Bharat 6G VISION

Taskforce Report
Multi-Disciplinary Innovative Solutions

सत्यमेव जयते

Government of India
Ministry of Communications
Department of Telecommunications
March 2023

6G Taskforce Report: Multi-Disciplinary Innovative Solutions

Chairperson: Prof. Bharadwaj Amrutur
Member Secretary: Shri. Kishore Babu

Executive Summary

6G is expected to push the boundaries of communication technology by ushering in bandwidths of 1Tbps which will be 100x that of 5G. With latencies of less than a millisecond, it can potentially revolutionise the way people interact with other humans, machines, and data. 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.

We will have to evolve a road map to explore various use cases to discover the full potential of 6G as well as inform the 6G technology and standards development to ensure that they meet the needs of future use cases. We can broadly classify the use cases for 6G under these four categories, as described by Next G Alliance of North America:

- **Living**: Use cases that improve the quality of everyday living, especially in the context of an aging population, and support them in everyday activities. Geriatric care via telepresence and remote nursing, assistive and rehabilitation care to patients, etc.
- **Experience**: Use cases that enhance the quality of experience in areas like entertainment, healthcare, and education, by utilizing the significant advances in bandwidth and latency and incorporating new interfaces such as touch. 6G can be expected to change the way stories are told, training delivered, ailments are diagnostics and health care provided, and more generally, the way experiences are delivered and shared.
- **Critical**: Use cases that improve the quality of critical services in sectors like health care, manufacturing, agriculture, transportation, public safety, disaster response, defence, etc. We expect humans and robots will work together in many sectors. 6G capabilities of high bandwidth, low latencies, differentiated service levels, inherent sensing capabilities, and attention to security and reliability of the communication technologies will become necessary and key features to build very reliable critical services.
- **Societal**: Use cases that improve and attain high level societal goals like sustainability and equitable development. Equitable access to communication, ubiquitous coverage and green technologies will be key foundational pillars for sustainable and just societal development, without compromising the environment. In addition, security and privacy will be key pillars to be considered from ground up in the technology specifications, to ensure trust in the system.

Identification of marquee use cases from various sectors and forming a consortium of partners who can bring to bear an interdisciplinary approach, will help further our understanding of the needs of 6G as well as guide its further development in a holistic manner. These use cases can be identified keeping various considerations in mind and especially evolving from ongoing or planned work for 5G,

We recommend setting up of a 9-year national mission for 6G, with a clear goal of creating some minimum indigenous IP which becomes part of the 6G standards and leads to creation of commercial products made in India by 2030. It should have reasonable funding allocation with freedom to foster public-private collaboration partnership, with funds disbursement and mission objectives accomplished over three phases:
Phase I (Years 1-4): Setup horizontal centres of excellence focusing on new breakthrough technologies, that can lead to creation of new IPs, with a view to make them a basis for

standardization and eventual commercialization. Simultaneously, vertical centres of excellence (or field labs) should be setup to focus on implementing use cases at a reasonable scale, beyond that of a pure research laboratory. These can start with using 5G technologies and should focus on identifying and measuring KPIs for each use case. We recommend the government to largely fund this phase (through the mission), with amounts in the range of 8k-16k Crores (USD 1-2Billion).

Phase II (Years 4-6):, The horizontal centres should focus on translation of lab scale technologies to pilot scale validation and field trials in the various vertical use case Labs. This will also lead to participation and contribution to international and national standards. The vertical centres (use case labs) should keep upgrading their installations to keep pace with advances in 5G and eventually transition to testing early versions of 6G being developed in horizontal centres. This will enable a solid validation of 6G technologies which can then form a good foundation for proposals for standardization and eventual commercialization. We expect a significant contribution from industry to fund this phase of the activity. The government can provide partial funding in the range of 8k-16k Crores, with the industry putting in the rest.

Phase III (Years 7-9): The centres (especially the horizontal ones) could transition into skilling as well as incubation activities. We expect most of the funding to come from industry and venture communities in this phase. The goal will be for the start-ups and other industries to transition to full 6G based commercialization along with the expansion of the ecosystem to support manufacturing and supply chains. The government may provide seed funding for venture funds to catalyse co-investments in start-ups.

1. Introduction

The current internet penetration in India is largely through smart phones with about 45% of the population having internet access with about 13GB monthly data consumption per user. Most of the current usage is for online video and hence is dominated by download speeds. The expectation with 5G and eventually 6G is that upload bandwidth will also increase as there will be many use cases involving tele-interactions where high bandwidth will be required for both directions.

Though 5G roll out is imminent, it will only provide about 10Gbps bandwidth with 1mS latency. However, many applications that involve immersive presence or haptics interaction like tele-surgery, will require bandwidths of 10Gbps/user[1] or sub-millisecond latency[2]. To address these applications, the targeted capability for 6G is 1Tbps with sub-1 ms latency, with almost ubiquitous coverage across the entire planet. To achieve these high bandwidths, the carrier frequency will move to 0.1-1THz with bandwidths of 7-35GHz. Such high frequencies will also enable the capability for sensing hence 6G is also expected to converge communications with some sensing capability[3].

While researchers and technologists will work towards realising these capabilities, it is paramount that we also start exploring use cases in parallel, especially those that get enabled via innovative applications of these 6G capabilities. This will lead to a collaborative innovation process - where the use cases and capabilities can iteratively push each other, thus leading to practical and useful technologies with readymade applications.

With this broad context, we will next describe the key aspects of this report.

1.1. Terms of Reference

This report covers the following aspects, which form the terms of reference for this task force:

- Use-case definition
- Developing indigenous globally competitive `ahead of state-of-art` solutions and piloting them in real field environment
- Creating inputs for advanced research by practically establishing the limitation of available technology
- Providing substantial implementation inputs for global standardisation
- Pilot-Trials
- Other items in the scope of 6G activities and overall deliverables.

2. Use-case definition: approach, identification, definition.

While we still don't have 5G deployed, it requires quite a leap of imagination and further exploration and understanding to describe use cases for 6G

[1] E Bastug, et. al., “Towards interconnected Virtual Reality”, IEEE Communications Magazine 2016
[2] Qi Zhang et. al., “Towards 5G enabled Tactile robotic telesurgery”, CoCoNet 2019
[3] Carlos Lima et al., “Converged Communications, Localization & Sensing for 6G”, IEEE Access 2021

2.1. Global Actions on probable 6G Use cases

2.1.1. European Union

Hexa-X[4] is EU's flagship 6G consortium created with a selective and well-composed choice of participants to lay the foundations for 6G systems and with the goal to enable EU leadership in B5G/6G research and development. Hexa-X has published a number of documents sharing the outcomes of deliberations in its different working groups and the deliverable D1.2 captures the 6G vision, use cases and societal values – including aspects of sustainability, security and spectrum.

The use cases for the 6G era defined by Hexa-X have been identified combining two approaches. Firstly, driven by the Hexa-X vision of combining the Digital, Physical and Human worlds while keeping Sustainability, Inclusion and Trustworthiness as the key values driving the future society. Secondly, collecting views from the partners and the ecosystem.23 use cases have been identified and broadly classified into 5 categories.

- Sustainable development
  - E-health for all
  - Institutional coverage
  - Earth monitor
  - Autonomous supply chains
- Massive twinning
  - Digital Twins for manufacturing
  - Immersive smart city
  - Digital Twins for sustainable food production
- Immersive telepresence for enhanced interactions
  - Fully merged cyber-physical worlds
  - Mixed reality co-design
  - Immersive sport event
  - Merged reality game/work
- From robots to cobots
  - Consumer robots
  - AI partners
  - Interacting and cooperative mobile robots
  - Flexible manufacturing
- Local trust zones for human & machine
  - Precision healthcare
  - Sensor infrastructure web
  - 6G IoT micro-networks for smart cities
  - Infrastructure-less network extensions and embedded networks
  - Local coverage for temporary usage
  - Small coverage, low power micro-network in networks for production & manufacturing
  - Automatic public security

[4] Hexa-X D1.2: Expanded 6G vision, use cases and societal values, https://www.google.com/url?q=https://hexa-x.eu/wp-content/uploads/2021/05/Hexa-X_D1.2.pdf&sa=D&source=docs&ust=1649135784835864&usg=AOvVaw1OuR_5X886It3aOguwGrPa

In addition to the Use cases, enabling services harnessing new capabilities have been identified

- Compute-as-a-Service (CaaS)
- AI-as-a-Service (AIaaS)
- AI-assisted Vehicle-to-Everything (V2X)
- Flexible device type change service
- Energy-optimised services
- Internet-of-Tags
- Security as a service for other networks

The following research challenges were identified

- Connecting intelligence
- Network of networks (e.g., millions of (specialised) subnetworks)
- Sustainability
- Global service coverage
- Extreme experience
- Trustworthiness.

Each use case family addresses multiple of these research domains and is analysed for the different Key Performance Indicators (KPIs), and a set of Key Value Indicators (KVIs) featuring the trustworthiness, inclusiveness, and sustainability abilities. Please refer to D1.2 for details

2.1.2. North America

The US SDO ATIS launched the Next G Alliance[5] as a consortium of stakeholders from Industry - Academia - Government to North American technology leadership in the 6G era with a strong emphasis on technology commercialization including full lifecycle of research and development, manufacturing, standardisation, and market readiness. One of the key stated goals is to leverage the deliverables to "*influence U.S. government funding priorities and actions that will incentivize the technology industry, laying the foundation for a vibrant marketplace for North American products and services globally*."

The Next G alliance is organised into 6 working groups, namely - Roadmap, Technology, Green, Societal Needs and Economic Drivers, Spectrum, Applications.

In terms of the broad technology roadmap for 6G, the forum has published the roadmap whitepaper, which indicates the following areas as top priorities for technical leadership and contributions.

- Trust, Security and Resilience
- Sustainability
- AI Native Wireless Networks
- Distributed Cloud and Communications systems
- Digital World Experiences
- Cost Efficient Systems

[5] Road map to 6G: Building the foundation for North American Leadership in 6G and beyond. https://www.google.com/url?q=https://nextgalliance.org/&sa=D&source=docs&ust=1649135784837377&usg=AOvVaw2N3T1WCKScdDaVxLKAcqZN

The alliance has identified four key foundational areas under which they have studied various use cases. These are:

- Living: how to improve quality of everyday living?
- Here they are particularly concerned about the ageing population and envision how robotics technologies can benefit from 6G capabilities to allow better support in everyday activities.
- Experience: how to enhance quality of experience in areas like entertainment, healthcare, and education?
- Here, novel, bandwidth hungry user interfaces like 16k and even 32k displays along with haptics technologies - which will be very latency sensitive, will enable creation of new mixed reality content to be delivered. These are expected to change the way stories are told, training delivered, health diagnostics and care provided and in general way experience is delivered and shared.
- Critical: How to improve quality of critical roles in sectors like health care, manufacturing, agriculture, transportation, public safety etc.?
- A key observation they make is that the humans and robots will work together in each of these use cases, where robots will serve to augment/complement the humans. Hence human robot interfaces and interactions will be critical and 6G capabilities of high bandwidth, low latencies, differentiated service levels, inherent sensing capabilities, and attention to security and reliability of the communication technologies will become necessary features to build upon in these use cases.
- Societal: how to improve and attain high level societal goals?
- Equitable access to communication, ubiquitous coverage and green technologies will be key foundational pillars for sustainable and just societal development, without compromising the environment. In addition, security and privacy will be key pillars to be considered from ground up in the technology specifications, to ensure trust in the system.

Finally, the alliance recommends that inter-disciplinary approaches to the use case studies will extract functional, performance and value requirements that will in turn help inform technologists as they proceed with 6G development.

2.1.3. Japan

The Japan Beyond 5G (B5G) consortium was established in December 2020 to achieve early and smooth introduction of communication networks evolving Beyond 5G and to strengthen the international competitiveness of Japan in “Beyond 5G” domain to realise the strong and vibrant society expected in the 2030s.The consortium consisting of all stakeholders of the Japanese ecosystem - Govt., Industry (both telecom and other verticals) and Academia has been organised into 2 committees.

- Committee for Planning and Strategy
  - Study comprehensive strategies to promote B5G and prepare B5G whitepaper
- International Committee
  - To identify international trends for promoting B5G and international dissemination

The first version of the B5G whitepaper was released in March 2022 and summarises needs from different industry verticals that are consumers of B5G, capabilities required, and technological trends.
For each of the industry verticals, the report captures the current challenges, future vision. To realize that future vision, the use cases that are achievable with B5G technology are identified. With this perspective in mind, the following industries are surveyed leading to many use cases and their specific requirements on B5G:

- Finance
- Construction and Real Estate
- Logistics and Transportation
- Telecommunications and IT
- Media Industry
- Energy resources and Materials
- Automotive Industry
- Machinery industry
- Electronics and Precision electronics industry
- Living, Food and Agriculture Industry
- Retail, Wholesale and Distribution sectors
- Services, Public services, and Corporate Services
- Restaurant Industry
- Entertainment and Leisure
- Academic and others

From the gaps and KPI study the following B5G technology trends are arrived at

- System platforms and applications for X-As a Service, where X = [R] Robots, [M] Mobility, [XR] extended Reality
- Trustworthiness - Security, Privacy and Resilience with DLT, Confidential Compute systems, AI based security, etc.
- Network Energy Efficiency Enhancement including network energy savings, use of renewable energy and architectural framework to solve AI power consumption issues
- Network coverage extension including Non-Terrestrial Networks and High-Altitude Platform Stations
- Architectural enhancements to improve overall user experience, and performance of ubiquitous sensors and AI systems
- Future Wireless and Optical Network technologies like Reflective Intelligent Surfaces, Large Scale MIMO, Evolved Air Interface for new bands and improved energy efficiency, Integrated Sensing and Communication, and Optical Wireless and Acoustic communications

2.2. Strategy for the development of Indian specific scenarios and setting up of CoEs

The main purpose of identifying potential use cases at this early juncture in 6G development is to help push and refine the technical capabilities for 6G which will eventually lead to practical solutions, and simultaneously result in valuable IP creation as well as a better chance for getting accepted in international standards. Hence the use cases should be demanding of the communication technologies and should be asking for capabilities beyond 5G.

The process to select the Use Cases can consider the following questions to test their suitability for adoption as part of 6G R&D

- **Is the use case supported by any planned 5G Application layer standards?**
  The final revision of the 5G Application Layer Standards (ALS) Report has been submitted to the DOT last year. In it, two verticals were accorded priority over all others. These were Smart City & Banking Financial Services. Agriculture & Healthcare were close but lower in the priority order.

- **Is there an availability of Nationally published reports for KPI metrics data?**
  Availability of any ground level KPI data for the Use case from Nationally published reports will help create benchmarks for quantifying the efficacy of achieving the use cases and the impact of communication technologies. This data can be baselined over which improvement can be targeted by 6G capabilities like "Sensing" of both active and passive vulnerable road users for collision avoidance. e.g.: for Intelligent Transport Systems: Yearly Road Safety Reports show India in the lowest bracket of Road safety globally. [Refer [8] in Appendix for Report]
  The purpose will be to serve as the baseline against which the Govt can set targets for the technology to prove itself.

  Other reports can point to Net Energy consumption by current 4G/LTE systems in India. This should also include the device ecosystem plus Data Centres. As per Mckinsey report on Green Telecom, currently, each 5G site requires two to three times more energy than an equivalent 4G site. Further, with more services at the edge the number of Data Centres will increase. With the advent of 6G the Energy requirement will be astronomical. Therefore, Green Energy, net energy reduction will be of paramount importance [see reference 26 for more details].

- **Is there an Assessment of the 5G use cases experimented in 5G Innovation Hubs, specifically the horizon 2 and 3 use cases?**
  Availability of performance test results of varied 5G use cases, specifically horizon 2, 3 use cases helps to map and explore further with 6G. The existing 5G Innovation Hubs can be extended for 6G research.

- **Is there a report available on the 5G use cases planned, experimented in the STPI COEs, Centre of Entrepreneurship (https://stpi.in/index.php/stpi-coe) established at National level on varied technologies?**
  Out of 25 COEs planned (e.g., Quantum, Image, IOT), 20 are established at the national level for varied technology areas. These COEs are aligned with vertical industries, for e.g.,
    - IOT Open Lab at Bengaluru for multiple industries (Industrial IoT, Automotive, Wearables, EduTech, AgriTech, NanoTech, Mobility & Home Automation, and Smart City)
    - Motion (Autonomous Connected Electric Shared (ACES) Mobility) at Pune for Auto Industry
    - Establish new COEs that are needed for 6G to explore new use cases.

The purpose will be to serve as the baseline against which the Govt can set targets for the technology to prove itself.

2.3. Sectoral Engagement Strategy

[Each sector like Agriculture, Manufacturing, Disaster Response, Finance, Education, Logistics, Mobility, Entertainment etc could potentially contribute to 6G use cases. We would need to have a champion for each sector - could be a line ministry or a reputed organisation, which drives the articulation of the use case looking 10-15 years into the future, via consultation with appropriate stakeholders. These could then form the basis of setting up centres of excellence (COE) for the said use cases for each sector, with appropriate allocation of funding. The use case (or "Vertical") COEs can first identify and realise their solutions via existing 4G and upcoming 5G technologies. As 5G technologies are expected to bring digital change to a variety of other sectors]. To promote and smooth adoption of 5G potential use cases, the Department of Telecommunication has constituted an inter - ministerial committee with representatives from 17 ministries. The existing 5G use case engagement experience will be extended on to the 6G engagement. The KPIs and benchmarking will serve as a starting point for future enhancements to the use cases, some of which may require 6G.

2.4. Indigenous IP Creation Strategy

We should also create "horizontal" COEs which focus on foundational technology creation to enable 6G capabilities. This will lead to creation of fundamental IPs and contributions to international standards, as well as support for indigenous manufacturing. However, the funding requirements will be substantial and hence a strategic approach will be required to achieve these aspirations. Some of the key points for this will be:

- Generating IPs to the extent maximum in next 3-4 years
- Focus on strengths due to limitations in budget
- Form Consortiums of entities (Academia & industry) and include strategic international partners
- In the initial research phase, provide funding support to the private sector (including large and SMEs).
- Incentivization contribution of R&D funding from the private sector through tax breaks etc. especially for the productization and standardisation phase.

3. Potential 6G Use cases of relevance to India

3.1. Healthcare

Ambulance services will get augmented to provide continuous high-quality care from home-to-hospital to enable Hospital-to-Home (H2H) services. 6G will enable hospitals to reach home on demand and in an emergency. The future ambulance vehicles will be fully AI enabled and connected with the infrastructure. Therefore, H2H will be realised as a mobile hospital on an intelligent vehicle platform that will have a minimum dependence on hospitals including doctors and nurses. This mobile hospital will replace ambulance services.

Intelligent Wearable Devices (IWD) that are connected to the Internet will transmit psychological and physiological data to test and monitoring centres. These devices will monitor all vitals like, heartbeat, blood pressure, blood tests, health conditions, body weight and nutrition. This data will be available in real-time at the diagnostic centres. IWD

data will enable personalised treatment and care plan and advise the person for the next action, for instance, advising for walk or running. IWD will allow maintaining a digital twin of the individual for health, nutrition, and habits.

Tele-diagnosis, remote surgery and telerehabilitation are just some of the many potential applications in healthcare. We have already witnessed an early form of this during the ongoing COVID-19 pandemic, whereby a huge number of medical consultations are via video links. However, with the aid of advanced tele diagnostic tools, medical expertise/consultation could be available anywhere and anytime regardless of the location of the patient and the medical practitioner. Remote and robotic surgery is an application where a surgeon gets real-time audio-visual feeds of the patient that is being operated upon in a remote location. The surgeon operates then using real-time visual feeds and haptic information transmitted to/from the robot. This will definitely create a significant impact on Rural medical arrangement and overall cost of treatment will be drastically reduced.

A smart pharmacy box (cabin) installed in rural areas where patients can enter and describe the symptoms to an interface (virtual), accordingly the pertinent doctor (virtual doctor or holograph) can prescribe the medication and the medicines are dispatched by the box thus realising an ATM using a health card. Connectivity provided by 6G will make the box portable.

3.2. Agriculture

Agriculture use cases can consider smart and precision agriculture with connectivity to every square metre in the country. 100 Kisan Vigyan Kendra's run by ICAR can provide the testbed or living labs to experiment with communication technology evolutions for agriculture over this coming decade.

For vertical farming and green houses, highly dense and large-scale sensor network can be deployed where connectivity is provided using a set of 6G micro base stations, including drones working as wireless access points.

3.2.1. Smart Agriculture using 6G-IoT and AI

Objective is to develop an intelligent predictive system fusing IoT and AI/ML techniques to forecast yield, irrigation schedule, pesticide schedule and crop health information with specific goals as listed below:

- Development of a sensor network to collect location specific soil, weather, and plant health data for the purpose of precise management of soil and crop.
- Design of communication framework and Protocols.
- Building of Rice specific analytics model and development of PC / mobile based application software
- Pilot implementation.

It is required to develop Message Exchange Middleware (MEM) for exchange of data between the devices which is fast and reliable after finalisation and deployment of the selected IOT devices and finalisation of protocol. Two standard and frequently used protocols, namely, MQTT and CoAP are being proposed; any one of them can be selected based on mutual acceptability.

MQTT is preferred over CoAP for mission-critical communications because it can enforce quality of service and ensure message delivery. CoAP, for its part, is preferred for gathering telemetry data transmitted from transient, low-power nodes like tiny field sensors. Despite fulfilling different needs, both protocols are fundamental in IoT and IIoT deployments, where fast and flexible data exchange is a basic operational requirement. After evaluation of the field situation, the most appropriate protocol out of the two will be selected and implemented.

3.3. Defence & Internal Security

The following use case scenarios are recommended

(i) **Battlefield Surveillance**
With integration of sensors, drones and Satellites, an unmanned surveillance grid mapping every inch of border (high accuracy localization) will enhance the operational efficiency by providing real time inputs to the commanders in the field formations.

(ii) **Security protocol**
A Novel protocol exclusively for defence may be developed in conjunction with academia and industry for authentication and key management in 6G. This can be leveraged to exploit the same network infrastructure for providing communication to local population and armed forces in the given area. The concept can be akin to a Military grade network slice.

(iii) **Dynamic Radio Illumination of Battlefield**
With advanced beamforming techniques already available in 5G, the 6G should look at dynamic radio coverage in the heterogeneous environment based on the progress of operations.

(iv) **Digital Twin of Battlefield**
The real-time dynamic interaction between the virtual and the real battlefield can be simulated using the digital twin to provide automated flow of info in ops. This will enable commanders to take timely decisions and shape the response in battle.

3.4. Disaster Response

Wildfires are associated with human evolution and almost all forests across the world have faced incidents of wildfires, however, when these fires become uncontrollable, they often turn into disasters. Raging wildfires results in loss of natural resources, biodiversity, property, and often human lives.

In Indian context significant wildfires have been reported in some of the states like Uttarakhand, Nagaland, Odisha, Tamil Nadu and in the other states in the last couple of years. Many extreme climate events have occurred in India in the last decade which have resulted in occurrence of significant wildfires. The higher number of wildfires in the year 2009 and 2012 have resulted due to the effect of El-Nino which brought in significant dryness.

Key Challenges: Fire can be detected through satellites, ground sensors, unmanned aerial vehicle (UAV), and physical observation by public and forest officials. However still there are gaps in accurate and timely reporting of wildfire.

- One of the major challenges in managing the wildfires is early detection of the same. Early detection of wildfires is important for timely deployment of resources towards control the spread and to take mitigation steps.
- MODIS and VIIRS sensors can report the wildfire at 1km and 375m spatial resolutions respectively six times a day, however, small wildfires (which may turn into large fires) remain undetected.
- Depending on the satellite pass, fire alert data can be obtained for a limited duration. Also there exists latency to the tune of one to one and half hours before data reaches the end user.

It is therefore important to deploy sensor networks at strategic locations so as to have continuous data collection on the remote server. Whenever some sensor records value more than a specified threshold it may enable early detection of wildfire. Also, it may be required to deploy the UAVs in sync with satellite and ground sensor networks to monitor the occurrence of wildfire. In addition, crowd-based systems are also required to collect instant geotagged locations of wildfire along with text, audio, image, and video data of that location.

Multi-source Data Analysis & Visualization: Wildfire management required real-time response to dynamically evolving situations, spread over many hectares. Use real-time data feeds from multiple sources: satellite, on-ground sensors, drones, meteorological services etc., and combine these with other contextual data (terrain maps, vegetation type and cover etc) to analyse with high fidelity scientific models on HPC systems to predict spread of fire and allow visualisation. This visualisation can be communicated in real-time to on-field personnel to enable them to make more effective decisions. The resulting latency and data bandwidth requirements is potentially a good use case for 6G (along with its inherent sensing capability). CDAC (HPC Capability) and IITKGP (Fire Dynamic Scientific Model and Simulations) are working together for this use case. Test site can be in Sikkim.

The low latency 6G technology will enable development of advanced real time fire danger rating systems, which will be based on data streaming not only from ground sensors but also from satellites, UAVs, IoT network, crowd, and climate models. Therefore, considering the future challenges it is inevitable to carry out targeted research now to define the strategies for handling the big data towards very optimum handling of the fire disaster.

Other similar use cases in Civilian (disaster management for flooding, landslides, etc.) and Defence for communicating and rendering in real-time, situational awareness and what-if predictions.

3.4.1. 6G Offerings specific to Disaster Management

- Very Large Volume & Tiny Instant Communications
- Beyond best effort and High-Precision Communications and lossless networking and latency guarantee
- Many Nets (Satellite, MEC, Dense network)
- Intelligent Connected Management and Control functions, Programmability and Integrated sensing and communication

3.4.2. Other Disaster Management Use cases

Almost all large spatial scale disasters such as flood, air pollution, GLOF require significant data processing power and dissemination protocols so as to enable governments to take mitigative measures in good time. The development of grid consortium for very high-speed collaborative computing, data transfer will be required in future for effective decision making considering the deluge of data from different sources. In India many times potential cyclone related disasters have been averted by collaborative coordination among different stakeholders. Such type of collaborative, spontaneous, real time disaster control measures also need to be taken for forest fires. 6G technology has the potential to bring revolution in disaster alert, processing and information dissemination activities, thus strong research needs to be carried out for future disaster management activities.

There are also potential applications in other environmental use cases - rope in Ministry of Environment to explore applications for reducing carbon footprint and meet India's commitment

The mining sector needs smart technology for real-time monitoring for worker's safety as well as allow remote-tele operation of mining equipment. Difficult wireless propagation medium, including need for ad-hoc network setup, good localization capabilities, sensing capabilities etc.

There are also potential applications in other environmental use cases - rope in Ministry of Environment to explore applications for reducing carbon footprint and meet India's commitment
The mining sector needs smart technology for real-time monitoring for worker's safety as well as allow remote-tele operation of mining equipment. Difficult wireless propagation medium, including need for ad-hoc network setup, good localization capabilities, sensing capabilities etc.

3.5. Transportation/Air mobility

Unmanned Aerial Vehicles (UAV) is one of the prominent use cases for 5G which has exponential growth of the market owing to numerous applications that have been facilitated by advances in battery technology and wireless communications. Given the successes of UAVs thus far, researchers are already gearing towards aerial transport systems that consist of dense deployment of both UAVs and Personal Aerial Vehicles (PAVs) with human passengers. However, future aerial transport systems will require stricter network key performance indicators to support the expected massive deployment of aerial vehicles considering network capacity and distance between the base station and the aerial vehicles, among others. Hence 6G will be required for Urban Air Mobility (UAM). These electric vertical take-off and landing (eVTOL) aircraft for passengers will be very much applicable for cities like Mumbai and Bangalore where peak hour traffic is one of the biggest challenges. It is expected that the market for eVTOL Air Taxis to Grow to $14.7 Billion by 2041.

Safe ITS
"Safe" Intelligent Transport Systems (ITS) that protect the Vulnerable Road Users.
Innovations in Location/Speed Sensing will be required for improving Safety metrics.

The technology can be applied to all transport modes including Robots.

3.6. QKD and integration with 6G

Quantum technology (QT) is envisioned to play a critical role in the 6G framework [9 - 12]. Considering the spectra of utilities and applications that is brought forth by 6G technologies, security will be one of the greatest challenges. This can be primarily addressed by secure quantum communication. The technology has been demonstrated globally and has many commercial players as well. However, another important aspect is Quantum computing which can contribute to solving computationally difficult optimization problems in 6G, the problems that are computation-intensive can be expedited and several protocols are explored which can contribute to privacy-preserving applications.

In quantum communication we use the quantum property of light to communicate between remote parties. We generate spontaneous secure symmetric encryption keys through a quantum process and the quality of the keys are high in entropy and generated via true random process. This methodology has elevated the nature of security from computational security in modern cryptography to information theoretic security in the Quantum era. As a matter of fact, the resources of QT like superposition, coherence and entanglement serves dual purpose. On one hand it strengthens the cryptography and on the other hand it provides unprecedented computational power. The laws of quantum mechanics like no cloning theorem, Heisenberg uncertainty principle and non-locality principles forms the basis of provable security of Quantum Key distribution (QKD).

Quantum Key distribution: In Quantum Key distribution [14], we begin by selecting a protocol which has a proven information theoretic security guaranteed by the laws of quantum physics. The BB84 with single photons is the most secure QKD protocol having security proven for most general eavesdropping attacks on the quantum channel. We can categorise the QKD protocols into discrete variables DV-QKD and continuous variable CV-QKD based on the nature of detection. We have a quantum transmitter and receiver connected with quantum and classical channels. Once we identify the QKD protocol, the QKD transmitter will generate quantum states, encode the quantum states, and transmit it either by free space or by fibre-based channel. The QKD receiver will receive the states and proceed to sifting and post processing the detected states according to the protocol. The quantum states being fragile will suffer from vulnerabilities in implementation, transmission, reception, and environmental factors giving rise to errors. If the error rate of the system exceeds the threshold, then we drop the generated encryption keys, otherwise we accept the keys as tamper free and proceed with generating symmetric keys on either end. The future quantum secure network and a quantum network will require QKD nodes easily provided by free space and fibre-based quantum communication (QC). This can be achieved using three approaches (1) direct ground-to-ground free space/fibre-based QC, (2) satellite QC and (3) Drone based QC. An integrated model would combine the satellite communication networks, aerial networks, terrestrial networks, and marine communication networks

Space-air-ground-sea integrated network (SAGSIN), which provides a promising network architecture for 6G [11]. In Figure 2, we have presented different components of quantum communication which will play a critical role in boosting the security of 6G. This includes a hybrid communication system which will encompass PQC, QRNG and different forms of quantum communication i.e., QKD and QSDC as presented in the figure. This will

further lead to establishing a quantum internet across PAN country quantum network supporting several applications using entangled photons as a resource.

In QKD, the adversarial model encompasses the present and future attacks by quantum adversaries (with quantum computer and quantum memory) and classical attacks with present state of art technologies obeying the laws of quantum physics. The keys are obtained from a composable security framework ensuring further usage of keys for cryptographic purposes. Another important application of QT is the quantum random number generator (QRNG). These RNG are quantum based TRNG providing high entropy and Information theoretic quantum certified random numbers for conventional cryptography. Post quantum cryptography (PQC) is another aspect of quantum safe cryptography where the mathematical problems used in cryptography are believed to be quantum safe. Recently, NIST [13] has shortlisted in round 3 (2020) the finalists of the NIST Post-Quantum Cryptography Standardisation Process, three PQ algorithms for use in digital signatures and four PQ algorithms in Key encapsulation mechanism (KEM) along with alternate candidates for each.

Recent achievements

QKD Network

- The Cambridge Quantum Network [15] is another such example, this network has been operating for several years with secure key rates of about 1 Mb/s and interestingly the network operates in the presence of 100Gb/s classical traffic.
- Toshiba [16] breaks quantum communication record with 600 km of optical fibres.
- An integrated space-to-ground quantum communication network [17] over 4,600 kilometres consisting of (1) fibre network of more than 700 fibre QKD links and (2) two satellite-to-ground free-space QKD links.

QKD in 5G:

- SK Telecom has deployed a form of QKD in its 5G mobile networks to provide increased security in its 5G network [18].
- In 2020, Verizon tested QKD over fiber optic links in its network, encrypt live video streams over a fiber network between three locations, which are the Washington D.C. Executive Briefing Centre, the 5G Lab in D.C., and Verizon's Ashburn [19].
- It is reported that the first demonstration of quantum-secured, inter-domain 5G service orchestration and on-demand NFV chaining over flexi-WDM optical networks was performed by the University of Bristol [20]. software-defined
- A software defined QKD network (SDQKDN) was demonstrated using (1) CV QKD by Huawei Technologies Duesseldorf GmbH (HWDU), Munich Research Centre, and (2) SDN by UPM and Telefonica on a production-level optical fiber infrastructure of Telefonica to demonstrate [21].

Global initiatives:

- In the US, The National Quantum Initiative Act was signed into law in 2018.
- The EU also launched its Quantum Technologies Flagship in 2018.
- India has announced a National Mission on Quantum Technologies & Applications (NM-QTA) in 2020.

- The Quantum Internet Alliance (QIA) [22] is preparing for a pan-European Quantum Internet towards implementing a fully integrated network stack running on a multi-node quantum network.

Standardisation and certification

At present there is a parallel global effort on standardisation and certification. In this direction ITMO University and Kazan Quantum Centre launched Russia's first multi-hub quantum network which will form the basis for development of quantum communication in Russia. China Communications Standards Association CCSA-ST7, and it has several related contributions to international SDOs including ITU and ISO/IEC. The ETSI-QKD/ISG [23] has developed testing and evaluation methods and methodologies, system test, interfaces, component specifications which have been released for commercial quantum communication. The ISO group [24] developing two standards: "ISO/IEC 23837-1 Information security—Security requirements, test, and evaluation methods for quantum key distribution—Part 1: Requirements (containing predefined security functional requirements for use in QKD PPs) and ISO/IEC 23837-2 Part 2: Test and evaluation methods. Both are currently in advanced committee draft (CD) stage and publication is planned for spring 2022.

Advantages of QKD in 6G: Hardening of the 6G security

- QKD may be deployed over the backhaul connecting radio access networks and the core network.
- Quantum communications can also be leveraged for securing communications between an SDN controller and SDN enabled devices as successfully demonstrated by Telefonica and its partners in 2020.
- In future, we can expect mesh-like Space Information Networks (SIN) under 6G. In this regard Quantum Space Information Network (qSIN) is a reality today and several demonstrations and this will offer novel methods of key relay which will have its own advantages. For example, Huang et al. [25] demonstrated a double-layer quantum satellite network architecture based on a trusted repeater and implemented a quantum key pool (QKP) showing an improvement of the success probability of key relay services.
- The security can be approached in a hybrid manner leveraging QNRG, QKD, PQC and state of art communication techniques.
- Quantum-Assisted Blockchain (qChain) can use quantum communications to address the security in blockchain nodes. There is a good opportunity to evolve new protocols based on quantum entanglement to assist the technology.
- The 6G system will involve application of AI algorithms such as deep learning, deep reinforcement learning, etc and the communications among participants can be secured using quantum secure communication.

3.7. Education

There are so many opportunities in the Education sector like Remote learning. However, another prominent area is robust infrastructure for exam conduction. Total 1,26,30,885 applications were received for the RRB CEN NTPC 2021 exam. Online examinations have always a potential to save cost in exponential factor, however that requires robust infrastructure. If Person needs to appear from home or remote centre, then 6G will play a significant role.6G will allow the video to transmit at such a high speed and nearby edge processing will help in managing the compliance. All major examinations like JEE, NEET,

State Government, Banking, Defence, and other related sectors can leverage 6G in exam conduction.

3.8. Metaverse

Metaverse bridges the physical world and the avatars in the virtual world built by human imagination, leveraging Extended Reality, AI, Spatial Computing, IoT, Wearable Technologies, Decentralized, Crypto Currencies and 5G / 6G and brings in next generation User Experience.

The Metaverse requires real time experience between what a person does and what their avatar does without lag, hence very low latency. This requires, the network connections to be super-fast, super-reliable and available everywhere. Also support the processing power leap as there is a move from 2D to 3D, holographic displays.

Holographic displays used for real-time multi-dimensional interaction, requires a very high throughput. This increases further with concurrent data streams, hence requires Tbps, and latency to be less than 1ms.

Use Cases extends from

- Digital Twin, with physical and digital world interactions across industry sectors
- Immersive product design, reviews with 3D models, VR in manufacturing with distributed teams
- Media, Entertainment & Sports for interactive immersive experiences
- Collaborative Learning and remote working through' Virtual Spaces

4. Roadmap for Infrastructure/funding Support

- GoI will need to allocate good funding for basic and applied research for the next three to four years (Y1-4) - with the setting up of “Horizontal” Centres of Excellence across the country. (~USD 1-2B)6. These could be anchored in academia - but have industry partners. We can choose to focus on a few key foundational areas, where we might have inherent strengths and capabilities
- GoI can set up “Vertical” use case field labs across the country for various verticals (Agri, Industrial Automation, Logistics (transportation), Health, Security, Education) (~USD 1-2B). These could be anchored in industry/other domain specific institutions - but have academic and international partners . The R&D money should allow co-innovation from academia/industry consortiums (which means industry should also be eligible for a slice of the R&D grants - in the first phase).
- GoI can also create a venture fund of funds to co-invest in translation and start-up creation (Y7-9) (USD 1-2B) through accelerators in academic and other institutions.

[6] Numbers are indicative. As a comparison, the EU has invested USD2B (with countries/companies putting in additional money).

5. Key Recommendations

- Create a National Mission for 6G which has a 9-year tenure (2022-2031), with funding allocation in three tranches - phase 1 for Years 1-4 and Phase 2 for Years 4-7 and Phase 3 for years 7-9. The mission's purpose will be to catalyse
  - Coordination and interactions between various stakeholders in Central and State governments and their respective line ministries as well as with industry and academia.
  - Fundamental and applied research for 6G technologies, leading to creation of new IP, knowledge, and skilling.
  - Pilot scale demonstration and validation of these technologies in field trials for various use cases.
  - Participation and contribution to national and international standards. This is expected to start from 2025 onwards.
  - Creation of start-ups and other translation mechanisms to convert these technologies to products designed and manufactured in the country for the global market.
  - Formation of consortia between academia, industry, and government agencies nationally and internationally for various activities in each of the phases.
  - Competitive selection of consortiums for funding support to undertake various activities of the mission to realise its objectives in each of the phases.

- Invite proposals from consortia of Academia, Industry and Government agencies to set up “Horizontal” Centres of Excellence across the country. These could be anchored in academia - but have industry and other partners.
  - In phase I (Y1-3), these centres will focus on basic and applied research, with lab scale validation.
  - In phase II (Y4-6), these centres will focus on translation to pilot scale validation and field trials in the various “Vertical” Use case Labs. This will also lead to participation and contribution to international and national standards.
  - In Phase III (Y7-9), these centres will largely focus on large-scale skilling and manpower development.

- Invite proposals from consortia of government agencies, industry, and academia to set up “Vertical” use case field labs across the country for various verticals (Agri, Industrial Automation, Logistics (transportation), Health, Security, Education).
  - In phase I (Y1-3), these field labs will start with field scale deployment of 5G and focus on KPIs for each use case. They will keep upgrading their installations to keep pace with advances in 5G.
  - In phase II (Y4-6), these field labs will start adopting components of 6G technologies - with an aim to validate and contribute to standards. These will also allow the eco system to mature to enable targeting of productization for next phase.
  - In phase III (Y7-9), start-up and other industries will work towards transitioning to full 6G based use cases (where needed) and will allow the ecosystem to expand its manufacturing and supply chain footprint, to plan for full deployment.

    - Each consortium, running these use case field labs, will work together with concerned stakeholders to define the scope of the pilot trials for evolving the use-cases in phases.
    - The consortia will also Invite other solution providers who are ready for pilot testing of their technologies and provide all necessary support for successful testing.
    - The results of all pilot trials in these use case field labs, will provide feedback to research teams, Standardisation teams and solution development teams for further capability enhancement and solution optimization.
- Phases II & III can focus on creating a national ecosystem (including start-ups, MSMEs, and large Industries) of developing and mass manufacturing of solutions and helping manufacturers with appropriate incentive schemes.
- Plan and organise adequate funds with firm commitment of timely, inclusive, and merit-based support based on delivery and progress.
- Partial/Seed funding for Use Case Field Labs should be obtained from appropriate line ministries.
- We anticipate about 1-2B USD for Phase I (Y1-4), 1-2B USD for Phase II (Y4-7) and USD 2-10B for Phase III (Y7-9).

6. References

- Tech Mahindra solution for Health care segment.
- Holocenter, “What is a hologram?" Accessed from http://holocenter.org/what-is-holography.
- S. Ullah, H. Higgins, B. Braem, B. Latre, C. Blondia, I. Moerman, S. Saleem, Z. Rahman, and K. S. Kwak, “A comprehensive survey of wireless body area networks," Journal of medical systems, vol. 36, no. 3, pp. 1065–1094, 2012.
- S. Nayak and R. Patgiri, “6G: Envisioning the Key Issues and Challenges," CoRR, vol. abs/2004.040244, 2020. [Online]. Available: https://arxiv.org/abs/2004.04024.
- S. J. Nawaz, S. K. Sharma, S. Wyne, M. N. Patwary, and M. Asaduzzaman, “Quantum machine learning for 6g communication networks: State-of-the-art and vision for the future," IEEE Access, vol. 7, pp. 46 317–46 350, 2019.
- F. Tang, Y. Kawamoto, N. Kato, and J. Liu, “Future intelligent and secure vehicular network toward 6g: Machine-learning approaches," Proceedings of the IEEE, vol. 108, no. 2, pp. 292–307, Feb 2020.
- 6G Communication Technology: A Vision on Intelligent Healthcare “Sabuzima Nayak and Ripon Patgiri" Senior Member, IEEE
- **Road Safety** in India: Status **Report** 2019. New Delhi: Transportation Research & Injury Prevention Programme, Indian Institute of Technology Delhi
- Wang, Chonggang; Rahman, Akbar (2021): Quantum-Enabled 6G Wireless Networks: Opportunities and Challenges. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.14785737.v1
- S. J. Nawaz, S. K. Sharma, S. Wyne, M. N. Patwary and M. Asaduzzaman, "Quantum Machine Learning for 6G Communication Networks: State-of-the-Art and Vision for the Future," in *IEEE Access*, vol. 7, pp. 46317-46350, 2019, doi: 10.1109/ACCESS.2019.2909490.
- H. Guo, J. Li, J. Liu, N. Tian and N. Kato, "A Survey on Space-Air-Ground-Sea Integrated Network Security in 6G," in IEEE Communications Surveys & Tutorials, vol. 24, no. 1, pp. 53-87, Firstquarter 2022, doi: 10.1109/COMST.2021.3131332.
- Soldani, D. (2021). 6G Fundamentals: Vision and Enabling Technologies: From 5G to 6G Trustworthy and Resilient Systems. *Journal of Telecommunications and the Digital Economy*, *9*(3). https://doi.org/10.18080/jtde.v9n3.418
- https://csrc.nist.gov/projects/post-quantum-cryptography/post-quantum-cryptography-standardization
- S. Pirandola, U. L. Andersen, L. Banchi, M. Berta, D. Bunandar, R. Colbeck, D. Englund, T. Gehring, C. Lupo, C. Ottaviani, J. L. Pereira, M. Razavi, J. Shamsul Shaari, M. Tomamichel, V. C. Usenko, G. Vallone, P. Villoresi, and P. Wallden, "Advances in quantum cryptography," Adv. Opt. Photon. 12, 1012-1236 (2020)
- Adrian Wonfor, Catherine White, Andrew Lord, Reza Nejabati, Timothy P. Spiller, James F. Dynes, Andrew J. Shields, and Richard V. Penty "Quantum networks in the UK", Proc. SPIE 11712, Metro and Data Center Optical Networks and Short-Reach Links IV, 1171207 (5 March 2021); https://doi.org/10.1117/12.2578598
- Pittaluga, M., Minder, M., Lucamarini, M. et al. 600-km repeater-like quantum communications with dual-band stabilization. Nat. Photon. 15, 530–535 (2021). https://doi.org/10.1038/s41566-021-00811-0.
- Chen, YA., Zhang, Q., Chen, TY. et al. An integrated space-to-ground quantum communication network over 4,600 kilometres. Nature 589, 214–219 (2021). https://doi.org/10.1038/s41586-020-03093-8

- https://marketing.idquantique.com/acton/attachment/11868/f-7e1d0180-774b-4b3e-8b05-1dff8c2da45d/1/-/-/-/-/SK%20Telecom%20Contines%20to%20Protect%20its%205G%20Network%20with%20Quantum%20Cryptography%20Technologies_PR.pdf]
- Article: Verizon Boosts 5G Security, Deploys Quantum Key Distribution byJessica Lyons Hardcastle, https://www.sdxcentral.com/articles/news/verizon-boosts-5g-security-deploys-quantum-key-distribution/2020/09/
- R. Nejabati et al., "First Demonstration of Quantum-Secured, Inter-Domain 5G Service Orchestration and On-Demand NFV Chaining Over Flexi-WDM Optical Networks," 2019 Optical Fiber Communications Conference and Exhibition (OFC), 2019, pp. 1-3.
- Demonstration of Software Defined Network Services Utilizing Quantum Key Distribution Fully Integrated with Standard Telecommunication Network by Diego R. Lopez, Quantum Rep. 2020, 2(3), 453-458; https://doi.org/10.3390/quantum2030032
- https://quantum-internet.team/
- Industry Specification Group (Isg) On Quantum Key Distribution For Users (Qkd), https://www.etsi.org/committee/qkd
- QKD standardization in ISO/IEC JTC 1/SC 27, https://www.itu.int/en/ITU-T/Workshops-and-Seminars/2019060507/Documents/Presentation_Hongsong%20Shi_QKD_in_ISO-V5.pdf
- D. Huang et al., "Quantum Key Distribution Over Double-Layer Quantum Satellite Networks," in IEEE Access, vol. 8, pp. 16087-16098, 2020, doi: 10.1109/ACCESS.2020.2966683.
- Mckinsey Report: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-case-for-committing-to-greener-telecom-networks
- Hexa-X D1.2 – Expanded 6G vision, use cases and societal values – including aspects of sustainability, security and spectrum, https://hexa-x.eu/d1-2-expanded-6g-vision-use-cases-and-societal-values-including-aspects-of-sustainability-security-and-spectrum/
- Next G Alliance Report: Roadmap to 6G, https://nextgalliance.org/white_papers/roadmap-to-6g/
- Beyond 5G White Paper, ～Message to the 2030s～, Japan B5G Promotion Consortium Whitepaper Subcommittee, whitepaper_en_1-0.pdf (b5g.jp)

7. Appendix: Detailed Use cases

7.1. A detailed study of a Health care use case

The 6G revolution is envisioned to connect everything and control trillions of devices—macro to micro to nano—for the digitization future. Time-sensitive healthcare applications such as haptic (involving touch, sight, and sound) actions and holographic connections displaying three dimensional images assist healthcare professionals using emotion-sensing wearable devices to monitor mental health, heartbeats, oxygen level, glucose, blood pressure, and much more, as shown in below.

At present, the healthcare sector is facing numerous challenges. The deficiencies of the 5G mobile system as an enabler of IoE (Internet of Everything) have inspired global research activities to focus on the 6G wireless system.

The requirements of 6G communication technology for future healthcare are high data rate (≥1 Tbps), high operating frequency (≥1 THz), low end-to-end delay (≤1 ms), high reliability (10^{-9}), high mobility (≥ 1000 km/h) and wavelength of ≤300μm. Telesurgery requires real-time communications. Also, holographic communication and augmented/virtual reality will boost up the intelligent healthcare systems. However, 5G and B5G will be unable to support intelligent healthcare. In the 5G communication era, intelligent healthcare will be implemented partially which will push forward a step ahead.

6G communication technology requires supporting technologies to fulfil the promises. 6G is truly AI-driven communication technology, and thus, it requires AI to integrate its communication technology. Moreover, 6G will enable Internet of Everything (IoE), and it will boost up many fields. Also, edge technology is necessary for 6G technology for bringing the Cloud features closer to intelligent devices. Thus, 6G communication technology comprises of many technologies. Some of the technologies that are vital for healthcare industry is listed below.

- **Edge Intelligence:**
  6G will rely on Cloud computing for storage, computing and analysis of Big Data. Data produced by the intelligent devices are transferred to Cloud for storage, however, it consumes communication resources and bandwidth. Off late, the technologies are brought closer to the data source due to the exponential growth of data. This technology is Edge technology. 6G is claiming to have a high capacity to provide
  smooth services to billions of intelligent devices. 6G will rely on Edge technology to provide the smooth and high-speed Internet services to the intelligent devices which is vital for healthcare.

- **Artificial Intelligence**
  6G will be a truly AI-driven communication network. 6G will make every aspect of network communication intelligent to make the system self-aware, self-compute and self-decide on a situation. The goal of 6G is to provide global coverage, including space-air-water. This is achievable only by making the different aspects of communication “intelligent. Implementation of AI algorithms is generating high accuracy and performance in communication networks. Truly AI-driven communication can offer real-time communication which is very important for modern healthcare.

- **Holographic Communication**
  Hologram is a physical recording of an interference pattern that uses diffraction to generate a 3D light field. The image generated has parallax, depth, and other properties of the original object. Holographic communication uses cameras from different angles to create a hologram of the object. It will use the core service of 6G. It will require high data rates to provide good quality of service and streaming high-definition videos. Moreover, very low latency is required for real-time voices and immediate control responses. Holographic communication will be a breakthrough for healthcare.

- **Augmented reality and virtual reality**
  Augmented reality (AR) helps to include virtuality to real objects. Moreover, it is combined with multiple sensory abilities such as audio, visual, somatosensory, haptic etc.
  AR also provides real-time interaction and presents 3D images of virtual and real objects accurately. Virtual reality (VR) refers to presenting an imaginative or virtual world where nothing is real. AR and VR will use the core service of combined and enhanced 6G features.

- **Tactile/Haptic Internet**
  Haptic technology creates a virtual touch using force, motion, or vibration on the user. Tactile Internet is used to transfer the virtual touch to another user, maybe human or a robot. Tactile Internet requires high speed of communication to grab the tactile in real-time. This technology will be used for remote surgery, i.e., telesurgery. It will also help doctors for diagnosis using touch without being physically
  present. Haptic human-computer interaction (HCI) is classified into three types, namely, desktop, surface, and wearable.

- **Intelligent Internet of Medical Things**
  In 6G communication paradigm, Intelligent Internet of Medical Things (IIoMT) will evolve and serve many purposes for well-being of humankind. IIoMT are intelligent devices that are AI-driven that makes its own decision using communication technology. IoE will also emerge along with IIoMT, and thus, medical things can connect to the Internet. For instance, MRI and CT scan. The scanner will scan the devices and send the data to remote locations through 6G technology.

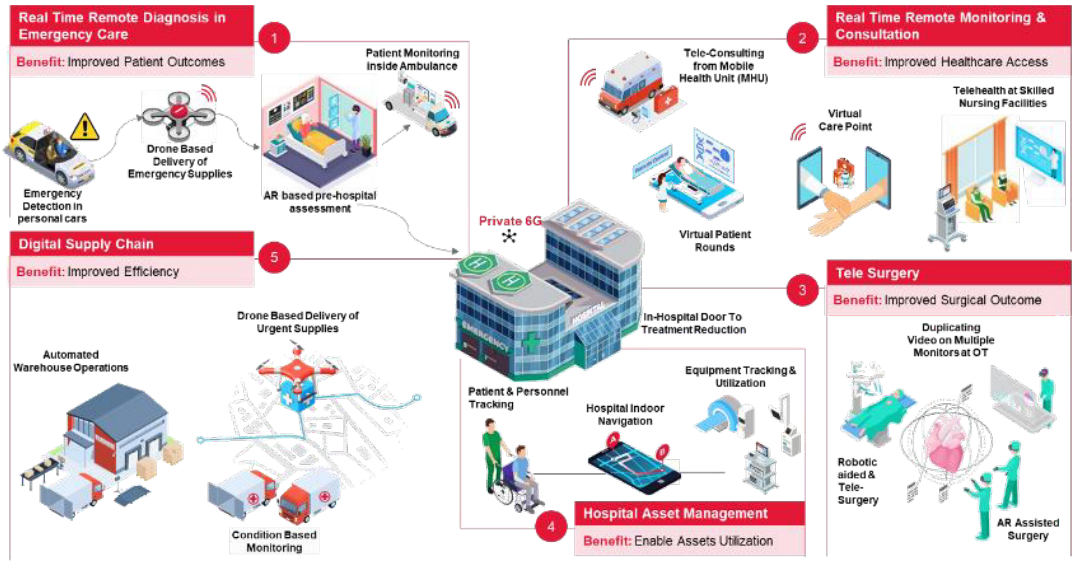
- **HOSPITAL-TO-HOME SERVICES (H2H)**
  Currently, the ambulance services are just a transporter of patients with oxygen and road traffic priority. It does not serve the purpose of emergency service due to absence of intelligence. Therefore, the ambulance services are not impacting on our lives. Any normal car can also solve the same purposes if we keep oxygen and emergency signal. Therefore, a new kind of ambulance service is required to improve lifestyle.

  To replace ambulance services, the Hospital-to-Home (H2H) services will be emerging. Due to the advent of communication technology, hospital can reach to

home on demand and in an emergency. The future vehicles will be fully AI driven to make intelligent vehicles. Therefore, H2H will be implemented upon mobile hospital on an intelligent vehicle platform that will have a minimum dependence on hospitals including doctors and nurses. This mobile hospital will replace ambulance services.

- **Intelligent Wearable Devices**
  Intelligent Wearable Devices (IWD) are connected to the Internet and transmit psychological and physical data to test centres and monitoring centres. This device will monitor heartbeat, blood pressure, blood tests, health conditions, body weight and nutrition. The test result will be received quickly.
  Also, IWD learn from the personal body history and advise the person for the next action, for instance, advising for walk or running. IWD will maintain a personal history of health, nutrition, and habits.

Based on the above technology that enhances / uses the underlying 6G Core services, probable use cases are depicted below.



A landscape of intelligent healthcare systems. This figure includes Intelligent Internet of Medical Things sensor, Intelligent Wearable Devices (IWD), Online Prescription, MRI, CT scan), Hospital-to-Home (H2H) Services implements mobile hospital, Pathology, Local Doctors, Remote Doctors, and Data Scientist.

- **Use case 1: Real Time Remote Emergency Care:**
  Emergency detection in personal cars: Acquisition of vitals through Bi-directional Tactile / Haptics Internet, Alert to Driver, Notification to Emergency Control Centres

  Drone based delivery of emergency supplies: Timely emergency medical supply to remote location, receive emergency notification, Determine emergency location, Dispatch emergency supplies

  Telepresence / Holographic based pre-hospital assessment: Remote trauma assessment, Telepresence / Holographic examination, Remote Annotation, Receive AR based instruction

Patient monitoring inside Ambulance: Pre-hospital remote diagnosis and treatment, Monitoring of vitals, Acquisition of medical images.

- **Use case 2: Real Time Remote Monitoring and Consultation**
  Virtual Care Point (Rural, Public Space, Clinics): Remote Telepresence / Holographic consultation and collaboration, Real time acquisition of Vitals through Tactile / Haptics Internet,

  Tele-Consulting from Mobile Health Unit (MHU): Remote Telepresence / Holographic consultation and collaboration, Real time acquisition of Vitals through Tactile / Haptics.

  Telehealth at Skilled Nursing Facilities (SNF): Teleconsultation and remote monitoring, Remote Telepresence / Holographic consultation and collaboration, Real time acquisition of Vitals through Tactile / Haptics, Generate alerts and notifications

  Virtual Patient Rounds: Examine and treat inpatients remotely, Real time acquisition of Vitals through Tactile / Haptics, Remote Telepresence / Holographic consultation and collaboration, Remote diagnosis, and treatment
- **Use Case 3: Tele Surgery**
  AR/VR Assisted Surgery: AR projection of diagnostic imaging during surgery: Rendering and projection of imaging using AR/VR, Uncompressed real time video stream using holographic techniques, AR/VR content caching

  Duplicating Video on Multiple Monitors at OT: Optimize OT layout to increase efficiency Telepresence / Holographic consultation and collaboration, Broadcasting video to multiple screens

  Robotic Aided and Tele Surgery: Improve accuracy to improve surgical outcomes, Haptic feedback & motion control data stream, Telepresence / Holographic consultation, and collaboration.

- **Use Case 4: Supply Chain, Asset Mgmt., Vision Controlled Access**
  Equipment Tracking & Utilization: Increase efficiency, reduce shrinkage: Track and trace of assets, plan scheduled maintenance and reduce downtime

  Patient and Personnel Tracking: Utilization of personnel, safety of patients, Wearables used for tracking, Safety of patients and hospital staff, Geo-fencing of vulnerable patients

  Compliance, Access & Navigation: Control Access, Verify Compliance & help navigation, PPE
  Compliance, Video based Secure Access, Mobile app based indoor navigation

  Drone based delivery of urgent supplies: Timely emergency medical supply to remote location, Receive notification & dispatch medical supplies.

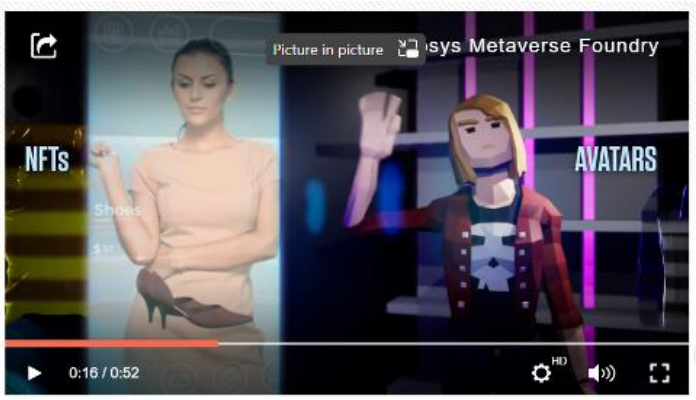
7.2. A detailed study of Remote Education Use case

Remote Education provides a new approach for engaging teachers and students in India's rural areas seamlessly providing live classroom sessions, interactive immersive experiences, digital content, exams, and assessments by leveraging the benefits of 5G and 6G technologies.

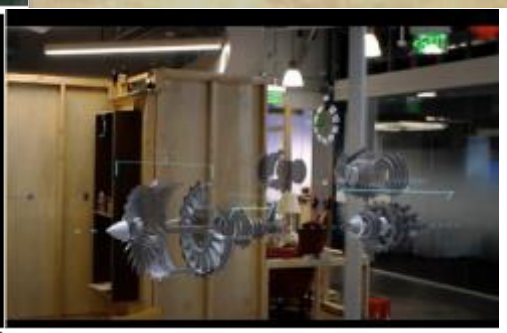
This digital collaboration can bring in varied capabilities,

- ***Omni-Channel Experiences***, focused on engaging with students where they are
- Capability to schedule ***real-time classroom sessions*** for subjects where volunteers and SMEs can conduct classroom sessions and live interactions
- ***Quality content available*** for students and teachers to access it on demand through their smart devices and tablets.
- Evaluation capability to ***conducting assessments*** on the subjects for students with remote monitoring of distributed students taking up national level exams
- Capability for the students to experience ***industry interactions and virtual visits*** to gain knowledge via immersive experiences. Holographic displays for real-time multi-dimensional interaction, that requires a very high throughput.
- Enhanced video experience using content ***Caching at Edge*** and levering ***5G network Slicing (eMBB) and future 6G technologies***
- ***Gamification techniques*** to monitor and track the progress of Students and Teachers.
- Partnership with various content providers to democratize the content creation and ***bring in the best of the content*** to the students and teachers.
- ***Video Analytics at Edge*** for better student engagement and ***real time attention dashboard.*** Also, for ***online assessments with real time video monitoring with 6G***
- Ability for students to ***learn and develop expertise*** in areas based on their interest, capability, and passion
- ***Interactive voice-based chat bots*** to assist students in their learning journey.
- ***Predictive analytics and insights*** to track student behaviour and performance to enable success of students
- ***AI/ML based language conversion in local languages*** for learning content and live course delivery
- Collaboration via '***Virtual Spaces'***

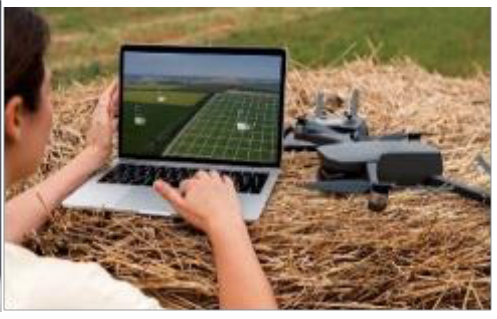

Remote Education: Interactive Expert Sessions
Powered by Infosys Education Platform
Rural classrooms attends interactive live expert sessions from urban classroom, remote
Infosys Education Platform helps in engaging teachers and students in India's rural areas leveraging 5G and Edge technologies
Live classroom sessions, deliver on demand digital content (Content Caching @ Edge)
Assessments across various channels including Edge analytics for 'Student Engagement'
Gamification for Q&A, tracking students' progress
AR / VR enabled teaching
Network API integration for on demand QoS upgrade, Charging party change, sponsored events..
1
Live urban classroom session to the rural school
2
Leveraging AI driven Chat Bot for Q&A Sessions
3
Student Engagement Analytics
4
Industry interactions, Industry visit using AR/VR


Picture in picture
sys Metaverse Foundry
NFTs
AVATARS
Shoes
0:16 / 0:52
HD


INFOSYS




B
STAGE
R022
R023
R024
This is the second step in amplifying the VERO cells of IPV Vaccine. To reach the cells quantity needed, the volume of the bioreactor increases at each step.



Education and other Metaverse Use Cases

- **Augmented, Virtual and Extended Reality**
  Usage of immersive experiences, with XR helps students to gain better experience specifically in medical field. Remote access to surgeons in theatre can be provided to students which expands the reach to medical consultants in teaching hospitals. Similar scenarios in bringing industry experiences and real, interactive experiences with manufacturing industries which brings in more practical experiences.

- **Edge and Video Analytics**
  Recent pandemic has pushed many educational institutions to adopt remote and online learning and assessments. It's important to get a real time view on students' engagements to bring in varied interventions like immersive experiences, industry views and interactions as part of the learning process. To analyse the student engagement levels, edge and video analytics are performed on these video streams. Similarly, if a large-scale assessment remotely is required, there is a need for video analytics to make sure assessment happens in a fair manner without any malpractices.

- **Transformation in Global Education**
  With 6G, networks evolve to support immersive, multi-dimensional interaction and collaboration that can remove distance as a barrier to interaction.
  Educational institutions can re-imagine the bring in more global university collaboration that helps our students and faculty to gain global education from varied universities, from digital content, living labs, to expert sessions.
  This further helps students to be more prepared with varied skills that industry needs and be ready to take up variety of jobs, research programs and many more.

- **Metaverse & Education**
  Metaverse bridges the physical world and the avatars in the virtual world built by human imagination, leveraging Extended Reality, AI, Spatial Computing, IoT, Wearable Technologies, Decentralized, and 5G / 6G and brings in next generation User Experience. This can re-imagine the learning experience with more collaboration, industry-academia interactions, global connects.
  The Metaverse requires real time experience between what a person does and what their avatar does without lag, hence very low latency. This requires, the network connections to be super-fast, super-reliable and available everywhere. Also support the huge processing power as we move from 2D to 3D, holographic displays.
  Complex topics e.g., Medical, Manufacturing can be addressed through' Holographic displays used for real-time multi-dimensional interaction, requires a very high throughput. This increases further with concurrent data streams, hence requires Tbps, and latency to be less than 1ms.
  Extend across varied other industry learning,
    - Digital Twin, with physical and digital world interactions across industry sectors
    - Immersive product design, reviews with 3D models, VR in manufacturing with distributed teams

    - Collaborative Learning and remote working through' Virtual Spaces
- References
    - https://infyspringboard.onwingspan.com/
    - Infosys Metaverse Foundry
    - https://hexa-x.eu/wp-content/uploads/2021/02/Hexa-X_D1.1.pdf
    - 5G | Infosys

सत्यमेव जयते

Ministry of Communications
Department of Telecommunications
Sanchar Bhawan, 20 Ashoka Road
New Delhi - 110001
E-mail: ddgic-dot@gov.in