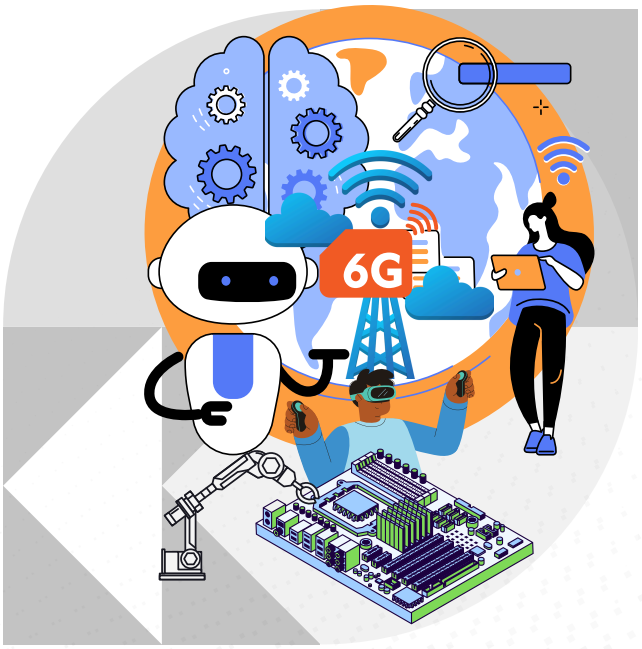
Bharat6G Alliance



Bharat 6G Alliance Report

6G USECASES & REVENUE STREAMS

6G Use Cases and Revenue Streams Working Group

OCTOBER 2024

VERSION 1.0

6G Usecases & Revenue Stream

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Executive Summary

India has seen massive rollouts of 5G network. Today India is among the markets with cheapest / affordable broadband access. This is remarkable feat achieved by India. In a short span starting from Oct 2022, more than 462K sites have been deployed, making India #2 market in the world. Network experience has been remarkably improved from a download speed of 20 Mbps in Nov 2022 to 107 Mbps in May 2024, in the global benchmarking.

This document provides a high-level recommendation from B6GA for India centric recommendations on 6G Use cases in India and enabling policy framework. The scope of the document includes the following –

a) Identify use cases that can leverage 6G and emerging technologies that have the potential to drive societal and economic transformation.
b) Explore how the use cases can be integrated to deliver tailored solutions for enterprise and retail telecom customers.
c) Propose monetization strategies for the identified use cases.
d) Recommend actions for the Central and State Governments and industry, to position India as a leader in 6G innovations
e) Providing a high-level view of requirement on 6G technology to support the identified usecases that are likely to evolve in new few years
f) Suggest regulations and policy initiatives necessary for ensuring success of 6G technology in India

This document serves as a strategic guide for researchers, industry players, and policymakers as a guide to relevant usecases and opportunities presented by the advent of 6G technology.

Introduction

The telecommunications industry is constantly developing, with a high rate of technical obsolescence. It has seen the transition from wire-line to mobile services, which has become people's lifeline. Mobile services have likewise evolved from 2G to 3G to 4G to 5G, and now 6G is on the horizon. India is a bright spot in the global economy, and the telecom sector is the brightest area in India. India's journey towards digital transformation has been marked by significant strides in leveraging technology to drive socio-economic development and innovation. With initiatives spanning various sectors, the country is charting a path towards a digitally empowered society and economy. Telecom industry in India is the second largest in the world with a subscriber base of 1.205 Bn as of Jun 2024 (wireless + wireline subscribers). India has an overall tele-density of 85.95%, of which, the tele-density of the rural market, which is largely untapped, stands at 59.65% while the tele-density of the urban market is 133.46%. Broadband connections rose to 940.75 Mn in June 2024 from 69 Mn in Mar 2014, growing by 1266%.

India is placed at 60th rank as per Network Readiness Index 2023 and secured 2nd rank in "Mobile broadband internet traffic within the country" and "International Internet bandwidth". The industry's exponential growth over the last few years is primarily driven by affordable tariffs, wider availability, expansion of 4G coverage, rollout of 5G networks, evolving consumption patterns of subscribers, Government's initiatives towards bolstering India's domestic telecom manufacturing capacity, and a conducive regulatory environment.

According to latest report from Counterpoint research, India has emerged as the world's second-largest market for 5G smartphones overtaking the US, trailing only behind China. According to International Data Corporation's (IDC) India Monthly Wearable Device Tracker, 2023 ended with the India wearable market achieving a 34% growth to a record 134.2 million units. 4Q23 (Oct-Dec) saw 28.4 million units, growing 12.7% year-over-year (YoY).

India's 5G deployment was one of the fastest rollouts in the world. 5G has already been rolled out in all 28 states and 8 Union Territories which has significantly improved the mobile internet speeds in the country and currently ranks 20th in terms of median country speeds in Aug 2024 report by Ookla.

Potential of 6G technology in India

India is already looking beyond the adoption of 5G technology, to develop and deploy its faster and superior successor: the sixth generation of telecom network or 6G. 6G holds the potential to transform the Indian landscape through its offerings of faster data transfer speeds, lower latency, improved security, and advanced features such as holographic communications and AI-powered networks. The implications of 6G span multiple sectors and promise to deliver an advanced user experience, in line with the goals of 'Atmanirbhar Bharat.' For example, in the education sector, 6G technology will facilitate industry

interactions and virtual visits, providing students with immersive experiences to enhance their knowledge.

Similarly, it will strengthen the diagnosis and treatment options in the healthcare sector. Other sectors such as manufacturing and agriculture will see an increase in production efficiency and improvement in supply chain management due to greater automation and precision powered by 6G. Additionally, with increased reliability and coverage, transportation could become safer and more efficient, while public infrastructure could be managed more effectively in smart cities.

In alignment with the Hon'ble Prime Minister's vision of telecom technology being a mode to empower, the widespread adoption of 6G technology is expected to bridge the gap in regional and social infrastructure and economic opportunities, providing viable alternatives to rural exodus and metro-driven urbanisation. With the potential to reduce disparities in e-service availability between urban and rural communities, the deployment of 6G technology could facilitate the growth of small businesses in rural areas, promote innovation, and enhance job opportunities.

TIG-6G, the Technology Innovation Group on 6G, has devised a plan to establish 6G technology in India by 2030, called the Bharat 6G Vision. The objective of this vision is to develop and implement 6G network technologies that provide secure, intelligent, and widespread connectivity, enabling a high-quality living experience for people worldwide. The Vision statement emphasizes India's dedication to socio-economic growth, and the potential benefits of India leading the way in 6G technology, which offers ultra-low latency and speeds up to 1 terabit per second. This could be a game-changer for the Indian economy.

Bharat 6G Mission

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.

Hyperconnectivity 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.

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 not just for the Indian market but also for the entire world, transforming India into a global leader providing life and livelihood-transforming solutions.

The International Telecommunication Union (ITU) has accepted the 6G Vision Framework. India, through the Department of Telecommunications and the Ministry of Communications, played an important role in developing the Framework. 6G standardization has successfully adopted ubiquitous connectivity, ubiquitous intelligence, and sustainability as essential components of 6G Technology, which has also improved India's standing in the global telecommunications industry and will help bridge the digital divide by providing fast and quality broadband services to everyone

The primary goals of the Bharat 6G Vision Document are to position India as a global leader in 6G technology, to support indigenous 6G research and development, and to foster innovation and growth in the Indian telecom industry. On March 23, 2023, Prime Minister Mr. Narendra Modi presented India's 6G Vision "Bharat 6G Vision" manifesto, which envisions India as a front-line contributor to the design, development, and implementation of 6G technology by 2030.

The Bharat 6G Vision is founded on the principles of affordability, sustainability, and ubiquity. It assures that India takes its due place in the world as a leading supplier of modern telecom technology and solutions that are affordable and contribute to the global good.

The government has invested INR 2,240 million in a new 6G Test Bed, co-developed by a consortium of Indian Institutes of Technology (IITs), to provide an R&D platform to start-ups, researchers, industry, and other broadband wireless applications. The first phase of the Bharat 6G vision focuses on explorative ideas, followed by the second phase, which lays emphasis on supporting ideas and concepts that show promise, and creating implementational IPs and testbeds leading to commercialization. An Apex Council has been constituted and endowed with the responsibility of defining the phase-wise objectives, consulting the Bharat 6G Alliance, recommending research and innovation directions, monitoring progress periodically, conducting external evaluations, and proposing corrective actions if necessary.

6G Technology Overview

Since its introduction in Release 15, 5G has targeted three main use case families, namely enhanced Mobile Broadband (eMBB), critical Internet of Things (IoT), and massive IoT. Together with the support for new verticals added in later releases of 5G, the system enables

many new use cases compared to previous generations of 3GPP systems. It provides superior network performance in terms of capacity and coverage and has increased the focus on sustainability. 5G Advanced is the next wave of 5G starting in Release 18. It includes additional capabilities for new market segments as well as architecture enhancements of 5GS. 5G Advanced will enhance network performance and add support for new applications and use cases.

As 5G networks continue to expand worldwide, heralding new communication capabilities and services, attention is already turning to the next frontier: 6G. With the potential to revolutionize society, industries, and everyday life, 6G networks are poised to become the backbone of future communication needs, serving both humans and intelligent machines. To capitalize on this potential, collaboration between industry and research communities is crucial, with a shared vision driving advancements in critical services, immersive communication, and the omnipresent Internet of Things (IoT). For example, XR in 5GA will gradually evolve into immersive communication for human-machine interaction which may pose new requirements on 6G to provide an even better experience. In the area of machine-type communication, RedCap can be complemented by zero-energy devices, a class of devices harvesting energy from the surroundings and providing input to digital twins. AI/ML will also play an important role in the fully data-driven architecture of 6G and the intelligent network platform of the future.

6G is expected to address the demands for consumption of mobile networking services in 2030 and beyond. These are characterized by a variety of diverse requirements, technical ones such as extremely high data rates, unprecedented scale of communicating devices, high coverage, low communicating latency, flexibility of extension, etc., to non-technical ones such as enabling sustainable growth of the society as a whole, e.g., through energy efficiency of deployed networks. On the other hand, 6G should also enable use cases characterized by combinations of these requirements never seen before (e.g., both extremely high data rates and extremely low communication latency).

Key technologies include the use of ultra-high frequency bands, full-duplex communication, AI/ML, integrated sensing and communication, and network energy efficiency optimization. These technologies will provide 6G with higher transmission rates, lower latency, and wider connectivity. 6G will further bridge the physical world and virtual world in these applications, from the initial mobile broadband to industrial IoT, Internet of Vehicles, telemedicine, gaming, etc., and introduce more emerging applications. The evolution of 6G would enable hyper-connectivity, intuitive interfaces, universal computing, multi-sensory data fusion, and precise sensing. 6G technology in India has the potential to revolutionise connectivity and provide a variety of advanced features and capabilities to the industry.

In the 6G era, the digital, physical and human world will seamlessly fuse to trigger extrasensory experiences. Intelligent knowledge systems will be combined with robust computation capabilities to make humans endlessly more efficient and redefine how we live, work and take care of the planet.

(6G Explained|Nokia, n.d.)

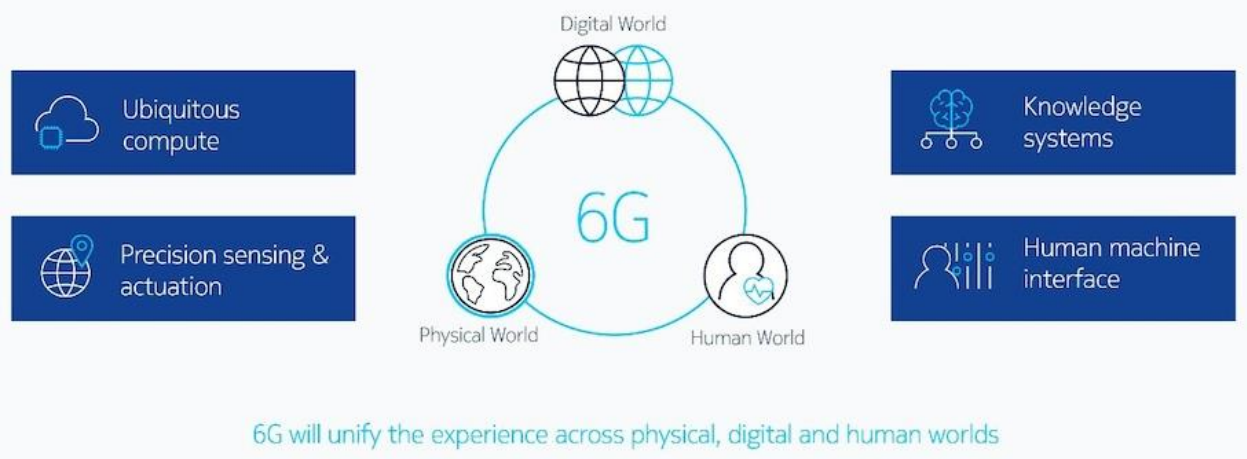


Figure 1 : 6G Unified Experience across Physical, Digital & Human worlds

6G will connect the physical world to human world, thanks to the massive scale deployment of sensors and artificial intelligence and machine learning (AI/ML) with digital twin models and real-time synchronous updates. These digital twin models are crucial because they allow us to analyze what's happening in the physical world, simulate possible outcomes, anticipate needs and then take productive actions back into the physical world. Digital twin models are already being used with 5G. With 6G, we can expect these technologies to operate at a much larger scale. Digital twins will be found not only in factories but also in wide area networks of cities and even digital twins of humans which will have a major impact on the network architecture.

6G will make it possible to move freely in the cyber-physical continuum, between the connected physical world of senses, actions and experiences, and its programmable digital representation. The cyber-physical continuum of 6G includes the metaverse as it is typically understood – a digital environment where avatars interact in a VR/AR world – and goes further, providing a much closer link to reality. In the cyber-physical continuum, it will be possible to project digital objects onto physical objects that are represented digitally, allowing them to seamlessly coexist as merged reality and thereby enhance the real world.

6G networks will be a fundamental component for the functioning of virtually all parts of life, society, and industries, fulfilling the communication needs of humans as well as intelligent machines. As accelerating automatization and digitalization continue to simplify people's lives, the emerging cyber-physical continuum will continuously improve efficiency and ensure the sustainable use of resources. Countless sensors will be embedded in the physical world to send data to update the digital representation in real time. Meanwhile, functions programmed in the digital representation will be carried out by actuators in the physical world. The purpose of the 6G network platform is to provide intelligence, ever-present connectivity and full synchronization to this emerging reality.

(6G - Follow the journey to the Next Generation Networks | Ericsson, n.d.)

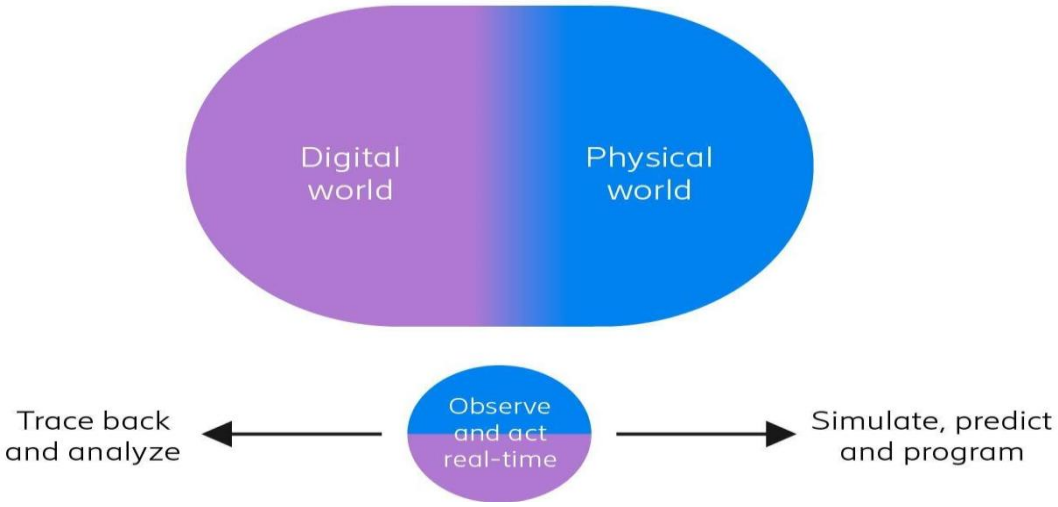


Figure 2: Cyber Physical Continuum

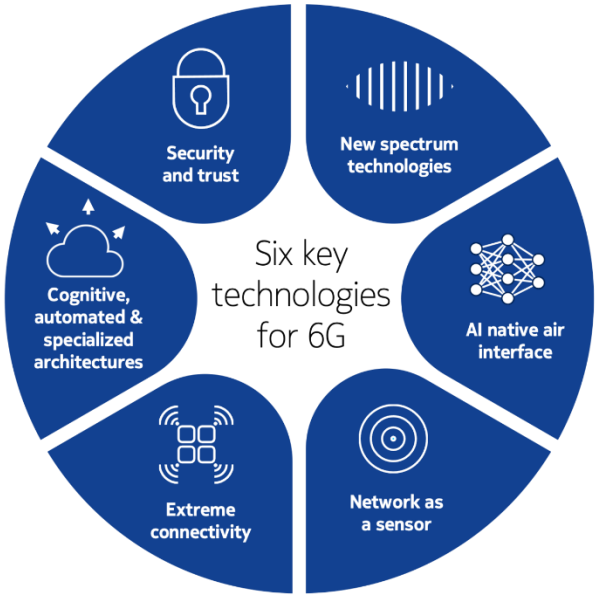
While the smartphone will remain a key device in the 6G era, new man-machine interfaces will make it more convenient to consume and control information. Touchscreen typing will gradually get replaced by gesture and voice control. Devices will come embedded into clothing and even transform into skin patches. Examples of important 6G use cases include e-health for all, precision health care, smart agriculture, earth monitor, digital twins, cobots and robot navigation. These use cases can be sorted into three broad use case scenarios: the Internet of Senses, connected intelligent machines, and a connected sustainable world. Healthcare will be an important benefactor as wearables facilitate 24/7 monitoring of vital parameters.

The immersive communication of 6G will deliver the full telepresence experience, removing distance as a barrier to interaction. Extended reality (XR) technology with human-grade sensory feedback requires high data rates and capacity, spatial mapping with precise positioning and sensing, and low latency end-to-end with edge cloud processing. One example will be the ubiquitous use of mixed reality in public transport, offering separate virtual experiences for each passenger, enabling them to run virtual errands, get XR guidance and have games overlaid on the physical world.

Personal immersive devices capable of precise body interaction will allow access to experiences and actions far away to better support human communication needs. At the same time, 6G networks will also add completely new communication modes with strict control over access and identities.

The maturing of AI and machine vision and their capacity to recognize people and objects will turn wireless cameras into universal sensors. Radio and other sensing modalities like acoustics will gather information on the environment. Digital cash and keys may become the norm. We may even start relying on brain sensors to actuate machines.

6G will also promote sustainability in a variety of ways. By enabling faster and lower cost per bit connectivity, it would be able to support data collection and closed-loop control of numerous appliances. The data can be analyzed using sophisticated tools to improve energy efficiency in industries. The advanced multi-sensory telepresence that is created with very high data rates will reduce the need for travel through the introduction of multi-modal mixed reality telepresence and remote collaboration.



(Nokia, n.d.)

Figure 3: Key 6G Technologies

6G will be significantly more energy-efficient, turning off components and scaling down capacity when the demand is lower. Energy efficiency will be a major design criterion in 6G along with the other metrics such as capacity, peak data rate, latency, and reliability.

The evolution of 5G-Advanced to 6G is driven by the demand for higher-level intelligence and the speed of supporting these intelligent operations.

Communication and control co-design will enable lower cost and higher data rate and increase the number of use cases. 6G network as a sensor will enable joint communication, sensing and localization that will address the needs of industries with a single system, thereby reducing cost.

New zero energy or battery-less devices could be enabled in 6G using backscatter communications that will allow a massive scaling of data gathering for analytics and closed loop control. There will be extensive use of mobile robot swarms and drones in various verticals such as hospitality, hospitals, warehouses and package delivery.

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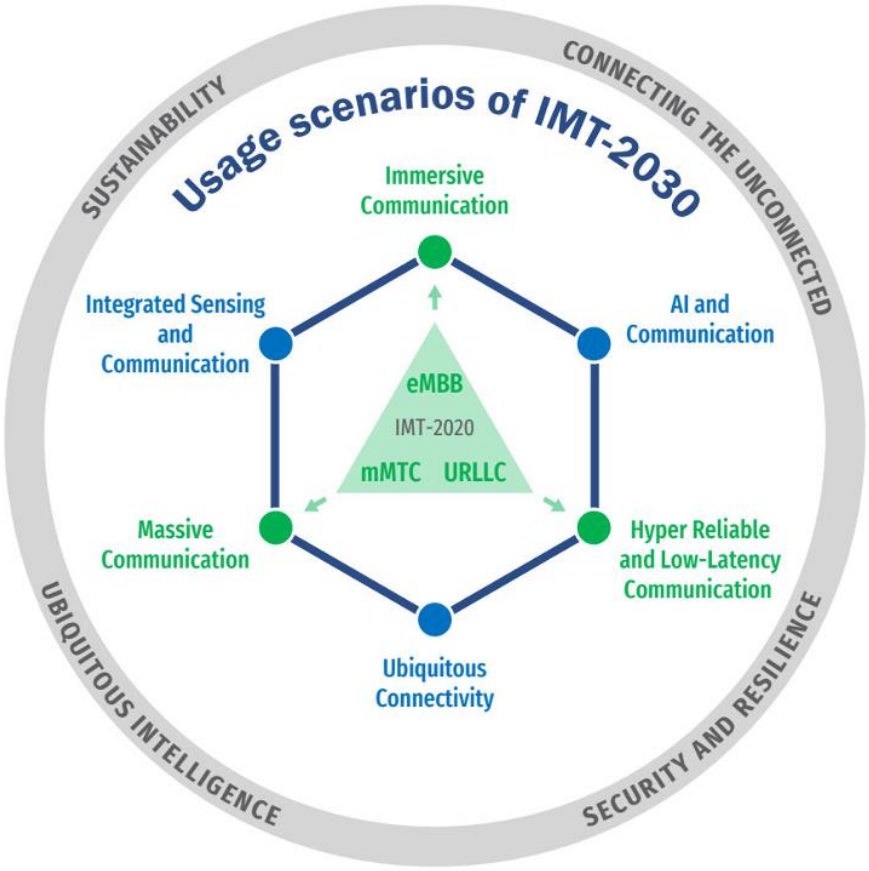
Future networks will be a fundamental component for the functioning of virtually all parts of life, society, and industries, fulfilling the communication needs of humans as well as intelligent machines. As accelerating automatization and digitalization continue to simplify people's lives, the emerging cyber-physical continuum will continuously improve efficiency and ensure the sustainable use of resources.



(6G Usage Scenario)

Figure 4: 6G Wheel Diagram

Countless sensors will be embedded in the physical world to send data to update the digital representation in real time. Meanwhile, functions programmed in the digital representation will be carried out by actuators in the physical world. The purpose of the 6G network

platform is to provide intelligence, ever-present connectivity and full synchronization to this emerging reality. In the Internet of Senses scenario, the immersive communication of 6G will deliver the full telepresence experience, removing distance as a barrier to interaction. Extended reality (XR) technology with human-grade sensory feedback requires high data rates and capacity, spatial mapping with precise positioning and sensing, and low latency end-to-end with edge cloud processing. One example will be the ubiquitous use of mixed reality in public transport, offering separate virtual experiences for each passenger, enabling them to run virtual errands, get XR guidance and have games overlaid on the physical world.

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(Bharat 6G Vision)

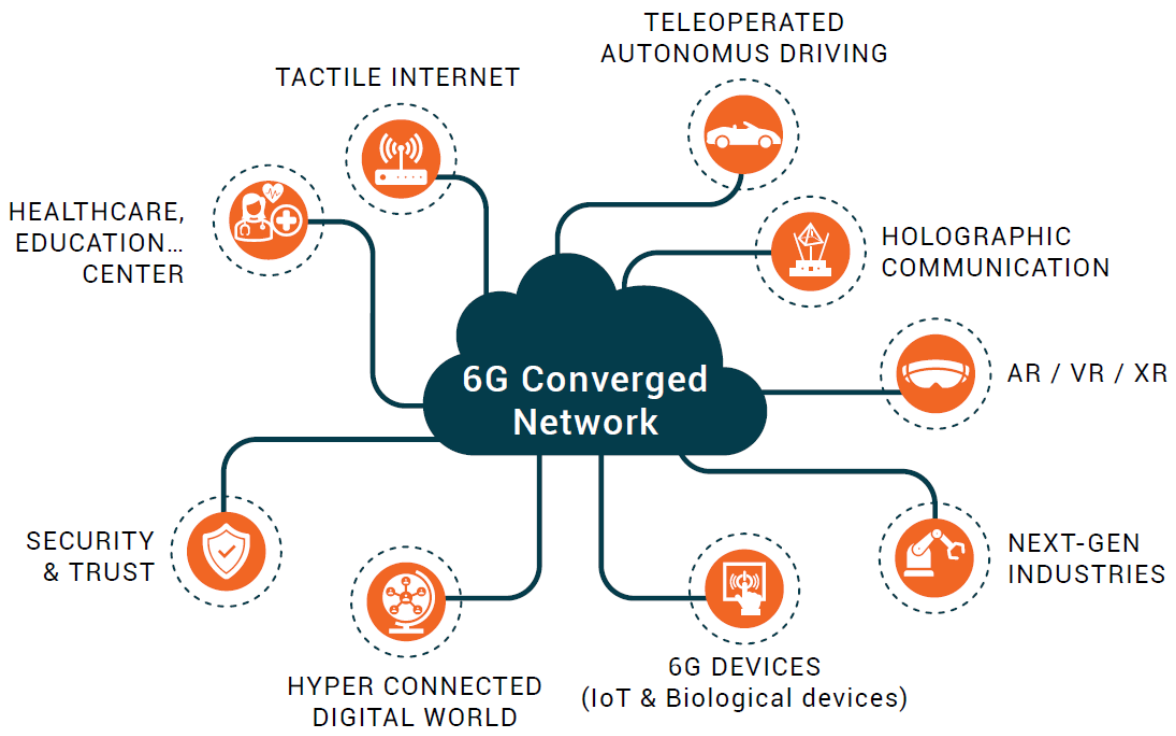

Figure 5: 6G Use cases

A digitalized and programmable world can deliver interactive 4D maps of whole cities that are precise in position and time and can be simultaneously accessed and modified by large numbers of humans and intelligent machines for detailed planning of activities. Such cyberphysical service platforms can issue commands to large-scale steerable systems, like

public transport, waste handling, or water and heating management systems, achieving higher levels of resource efficiency, better control, and increased resilience.

The advent of precision healthcare, enabled by miniature nodes measuring bodily functions and devices issuing medications and physical assistance, will be supported by a continuously analyzed digital representation online. Such a high integration of technology in people's lives emphasizes the importance of trustworthiness through availability, security, and data privacy. It also requires new types of devices that can be safely embedded virtually anywhere and that are maintenance-free, using efficient and distributed processing and management, and communicating securely in local body networks.

Real-time 4D maps are also needed to manage the intense traffic of future cities with autonomous vehicles on the ground and in the air. A network sensor fabric, where accurate measurements and world data are aggregated from sensing base stations and on-board vehicle sensors, and then shared together with trajectories, can be used to guide safe, clean, and efficient transport.

An automated society would harvest the benefits of AI assistance for improving people's welfare and simplifying their lives. For instance, collaborative AI partners could perform many challenging tasks involving manual labor more safely and efficiently, assisting in industries as well as in our homes, acting autonomously, and adapting to human action.

Such high-trust cyber-physical systems can smoothly interact with groups of humans and other intelligent machines, requiring extreme reliability and resilience, precise positioning and sensing, low-latency communication, and AI trust and integration. On the personal level, intelligent identity and preference handling will assist people in everyday life, managing interactions with and adapting the connected world around them in line with their preferences.

Building a sustainable world requires huge efforts throughout society, with networks ensuring digital inclusion on a global scale. This includes diverse elements, such as the support of smart automation services everywhere on the planet, connectivity for global sensors monitoring the statuses of forests and oceans, resource-efficient connected agriculture, access to digital personal healthcare for everyone, and access to high-end services for institutions such as schools and hospitals everywhere. Through the global, endtoend life-cycle tracking of goods, autonomous supply chains can accelerate a full circular resource economy. Digital-asset tracking can reduce waste and automatize recycling. Taken together, this requires truly global coverage with excellent energy-, material-, and costefficiency, embedded autonomous devices and sensors, and a network platform with high availability and security.

Potential 6G Use cases

Enhanced Human Communication

A few use cases belonging to Enhanced Human Communications are listed below:

XR Immersive Holographic Telepresence Communication

Holographic Communication is taking human communication to this next level: enabling immersive, real-time 3D experiences that can be built with consumer-grade mobile devices. With this holographic technology closely replicating face-to-face interaction, the work is opening a wide variety of applications in areas such as manufacturing, utilities, and education.

Creating more of an emotional connection is vital in remote forms of communication, and Holographic Communication will go a long way towards achieving this. It will overcome that sense of distance with friends and family in other countries and help sales and marketing teams understand and empathize with their customers more. When this happens, the possible benefits to industry and society are vast.

Human centric extended immersive and 3D reality (encompassing VR, MR and AR) and holographic telepresence may eventually become the norm for both work and social interaction. With this, it will be possible to make it appear as though one is in a certain location while really being in a different location – for example, appearing to be in the office while being in the car. We will have systems that combine current facial expressions with a virtual self within the digital representation of the physical world.
Merged reality telepresence experience and use case will be enabled by wearable devices, such as smart contact lenses or glasses and those embedded in our clothing; skin patches and bio-implants etc. We will have multiple wearables that we carry with us, and they will work seamlessly with each other, providing natural, intuitive interfaces. Touchscreen typing will likely become outdated and be replaced with more intuitive interfaces such as gesturing, talking, and eye tracing. The devices used will be fully context-aware, and the network will become increasingly sophisticated at predicting our needs. This context awareness combined with new human–machine interfaces will make our telepresence interaction much more intuitive and efficient.

Multimodal Communication for Teleoperation

Human Multimodality Information such as audio (hearing) and visual (sight) or a combination thereof (audio-visual) are transferred over communication networks. Yet interacting sense of touch (haptic) and particularly the kinaesthetic (muscular movement) component has much stricter end-to-end latency communication requirements for Human-In-The-Loop (HITL) interactions for teleoperation. Enabling

bi-directional haptic teleoperation is one of the key drivers behind 6G technology aiming to benefit from combining inputs from more than one sources and/or output to more than one destination for the multi-modal communication services to be perceived closer to reality.

Human Multimodality Information (i.e., audio, video, taste, odour, haptic and emotion) captures information from wearable terminals as well as inferential knowledge gained from ambient sensors and social sensory insights can provide complementary methods to enhance remote HITL communication and control. The sensing part of this technology is rooted in industrial sensor technology. The communication side of it comes from the evolution (and convergence) of wireless sensor networks and cellular communications technology, to complete this convergence because of its combination of extreme high availability, reliability, and ultra-low latency. With 6G, multimodal sensing and communication fusion will realise the transmission of synchronised multimodal information varying requirements for different modalities (e.g., bitrate, latency, reliability, security) across groups of distributed devices. This enhances delivering customised services that will enrich the user experience, using new sensors and new data modalities to support multimodal interaction and operation.

Intelligent Interaction & Sharing of Sensation, Skills & Thoughts

People will be able to interact with devices or control machines via brain-machine interfaces. With 6G, Brain-Computer Interfaces (BCIs) may realise the sharing of sensations and thoughts between human and machine, human and human, crossing a long distance and in real-time. People would feel to have sort of telekinesis, with their thoughts immediately realised without legacy human interaction in between. With 6G a new term seems to come into play which will be called Internet of Behaviour (IoB), where humans will include their individual characteristics into the information flow. With more and more systems being driven by AI technologies, the machine no longer passively waits for users to input. This brings fundamental changes to the Human-Computer Interface. Machines may sense what humans “do” and reason what humans “want”. For example, self-driving cars and personalized healthcare robots are emulating human behaviours. Machines are more focused on understanding and replicating the human mind and brain. Those machines are trying to perceive, recognize and think like humans, and human-machine interactions will evolve to equal human-like interactions with emotions and mutual understanding.

BCI systems are providing an alternative method of interaction between humans and the world. In the past, most BCIs focused on helping people with severe movement disability by replacing or restoring lost movements. Today, more and more BCIs are aiming as consumer products for all users. Certain functions of the human body can be replaced with machines manipulated by mind.

Enhanced Machine Communication

A few generic use cases belonging to this high-level class are proposed below:

Robot Network Fabric

The cities in 2030 are expected to be traversed by a high number of autonomous mobile robots, drones, automatic guided vehicles (AGV) for packet delivery and personal traffic. Key objectives will be to keep this traffic safe for people, collision-free, and efficient. Here, 6G networks can play a crucial role by enabling traffic management of connected robot vehicles in a central coordination of robot trajectories, taking into account an aggregated set of data containing other robots and unconnected objects. Negotiation of paths through stated intentions from robots can ensure collision avoidance. By collecting, processing, and distributing sensor data from all connected nodes in the network (robots, base stations, etc.) and dynamically mapping in high-precision in 3D, the robots can effectively see around corners and predict the future path, and do not need to carry so many onboard sensors but can rely on the larger network. This allows for smaller, less expensive, and lighter robots that can be used for new types of autonomous transport. Traffic can be made easy and safe for connected robots and humans navigating through the busy connected city.

Interacting Cobots

A much closer interaction is expected to develop between humans and robots, through the form of collaborative robots, cobots. These connected cobots should be able to reliably read and interpret human actions and intents and react in a trustworthy way, and thereby assist humans in an efficient and safe way. They should be able to work as colleagues on precise and challenging tasks in industries, with the help of digital twins to do the job of robots more efficient, or as care assistants in the homes of elders or disabled, doing the heavy work of humans. A cobot could be a separate machine taking commands or adapting to the situation presented, or closer to humans as an exoskeleton or adaptive wheelchair. Cobots could also form teams amongst each other, solving tasks together and collaborating with humans on group level. To unleash the highest potential and efficiency it should be possible for sets of cobots to jointly define the way they collaborate and even communicate, naturally under the control of the network.

Enabling Services

A few generic use cases belonging to this high-level class are proposed below:

3D Hyper-Accurate Positioning, Localization, and Tracking

High-accuracy 3D localisation and improved tracking capabilities at centimetre or better level, particularly in indoor environment, will open many new opportunities in future smart factories, warehouses, hospitals, and libraries to enable full automation especially for autonomously moving collaborative robots. For instance, the capabilities of future assistant robots will approach that of human in daily work and life. To adapt to human's living and working environment, high precision at centimetre level is needed such as to find and rotate door handle, pick up the right box/book from the shelf, and capture the right tool from the drawer. Another example in future libraries, where all books with positioned sticker (wireless module) can be randomly placed in shelves without sorting. Their positions will be automatically collected, and a 3D digital twin model can be established which contains precise locations of each book. A robotic librarian can fetch a book for a patron using positioning information.

High precision relative localisation is also much desired for autonomous systems that are becoming pervasive in smart manufacturing when two or more robots operate in collaboration. For instance, a drone may need to land on a moving carrier vehicle to get charged; a delivery robot may need to refill liquid or solid substance to a smart container (bin/tank) when it is detected as empty, etc. In such proximity use cases, centimetre-level relative localisation accuracy is required to perform the task.

Interactive Mapping

Digital twins are means to get an accurate and updated view of situations in a machine or a house. They form the basis of smart cities and digitalised factories. In the 2030s they have the potential to become ubiquitous tools and knowledge platforms in many sectors of society for learning, steering, analysis, and more purposes. By connecting a large set of digital twins of separate parts of a city a real-time representation of physical assets can form a continuous interactive map, i.e. a virtualised model of the physical world. This would enable efficient large-scale system management, for instance a municipality governing transport, heating, water, waste etc. Further it can enable real-time representation of the environment for surveillance, navigation, and other purposes. Large numbers of wireless sensors and actuators give accurate map information and perform actions when the map is updated. It becomes possible to plan future activity, and even to simulate future map status based on past events on which analysis can be made. The processing and analysis powers can be provided as a network service together with the links to the physical world which is constantly synchronized with the digital map.

Digital Healthcare

Health care will be substantially transformed into what we call digital healthcare, with 24/7 monitoring of vital parameters for both the healthy and the sick through numerous wearable devices. Health monitoring and medical research will also include in-body devices that communicate with on-body devices outside, which in turn can transport the data to the internet where a digital body double is analysed: 6G telemedical paradigm will be enabled by body sensing and analytics in conjunction with wide area connectivity. This will enable options of daily life support and supervision with special relevance of inclusion of for example the elderly. XR tooling in conjunction with haptic information, including surface, touch, actuation, motion, vibration and force, along with audio/visual information will allow medical staff an immersive experience while leveraging digital twin insight.

a. Remote Diagnostics

The role of 6G in remote monitoring and diagnostics cannot be overstated. With the integration of wearable devices and smart sensors, continuous health monitoring will become more precise and reliable. These devices will collect and transmit data in real-time, allowing for immediate analysis and intervention. Additionally, the use of AI and machine learning in conjunction with 6G will enable predictive analytics, identifying potential health issues before they become critical.

Therefore, body networks with connected medical sensors and actuators can contribute to help fix the shortcomings of today's healthcare system as regards closed-loop interactive remote monitoring and predictive therapy, i.e., enabling a paradigm of actuation, such as medicine dispensers and pacemakers. State-of-the-art consumer-grade wearables of today are IoT based. They provide basic personal health monitoring and reporting (temperature, pulse, glucose level, blood pressure).

Doctors will be able to diagnose patients remotely using holographic communication, which will reduce the financial and physical burden placed upon them by the medical system. For improved diagnosis, augmented reality and holographic communication can be integrated.

b. Remote Surgery

The concept involves surgeons performing operations from a distance using robotic arms and real-time video feeds. A Tele-Robotic surgical system consists of one or multiple arms managed remotely by a doctor, a master console and sensing system works in combination with the robotics communication technologies and the element of management information. The low latency and high reliability of 6G will address existing challenges such as delays and imprecisions, making remote surgery more feasible and safer.

Benefit to healthcare providers will be the increased accessibility to specialized care means that patients can receive expert consultations without the need for travel. This can lead to cost reductions and efficiency improvements within the healthcare system and for patients, it will enable the ability to access high-quality care from anywhere in the world improves health outcomes and satisfaction.

c. Advanced Medical Imaging and Diagnostics

The implementation of 6G technology in healthcare is set to revolutionize medical imaging and diagnostics, leveraging its high data transfer rates and low latency to enhance the speed, accuracy, and reliability of medical procedures. 6G networks will support the transmission of high-resolution images and videos with minimal delay, significantly improving the quality of medical imaging. This capability is crucial for procedures such as MRI and CT scans, where high-definition images are essential for accurate diagnosis and treatment planning. The enhanced data rates and bandwidth of 6G will allow for real-time image processing and analysis, providing immediate results to healthcare professionals. This will provide various benefits:

- Real time feedback: One of the primary benefits of 6G in medical imaging is the ability to provide real-time diagnostic feedback. The low latency of 6G networks ensures that data from imaging devices can be transmitted instantly to diagnostic tools and specialists, facilitating immediate interpretation and decision-making. This real-time capability is particularly beneficial in emergency situations, where rapid diagnosis can be life-saving.
- Integration with AI and Machine Learning: The advanced connectivity of 6G will enhance the integration of artificial intelligence (AI) and machine learning (ML) in medical diagnostics. AI algorithms can process large volumes of imaging data quickly, identifying patterns and anomalies that may be missed by the human eye. The seamless connection provided by 6G will enable continuous learning and updating of these algorithms, improving their accuracy and efficiency over time.
- Remote Imaging and Tele-Radiology: With 6G, remote imaging and tele-radiology will become more feasible and effective. High-speed data transfer will allow images taken in one location to be sent to specialists in another location for analysis. This capability will be particularly valuable in rural and underserved areas, where access to advanced imaging technology and specialist radiologists may be limited. Patients in these areas can receive high-quality diagnostic services without the need to travel long distances.
- Enhanced Collaborative Diagnostics: The enhanced connectivity of 6G will facilitate collaborative diagnostics, where multiple specialists can simultaneously view and analyze medical images from different locations.

This collaborative approach can lead to more accurate diagnoses and comprehensive treatment plans, as specialists can share insights and expertise in real-time. The use of augmented reality (AR) and virtual reality (VR) in conjunction with 6G can further enhance this collaboration, providing immersive and interactive diagnostic environments.

d. Wireless Brain Computer Interactions (BCI)

Brain–computer interactions are another form of haptic communication in which humans interact with their environment via haptics and control it using digital gadgets such as brain-embedded wireless chips that respond to human emotions. This will enable several healthcare scenarios in which humans use brain implants to operate prosthetic limbs or nearby computing devices or passing on information related to surroundings to the visually impaired patient.

e. Automatic Detection, Recognition and Inspection

Supported by the communication systems of the future, the 6G network may sense the environment. Advanced techniques will be used in security-screening procedures to eliminate security lines at airports, for instance. A combination of various sensing modalities may be used to screen people as they move through crowded areas rather than only at entrances. For example, it could be programmed to detect metallic objects of certain kinds that people may be carrying in a crowded controlled area automatically. The network can sense and identify potential threats.

In a smart hospital in the foreseeable future, device-free gesture and activity recognition enabled by 6G networked sensing and machine learning will enable functionalities such as gesture recognition, heartbeat detection, fall detection, respiration detection, sneeze sensing, intrusion detection, etc., providing automatic protection to the patients during their daily routines. For instance, the medical rehabilitation system could provide automatic supervision of patients during their physiotherapy exercises. Prompt alerts will be sent upon incorrect movements or gestures in an automatic way, thus significantly improving the capacity of medical rehabilitation.

In future intelligent factories, 6G will enable ultra-high resolution imaging monitory systems and remote operation platform systems. Intelligent factories will leverage these superior sensing solutions to implement contactless ultra-high precision detection, tracking, and quality control. It enables applications such as detection of slits or leakage on products or equipment using 6G communication networks and devices without the need to install extra infrastructures.

A variety of application scenarios may include eliminating security lines at airports, intelligent health care of gesture recognition, heartbeat detection, fall detection, respiration detection, sneeze sensing, and intrusion detection,

intelligent factories of contactless ultra-high precision detection, tracking, and quality control.

Education

a. Immersive Digital Experience Suite

VR and AR Content for Virtual Classrooms, Educational Programs, and Interactive Learning

6G technology will enable the development and deployment of high-quality Virtual Reality (VR) and Augmented Reality (AR) content, creating immersive educational experiences that enhance learning and engagement in both classroom and remote settings.

- Virtual Classrooms:
  - Immersive Learning Environments: 6G's high-speed, low-latency network will support fully immersive VR classrooms where students can interact with 3D models, simulations, and virtual environments as if they were physically present. For example, students could explore ancient civilizations, conduct virtual chemistry experiments, or participate in historical re-enactments.
  - Real-Time Interaction: Teachers and students can interact in real-time within a virtual classroom setting, allowing for collaborative learning experiences and dynamic teaching methods that are more engaging than traditional classroom settings.
- Educational Programs:
  - Interactive Lessons: AR content can overlay digital information onto the physical world, enhancing textbooks and other educational materials with interactive elements. For example, AR could bring historical events, scientific concepts, or mathematical problems to life through interactive visuals and simulations.
  - Enhanced Understanding: VR and AR can provide experiential learning opportunities that deepen understanding of complex subjects. For instance, VR can simulate ecological systems or medical procedures, offering students hands-on experience in a safe and controlled environment.
- Benefits:
  - Enhanced Engagement: Immersive technologies will make learning more engaging and interactive, which is especially beneficial in diverse and large classrooms where traditional methods may fall short.

- Access to Quality Education: Students in remote or underserved areas can access high-quality educational content and experiences that would otherwise be unavailable, bridging educational gaps.
- Support for Diverse Learning Styles: VR and AR cater to different learning styles (visual, kinesthetic, etc.), allowing for personalized learning experiences that can address the needs of various students.

b. Virtual Concierge Service

AI-Driven Assistance for Educational Resources and Support

6G technology will enable advanced AI-driven virtual concierge services to provide students, teachers, and educational institutions with real-time support, resources, and personalized assistance. This use case focuses on enhancing the accessibility and efficiency of educational support services.

- AI-Driven Assistance:
  - Personalized Learning Paths: AI can analyze student performance, preferences, and learning styles to recommend personalized study materials, resources, and learning paths. For example, it can suggest additional resources for a student struggling with a specific topic or provide advanced materials for those excelling.
  - 24/7 Support: Virtual concierges can offer round-the-clock support for students and teachers, answering questions, providing guidance, and troubleshooting issues related to learning platforms or resources.
- Resource Management:
  - Smart Resource Allocation: AI can assist educational institutions in managing and allocating resources more effectively, such as identifying which courses or materials are in high demand and ensuring they are available to students as needed.
  - Course Recommendations: Students can receive recommendations for courses, extracurricular activities, and career paths based on their interests, academic performance, and career goals.
- Interactive Learning Support:
  - Virtual Tutoring: AI-powered virtual tutors can provide additional support for students who need help with specific subjects or assignments, offering explanations, answering questions, and guiding them through problem-solving processes.

    - Teacher Assistance: Teachers can benefit from AI-driven insights and tools that help in grading, lesson planning, and identifying students who may need additional support.
- Benefits:
    - Accessibility: AI-driven concierge services will make educational support more accessible, particularly for students in remote or underserved areas who may not have immediate access to academic help.
    - Efficiency: By automating and personalizing support services, educational institutions can operate more efficiently, reducing administrative burdens and enhancing the learning experience.
    - Customized Learning: Students and educators can benefit from tailored recommendations and support, leading to more effective and individualized educational experiences.

Smart Industry

The “Smart industry” takes care, not only of the production process but also, of the whole business process, while paying attention to the carbon footprint reduction, the resource circularity, and a recent trend on reduction of employees’ daily commute and of physical transportation that an environmental consciousness and concerns with COVID-19 set recently.

For manufacturing, the business practice consists of production process research, product research, product design, prototyping, production, shipping, warehousing, and delivery. The “Smart industry” that the mobile communication offers supports all those steps, where the entire process constitutes an overall closed loop, while each step forms its own closed loop, between the physical and the digital worlds. It is this end-to-end smart loop, among others, that further evolves, and has potential opportunity for differentiated opportunities in 6G usage scenarios, including some highlighted in other sections. This is to be further explored.

Production process research and product research: The interactive mapping, introduced earlier, is the enabler of the big, closed loop and allows analysis of real-time dynamics for industrial production, storage and sales. The interactive mapping gives feedback to the research process so that it can develop new scenarios for future products and even a new business process. This then decreases time-to-market, increases cost efficiency, and effectively protects the maximum benefit of production.

Product design and prototyping: Mixed reality co-design and the advanced manufacturing concept is the enabler to design, create, test and build equipment in a virtual environment or in a virtual-real fusion of worlds. Only when that equipment performs to exact specifications in such environment,

will the physical manufacturing be allowed to start. This then allows remote collaboration. Production intelligent robots with recognition capability and backed by a trusted data platform becomes the main force of agile manufacturing, leading to more self-driven, intelligent manufacturing. Such robots complete even difficult, dangerous tasks.

Motion control is the core logic of automation process, and responsible for controlling, moving, and/or rotating the machine's parts in a well-defined manner. It is supported by the integrated sensing and communication with hyper-high accuracy synchronization and scheduling, hyper-low latency, and hyper-high reliability both in communication and node processing. These then enable a higher-quality product and a highly efficient production process at any time and place.

Shipping, warehousing, and delivery: Products are equipped with biodegradable tiny tags, enabling identification and positioning by the cellular system. Tagged items are posted in a map. The use of tags can help to enable resource circularity and reduce material consumption. Cargo-carrying drones, AGVs, and intelligent robots increase efficiency. •

Benefits:

o Increased Productivity: Automation and real-time monitoring will boost manufacturing productivity, making Indian factories more competitive on a global scale.

o Quality Improvement: Continuous monitoring and precise automation will enhance product quality and consistency.

o Cost Efficiency: Reduced downtime, optimized production schedules, and lower labor costs will result in significant cost savings.

Retail

a. Immersive Shopping Experience

- AR-Powered Virtual Try-Ons and Personalized Shopping Experiences:
  6G technology will enable highly interactive and immersive shopping experiences through Augmented Reality (AR). This includes virtual try-ons and personalized shopping experiences that bridge the gap between physical and online retail environments.
  - Virtual Fitting Rooms: AR technology will allow customers to try on clothing, accessories, or makeup virtually using their smartphones or AR glasses. For example, customers can see how a piece of clothing looks on their body or how a pair of glasses fits their face without physically trying them on.
  - Real-Time Visualization: High-resolution AR enabled by 6G will provide realistic and detailed visualizations of products, allowing customers to see how items will look in different colors, sizes, or styles in real-time.

        - Customization: Customers can personalize products (e.g., choosing different fabric patterns, colors, or sizes) and see instant visualizations of their customizations before making a purchase.
    - Personalized Shopping Experiences:
        - Tailored Recommendations: Using AI and 6G's high-speed data processing, retailers can analyze customer preferences, purchase history, and browsing behavior to provide personalized product recommendations and promotions.
        - Interactive Store Navigation: AR can assist customers in navigating large stores or malls by providing interactive maps and location-based product suggestions. For example, AR navigation can guide a customer to the exact location of a product within a store.
        - Enhanced Engagement: Interactive AR experiences, such as virtual product demonstrations or gamified shopping experiences, can engage customers more deeply and encourage longer in-store or online browsing.
    - Benefits:
        - Enhanced Customer Experience: Virtual try-ons and personalized experiences will make shopping more engaging and convenient, potentially reducing return rates and increasing customer satisfaction.
        - Broader Reach: AR technology can help bridge the gap for customers who may not have easy access to physical stores, making high-quality shopping experiences more accessible.
        - Increased Sales: Personalized recommendations and interactive experiences can drive higher conversion rates and sales by catering to individual customer preferences and enhancing their shopping journey.

Virtual Tourism

The virtual tourism space situations that integrate realistic visual, audio, and temperature sensations can restore the real tourism environment to the greatest extent, and improve tourists' perception and satisfaction with the experience. By dynamically presenting the real or non-existent touristic landscape to tourists through the Internet, virtual tourism allows tourists to have an immersive travel experience without leaving home. Other such examples can be Deep-Sea Sightseeing, space exploration, tour of Taj Mahal on full moon night etc.

Internet of Bio-Nano-Things

6G will support the development of the internet of bio-nano-things, allowing for the communication and control of biological and nanotechnology systems. This will enable new applications in precision medicine, environmental monitoring, and scientific research. Deploying "zero energy devices" will remove existing use case limitations associated with battery replacement or charging requirements. They identify both wide-area and local-area scenarios as suitable use cases. Wide area includes logistics and warehousing, environmental monitoring, smart agriculture, railroad operation and maintenance, powerline inspection, and industrial IoT; while local area includes smart home, wearable devices, low power health monitoring, and implantable medical.

Logistics & Warehousing

Logistics and warehousing form the backbone of supply chain management, ensuring the smooth movement and storage of goods from manufacturers to consumers. This vital sector faces numerous challenges, ranging from increasing customer demands and globalization to environmental concerns. However, the industry has experienced significant advancements through the integration of emerging technologies, leading to improved operational efficiency and enhanced customer satisfaction.

6G technology will support advanced IoT solutions for smart inventory management, enabling real-time tracking of stock levels and automating restocking processes. This will optimize inventory management, reduce out-of-stock situations, and improve operational efficiency.

- Real-Time Stock Tracking:
  - IoT Sensors: IoT sensors and RFID tags will track inventory levels in real-time, providing up-to-the-minute information on stock quantities and locations. For example, sensors on shelves can monitor the number of items remaining and send this data to the inventory management system.
  - Automated Updates: 6G's low-latency network will ensure that inventory data is updated instantaneously, allowing for accurate tracking and management of stock across multiple locations.
- Automated Restocking Solutions:
  - Predictive Analytics: AI and 6G will enable predictive analytics to forecast demand based on historical sales data, trends, and seasonal variations. This will help in predicting when and how much stock needs to be reordered.
  - Automated Ordering: The system can automatically generate and place orders with suppliers based on real-time inventory data and

predictive analytics. For instance, when stock levels fall below a predefined threshold, the system can trigger an automatic reorder to ensure shelves are always stocked.
    - Dynamic Replenishment: Automated restocking solutions will adjust orders dynamically based on current sales trends, promotional activities, and other factors, ensuring optimal inventory levels and reducing excess stock.
- Benefits:
    - Improved Efficiency: Real-time tracking and automated restocking will streamline inventory management processes, reducing manual effort and operational costs.
    - Reduced Stockouts and Overstocks: Accurate stock data and predictive analytics will minimize stockouts (running out of items) and overstocks (excess inventory), leading to better customer satisfaction and optimized inventory levels.
    - Enhanced Customer Experience: Reliable stock levels and timely restocking will ensure that customers can find the products they want, enhancing their shopping experience and increasing loyalty.

Agriculture

a. Smart Agriculture Solutions

IoT-Based Monitoring of Crop Health and Automated Farming Practices:
6G technology will enable advanced IoT-based solutions for monitoring crop health and automating farming practices. This use case focuses on using real-time data and automation to enhance agricultural productivity and sustainability.

- IoT-Based Crop Health Monitoring:
    - Sensor Networks: IoT sensors deployed in fields can monitor various environmental and crop health parameters such as soil moisture, temperature, humidity, light levels, and nutrient content. For example, soil sensors can measure moisture levels to determine the optimal irrigation needs.
    - Real-Time Data Transmission: 6G's high-speed, low-latency network will ensure that data from these sensors is transmitted in real-time to farmers or central management systems. This allows for immediate analysis and decision-making.
    - Health Analytics: AI algorithms can analyze data from IoT sensors to assess crop health, detect early signs of diseases or pests, and provide actionable insights. For instance, if sensors detect a sudden drop in soil moisture, the system can alert the farmer to initiate irrigation.
- Automated Farming Practices:

- Precision Irrigation: Automated irrigation systems can use data from soil moisture sensors to deliver precise amounts of water to crops, optimizing water usage and reducing waste. For example, a smart irrigation system can automatically adjust water levels based on real-time soil conditions.
- Drones and Robotics: Drones and robotic systems can perform tasks such as planting seeds, applying fertilizers or pesticides, and monitoring crop health. 6G's low latency enables these systems to operate with high precision and coordination.
- Data-Driven Decisions: Automated systems can integrate data from multiple sources (e.g., weather forecasts, soil conditions) to optimize farming practices, such as adjusting planting schedules or fertilizer application rates.

Benefits:

- Increased Productivity: Real-time monitoring and automation will help optimize farming practices, leading to higher crop yields and more efficient use of resources.
- To create an intelligent predictive system using IoT and AI/ML approaches to anticipate yield, irrigation schedule, pesticide schedule, and crop health information.
- Resource Efficiency: Precision irrigation and targeted application of inputs (e.g., water, fertilizers) will reduce waste and environmental impact, promoting sustainable agriculture.
- Enhanced Crop Management: Early detection of issues and data-driven decision-making will improve crop management, reducing losses and improving overall farm profitability.

b. Predictive Maintenance for Farm Equipment

6G technology will enhance predictive maintenance capabilities for agricultural machinery through advanced IoT sensors and real-time data analytics. This use case focuses on improving equipment reliability and reducing downtime through early diagnostics and maintenance alerts.

- IoT Sensors for Equipment Monitoring:
  - Continuous Monitoring: IoT sensors installed on agricultural machinery (e.g., tractors, combines) can continuously monitor parameters such as engine performance, vibration levels, fuel usage, and operational hours. For example, sensors can track engine temperature and detect anomalies that may indicate potential issues.
  - Real-Time Data Transmission: 6G's low-latency network will enable real-time transmission of data from these sensors to

maintenance management systems, allowing for immediate analysis and action.

- Predictive Diagnostics:
  - Data Analysis: AI-powered analytics will process sensor data to identify patterns and predict potential equipment failures before they occur. For instance, if sensors detect increased vibration levels in a tractor, the system can analyze historical data to forecast possible mechanical issues.
  - Maintenance Scheduling: Predictive maintenance systems can recommend or schedule maintenance activities based on the condition of the equipment rather than on a fixed schedule. This approach ensures that maintenance is performed only when needed, reducing unnecessary downtime and extending equipment life.
- Real-Time Maintenance Alerts:
  - Immediate Notifications: 6G technology will facilitate instant alerts to farmers or maintenance teams when potential equipment issues are detected. For example, if a sensor detects an abnormal condition, an alert can be sent via SMS, email, or a mobile app.
  - Automated Responses: In some cases, automated systems can trigger maintenance actions, such as shutting down equipment to prevent further damage or initiating diagnostic procedures remotely.
- Benefits in India:
  - Reduced Downtime: Predictive maintenance will minimize unexpected equipment failures and downtime, ensuring that machinery is always in optimal working condition.
  - Cost Savings: Early detection of potential issues and optimized maintenance schedules will reduce repair costs and extend the lifespan of agricultural machinery.
  - Operational Efficiency: Improved equipment reliability and timely maintenance will enhance overall farm operations, leading to increased efficiency and productivity.

Transportation

a) Tele-Operated Driving

Tele-operated driving (ToD) refers to a remote driver taking control of the vehicle (human driven or automated) and driving it efficiently and safely from the current location to the destination. Being able to remotely drive a vehicle requires the availability of wireless links between the vehicle and the ToD server. Apart from availability of the wireless networks, the networks might

need to further fulfil certain Quality-of-Service (QoS) metrics on the available wireless links. Since a request to take control or assist a vehicle to drive can originate at time and from anywhere, availability of continuous wireless network coverage along the trajectory of the tele-operated vehicle is crucial. With the current deployment of mobile communication networks, there exists coverage and capacity gaps, for reasons such as, due to low demand. Such gaps and unknown availability of mobile networks can hinder the operation of ToD. Examples of scenarios where a vehicle could encounter mobile network coverage gaps include, among others, travelling from coverage of one base station to another, travelling from coverage of one PLMN to another, while crossing national border, traveling from urban to rural areas.

The wireless networks shall allow service continuity despite mobility of the vehicles. The wireless networks and the vehicle shall be capable of switching their communication links to the application provider to ensure service availability. From KPI perspective, the wireless links, via mobile network operators or satellite operators need to fulfil certain metrics such as: Latency, Throughput, Reliability, Service availability.

b) Integrated sensing and communication for V2V communication

The goal of this use case is to enable an automated vehicle to maintain a direct communication link with a desired vehicle in its vicinity. Since vehicular networks are inherently dynamic in nature, maintaining such a direct communication link requires up-to-date knowledge of the surrounding environment at all times. Today's vehicular networks largely rely on periodic broadcasts of awareness messages from other vehicles in order to perceive the environment. Additionally, certain vehicle manufacturers offer proprietary services to share sensor information with other vehicles provided they belong to the same manufacturer. Considering that the vehicular environment comprises of objects with diverse communication capabilities and possibly uncertain network coverage, being aware of surrounding objects at all times may not be possible by purely relying on message exchanges. Sensing the environment and detecting different kinds of objects in the vicinity, despite the diverse vehicular communication scenarios, may enable an automated vehicle to become aware of its environment. Based on such environment perception, an automated vehicle could efficiently adapt in order to maintain the direct communication link with the desired vehicle by triggering appropriate mechanisms (such as transmit power control and beam alignment).

From service point of view, the requirements are as follows:

- It should be possible for vehicles to precisely detect other vehicles in the vicinity.
- It should be possible for vehicles to instantaneously communicate and coordinate their behaviour based on changes in the environment.

From performance metrics point of view, the requirements are as follows:

• Communication requirements:

- Latency
- Throughput
- Reliability

• Detection/Sensing requirements:

- Range resolution: If range resolution is ‘x’ (m), this means that the sensing system should distinguish between elements that are ‘x’ (m) apart.
- Velocity resolution: If velocity resolution is ‘x’ (m/s), this means that the sensing system should distinguish between elements with velocity difference of ‘x’ (m/s).
- Maximum range: Maximum detection range (or distance) of the sensing system.
- Maximum and minimum velocity: The sensing system needs to be able to detect elements moving with a certain maximum and minimum velocity.

Network APIs

Network APIs (Application Programming Interfaces) allow developers to easily access advanced 6G network capabilities such as differentiated connectivity, location, security/authentication and network insights to enhance existing applications to provide services to their customers. These standardized programming interfaces enable applications and mobile networks to communicate with each other, offering service providers new ways to monetize the network through performance-based business models. These APIs will help unlock the power of the network via global open APIs will enable developer communities to innovate new applications and features for any device and service that benefits from network connectivity.

Network as a sensor

6G will give our networks the ability to sense. By bouncing signals off objects, the network will determine what’s there, how things are moving – and

potentially even what they're made of. The network becomes our sixth sense, extending our awareness beyond our immediate surroundings.

These future sensing capabilities could be used to enhance the performance of the network itself by providing optimization input for network steering. For example, the sensing would be able to detect objects that (temporarily) obstruct the direct propagation path between a transmission node and a device. This input would be very useful for rapid beam steering, such that the network could instead utilize another, reflected beam or switch to a different transmission point for communication with this device.

A traffic monitoring scenario is a concrete use case for future sensing, where not only the positioning capabilities would be valuable, but also the ability to measure the speed of objects. Other possible use cases are Obstacle detection on Railways/Highways, Health Monitoring, Local Pollution, Rain Detection etc.

(Nokia)

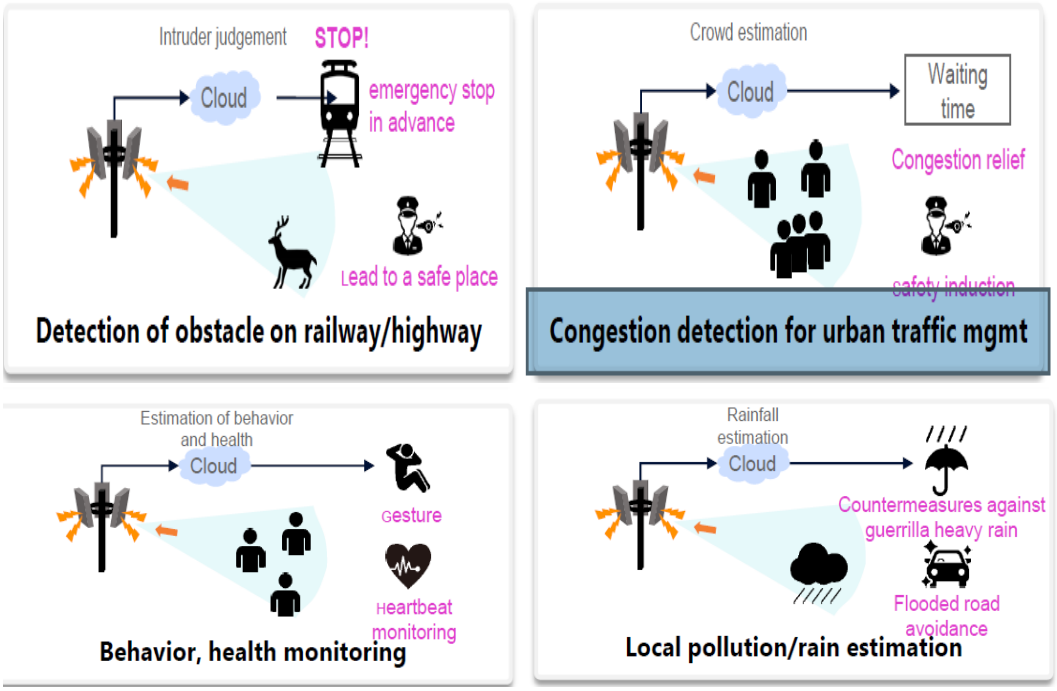

Figure 6: Network as a Sensor Use cases

6G Network generated insights on population movements, aggregation, speed and preferred routes can then be monetized by offering them to various industries, such as urban planning, tourism, and public transportation. A few potential scenarios are as under:

- A metro planning authority would leverage data to know how many people take which specific routes at different times of the day, to plan urban infrastructure.
- A shopping mall can gain insights would like to know the originating points of its footfalls for different days of the week
- A quick-commerce (delivery) company can use data to know which routes are least congested at what time of the day
- An emergency response team in a large event like Kumbh Mela can utilize data to determine best points for deploying manpower and resources

Beyond these direct applications, the recipient industries can further enhance the value of this data by feeding it to machine learning models to identify patterns, forecast trends and provide actionable predictions, opening even more revenue opportunities.

a) Monitoring of crossings on Railroads

Railroad operators currently use cable-based communications for their cross levels. Here, sensors placed in the railroad tracks a few kilometers away from the cross level need to communicate with actuators therein, activating alarm lights and lowering or raising the barrier that prevents cars and people from crossing the railroad when a train approaches. Additionally, railroad operators are interested in receiving data about the wellbeing of the sensors and actuators, or even video surveillance existing at the cross-level passage. This mix of traffic with different requirement, along with the geographical dispersion of available assets, make mobile communications an attractive paradigm since the deployment of cable-based communications is very expensive. 5G networks have started to be explored for these cases. However, the required security, isolation and reliability required in such cases places extreme requirements over network slicing mechanisms (particularly the certification in communications involved in this sector, due to the impact in equipment and human lives in case anything goes wrong), so further network slicing needs to be researched.

b) Livestock Health and Behavior Monitoring

In agribusiness, improving animals' health and life conditions are important factors for guaranteeing quality and production. Open field grazing is one of the strategies employed in several countries to attain such an end. The challenge, in

this case, is to keep track of the health and social behavior of all animals---reaching the order of tens of thousands in some properties---while preventing fast-spreading diseases (foot-and-mouth disease) that, in the event of an outbreak, may substantially impact the economy of an entire country. Sensors capable of measuring biological data, i.e., temperature, motion, and position, can be used to monitor vital information of every animal while assuring higher productivity. These sensors must have low energy consumption, which hinders the transmission over very long distances. Self-sustainable data collector gateways can provide communication between sensors and the server. Based on the animal's health condition (high temperatures) and social behavior (laying down longer than expected or not visiting drinking areas), alarms can be triggered to allow a fast and adequate treatment. Moreover, the sensors can also be employed as a security system by setting up alarms whenever a sensor is removed, or an animal leaves a predefined area.

The implementation of this use case will demand a long-range communication system (reaching at least 50 km) or a satellite-integrated network.

Defence and Security

The Convergence of Defence and Telecommunications is all about the growing interplay between defence and telecommunications. The integration of the defence sector is becoming more embedded today where national security relies heavily on secure and resilient communication networks. It is essential to integrate TN (Terrestrial Networks) and NTN (Non-Terrestrial Networks) seamlessly to realize a robust 3D network. This convergence of defence and telecommunications underscores the need for robust and secure communication protocols to safeguard critical infrastructure.

6G benefits will go beyond data transmission speed. Better internet access, high transmission rates, low delay and broad bandwidth assisted with a vast network of sensors, robots and autonomous vehicles connected through sophisticated artificial intelligence, which could be the future of faster, deadlier, and may be partial autonomous warfare. would deliver military advances such as: -

- **Battlefield Surveillance**

With the integration of sensors, drones, and satellites, an unmanned surveillance grid mapping every inch of the border (high-accuracy localisation) will improve operational efficiency by delivering real-time inputs to commanders in field formations. 6G would give operators greater control over the unmanned military machines that would play a lead role in future. Especially in drone technology,

and medical sciences, the role of critical networks from the advancements brought about by 6G will radically transform. 6G would help in the development of cutting-edge AI systems that can crunch through vast amounts of data which military receives through multitude of sensors and sources for its operations. It will enable real-time analytics, provide commanders solutions or courses of action based on the influx of data the military receives, cut latency, and cull out most suitable data to enable an effective kinetic response.

- **Digital Twin of Battlefield**

  The digital twin can be used to imitate the real-time dynamic interplay between the virtual and actual battlefields to give an automated flow of information in operations. The 6G superiority will change the battlefield management system, and future infantry soldier as a system, allowing people to network with their position their weapons with their capabilities. On such a quantum of network capacity, it has the potential to redefine the armed forces as the next-generation smart forces.

- **Delivering precise logistical support and rescue operation**

  Superior positioning and sensing capabilities of 6G will help deliver precise logistic support to the defence personals in the battlefield and carry out the rescue operations for injured soldiers and save crucial lives. A robot should be able to “search for a wounded soldier left on the battlefield”.

Healthcare

6G will enable hospitals to access patients on demand and in an emergency. Future ambulances will be fully AI-enabled and connected to the infrastructure. As a result, Hospital-to-Home (H2H) will be implemented as a mobile hospital on an intelligent vehicle platform with little reliance on hospitals, including doctors and nurses. Intelligent Wearable Devices (IWD) connected to the Internet will send psychological and physiological data (such as heartbeat, blood pressure, blood tests, health conditions, body weight, and nutrition) to testing and monitoring centers.

Remote Area Coverage with NTN

Mining is done mostly in remote areas where connectivity can be provided cost effectively using non-terrestrial satellite link. Providing seamless communication for the surveillance and safety of miners is a big problem. Existing solutions have many challenges including deployment cost, transportation cost during movement of adhoc networks system in remote areas, reliability and latency

issues specially with video transmission. Another challenge is to setup network for individual mining areas. 6G enabled satellite based non-terrestrial system complements the terrestrial networks can address above challenges and to provide seamless connectivity for mining application. NTN can provide a global coverage and connectivity with reduce deployment costs.

6G network is expected to support large number of handheld multimedia devices/wearable sensors with the ability to intercommunicate with each other in application scenarios using VR/ AR games or video streaming that will require low response times. While the 5G is handling the communication between machines very well, however 6G will be involving interactive communication between humans and machines which is the upcoming concept of Tactile Internet with Human-in-the-Loop (TaHiL). In this scenario, the communication would be between a Controlled domain, machines, and Master domain, Human beings, thus involving a feedback loop. Other similar use cases which can use complementary coverage from NTN are:

- Offshore oil drilling points
- Large distance tunneling work
- Remote army camps
- Hill stations villages and mountains
- Remote Islands in Lakshadweep
- Coverage in LWE impacted areas
- Army troops on inter-continental mission
- Deep sea communication
- Inflight Communications

Role of Govt & Regulators

6G initiatives offer a good framework for governments to consider the long-term goals for their national infrastructure. It should embrace digital and communications infrastructures and a future converge, fixed mobile world, in which mobility will always be an important component.

Governments need to engage with industry from the outset to shape the right conditions to sustain long-term research and, eventually, new investments in upgrading national infrastructures.

The competitive market and industry will inevitably look vastly different 10 to 15 years from now. The most impactful benefit of 6G to consumers, and national economies, will come from regulation and 6G technology innovation developing in sync.

A high ambition should be set for 6G, inspired by societal challenges such as sustainable economic growth, pandemics and climate change. To this end, 6G needs an adequate pre-standardization research phase.

6G should be the catalyst to bring everything that needs to be modernized at the same time. The principle justification for inclusion should be the need to sustain interoperability or secure global scale economies through a coordinated introduction of common standards.

The research phase of 6G needs to be guided towards building a consensus on the most promising lines of research. This is to secure scale while keeping the door open for 'left field' breakthrough discoveries. A promising candidate is the Internet of Senses; arising from the fusion of the physical, digital and non-physical worlds. The research phase should be viewed as a competition of ideas with the standards body pulling the best ideas into standardisation.

6G should be planned and implemented as a rolling programme of improvements well into the late 2030s to smooth out the investment profile.

Regulatory framework for 6G

The most successful periods for the mobile industry have been when regulatory changes were in sync with technology changes. This should be the objective for 6G, some longer-term regulatory issues can be identified.

- The future mix of mobile network operator investment, investment by other economic actors such as ecosystem players etc and public subsidy in future wireless infrastructure is likely to benefit from a re-optimised regulatory framework.
- Net neutrality has been good in driving an explosive growth of video streaming over broadband wireless networks, however the same can be explored to replace it with regulated neutrality, which shares cost benefits more equally in the 6G era.
- If a 6G initiative is to connect with the global challenges we face, governments and regulators must engage with industry from the outset to shape regulatory changes that will support the desired 6G technology outcomes
- Promote wearables /sensors ecosystem development in the country under "Atmanirbhar Bharat" schemes.
- Spectrum is critical to enable the 6G usecases and specific recommendations are captured in the Spectrum task group report.

Appendix

a) Members

S.No	Name of Member	Designation	Organisation	Role
1	Mr. Rajesh Singh	EVP - NW Planning and Strategy	Vodafone Idea	Chair
2	Mr. Sandeep Sharma	VP	Tech Mahindra	Vice Chair
3	Prof. Rohit Budhiraja	Professor	IIT Kanpur	Vice Chair
4	Prof Himanshu Tyagi	Professor	IISc, Bengaluru	Member
5	Dr. Jagannath Malik	Professor	IIT Patna	Member
6	Dr. Brajesh Mishra	DDG	DoT	Member
7	Mr. Mombasawala Mohmedsaeed	Chief Technology Officer	Keysight Technologies India Pvt Ltd	Member
8	Mr. Vinosh James	Director, Technical Standards	Qualcomm	Member
9	Mr. Kumar Satyam	CEO	CEQU Labs	Member
10	Mr. Abhay Tripathi	VP - Strategy & Standards	Vodafone Idea Limited	Member
11	Mr. Abhijeet Abhimanyu Masal	Lead Research Engineer	CeWiT	Member
12	Sonali Garg	Senior Manager	HFCL Limited	Member
13	Mr. Prakash R	Scientist	C-DOT	Member
14	Mr. Rahul Joshi	AVP & Lead - Network Analytics & Automation	Reliance Jio	Member
15	Mr. Naveen Thaduri	ADG	DoT	Member
16	Sh. Avneesh Kumar	AWA	WPC, DoT	Member
17	Mr. Sidharth Shukla	GM- Network Mobility	Bharti Airtel Limited	Member
18	SAGARIKA KHATUA	CEO	SMPS Electric Control Pvt. Ltd.	Member
19	Mr. Dileep Lakhera	SM- Network Mobility	Bharti Airtel Limited	Member
20	Mr. Nishant Gupta	Staff Engineer, Technical Standards	Qualcomm	Member
21	Mr. Ravi Lakhotia	GM, NW Planning & Strategy	Vodafone Idea	Member
22	Om Prakash Mishra	Dy. General Manager	TCIL	Member
23	Mr. Ram Babu	Director	DoT	Member
24	Gaurav Saini	Associate Vice President	Amantya Technologies	Member
25	Chanchal Pathak	Joint General Manager	TCIL	Member
26	Ms. Pamela Kumar	Chief Strategy Advisor	IISc, Bengaluru	Member
27	Velmurugan P G S	Associate Professor	Thiagarajar College of Engineering, Madurai	Member

Editorial Board

Mr. Rajesh Kumar Pathak, Bharat 6G Alliance
Dr. Astha Sharma, Bharat 6G Alliance
Ms. Swapnil Tripathi, Bharat 6G Alliance

b) Terms of References (ToR)

Terms of Reference for the B6GA 6G Use Cases and Revenue Stream Working Group

1. Background

6G will further revolutionize the way we interact with technology with all the new usage scenarios like Integrated Sensing and communication, Artificial Intelligence and Communication etc. To harness its true potential of 6G Usage Scenarios, monetisation is crucial. The B6GA 6G Use Cases and Revenue Stream Working Group is established to

- Built recommendations to identify new use cases and their revenue generating potential for 6G Technology
- Ensure B6GA recommendations on 6G use cases and Revenue stream meet the economic and technological requirements/expectations and have *maximum impact for Indian people & Industry and leverage digital technology*

2. Objectives

- Identify new use cases which uses 6G technologies and other evolving technologies which can be combined to provide new use cases to B2C and B2B customers; and
- Suggest possible monetization options for each of the use cases identified by this WG and applications suggested by the applications WG to improve the overall health of the telecom industry.

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.
- Identify potential use cases of relevance to India in various sectors such as healthcare, agriculture, defence, disaster management, transportation, education, metaverse etc.
- Developing and reviewing materials, such as reports, proposals, technical and revenue potential analysis.
- Liaising with their respective organizations and working groups to ensure alignment and gather additional input.

5. Meetings

The working group will meet *<fortnightly/monthly>*, with additional meetings scheduled as required. Meetings may be held in person or via teleconference, depending on circumstances.

6. Reporting and Output

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

- A comprehensive report on new 6G use cases and potential revenue streams and strategies for the identified use cases.
- Regular updates on the group's progress to stakeholders.

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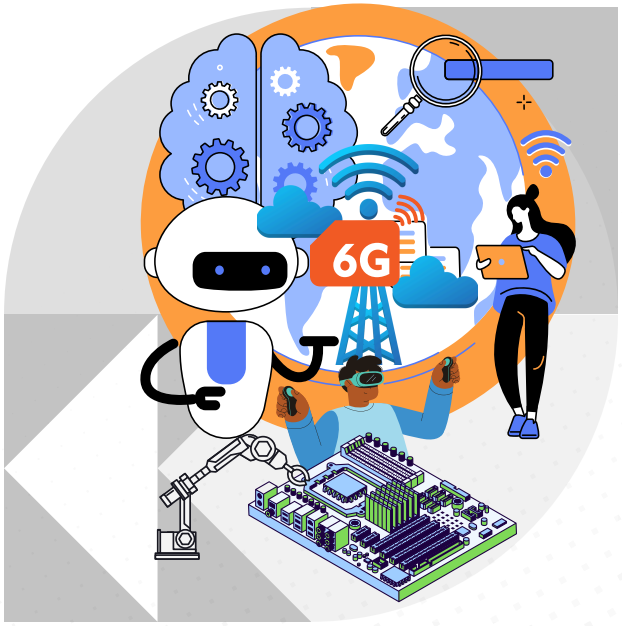

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