.docomo.ne.jp/english/binary/pdf/corporate/technology/whitepaper_6g/DOCOMO_6G_White_PaperEN_v4.0.pdf

E

ITU's Focus Group on Network 2030[8] foresees high-resolution immersive multimedia over the Internet, smart IoTs, factory automation, and autonomous vehicles, in other words, the fusion of the real and digital worlds, to become commonplace with 6G. Internet of Things operating at hyper-scale at the system level, not in isolated environments such as private networks, will require distributed intelligence all over the connectivity fabric. Information transfer must occur with much lower latency between machines, robots, and their virtual counterparts to support autonomous operations. The proliferation of public and private networks created using Converged Service Platforms will require network intelligence to integrate and manage. Proof-of-concept trials will require access to at-scale physical and virtual testing facilities with embedded measurements. The Focus Group has published reports on Use Cases and Key Network Requirements, New Services and Capabilities, Architectural Framework, and Technology, Applications and Market Drivers for the 6G Network of 2030.

F

Key developments in 6G have been identified and are being pursued in China[9]. It is forecasted that the next generation 6G network will support connectivity plus sensing plus AI, with security implemented by design throughout the network. The network will employ model and data-driven algorithms to leverage AI and ML to deal with analytically intractable conditions better. Such a complex network will be managed without "touch" in a heavily automated manner. AI will also be provided as a service through a converged distributed cloud and network architecture. Further, the network will extend into space through mega-LEO constellations.

From a more theoretical point of view 6G must provide an infrastructure to enable remote-controlled mobile robotic solutions for everyone—the Personal Tactile Internet – and not just for businesses. While some enhancements will appear as "5.5G" or advanced 5G standard, more disruptive advances in the radio technology such as switched Physical Layers (horses for courses) referred to as a "Gearbox PHY[10]" will be possible only in 6G. Seventy-five years after Shannon advanced fundamental information theory concepts, several issues remain open to be addressed on the way toward 6G. Creating the Tactile Internet while simultaneously reducing the energy consumed and operating under constraints imposed by semiconductor technology throws up a wide variety of challenges. These mostly cannot be solved using analytical techniques alone and require one to one account for the reality of networks and hardware. A true system understanding is a sine qua non for advancing the role of information theory in 6G.

8. https://www.itu.int/pub/T-FG-NET2030
9. https://www-file.huawei.com/-/media/corp2020/pdf/tech-insights/1/6g-white-paper-en.pdf?la=en
10. 6G: The Personal Tactile Internet—and Open Questions for Information Theory in IEEE BITS Sep 2021 (https://ieeexplore.ieee.org/document/9568233

4.2 6G Telecom Network in India

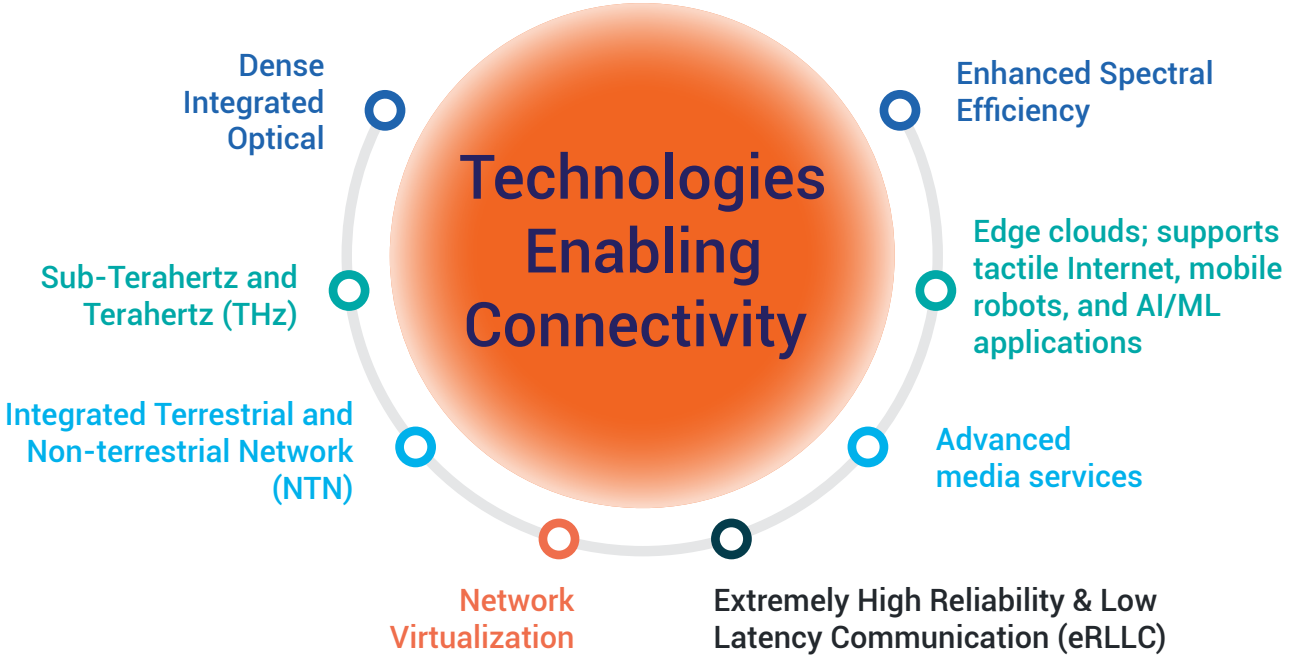
India, along with the world, is contemplating the next generation of telecom technologies and the transformations likely to be wrought by them. This paper presents a Vision for India's journey towards empowering its people with the most advanced, relevant, and affordable next-generation (6G) telecom technologies.

Hyper-connectivity and better experience delivered by 6G mobile communication technology will improve and enable access to required information, resources (both virtual and physical), and social services without constraints of time. Broad deployment of 6G technology will reduce differences in regional and social infrastructure, and in economic opportunities, thereby providing alternatives to rural exodus and metro-driven urbanization. We expect that 6G will play an important role in filling the gap in the availability of e-services between urban and rural communities. This will subsequently fulfil the UN's SDGs and tremendously contribute to improving the quality and opportunities of human life.

By harnessing 6G to embody innovations as per our requirements, we can specifically address the country's needs and improve the productivity of its people, particularly of those in rural areas for whom telecommunications is critical to overcome the tyranny of distance created by modern society. These technologies will provide immense opportunities for India's entrepreneurs to deliver new products based on their IP, for both domestic and global markets, thus transforming India into a leading global manufacturer and provider of telecommunications solutions with the power to transform lives and livelihoods.

This Vision document identifies key research pathways that are being pursued globally and that are particularly relevant for ideating new possibilities in the Indian context. These pathways straddle multiple platforms involving new hardware, software, hitherto unutilised spectrum at very high frequencies, AI and ML engines, quantum photonics and computing technologies, space-based assets, and devices with new user interfaces, sensors and displays that promise to unleash the so-called Tactile Internet.

Terahertz communication with ultra-high speeds will be essential for indoor and outdoor (worksite/factory) tether-less applications. Coupled with Intelligent Reflective Surfaces to overcome propagation hurdles, wireless communication at these frequencies is an important focus area to investigate. A flexible, seamless integrated optical and wireless network reaching each household, even in remote villages, is what we should aim for by the end of this decade. The varied demands from wireless communications in terms of speed, latency, and energy efficiency will require us to leverage the ever-expanding capabilities of semiconductor technology to innovate on a highly adaptable set of waveforms and protocols that can deliver the needed variety. Apart from moving into the new spectrum of the Terahertz band, India should also explore new avenues in cell-free communications and extreme MIMO to utilize the available spectrum in the lower bands much more efficiently. The oncoming integration of Space and Terrestrial networks into one seamless unified whole provides an opportunity for India to leverage her capabilities in space technology to plug the gaps in coverage of its vast rural hinterland and ensure that all Indians have broadband connectivity no matter where they are.



The impressive strides being made in telecommunications are with the help of ongoing technological leaps in semiconductors, photonics, devices, computing and display technologies. The time is ripe for the Indian telecommunication industry to leverage its capabilities in optical networking and develop robust, cost-effective techniques to take fibre to the nooks and corners of the country. The industry needs to utilize its prowess in software to rapidly expand edge computing clouds so that any citizen can inexpensively deploy compute-intensive AI and other applications on the go, and make a mark in new areas such as emerging display, wearable, sensor technologies to address specific UI needs of our applications. Innovations in these spheres can be leveraged by Indian manufacturers to deliver cost-effective competitive products to the entire world. We should focus on sensors and tactile interfaces that enable skilled tasks to be carried out remotely. This will be a game-changer for crafts-persons and technicians who often travel long distances to reach their workplaces and complete their tasks.

By nature, telecommunication is standards-based, which ensures that equipment manufactured by multiple entities communicates seamlessly with each other across national boundaries. Therefore, research into next-generation wireless and optical technologies, next-generation protocols and network architectures that are key to enabling and bolstering 6G implementation and adoption, must follow global standards to be considered as global products. The entire Indian 6G research effort should therefore dovetail into an equally strong and well-orchestrated standardisation drive. India has made rapid strides in standards-related research in recent years, and this trend should be amplified. We need to ensure that global standards adequately incorporate our innovations and address our specific needs. In this regard, telecommunication standards bodies of our country such as TSDSI working in tandem with TEC and other telecommunications forums have a major role to play.

India is one of the largest telecom markets in the world with a high dependency on wireless technology for broadband connectivity. Right now, the spectrum is congested, particularly in the low and mid-bands where the propagation characteristics are favourable. Apart from innovations in spectrum-efficient communications mentioned earlier, we also need to decongest the spectrum and innovate on ways to permit the co-existence of mobile broadband networks with other users in the same bands. Backed by a strong suite of co-existence studies, field measurement campaigns, and pilot trials, India can lead in such efficient shared use of spectrum across many bands. We must also deploy our resources in advanced monitoring and management of spectrum with real-time sensor-driven cognitive spectrum sharing enabled in some bands. Besides, as devices move beyond mm-wave to the terahertz bands, they can adopt the same bands for ambient sensing as well, which is very useful for mobile robotic applications.

While smartphones with their built-in cameras, touch screen and other sensors have delivered enormous value to their human users, the next generation of devices will seek to fuse inputs from multiple sensors and multiple devices to obtain a dynamic representation of the ambience of users or a machine/robot. It will extensively leverage AI and ML in this task with some heavy computing on user devices and some in twhe edge cloud. Like humans, machines will also be "users" who communicate amongst themselves to act in unison as desired by their human operators. The compute engines at the user end as well as in the edge cloud can be innovatively developed around the DIR-V Indian microprocessor program, with an impregnable security layer inbuilt to protect users and applications from cyber-attacks. While the primary device has been the smartphone until now, the next generation will witness an explosion of all kinds of user devices as well as devices that are connected to machines. This vast diversity of devices calls for a healthy ecosystem for developing SoCs by fabless companies/start-ups, new user interfaces particularly wearable ones, and a variety of form factors that suit every application. This presents a big opportunity for India to take a head start in this emerging family of devices and emerge as a global supplier.

5

Summaries of 6 Task Forces & their recommendations

5.1 Multi-Platform Next Generation Networks

The task force dedicated to multi-platform next-generation networks deliberated extensively on the current global thinking regarding the evolution of the telecom network in the year 2030 and beyond. The strands were evaluated in the context of India's own future needs and growth trajectory over the next decade. Depending on the degree of relevance of each of these strands in our context, the Task Force has emphasized some of the possible evolutionary paths over others. While evaluating the strands, it emphasized those that appeared more realistic and promising in a ten-year timeframe. The importance of a dense optical network right up to the homes and offices cannot be over-emphasised. Building the wireless network consumes time and resources but it not only serves the needs of the mobile users but also of the nomadic or the static users as well. Going forward, a seamless integrated optical and wireless network, with wireless fiber-like segments wherever appropriate, is imperative. Sufficient attention will have to be paid to GPON network engineering in rural areas.

The explosive growth in data volumes, the multiplicity of access technologies, the deepening of the optical access network, the proliferation of edge clouds, and the increasing need for content- and user-awareness in networks will lead to a more decoupled core network architecture and will increase the use of AI/ ML in optimization and intelligent network operation. As spectrum gets more heavily used, ever-higher frequency bands are being explored primarily due to the large bandwidths available and ever-improving operating frequencies of semiconductor technologies, despite the challenging propagation conditions at these frequencies. Mitigatory techniques such as Intelligent Reflective Surfaces may provide some workaround to the poor propagation at very high frequencies as will massive MIMO with the cell-free operation. The air interface may move radically to a virtualized user-defined mode enabling the radio to support the specific user requirements for a given wireless channel, moving away from the hitherto conservative design for the worst-case wireless channel. The wireless transceiver in many cases may additionally play the role of a radar sensor to capture the ambient environment around the transceiver.

While the remote operation of machines and robots may be attempted even with 5G networks in the coming years, the Tactile Internet for Remote Operations is a serious possibility a decade from now. This capability may be used not just for high-end applications such as remote robotic surgery, but also for a host of mundane applications in much the way multimedia communications is used today with the smartphone for all kinds of applications. This may require good support from edge computing clouds that run /AI/ML algorithms and will leverage a user-defined radio interface to ensure high reliability. The growth of Industrial IoT in the coming years will drive the growth of remote operations even if much of it is simply automation and not tactile. Digital Twins of complex, real physical systems and networks running in the edge clouds will enable automated control of the real system by predictive analysis of future events based on AI and other techniques.

With the increasing cost-effectiveness of Low Earth Orbit satellites and new technologies such as HAPS, it is increasingly likely that non-terrestrial wireless networks will finally get integrated with the terrestrial network to offer ubiquitous coverage not only on ships and aircrafts, but also in rural areas under-served by the terrestrial network in the Indian context. The explosive growth forecast in drone usage will necessitate drone communications to be supported by the integrated space-terrestrial network more reliably and securely.

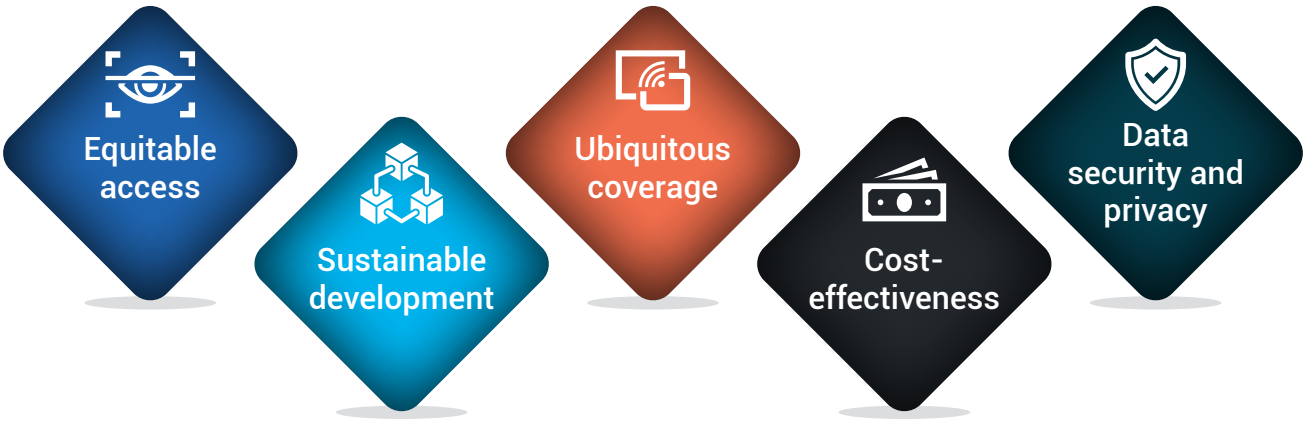
The very high data rates supported by 6G will likely provide a platform for realistic e-meetings where holographic-type or AR/ VR technologies are deployed along with multi-gigabit-per-sec tether-less links to provide a near-physical experience. User-defined virtualized air interfaces will enable such platforms to be invoked even by a mobile user based on the ability to set up a sufficiently fast, low-latency, low-jitter, reliable link, leading towards what could be described as hyper-personalised wireless networks.

The research efforts over the next few years should be aligned toward realising one or more of the highly promising, scalable and feasible (with high probability) technologies/platforms outlined herein. All of these are of great relevance in the Indian context and also have global applicability. Advances made in any of these areas will not only serve our needs but also give India an edge globally. India can use this decade to realise its aspiration of being a net global provider of telecommunications technology.

5.2 Innovative Solutions

6G will push the boundaries of communication technology by ushering in bandwidths of 1Tbps (about 100 times that of 5G). With latencies of less than a millisecond, it can revolutionise all interactions, like human-to-human, machine-to-machine, and human-to-machine, and change the way data is stored, processed and used in the future. In addition, 6G will also incorporate "sensing" as an inherent service - which will also have a profound impact on the design and delivery of new technologies and services in diverse areas such as education, medicine and gaming. While it is difficult to fully understand the implication of these capabilities currently, we need to identify and create a road map to explore various use cases to discover the full potential of 6G as well as pave the way for the 6G technology and standards development to ensure that they meet the needs of all identified future use cases.

From a 6G implementation perspective, certain key guiding principles for us to keep in mind are as follows:



The task force recommends the strategy of meta-use cases to drive the actual 6G use case selection process from an indicative list given in the report. Four guiding questions that will help the selection process are also discussed in the report. Identification of marquee use cases from various sectors and forming a consortium of partners who can bring an interdisciplinary approach, will help further our understanding of the needs of 6G as well as holistically guide its further development. These use cases can be identified keeping various considerations in mind and especially evolving from ongoing or planned work for 5G.

Allocation of reasonable financial resources is recommended in a public-private partnership model, over three phases:

1. **Basic research in some well-chosen key areas leading to the creation of new IP in Phase I**
2. **Translating these into potentially commercialize technologies and contributing to allied standards in Phase II**
3. **Finally, supporting commercialization and product roll-outs in Phase III**

Activities are recommended to be carried out via consortium groups involving a judicious mix of academia, industry and appropriate government institutions, through centres of excellence for both "horizontal" technology creation as well as for "vertical" applications and use cases.

5.3 Spectrum

Society's increasing use of radio-based technologies, and the tremendous opportunities for social development that these technologies provide, highlight the importance of radio-frequency spectrum and national spectrum management processes. To better drive spectrum management initiatives for 6G, the following objectives were set out by the 6G Spectrum Policy Task Force -

- Identify various spectrum needs to enable 6G in the coming years with a focus on spectrum availability and allocation among various radio services with reasonable certainty to bridge adoption lag, maximize socioeconomic benefits and provide high-speed broadband through various access technologies to address the digital divide
- Signal the identified 6G spectrum bands for the industry to efficiently plan and build wireless infrastructure across sectors and introduce new wireless technologies in a systematic manner
- Make spectrum available for 6G technology innovations and facilitate ease of doing R&D
- Deployment of spectrum efficient technologies by all stakeholders including Government, TSPs, Enterprise users
- Encourage spectrum sharing and optimal coexistence among various radio services
- Position India as a hub of 6G wireless technology R&D and manufacturing
- Facilitate enhanced use of wireless technologies in enhancing productivity and operational efficiency through Industry 4.0 and enterprise digitalization

The table below summarizes an indicative list of Digital India 2030 Mobile and Broadband Policy objectives along with tentative spectrum bands to be made available.

Three Dimensions of 6G Spectrum

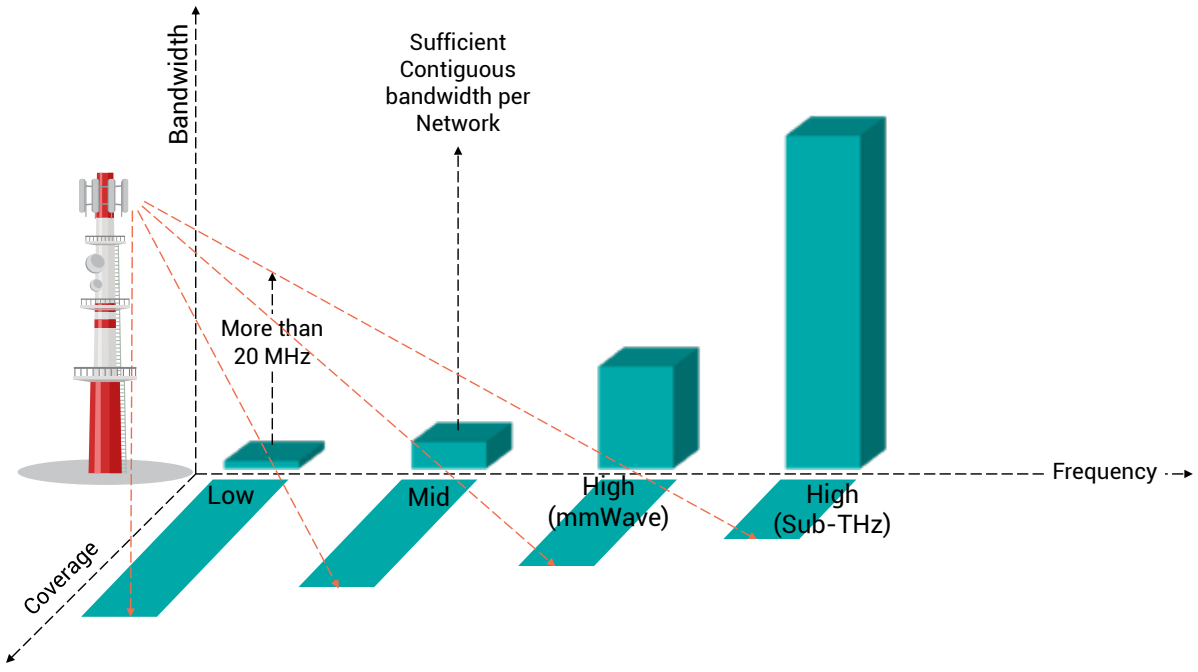


Table 5.3.1: Digital India 2030 Mobile and Broadband Policy Objectives (indicative)

2022 Roadmap	2030 Roadmap	Spectrum Requirements 2030 (5G+ and 6G)	Spectrum Bands to be made available
High speed broadband to citizens, Enterprises, public services. Connect all villages	100 Mbps to every citizen (large coverage of 5G and beginning of 6G)	Likely to double from the current planned spectrum quantities (covering lower, mild, millimeter and Tera Hz bands) Diverse access technologies Mobile, GSO, NGSO, HAPS, HIBS, etc.	<1 GHz Bands Mid Band: up to 10 GHz 6.425-24 GHz Bands Millimetre Bands: 26, 28, 40, 66, 70, 90 GHz, etc. Tera Hz bands
10 Gbps to every GP	500 Gbps to every GP	High speed backhaul to complement Fibre connectivity	Q, V, E, D, W Bands Free Space Optics 6.425-24 GHz Bands Free Space Optics
50% Households with Broadband	90% Households with High-speed Broadband	FWA – Fixed Wireless Access (would be a cost-effective option) using 5G and E, V Band links & other access technologies including fibre	Millimeter bands of 37, 50, 66 GHz V Band (57-66 GHz) 6.425-24 GHz Bands Free Space Optics
10 Million public Wi-Fi Hotspots	50 Million public Wi-Fi Hotspots	New License Exempt Spectrum Bands	6 GHz, V-Band, > 95 GHz Tera Hz Bands
5 Billion IoT Devices; Enterprise Digitization (ITS, Urban Management)	25 Billion IoT Devices Smart Enterprises & Factores (Smart Infrastructure Rural and Urban)	New License Exempt Spectrum for M2M connectivity to power smart cities and communities	915-935 MHz V Band 95 GHz bands Thz bands
Personal and Home Connectivity (SRDs)	Connected and Intelligent Living	Extremely low power intelligent devices of all kinds connecting everything around	Hundreds of bands to be identified continuously based on innovation
UAVs with limited action	UAVs in Delivery Services, Logistics, Disaster Management	Defined IMT and unlicensed bands with ultra-reliability and control (application specific)	1 GHz Bands Band: up to and above 10 GHz

In accordance with the above objectives, the 'spectrum for 6G' has been comprehensively analyzed from bands, services and ecosystem perspectives including current gap areas in the system. As spectrum is a resource with an interplay of different generations of technologies, all spectrum bands require a review of its efficient use among radio service users to enable sufficient spectrum for new-era services.

To enable the above, specific band-wise recommendations have been made taking note of global developments and the Indian opportunity to use spectrum as a key resource to attract R&D investments and to maximize spectrum use in line with NDCP-2018 objectives. Building demand in new bands is an important aspect, which is also critically studied as part of the activity. The following are some of the key recommendations-

- Review the spectrum bands in lower, mid and mmWave bands and announce respective actions to enable maximization of the spectrum and use and socioeconomic benefits.
- Open up a few bands to generate demand (for example 450-470 MHz, 526-612 MHz, 31-31.3 GHz, etc.).
- Expand and position a larger mid-band to meet the requirements of 5G+ and 6G technologies. This requires initiating a new inter-ministerial process of repurposing several bands like that has been done earlier.
- Enterprise use of 5G, 5G+ and 6G services is going to be mainstream and the spectrum Vision needs to be expanded in making spectrum available across the bands and for various use- cases. Assigning spectrum to private captive networks including coexistence bands is the need of the hour.
- Delicensed or license-exempt bands are key as a public good to enable innovation and gigabit public Wi-Fi by exploiting technology innovation for example Wi-Fi 6E or WiGig etc. In line with this, the lower part of the 6GHz band and at least 4.32 GHz in the V band should be delicensed.
- Tera Hz research should be encouraged considering the large swath of spectrum from 90 GHz to 3000 GHz. Industry and academia-driven research testbeds should be established to bring focus on 5G+ & 6G driven active antenna systems and Intelligent Reflector Surfaces (IRS) using mmWave and THz bands. A few countries such as the USA, UK, etc. have made some of the THz bands' licenses exempt for some periods both for commercial deployment and R&D.
- Set up spectrum sandboxes as envisaged in NDCP as a way forward to enable R&D and testing freely outdoors.
- An opportunity to take lead in new technology domains such as sensing, orthogonal sharing, broadband-broadcast convergence, etc., where there is significant research work in progress and some products are also being piloted.
- Strengthen WPC with state-of-the-art spectrum management software to enable spectrum audit, interference management and dynamic database systems. Capacity building is another important area to enable necessary competencies in spectrum management.

Structural mechanisms for coexistence studies, spectrum technology infrastructure and capacity building are critical to creating a systematic approach. This will not only help in studying the bands in an ongoing manner but will also make them available on time to minimise the adoption gap. These aspects are elaborated on as part of the Task Force report. Apart from the need for representation in WRC-23, there is a need to have an institutional mechanism to enable coexistence studies in an ongoing manner. Going forward, a participatory and transparent mechanism is proposed to be taken going forward considering its critical need to build consensus quickly on different bands and the feasibility of the coexistence of different radio services and users.

Further, generation of demand in new and greenfield bands (such as 450-470 MHz, 612-703 MHz and new IMT bands including 37-43.5 GHz, 47.2-48.2 GHz, 66-71 GHz) is necessary, similar to spectrum horizon program. This will ensure that the industry is incentivized to carry out R&D and build systems to commercialize them. This will subsequently enhance the value of the band and will help create business models out of it. Some of the bands mentioned in this executive summary form only part of the recommendations and the Taskforce report comprehensively presents all the bands and specific actions.

5.4 Devices

6G technology will have significant advancements in imaging, presence technologies, and location awareness and the computational infrastructure of 6G will automatically select the ideal place for computing, including artificial intelligence (AI) driven decisions regarding data storage, processing, and sharing. Future networks will be pervasive components of our life, fulfilling the communication needs of humans as well as intelligent machines. 6G will contribute to an efficient, human-friendly, and sustainable society through ever-present intelligent communication. The following four main drivers will emerge for the 2030 era:

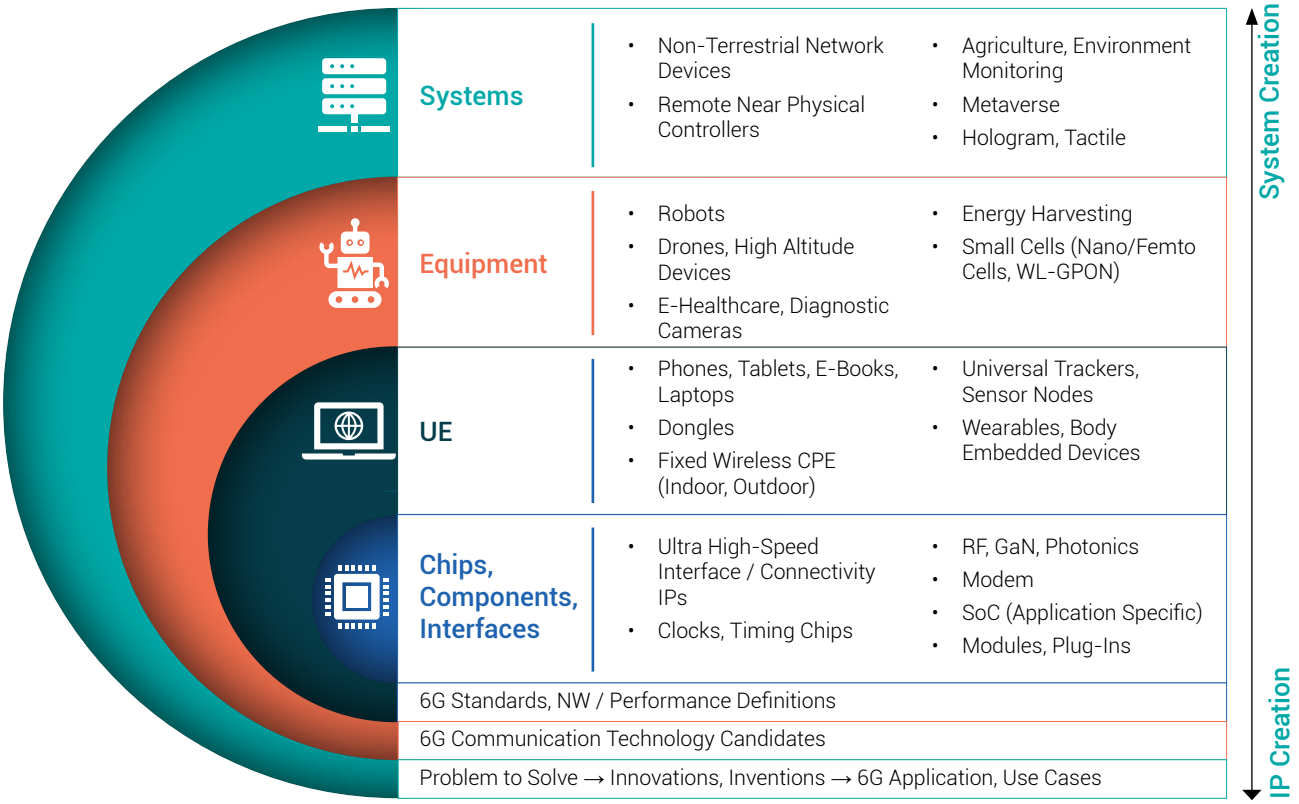
1. Trustworthiness of the systems that will be at the heart of society,
2. Sustainability through the efficiency of mobile technology,
3. Accelerated automation and digitization to simplify and improve our everyday lives, and
4. Limitless connectivity for meeting the demands of intensifying communication anywhere, anytime, and for anything.

It is expected that 6G will provide the ultimate experience for all through hyper-connectivity involving seamless interactions between humans and machines. New themes are likely to emerge that will shape 6G devices, such as:

- New man-machine interfaces created by a set of multiple local devices acting in unison; We will have more intuitive interfaces, with access through gesturing rather than typing
- Ubiquitous universal computing distributed among multiple local devices and the cloud
- Multi-sensory data fusion to create multi-verse maps and new mixed-reality experiences
- Precision sensing and actuation to control the physical world
- A certain class of devices will be extremely low-power and potentially battery-less, relying on the network to power the device
- The end device will evolve in many scenarios to be a network of devices or a sub network. As examples, we can imagine a machine-area network or a robot-area network involving connecting multiple parts of a machine such as a controller and its drives
- With the targeting of (Sub-)Terahertz spectrum, 6G devices will not only be communication endpoints; but will also be able to act as active network nodes in a data path and, ultimately, form standalone networks
- Future applications need to leverage high-performance connectivity, fulfilling required bandwidth, dynamic behaviours, resilience, and further demands. Network capabilities need to be available end-to-end and match the evolution of applications and internet technology. This affects, for instance, application–network collaboration, resilience mechanisms, the evolution of the end-to-end transport protocols, and ways to deal with latency
- Future services will require connectivity everywhere and in everything. 6G networks can support trillions of embeddable devices and provide trustworthy connections that are available all the time

- 6G connectivity can help India to leapfrog to become a highly industrialized society. While the technology adoption improves productivity, and quality of life for rural and urban citizens, achieving leadership in the development of technology will create immense job opportunities in the country
- 6G Connectivity can help India address many social issues like law and order, healthcare, knowledge-led job creation, improvements in living standards of the citizens in the urban and rural areas, improvements in government and citizen interaction through smart cities, internet of things, digitalization and G2C services, better governance of urban, rural, border areas, islands, forests, and animal kingdoms, vast ocean geography, sovereignty and security, cyber and physical integration among many others. In particular, disaster management with improved resilience, intelligent transportation for de-congestion, and efficient use of waterways are relevant in the Indian context
- New industry verticals will emerge driven by 6G technologies. These may include Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) Communication across road transport, trains, airlines, personal, community and public transport sectors, holographic communications, tactile and haptic internet applications, telehealth including diagnosis, surgery and rehabilitation activities, extremely high-rate information access, connectivity for everything, convergence of networking and computing among others.

Vision of 6G Device Universe



Our Vision for developing 6G devices is based on 6G standards, network and performance expectations and the use cases that the devices are expected to support. We propose an inside-out approach involving developing the required silicon level IPs, interfaces, and chips and enabling the leading applications to use the existing semiconductor and devices ecosystem. We may also own and steer a couple of strategic and mission-critical components, chips, devices and applications to showcase end-to-end capabilities as part of the 6G test bed program.

Regarding R&D funding for this purpose, a majority of the MEITY R&D funding in the semiconductor domain is limited to processor design. There is limited R&D push towards indigenization of 5G-adv/6G modem chipset. Considering the current domestic scenario, significant R&D investments are essential to achieve an Atmanirbhar Bharat in the 5G-adv/ 6G device space with the following key considerations.

- 6G R&D funding to have a 10-year horizon with the outcomes aligned with the IMT-2030 6G standards. However, the intermediate deliverables should target compliance with 5G-advanced specifications, viz. 3GPP Rel-17/18 and beyond
- The funding should cover the development of modem chipsets and end-to-end systems including software/firmware, security elements and applications. Adequate funding should also be given to emerging technologies such as AR/ VR, next-generation sensors, human-machine interfaces, etc.
- The funding should be prioritized for the development of
  - i. SOCs: Modem, RF ICs (Sub 6, mmWave and higher frequencies)
  - ii. Multiple classes of SOCs to address low-end and high-end IoT applications
  - iii. AI processors
  - iv. End-to-End Devices including the applications.

5.5 Standardisation

6G technologies are likely to become viable and impactful over the next ten years and will support ubiquitous instant communications, pervasive intelligence, immersive experiences, and the Internet of Things & Senses. 6G is expected to play a key role in the evolution of society towards the 2030s and shall also play a role in supporting the global sustainability goals, including India's objective to contribute towards climate emergencies. In this context, developing a strong technology that meets Indian interests and values, as well as economic and global societal goals, is the key. Secure and trustworthy India-based 6G infrastructure will help to ensure the sovereignty of India in terms of critical technologies and systems on one hand and will make sure that our primary values such as privacy, trust, transparency, accountability, security, and societal interests are considered on the other hand.

6G is also expected to integrate terrestrial, aerial and maritime communications into a robust network that would be more reliable, faster, and can support a massive number of devices with ultra-low latency requirements. Researchers around the globe are proposing the following cutting-edge technologies as the key technologies in the realization of beyond 5G (B5G) and 6G communication:

i. Quantum Communication/ Quantum Machine Learning (QML),

ii. Immersive XR,

iii. Tera-Hertz Communication

iv. Advanced Artificial Intelligence (AI)/ Machine Learning (ML),

v. Advanced Distributed Ledger Technologies (DLT) like blockchain etc.,

While contributing to the development of global 5G standards in 3GPP, ITU, etc., India as a nation has gained relevant experience with Indian companies also having developed core competencies in certain areas. During this period, there is also a greater understanding of the Standards Development Lifecycle especially that followed within 3GPP including aspects related to its workflow and working procedures. By leveraging this experience, India can contribute to the development of 6G standards in various international bodies such as 3GPP, ITU, IEC, IEEE, one M2M, etc., and can make its mark in the global standardization space and ensure a good number of key innovations are from India. To assess the ability of Indian Telecom and Technology Companies entities to participate in 6G standards development, inputs were collected from a select set of Indian entities based on a survey (provided by VoICE). Based on the inputs recevied, it is felt that R&D may be promoted in specific areas of competencies available in India, prioritizing the softwarisation of networks especially leveraging India's strength in AI/ML.

An Indian initiative led by industry and with support from the government will be essential for balancing the efforts and ensuring our 6G leadership. Government, industry, and academia will need to coordinate more closely in identifying research priorities. This should begin with a concerted effort by industry, academia, and government to develop a research agenda for 6G leadership in areas of shared interest. As a first step in the process, the government should facilitate a stakeholder's session jointly with industry and academic members to engage in a dialogue identifying mutual 6G research priorities.

This task force proposes a 6G program with the following attributes:

A 6G program be created with a broad category of ecosystem partners including operators, vendors, hyper scalers, academia, and Government research labs, that is agile and quickly adaptable to the evolving needs for driving 6G research and innovations, building on and strengthening India's competencies. (e.g., Next Gen Alliance was set up outside the ATIS, with its own working procedures)

The program should identify through a consensus-driven approach, the topics/themes of interest in 6G based on business and societal needs. The program should cover all aspects of technology development including early research on ideas, proof-of-concept, standardization, trials & testbeds, etc.

Govt. of India should take a lead in streamlining the process and fund research programs on the themes identified.

The program should take a lead in preparing well-defined measurable KPIs to assess the success of these program fundings.

The program should have cohesive policies to meet the common goal of national leadership, national 6G Roadmap, Sustainability goals, etc.

The program should have a timeline that aligns with the timeline of various 6G standards efforts across the globe.

The program should take a lead in developing consensus on solutions of interest and pursue the standardisation efforts at the corresponding international standardization bodies.

The program should facilitate early trials and prototype development, aimed at developing proofs-of-concept and supporting the domestic manufacturing process.

The infrastructure including the optical fiber network should be made ready before deployment of 6G keeping in mind the hyper capability of the technology

5.6 R&D Finance

On the whole, telecommunication technology products require significantly large funding and long gestation periods for R&D and commercialization. The stages move from ideation, research, incubation, prototyping, lab testing, miniaturization, field testing, hardening, securitization, outdoor readiness, licenses for background IPs, Standardization, etc. In the cases of deep tech SoCs (System on Chips), funding needs tend to be higher due to multiple layers of prototyping.

India has been witnessing the emergence of several small companies, start-ups and academia in niche areas which are adding newer avenues for positioning India on the global digicom technology landscape. The outcome of the supply-based assessment carried out by DoT a few years back reflects on the available competencies across industry and academia (indigenous 5G Testbed). It firmly established that with suitable and sufficient funding, policy handholding can enable Indian players to play an important role in global partnerships in 6G and beyond programs with significant value add to the global value chain.

R&D funding in telecom will be focused on strengthening the following enablers of the 6G technology:

- Promote the ecosystem for research, design, prototyping, development, proof of concept testing, Intellectual Property Rights (IPR) creation, field testing, security, certification, and manufacturing.
- Develop and establish relevant standards to meet national requirements as well as those of international standardization bodies.
- Enable proliferation of affordable broadband and mobile services and positioning state-of-the-art communication technologies for rural and remote areas to bridge the Indian digital divide.
- Create synergies within the Academia, Research Institutes, Start-ups and Industry for capacity building and development of the telecom ecosystem focusing on relevant technologies and solutions required for 6G implementation.
- Bridge the gap between R&D and commercialization of products and solutions with assistance from government bodies and the start-up ecosystem.
- Enable commercialization of developed technologies for domestic and global markets to ensure a distinctive presence in the telecom sector both today and in the coming years
- Build competencies far beyond 6G communication technologies.
- Identify or constitute an agency to engage in IPR management and obtaining licenses from licenser for the domestic industry to facilitate affordable and timely licenses for technology development.

The key recommendations to promote R&D in this regard and realise the above state are as follows:

- The programs under 6G should be planned to encourage building technology ownership, developing IPRs and SEPs, and moving from prototyping to commercialization as part of the project roadmap. CDoT, along with other research institutions, are envisaged to play a significant collaborative role.
- Funding needs are diverse for academia, industry, and research organizations to build capacities and competencies in different stages of R&D for the 6G program in the coming ten years. Different funding mechanisms and instruments should hence be adopted with flexibility and liberal norms to suit the unique requirements of all without adding to the complexity of the funding structure/ mechanism
- Funding must also cover different activities under research, design, prototyping, development, proof of concept testing, IPR creation, standardization (including pre-standardization) standards participation, field testing, security, and certification in the R&D process so that a clear identification and breakdown of involved costs can be mapped and planned accordingly

- The projects may include Research Testbeds, R&D in products such as network elements, antennas, reflectors, systems, devices, SoCs, etc and at a later stage, may extend to large-scale trials, CoEs for use cases, etc. As part of the funding, seed funding for joint international projects may be explored on bilateral and multilateral platforms. The CoEs should have sufficient autonomy to collaborate with the industry to deliver market-ready solutions with clear KPIs to measure success.
- Since the inception, i.e., the research stage, industry participation from technology companies and system integrators should be envisaged to enable swift and agile scaling of R&D to higher TRL levels.
- Apart from technologies that are upgrades of 5G+, several new research projects may be necessary to work on cross-platform projects requiring, and ultimately triggering, significant funding to contribute to IPRs in 6G research.
- A program to identify industry champions to facilitate funding on liberal terms may also be initiated. It should also identify "academia clusters" for taking up programs based on competencies in different verticals and 'system integrators' for orchestrating new generation products.
- Constitute an Apex Level Advisory board, with experts from India and across the world, for advising on programs and funding needs with members from relevant ministries to enable global and political synergies in funding-related programs.
- Create a large corpus of R&D funds to facilitate various funding instruments such as grants, loans, VC fund, fund of funds, etc. A pool of Rs. 10,000 Cr is envisaged to be created to service these requirements for the next 10 years. The government may take lead in creating this fund, considering the budding technology ecosystem in the country, to strengthen it for 6G and beyond technologies.
- Two tiers of grants are proposed i.e. up to Rs. 20 Cr to service funding requirements ranging from small to medium and grants above Rs. 20 Cr for High Impact projects.
- Administrative setup for vetting R&D projects may include the following depending on the size and scope.

a. Inter-ministerial committee: The mechanism could commence its work in line with other R&D funding schemes like DCIS etc., with TCOE India as its PMU.

b. Set up 6G Mission Apex Body and Directorate to take Bharat 6G Vision forward for its implementation

c. A Section 8 Company or Society may be set up exclusively as a delivery mechanism for 6G and other telecom-related programs; Alternatively, existing agencies of other ministries may also be considered on a need basis.

d. Telecom-focused VC funds and Fund of funds are envisaged for large-size high-risk funding needs. Define measurable KPIs to assess the success of these program funding.

Entities eligible for R&D funding, indicative process, and administrative structure are also identified to enable early take off of the program.


R&D
Research & Development

6

Key Recommendations to Enable Bharat 6G Mission

The Six Task Forces deliberated on various aspects of emerging telecom technologies and platforms in the next decade. They focused on innovations that leverage these new technologies to deliver solutions, the device ecosystem that will support these innovations, a spectrum policy that will enable the ongoing and oncoming explosion in wireless communications, the need to contribute our innovations to global standards and ensure interoperability, and requirement of adequate financing to carry out the Bharat 6G Mission.

The Task Forces' key recommendations to pursue to enable the 6G Mission have been summarised below:

- Innovative funding mechanisms to support industry, startups, academia, and national laboratories to undertake R&D and pursue select risky pathways in search of breakthroughs with clear KPIs and roadmap and partnerships for commercialization
- Innovative solutions through startups and CoEs that leverage the emerging 6G technologies to address key verticals such as transport, water, power grid and renewables, healthcare, education, digital twins and smart cities
- Shared use of spectrum, particularly in the higher frequency bands where the propagation is more akin to that of light
- Reassessment and rationalisation of congested spectrum bands, and adoption of captive networks for Industry 4.0 and enterprise use cases in hitherto less used bands
- New multi-sensor man-machine interfaces and devices leveraging edge cloud computing resources and AI to deliver tactile Internet, ambience awareness and realistic 3D experiences
- mmWave and (Sub-) Terahertz (THz) wireless communications at scale and very high data rates along with adaptive radio interfaces, advanced/ novel antenna techniques (Ultra massive MIMO) and increased virtualisation
- Participation and contribution to global standards forums to ensure interoperability and global reach of our innovation
- Fiber-broadband to every home and integrated dense wireless and optical network, with wireless communications primarily serving mobile users
- Tactile Internet and Remote Operations of machines/ robots, along with near-realistic 3D rendering of virtual participants in meetings
- Space-Terrestrial Integration for ubiquitous coverage
- Combined communication and sensing in (Sub-) Terahertz bands
- SoCs for modems, radios, AI processors

The Task Force Reports in the annexures provide details of the background and thought processes leading up to these recommendations.

7

Bharat 6G Mission

The 6G TIG has enunciated a clear Vision for India in a 6G-driven world. The importance of the impending innovations and developments in 6G cannot be overstated for a country poised to become a global leader in the 6G revolution and one of the top three global economies. It is critical for India to be among the drivers of these new technological developments to best address the country's unique needs, as well as to become a leading supplier of affordable and transformative solutions globally. A Mission-oriented approach is thus imperative to take up the diverse technology development initiatives, studies and innovation efforts necessary to achieve this objective. Based on the Vision 6G outlined herein, a Mission 6G shall be launched with the requisite organisational and financial resources to realise the Vision. Existing organisational strengths will be leveraged to the maximum and new governance structures will be kept lean to ensure agility and speed of execution. The research and start-up ecosystem will be tapped to bring innovations and new ideas to the table. Adequate provision for financial support will be made through explicit budgetary allocation to ensure that the efforts undertaken are not hobbled for want of funds.

The Mission can be divided into two phases:

i. Phase 1 from 2023-2025 (2 years)

ii. Phase 2 from 2025-2030 (5 years)

In Phase 1, support will be provided to explorative ideas, risky pathways, and proof-of-concept tests. Further, ideas and concepts that show promise and potential for acceptance by the global peer community will be adequately supported to develop them to completion, establish their use cases and benefits, and create implementational IPs and testbeds leading to commercialization as part of Phase 2.

An apex body is to be constituted to lay down the Phase-wise objectives, select the research and innovation pathways to be explored, and approve financial support for them. Towards this, the apex body may constitute expert groups to generate the calls for proposals or address technical challenges. This will be followed by the technical assessment of research and innovation proposals and will be rounded off with appropriate review mechanisms for assessing progress and milestones. The apex body shall approve and fund proposals and initiatives with the help of the technical groups.

Proposals and initiatives will leverage the creative impulses of the widest cross-section of the country, ranging from leading academic and research institutions to companies and start-ups, to young students who are unburdened by the wisdom of "what will not work". A thorough appraisal and review process as described above will separate the proposals that are well thought through from those that are based on the flavour of the day.

The apex body will also set up coordination efforts between the research initiatives being undertaken and the sectoral organisations such as TSDSI, TEC, WPC, Start-up India, TDB and others that provide support for standardization, representation and participation at ITU, spectrum needs, incubation, technology development support, etc. Such coordination is critical for an all-of-nation approach to the Mission, without which the Vision outlined cannot be realized. It will also ensure sufficient visibility to the Bharat 6G Mission globally through participation in international forums and meetings and collaborations with similar Missions worldwide.

The apex body will also assess the procedural roadblocks that often come in the way of Mission-mode research, such as processes for timely approval and release of funds and permits for global procurement when justified, well-orchestrated support at international forums when needed, as well as support for IP and value creation. It will also provide assessments and feedback to the government to fine-tune the budgetary and policy support for the Mission and provide corrective actions as necessary. The body will create a governance structure that is as lean as possible while leveraging existing organisational capabilities in the entire telecom sector, both within government as well as in industry and academia-driven sectoral bodies. This structure must be entirely Mission-based and should dissolve itself once the Mission is complete.

As a prelude to the launch of Bharat 6G Mission, the government may consider the recommendations of the 6G TIG for approval in full or in part. It may also constitute the apex body to oversee the Mission and approve the budget for the Mission split into two phases. Timeliness is the overarching requirement while executing this Mission. A successful effort or project may yet yield minimal or no returns if delayed in execution. Given the criticality of timeliness, the apex body must be tasked with ensuring this and empowered to modify processes and procedures as needed to remove roadblocks.

Bharat 6G Mission is fully aligned with the national Vision of ***Atmanirbhar Bharat*** and it seeks to empower every Indian to become ***Atmanirbhar*** (self-reliant) in their lives. At the same time, it ensures that India takes its rightful place in the world as a leading supplier of advanced telecom technologies and solutions that are affordable and contribute to the global good. Bharat 6G Mission is thus timed just right for India's ***Aazadi ka Amrit Kaal.***

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Notes

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Acknowledgements

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2	Shri Vijay Kumar Roy	Director, TEC	Document drafting and finalization
3	Rahul Hakeem	Partner, KPMG India	Document drafting and standardisation
4	Yasharth Srivastava	Associate Director, KPMG India	Document drafting and standardisation
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