Bharat 6G VISION

Taskforce Report
International Standards
Contribution

सत्यमेव जयते

Government of India
Ministry of Communications
Department of Telecommunications
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6G Taskforce Report:

International Standards Contribution

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Executive Summary

The Sixth Generation (6G) technologies are likely to become viable and impactful over the next ten years and will support ubiquitous instant communications, pervasive intelligence, immersive experiences, and the Internet of Things & Senses. The 6G is expected to play a key role in the evolution of the society towards the 2030's and shall also play a role in supporting the global sustainability goals, including India's objective to contribute towards climate emergencies.

In this context, developing a strong technology that meet Indian interests and values, as well as economic and global societal goals, is key. Secure and trustworthy India-based 6G infrastructures will help on the one hand to ensure the sovereignty of India in terms of critical technologies and systems, and on the other hand to make sure that our primary values such as privacy, trust, transparency, accountability, security, and societal interests are considered.

The Sixth Generation (6G) wireless communication network is also expected to integrate the terrestrial, aerial, and maritime communications into a robust network which would be more reliable, faster, and can support a massive number of devices with ultra-low latency requirements. The researchers around the globe are proposing cutting edge technologies such as Artificial Intelligence (AI)/Machine Learning (ML), Quantum communication/quantum Machine Learning (QML), Distributed Ledger Technologies (DLT) like blockchain, Immersive XR, Tera-Hertz communication, etc., as the key technologies in the realization of beyond 5G (B5G) and 6G communications.

With the contribution in development of global 5G standards in 3GPP, ITU etc., India as a nation has gained good amount of experience. Over the years, Indian companies have also developed core competencies in certain areas. During this period, there is also a greater understanding of the Standards Development Lifecycle especially that followed within 3GPP including aspects related to its workflow and working procedures. By leveraging this experience, India can contribute to the development of 6G standards in various international bodies such as 3GPP, ITU, IEC, IEEE, one M2M, etc. and can make its mark in global standardization space and ensure good number of key innovations are from India.

To assess the ability of Indian entities to participate in 6G standards development, inputs were collected from a select set of Indian entities. Accordingly, a set of questions were asked to these representative companies to assess the capability of these Indian Comm Tech Companies on Product, R&D and 6G Standards contribution. This forms a good basis for promoting R&D in specific areas of competencies available within India, prioritizing software-ization of networks especially leveraging India's strength in AI/ML.

We had also compiled a list of global initiatives on 6G, their focus areas, how they are structured for the purpose of our learning. NextG Alliance in USA and Europe's 6G-IA are those among the many globally, we had the benefit of interacting with.

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

This task force proposes the following:

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

- This set of stake holders through a consensus driven approach recommend topics/themes of interest in 6G based on business and societal needs. The program should cover all aspects of technology development including early research on ideas, proof-of-concept, standardization, trials & testbeds, etc.
- Government of India taking a lead in streamlining the process and fund research programs on the themes identified.
- The 6G program to take a lead in preparing well defined measurable Key Performance Indicators (KPIs) to assess the success of these program funding.
- The objective of this framework is also to have cohesive policies to meet common goal of national leaderships, national 6G Roadmap, Sustainability goals, etc.
- It is important that this initiative gains momentum immediately and aligns to the timeline of various 6G standards efforts across the globe.
- The 6G program should take a lead in developing consensus on solutions of interest and pursue the standardization efforts at the corresponding international standardization bodies.
- Concurrently, the program should facilitate early trials and prototype development, aimed at developing proof-of-concepts and support the domestic manufacturing process.

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1. Background

In the quest for higher data rates and lower latencies to end users, work has already begun globally at a fast pace to identify and develop new 6G wireless communication technologies. 6G technologies are likely to become viable and impactful over the next ten years and will support ubiquitous instant communications, pervasive intelligence, immersive experiences, and the Internet of Things & Senses.

6G is expected to play a key role in the evolution of the society towards the 2030's, as the convergence between the digital, physical, and personal domains, will increasingly become a reality. It shall also play a role in supporting the global sustainability goals, including India's objective to contribute towards climate emergencies. Some organizations are already considering defining 6G targets to include improving energy efficiency, reducing carbon emissions, and increasing the use of recyclable materials. This will greatly contribute to the United Nations Sustainable Development Goals.

One of the biggest promises of the next decade is that immersive communication, holographic telepresence, and AR/VR will become our default means of communication. With 6G, we should expect to approach a fully connected world, where the physical world is represented in high detail in the digital domain, where it can be analysed and acted upon. The network would provide the links between the domains by devices embedded everywhere, as well as provide the infrastructure and the intelligence of the digital domain. Just like 5G helped the industry 4.0 attempts to make digital twin of machines, 6G will enable humans to be placed in the middle of this cyber-physical continuum and remain fully interconnected.

6G will therefore become the basis of societies of the future. To this end, it must continue to address the pressing societal needs and deliver new functionalities at the same time. Privacy by design, trustworthiness by design, and societal fairness, shall be the foundations of the 6G infrastructure.

Digital technologies are more and more considered as critical and essential means for ensuring as one of the foundations of countries' sovereignty. Developing strong technology offers an alternatives, that meet Indian interests and values, as well as economic and global societal goals, is the key. Secure and trustworthy India-based 6G infrastructures will help on the one hand to ensure the sovereignty of India in terms of critical technologies and systems, and on the other hand to make sure that our primary values such as privacy, trust, transparency, accountability, security, and societal interests are considered. At the same time, it is important that we continue to interact with other areas of the world, promoting the adoption of its values, from the perspective of both the society and the environment, and for guaranteeing a level playing field, in which all human beings can hope for a better future.

Global standards and renewed regulations shall play a key role in the development and deployment of 6G and subsequently of services developed using 6G technologies in India and beyond, in many vertical sectors. It is one of the keys to ensure a sustainable and affordable 6G network available everywhere, to everyone. The International Mobile Telecommunications (IMT) systems for 2030 and beyond will be developed as a global standard to better serve communication needs in every continent of the world. Standards will be required in key technologies required for 6G, i.e., system network architecture and control, edge and ubiquitous computing, radio technology and signal processing, optical networks, network and service security, non-terrestrial networks communication, and device and components.

For a developing economy like India with a large population and significant opportunities, the challenge lies in identifying 6G technologies that are likely to make a major impact in addressing the needs of the growing economy in an affordable manner.

In view of the above and considering India's endeavour to take lead in 6G space, Technology Innovation Group (TIG) on 6G was constituted in the Department of Telecommunications (DoT). Six task forces have been constituted on various subjects to assist TIG. This Task Force on International Standards Contribution was constituted for:

- Mapping global 6G activities and capability definition
- Contribution for WP-5D on research views on IMT for 2030 and beyond

- Pre standardization activities on 6G and streamlining the processes to be inclusive of all stakeholders
- Inputs to standardization activities on 6G in TSDSI
- White paper on India's competency and potential pre standardization activities
- White paper on India mission 6G program, vision, mission, objective, and structure.

The task force currently focused on the following areas:

- White paper on India mission 6G program, vision, mission, objective, and structure
- Mapping global 6G programs and activities to recommend similar framework
- Stimulate competency and innovations from India through pre standardization activities
- Recommendations on contributing for WP-5D on research views on IMT for 2030 and beyond
- Formulate inclusive engagement framework for the 6G research areas to create synergy between with industry and academia
- Mobilize increased participation and contributions in various global standardization bodies from national entities/organizations like TSDSI, TEC, BIS

2. A Program for Technology Development and Contribution to Global Standards

The fusion of digital and real worlds across all dimensions will be the driving theme for 6G Networks. A hyper-scale of things will operate at the system level but not in isolated environments such as private networks. This will demand coordination of distributed intelligence all over the entire network connectivity fabric. It will be necessary to deliver information in fractional units of time between machines, robots, and their virtual counter parts to support autonomous operations safely.

The Sixth Generation (6G) wireless communication network is expected to integrate the terrestrial, aerial, and maritime communications into a robust network which would be more reliable, fast, and can support a massive number of devices with ultra-low latency requirements. Researchers around the globe are proposing cutting edge technologies such as Artificial Intelligence (AI)/Machine Learning (ML), Quantum communication/Quantum Machine Learning (QML), Distributed Ledger Technologies (DLT) like blockchain, Immersive XR, Full-Duplex, Tera-Hertz communication, etc., as the key technologies in the realization of beyond 5G (B5G) and 6G communications.

Standards-developing organizations, public-private partnerships, and industry alliances understand the significance of planning ahead with the 6G capabilities and identify opportunities for themselves: they build strategies to innovate and lead new markets; perhaps they use new technologies with 6G for increasing productivity and operations in their business.

With the contribution in the development of global 5G standards in 3GPP,, ITU etc., India as a nation has gained good amount of experience. Over the years Indian companies have also developed core competencies in certain areas. By leveraging the experience and the competencies developed in certain areas, India can contribute to the development of 6G standards in various international bodies such as 3GPP, ITU, IEC, IEEE, one M2M etc. and can make its mark in global standardization space and ensure good number of key innovations are from India.

2.1 The Standards Development Cycle

From the first analog systems to 2G, 3G, 4G and today 5G and beyond, the collaborations of Industry members with telecom operators, regulators and academia have played a crucial role in the developing standards that meet the needs of consumers, different industries, and society. By fulfilling their needs, the tools for a connected, safer, and more environmentally friendly society are provided, enabling an enriched life for consumers and increased efficiency for all industries.

Standardization is a framework of agreements for all relevant parties in an industry to ensure the creation of well-performing systems, products, and services in accordance with set guidelines. The objective is to maximize compatibility, interoperability, safety, repeatability, and quality. Development of a new technical standard within a standardization organization is based on the consensus of different parties, including vendors, operators, end users, interest groups and governments.

Various technology components are involved in the development of technology for devices, networks and interfaces, whose interworking are defined in technical specifications that get defined and developed within multiple standardization bodies, consortiums, industry groups, etc. For e.g., the IETF, ETSI Industry Specification Group on Network Functions Virtualization (ISG NFG), Web3D Consortiums for representing 3D objects over web, VRIF (Virtual Reality Industry Forum), e-CPRI, Open API specifications, 3GPP for the radio and core interfaces, etc. In this report, we focus on 3GPP, a reputed and well-attended engineering organization that develops technical specifications which form the basis of cellular systems1. Due to the complexity of both the cellular system and the fact that 3GPP is a collaborative effort amongst hundreds of different entities with potentially diverse interests/incentives,

[1] Example is reproduced from https://www.qualcomm.com/news/onq/2017/08/02/understanding-3gpp-starting-basics

understanding how work gets done and decisions are made inside 3GPP can sometimes be a mystery. One way to demystify the 3GPP process is to compare it to how any system-engineering effort works in any engineering company across the world. And utilizing this simple analogy helps to breakthrough some of the 3GPP complexity and confusing acronyms.

Let's say that instead of developing new technology specifications for cellular networks, we are instead a company that desires to build a new jet airplane, as depicted below in Figure 1.

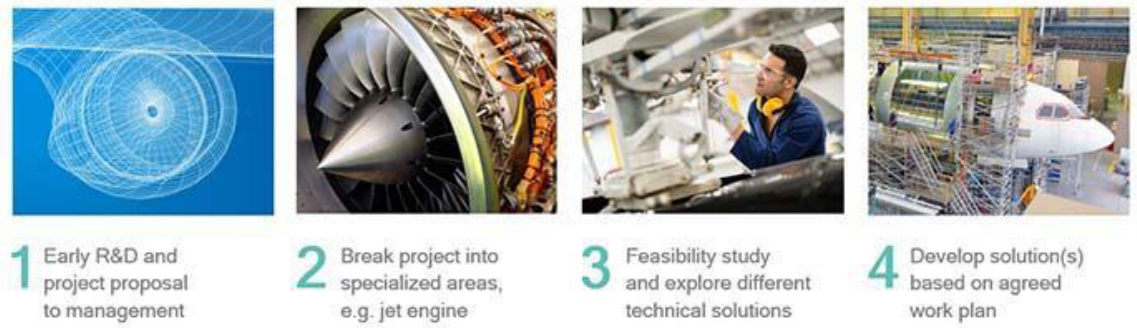


Figure 1: High-level system-engineering steps for building a plane (source: Qualcomm).

Step 1: We would be likely to begin the process by conducting some early R&D to specify requirements, assess constraints, and gather other useful data for the project before bringing the proposal to management. These initial efforts can be instrumental in setting the project in the right direction, or even allowing it to see the light of day. We would be then likely to enter a project proposal phase where we present the project to management for approval. This may require multiple iterations, where management requires us to go back and collect further data before being approved to proceed.

Steps 2 and 3: If approved, a jet plane would obviously need to be broken down into different sub-systems to allow different, specialized groups within (or outside) our company to work on it, for example, the jet engine or the cabin/seat design. Within each of those specialized areas, engineers would likely begin by conducting feasibility studies to test various potential solutions before proceeding with development.

Step 4: Once an agreed-upon solution was selected, development work would then proceed. Within a company-driven effort, it is likely someone or some group would be responsible for overseeing the overall project to ensure the different sub-systems come together as planned on time and within budget.

Although the nuances may change from effort to effort, and company to company, this process is relatively consistent for most system-engineering efforts. 3GPP's development of technical specifications is very much analogous to this. The only fundamental differences are that 3GPP develops technical specifications (vs. jet planes), is constrained by meeting time (vs. OPEX $ and resources) and is a collaborative effort across hundreds of different entities with potentially diverse interests/incentives. Furthermore, 3GPP has tens, if not hundreds of these system-engineering efforts going on at once. Some are more minor projects and some of them are very big projects — like designing a jet airplane.

3GPP is a collaborative, system-level engineering effort, and thus, the 3GPP workflow and working procedures reflect this. Figure 2 depicts a high-level view of the 3GPP process where you will notice a lot of similarities to the jet plane analogy above.

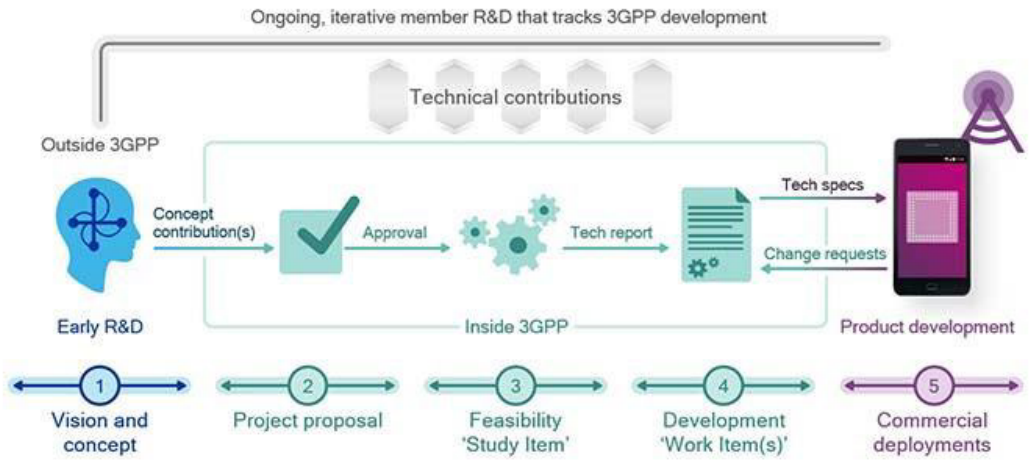


Figure 2: 3GPP working procedures and process.

A quick summary of the 3GPP process can then be listed as follows:

- Project proposals (Step 2 above) introduce new technical features/services into the cellular system and are initiated by individual members based on early development work (Step 1 above) done outside of 3GPP. In other words, there is no "Mr. 3GPP" deciding or driving what the next big cellular feature will be — it relies on the leadership of individual 3GPP Members (also called IMs).
- All new 3GPP work activity must be approved at the plenary meetings, which take place quarterly. Approval of significant features usually results in one or more approved Study Item(s) to conduct feasibility on multiple technology options/solutions (Step 3 above) based on the technical contributions of individual 3GPP members. The output of a Study Item is a Technical Report (TR) that details the agreed-upon concepts from the feasibility study.
- Once the Study Item is complete and TR approved, this may result in corresponding Work Item(s)2 to begin development work on the feature implementation details based on the agreed-upon concepts from the Study Item TR, as well as continued technical contributions from 3GPP members (Step 4 above). Agreed-upon implementation details are executed in 3GPP Tech Specification(s) — either creating new specifications or making updates to existing specifications. Once Technical Specifications are released, it kicks-off a race to deliver standards-compliant devices and infrastructure to enable wide-scale commercial deployments (Step 5 above).

There is one final and essential point on the way decisions are made in 3GPP. Decisions in 3GPP are technology-driven and result from a consensus-based process open to all members. 3GPP members submit technical documents, often referred to as contributions, to propose solutions and technologies. These contributions are discussed publicly in 3GPP meetings (time permitting). Any member can reject a contribution at any time, in which discussions about the contribution (and related alternative contributions) continue well beyond the 3GPP agenda and the 3GPP meeting in which the contribution(s) were originally presented. Thus, the 3GPP decision-making process is iterative and non-linear. Very few of the agreed-upon concepts in a Technical Report resulting from a Study Item or agreed-upon implementation details in Technical Specifications resulting from a Work Item are untouched from the initial member contribution(s). The agreed-upon concepts and implementation details instead come from a collaborative effort that involves iteration and negotiation between 3GPP members. One of the main reasons as to why 3GPP remains successful to date.

[2] Not all Work Items are the result of a Study Item — smaller, more evolutionary efforts may start directly and may have some study phase at the start of the Work Item

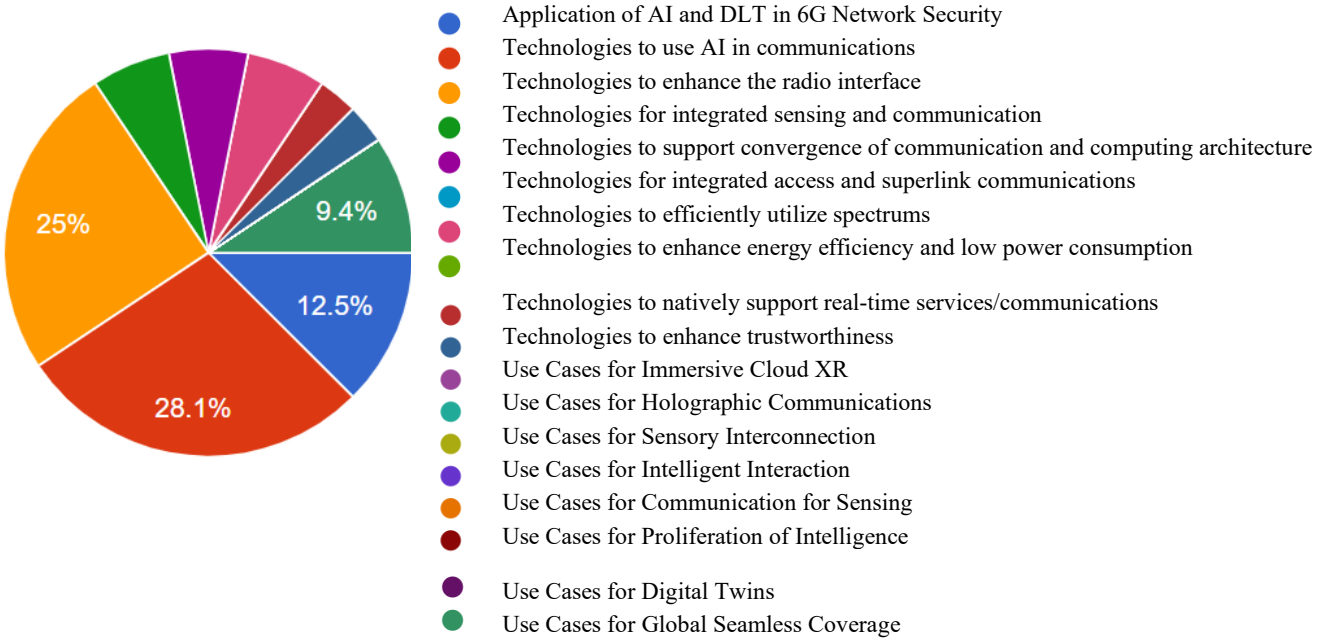
2.2 Classification of Industry Standardization

Industries worldwide that have an active Standardization engagement plan their engagements into the following four areas of standardization, which are critical to the development of communication systems and corresponding ecosystems:

- Spectrum and technical regulations: The timely availability of globally or regionally harmonized radio spectrum is a key requirement for the successful deployment of radio systems, including terrestrial mobile networks. Decisions are made by the International Telecommunication Union (ITU), regional regulatory bodies, or local bodies on a per country basis – all of whom place technical requirements on equipment to avoid inter-system interference. Additional technical regulations, including physical restrictions on the deployment of equipment, electromagnetic field matters (EMF), and cyber and physical security aspects must also be in place to ensure the successful rollout and use of mobile networks.
- Connectivity networks: Here, the rules dictating how to interact in the ecosystem of connectivity networks are set. These encompass, for example, the multivendor interfaces and application program interfaces (APIs) that ensures global connectivity across networks and enable the unprecedented scaling of products.
- Ecosystem expansion: Ecosystem expansion standardization ensures that markets using mobile technologies – especially those new to the industry – fully understand and can properly utilize connectivity networks. Activities within this area also include harmonizing the requirements of such markets within the standardization of connectivity networks.
- Implementation components: The standardization of implementation components ensures the availability of the components and technologies needed to implement connectivity network products and services worldwide.

2.3 Intent to contribute to 6G Standards

To assess the ability of Indian entities to participate in 6G standards development, inputs were collected from a select set of Indian entities(list available in Annex 1). Accordingly, a set of questions were asked to these representative companies to assess the capability of these Indian Comm Tech Companies on Product, R&D and 6G Standards contribution. Based on the information provided by them these Indian Communication technology enterprises have an intention to contribute to the following areas for 6G Standards:



Starting with the research above, India needs to put together a roadmap and vision for 6G technology development and Standards contribution.

2.4 Regional Research Initiatives on NextGen Networks

Various countries and regions have already announced formal plans of government support for their research and development efforts that will define 6G. They all have the goal of firmly establishing themselves as the epicentre for the next generation of innovation and economic growth.

Funding for such national programs is happening throughout the world today. Some programs worth mentioning are as follows:

- Europe
  - Smart network & services joint undertaking (EU - research program)
  - Hexa-X (EU - research project)
  - 6G Genesis (Finland – research project)
  - BMBF (Germany – funding body)
  - KTH Digital Futures (Sweden – research center)
- China
  - Promotion groups by the Ministry of Industry Information Technology (MIIT) and National Key R&D Program by Ministry of Science and Technology (MOST)
- USA
  - NSF Project (see details below)
  - RINGS
  - NextG Alliance
- Canada
  - NSERC, Mitacs, SIF
- Japan

  - B5G Consortium (MIC)
  - NICT
- Korea
  - 6G R&D strategy (Ministry of Science & ICT)
  - ETRI

US National Science Foundation funds research on Advanced Wireless Next Generation Systems, which involves a broad participation across industries. Some of their ongoing projects include:

- Resilient and Intelligent NextG Systems (RINGS): Accelerate research in areas with significant impact on next generation (NextG) wireless and mobile communication, networking, sending and computing systems
- Platforms for Advanced Wireless Research (PAWR): Research to enable experimental techniques, networks, systems, and devices
- Spectrum Innovation Initiative (SII-Center): New advanced and automated spectrum management techniques
- Spectrum and Wireless Innovation Enabled by Future Technologies (SWIFT): New technology or significant enhancements to existing wireless infra for improving spectrum utilization, beyond spectrum efficiency
- Machine Learning for Wireless Networking Systems (MLWiNS): Wireless specific ML techniques for dynamic spectrum access, improve radio/network resource efficiency, scale to address diverse and stringent QoS of future wireless applications.

The importance associated with programs around 6G cannot be underestimated and would revolve around the following aspects:

- Significant Global economic value expected from mobile / cellular industry
- Connectivity remaining crucial for economic and societal development
- Critical communications infrastructure increasingly dependent on mobile connectivity
- Indian leadership in key technologies and ensuring security and resiliency of Next G is important

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

3. Global Initiatives on 6G

Worldwide interest has also started among the industry members on aligning research outcomes to the standards development processes.

- North America: NextG Alliance
- Europe: 6G IA
- China: IMT 2030PG initiative Future Forum
- Japan: B5G Consortium
- Korea: 5G Forum (MoU with Next G Alliance)
- India: TIG-6G (in the formation stage)

A key to fast and seamless adoption of new technologies across the globe is a timely and effective standardization, performed by Standards Developing Organizations (SDO), aligned among all relevant stakeholders. Several SDOs are expected to work on 6G, e.g., 3GPP, ETSI, IETF and IEEE, in a much tighter way than they did for 5G, as 6G intends to merge and make work together different technologies, which have been taken care of, so far, by different SDOs.

Effective standardization requires sound regulation and governance that surround the technical work of the SDOs and ensure proper legal frameworks among different geo-areas. The national approach to regulation is an artifact of technological opportunities and institutional and social acceptance models. As 6G becomes pervasive the challenge of how and what to regulate becomes ever more intense.

3.1 Timeline

Standardization work on 6G is not expected to start till 2025. Initial efforts on identifying future service needs for the next decade, as the ones performed by ITU-T with the Focus Group on Network 2030, have fostered the definition of evolutionary steps from 5G networks being deployed nowadays. The International Mobile Telecommunications (IMT) systems for 2030 and beyond will be developed as a global standard to better serve the communication needs in every continent of the world.

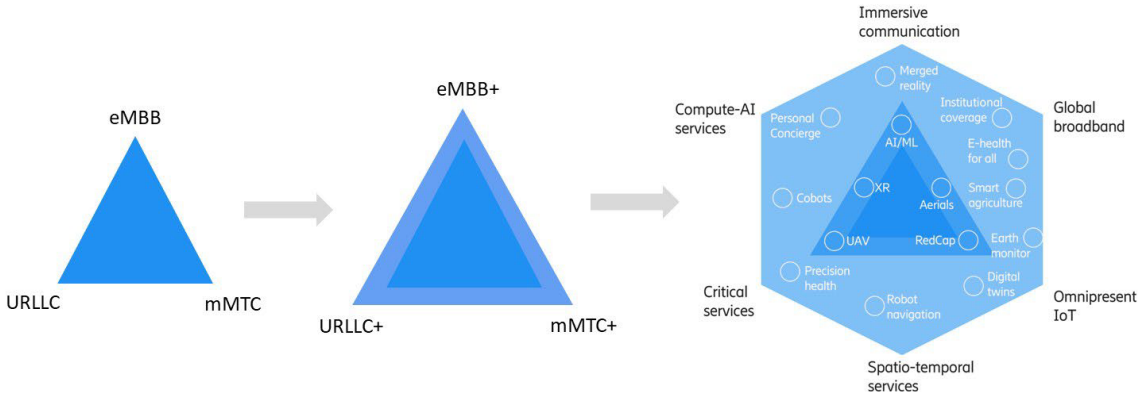


Figure-3: The evolution of usage scenarios from IMT-2020 to IMT for 2030 and beyond (source: ITU-R)

The overall usage scenarios in 6G are envisaged to emerge further from the three basic categories in 5G i.e., eMBB, mMTC and URLLC. These three basic categories are expected to expand into 6 different service categories based upon use case requirements. These usage scenarios can further be mapped into various key user applications and capabilities (Figure 3).

The 6G timeline is under development by SDOs, 3GPP, ITU, and other interested organizations. ITU-R Working Party 5D (IMT Systems) is responsible for overall planning for IMT (International Mobile Telecommunications) systems and develops its schedule based on input from SDOs, specification groups, and industry. The current timeline being discussed in the related ITU-R WP 5D group is made available in Figure 4.

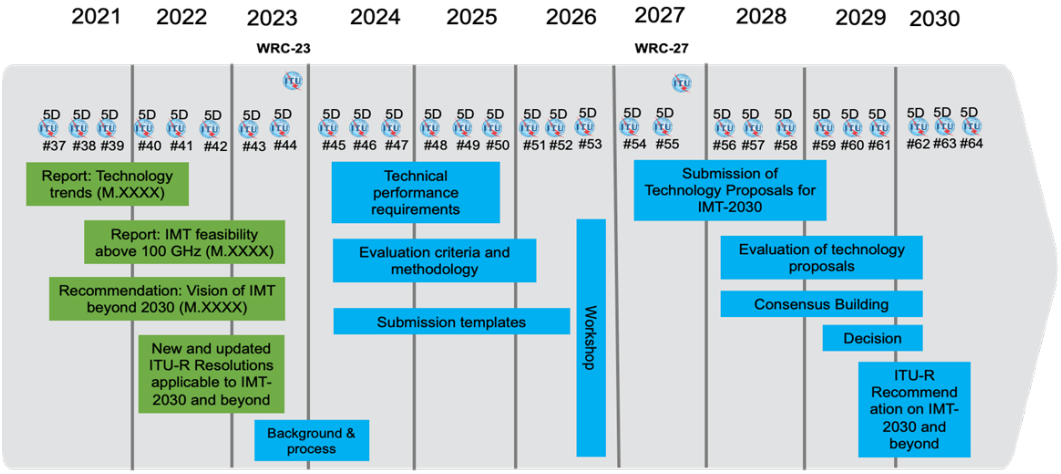


Figure 4: Current timeline consideration at ITU-R WP 5D on IMT specifications for 2030 and beyond

To achieve global interoperability, mobile systems are specified and standardized in international forums, such as ITU and 3GPP. The ITU approach is for external organizations and members to submit their 6G technical proposals for consideration. It is expected that the main technical specification of 6G systems will be done in 3GPP to maximize global harmonization. It is critical that India takes a leadership role in the development of 6G specifications and standards. While standards should continue to be private sector led, alignment between industry and government on key drivers for Indian success will ultimately deliver standards that meet the worldwide marketplace needs and values.

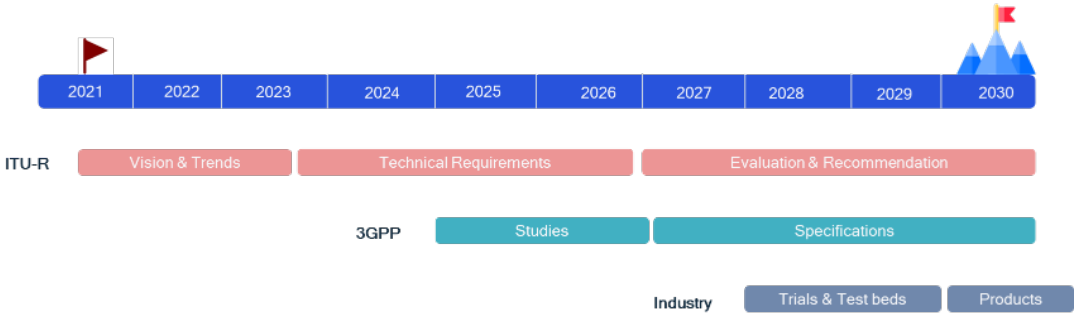


Figure 5: Overall roadmap for 6G development (tentative)

The development of 6G systems is expected to happen in parallel to various stages of the standardization effort; testbeds and trials can be used to validate technical choices made during standardization and to obtain experience with implementation options. Additionally, during the deployment and commercial operation, new services requirements will emerge for an evolution of the 6G systems, with input into the research, innovation, and development lifecycle. From 3GPP standards development point of view, there are yet features and capabilities from existing 5G solutions that require full specification, and which are expected to be completed in forthcoming 3GPP Release 18, targeting end of 2023. Next releases, by mid of the decade, i.e., 2025, are expected to be focused on 5G evolution, in parallel to the analysis of 6G, and finally on the proper 6G specification. Figure 5 illustrates the overall roadmap for 6G development.

4. Creating a vision for 6G success in India

The next generation of wireless technology will be woven into the daily lives of society to an even greater degree than today's technology. This role presents tremendous opportunities for 6G to facilitate key public policy objectives in areas such as security, privacy, environment, safety, health, sustainability, and equity, among others. But a policy framework that provides clarity to the industry, balanced with

the flexibility necessary to promote competition in innovation, will be critical to create a foundation for key 6G applications and use cases.

Successful implementation of India's 6G vision must include an effort to work with other market-driven partners on common approaches to key policy issues to the extent possible. The very nature of advanced communications technologies facilitates the ability to offer services and social benefits across borders. Identifying areas for consistent societal, legal, and regulatory regimes will enable 6G technologies to achieve their full potential. Additionally, agreement on approaches will promote greater leverage in support of those positions within international bodies establishing standards for 6G.

To achieve the above objective, it is essential that India starts working towards globally harmonized standards to leverage global economies of scale both for network & devices, as it ensures international roaming & interoperability across networks deployed globally. It is pertinent to note that this approach caters to all the segments of stakeholders. Most importantly, it will be beneficial for consumers leading to least cost implication in terms of handsets and service cost, availability of commercial devices, which will work across the networks in India and while roaming outside of India. For the industry, it leads to optimized use of investments, minimal implementation impacts on the evolution of existing networks and economies of scale. This also syncs with the Government's regulatory and policy measures in terms of least implications to prevailing regulatory requirements and attracting investments towards manufacturing in India for the world.

To successfully compete with the aggressive efforts of other countries, the Indian government must provide resources to support a collaborative framework for research engagements jointly led by the industry, academia, and other domestic stakeholders. Such support would include:

- Financial support and incentives for undertaking basic research,
- Access to government test bed facilities,
- Bridging the gap between research and development to promote adoption of early-stage technologies.

Public and private investments shall focus on key 6G technologies, such as programmability, integrated sensing and communication, trustworthy infrastructure, scalability, and affordability, as well as AI/ML, microelectronics (at least in design), photonics, batteries (e.g., for mobile devices), software, and other technologies that may help to reduce the energy footprint. India needs an effective and inclusive program to foster Entrepreneurship with private and public participation, complemented with tax policies, to create new businesses around the creation, development, and delivery of these technologies.

The ultimate completion of 6G requires full interoperability between all entities on all levels, i.e., global standards. This would ensure an affordable and scalable 6G system that may be utilized worldwide. Effective standardization requires sound regulation and governance, which in turn require a common certification process, considering the growing number of vendors that will develop for an ecosystem across the world, plus a lean process that would allow verticals to sell their services from anywhere to everywhere. While India can focus on doing Stage 1 (requirements) and 2 (architecture) standardizations work within the different structures identified (TEC, BIS, WPC, TSDSI, etc.), Stage 3 (normative) standardization work should focus on international bodies including the likes of ITU-R, ITU-T, 3GPP, IEEE, etc., so that there is more global acceptance, nd recognition to the efforts and commitments from India. We need to also do effective coordination among different Indian entities active in 6G and with global counterparts (viz., NextG Alliance, HEXA-X, IMT2030-PG, etc.) through the establishment of MoU's and cooperation agreements, to leverage our skills and avoid duplication of efforts.

To begin with, India needs to put together a roadmap and vision for 6G technology development. The scope of such a document is to provide a foundational vision for 6G that addresses both Indian needs and global alignment goals and to develop priorities and strategies for achieving Indian leadership alongside other regions' leadership. This includes describing the key challenges across social and

economic, technical, spectrum, applications, and sustainability (e.g., energy, environmental) considerations, and recommending governmental actions and standardization strategies. Progression in 6G development and standardization should lead to a proactive market readiness stage, where policies and incentivized innovation can set the stage for a robust 6G marketplace. Market-ready spectrum policies and incentives for widespread 6G deployment would lay the groundwork for rapid commercialization and deployment. It is imperative for industry and government to cooperate on policies and actions that facilitate strong market readiness for 6G.

In addition to internal discussions, the task force has also interacted with the representatives from global 6G initiatives like the US3 Next Gen Alliance (NGA) and the EU4 SNS-JU to understand the globally prevalent methodologies and best practices. Their presentations are attached as an annexure to this report.

This task force recommends the following aspects:

- A 6G program be created with a broad category of ecosystem partners including operators, vendors, hyper scalers, academia, and Government research labs, that is agile and quickly adaptable to the evolving needs for driving 6G research and innovations, building on and strengthening India's competencies. (e.g., Next Gen Alliance was setup outside the ATIS, with its own working procedures)
- This set of stake holders through a consensus driven approach recommend topics/themes of interest in 6G based on business and societal needs. The program should cover all aspects of technology development including early research, proof-of-concept, standardization, trials & testbeds, etc.
- Government of India taking a lead in streamlining the process and fund research programs on the themes identified.
- The 6G program to take a lead in preparing well defined measurable KPIs to assess the success of these program funding.
- The objectives of this framework are also to have cohesive policies to meet common goal of national leaderships, national 6G Roadmap, Sustainability goals, etc.
- It is important that this initiative gains momentum immediately and aligns to the timeline of various 6G standards efforts across the globe.
- The 6G program should take a lead in developing consensus on solutions of interest and pursue the standardization efforts at the corresponding international standardization bodies
- Concurrently, the program should facilitate early trials and prototype development, aimed at developing proof-of-concepts and support the domestic manufacturing process.

The internal framework that we propose to adopt and to build in India should be consistent with the framework that is being discussed in ITU and 3GPP. All aspects of technology development that we need to pursue should be converging with the universal standardization process happening globally. As independence existence of a country specific technology is not possible in this age, we can observe from the regulatory process, in which direction the wind blows, and accordingly revise our strategies dynamically. This can be realized only by participating in the standardization process actively by influencing in the creation of IMT 2030 framework as well as subsequent standardization process at 3GPP to be dictated by our national R&D activities and as per our tested prototypes. That means our technology development should sync with the progress of the regulation. As we could see, certain countries taking very aggressive approach in ITU-R and steer the discussion in that direction. This way only we can ensure that our technology, if shaped towards the objectives of 6G, is not alienated in the overall scheme of things.

Indian and Atmanirbhar Approach to 6G Standards:

[3] Next G Alliance by ATIS, https://nextgalliance.org/

[4] EU SNS https://digital-strategy.ec.europa.eu/en/policies/smart-networks-and-services-joint-undertaking

- 6G program imperatives
  - “Big Bets” by investing heavily on development of 6G Standards in defined/ focused areas, as opposed to natural evolution based on market driven forces
  - Evolution of the ‘Public Sector model’ of the 60s and 70s to the “Public Investment” for Atmanirbhar Bharat
  - “Identifying the process for discovery of prioritised areas for 6G Standards” rather than “Identifying the prioritised areas for 6G Standards”
- 6G Focus areas for India
  - For the Indian Society
  - For the Indian Industry
  - For international market forays/ global market access
- Sustainable Standards driven Research Program must include
  - Sustainable 6G Roadmap R&D/ Standards Contribution Areas
  - Sustainability Capability (Start-ups, Academia, Industry)
  - Sustainable Resource (Academia, Industry)
  - Sustainable Funding (Government, Industry)
  - Sustainable Global 6G Standards Participation program

India must step up to the 6G standards and technologies in a bold and aggressive manner, in order to create the ecosystem and framework for contributing meaningfully to the 6G economy in a sustainable and impactful manner.

Annexure A: 6G Standards Engagement for Atmanirbhar Bharat

Winning in the digital age will require India to demonstrate technical and technology leadership at the international stage. India must make the shift from Services to Products to claim a substantial part of the coming growth for itself. It must also change to its posture to an aggressive proactive contributor to 6G Standards, from being a follower or just a compliance seeker.

Successful implementation of India's 6G vision must include a deep dive to understand the state of art in the country. It must also understand the current state of research capabilities. And then, it must understand the areas in which the Indian ecosystem is committed towards contributing to 6G standards.

A very high-level research summary to this effect is produced below.

A.1. List of Companies participated in the survey

Sl.	Company Name
1	Accord
2	Alif Semiconductor
3	Astrome Technologies
4	Big Cat Wireless
5	CDOT
6	Cientra Techsolutions
7	Coral Telecom
8	DSP Works
9	Dyotis Technologies
10	Easiofy
11	Eigen Technologies
12	ELCOM
13	Enmovil Solutions
14	Frog Cellsat
15	HFCL
16	Indio Networks
17	Infinity Labs
18	Inventum Technologies
19	ITI
20	Kenstel Networks
21	Kotkar
22	Lavelle
23	Lekha Wireless
24	Linking Minds
25	Mannash Solution
26	Matrix Comsec
27	MCBS
28	NEXGE Technologies
29	Nimble Vision
30	Niral Networks
31	Nivetti Systems
32	NMS Works

Sl.	Company Name
33	Resonous Technologies
34	Saankhya Labs
35	Samriddhi Automation
36	Sparsh Technology
37	Sensegiz
38	Sensorise
39	Signaltron
40	Signalchip
41	SNS Softtech
42	Sookhta
43	Sterlite
44	TCS
45	Tejas Networks
46	UTL
47	Valles Marineris
48	VNL
49	Vista Inf.
50	VVDN Technologies
51	WiSig

A.2. Product Capability Areas

The Indian Communication technology enterprises have demonstrable products and capabilities in the following areas, where at least three or more companies provide a viable product portfolio:

Products & Capabilities	Org. count
Small Size LTE/ LTE-R Based Mobile Systems, with its various derivatives including rural & disaster communications, Macro & Micro eNodeB, Small Cells, EPC, NIB C-RAN BBU and RRH, LTE/ LTE-R/ LTE Advanced based broadband wireless access systems (eNodeB, gNB, EPC, etc.) in all standard LTE bands in the country	11
Smart City Solutions	10
IoT Modules	9
LTE/ LTE-R Based Mobile Systems, with its various derivatives including rural & disaster communications, Macro & Micro eNode B, Small Cells, EPC, NIB C-RAN BBU and RRH, LTE/ LTE-R/ LTE Advanced/ based broadband wireless access systems (eNodeB, EPC etc.) in all standard LTE bands in the country	8
Software Defined Radio, Cognitive Radio systems (all bands)	8
Telecom Network Management systems (NMS) with its various derivatives	8
IP/ MPLS Core routers/ Edge/Aggregation/ Enterprise Router	7
M2M/ IOT Subsystems including NB IoT in different verticals	7
Pico eNodeB, Category 2, TEC ENB GR (TDD/FDD)	7
Radio systems (IP/ Hybrid), Mobile Front haul BBU and RRH (CPRI, eCPRI, FlexE, RoE, NGFI)	7
Disaster Communication Systems etc., including backpack satellite products	6
IoT based SCADA Devices	6
IP based Soft Switches, IMS, Unified Communication Systems	6
Telecom & IT Software Solutions	6

Products & Capabilities	Org. count
Telecom Network Management systems (NMS) with its various derivatives including Operation Support System (OSS), Billing Support System (BSS), Trouble Ticketing System (TTS)	6
Ethernet Switches (L2 and L3)	5
GPON equipment (including ONT and OLT)	5
IoT Based Customer Feedback Devices	5
Mesh network of Hardware, Cloud, analytics and Software	5
Remote Device Management & Data Acquisition	5
Satellite based systems	5
Video Conferencing Applications	5
Wireline PABXs / IP PBX	5
Encryption/ UTM platforms (TDM and IP) (Unified threat management)	4
Gateways: GSM, V0IP, Signalling,	4
Home Automation based on Wi-Fi or sub-GHz solutions including sensors, remotes	4
IP audio phones / IP video Phones / Analog adaptor	4
mm Wave Systems	4
Other satellite equipment	4
Outdoor AP (802.11ac - MIMO 2.4 and 5 GHz bands - IP67 Rated	4
Satellite based IoT Systems including location, resources tracking	4
Satellite Communication- Ground/ Earth Station Antennas	4
Space Communication	4
Unified Communications and IP Telephony	4
VoIP and SIP Phones (User Terminals Phones)	4
XGS-PON,	4
Drone Communication	3
Embedded Transaction Device	3
EPC (Enterprise class)	3
Media Gateways	3
NB-IoT Geo Satellite Systems	3
NFV/ SDN CPE	3
NG-PON2	3
Outdoor AP (802.11n/b/g - MIMO 2.4 and 5 GHz bands - IP67 rated	3
Portable RAN Framework	3
Remote management platforms for SIM, Subscription and Device enablement	3
SDN Software Controllers, NVF and CNF software	3
Security and Surveillance Communication Systems (video and sensors based) including Perimeter Security Systems	3
SIM Applets for Subscription Management & Control	3
Telecom Consultancy	3
Telecom OSS with its various derivatives	3
VSAT Systems	3
Wi-Fi based broadband wireless access systems indoor & Outdoor (Including Access Point, Aggregation Block, Core Block)	3

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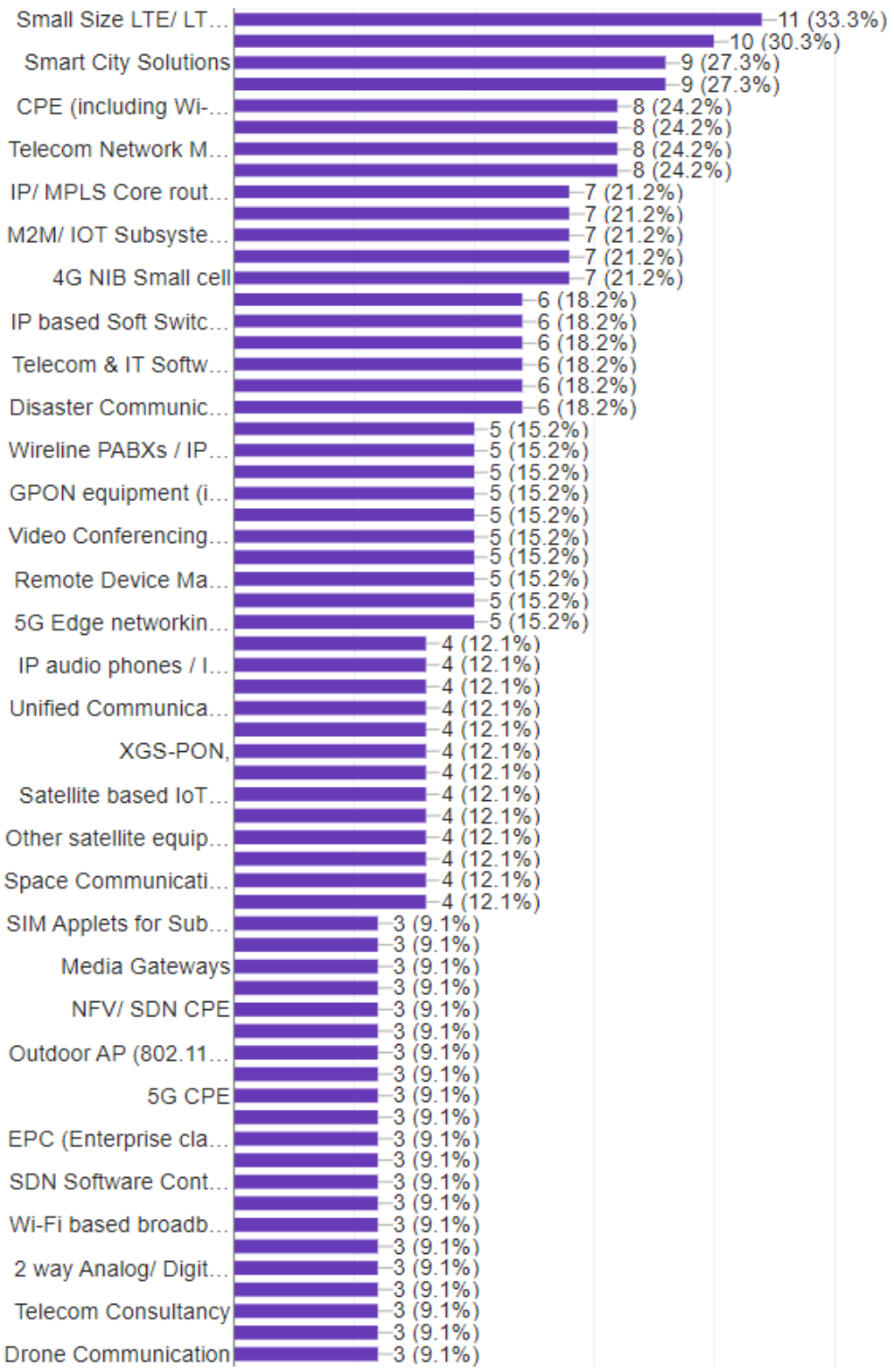
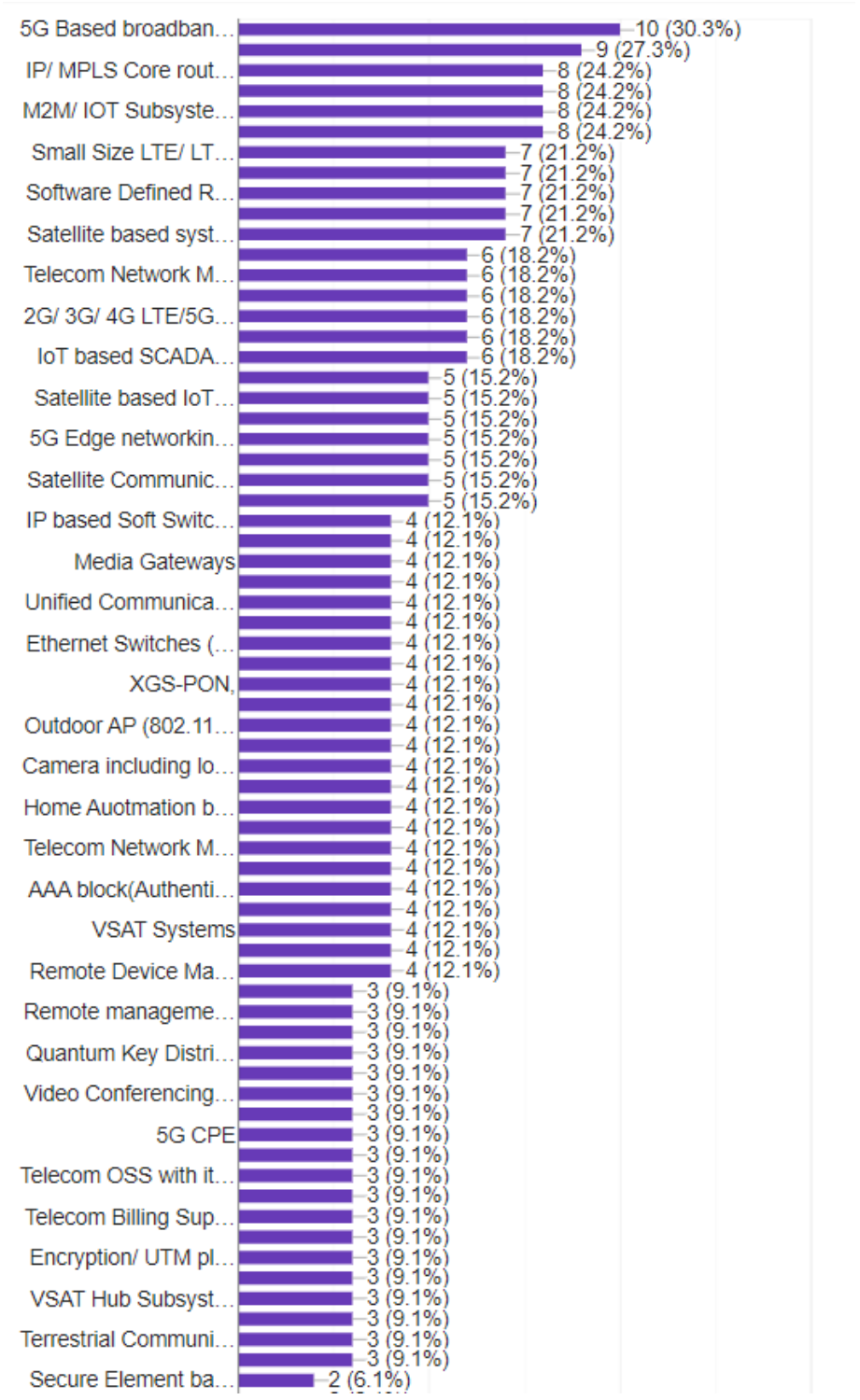

Small Size LTE/ LT...
11 (33.3%)
10 (30.3%)
Smart City Solutions
9 (27.3%)
9 (27.3%)
CPE (including Wi-...
8 (24.2%)
8 (24.2%)
Telecom Network M...
8 (24.2%)
8 (24.2%)
IP/ MPLS Core rout...
7 (21.2%)
7 (21.2%)
M2M/ IOT Subsyste...
7 (21.2%)
7 (21.2%)
4G NIB Small cell
7 (21.2%)
6 (18.2%)
IP based Soft Switc...
6 (18.2%)
6 (18.2%)
Telecom & IT Softw...
6 (18.2%)
6 (18.2%)
Disaster Communic...
6 (18.2%)
5 (15.2%)
Wireline PABXs / IP...
5 (15.2%)
5 (15.2%)
GPON equipment (i...
5 (15.2%)
5 (15.2%)
Video Conferencing...
5 (15.2%)
5 (15.2%)
Remote Device Ma...
5 (15.2%)
5 (15.2%)
5G Edge networkin...
5 (15.2%)
4 (12.1%)
IP audio phones / I...
4 (12.1%)
4 (12.1%)
Unified Communica...
4 (12.1%)
4 (12.1%)
XGS-PON,
4 (12.1%)
4 (12.1%)
Satellite based IoT...
4 (12.1%)
4 (12.1%)
Other satellite equip...
4 (12.1%)
4 (12.1%)
Space Communicati...
4 (12.1%)
4 (12.1%)
SIM Applets for Sub...
3 (9.1%)
3 (9.1%)
Media Gateways
3 (9.1%)
3 (9.1%)
NFV/ SDN CPE
3 (9.1%)
3 (9.1%)
Outdoor AP (802.11...
3 (9.1%)
3 (9.1%)
5G CPE
3 (9.1%)
3 (9.1%)
EPC (Enterprise cla...
3 (9.1%)
3 (9.1%)
SDN Software Cont...
3 (9.1%)
3 (9.1%)
Wi-Fi based broadb...
3 (9.1%)
3 (9.1%)
2 way Analog/ Digit...
3 (9.1%)
3 (9.1%)
Telecom Consultancy
3 (9.1%)
3 (9.1%)
Drone Communication
3 (9.1%)

A.3. R&D Capability Areas

The Indian Communication technology enterprises have ongoing research and development in the following areas, where at least two or more companies have a viable investment:



A tabular form of prioritized R&D capabilities is presented below:

Fields	Organisations in R&D
5G Based broadband wireless infrastructure systems including gNodeB, 5G Core	10

Fields	Organisations in R&D
IoT Modules	9
IP/ MPLS Core routers/ Edge/Aggregation/ Enterprise Router	8
LTE/ LTE-R Based Mobile Systems, with its various derivatives including rural & disaster communications, Macro & Micro eNode B, Small Cells, EPC, NIB C-RAN BBU and RRH, LTE/ LTE-R/ LTE Advanced/ based broadband wireless access systems (eNodeB, EPC etc.) in all standard LTE bands in the country	8
M2M/ IOT Subsystems including NB IoT in different verticals	8
Telecom & IT Software Solutions	8
CPE (including Wi-Fi Access points and Routers, Media Converters),	7
Pico eNodeB, Category 2, TEC ENB GR (TDD/FDD)	7
Satellite based systems	7
Small Size LTE/ LTE-R Based Mobile Systems, with its various derivatives including rural & disaster communications, Macro & Micro eNodeB, Small Cells, EPC, NIB C-RAN BBU and RRH , LTE/ LTE-R/ LTE Advanced based broadband wireless access systems (eNodeB, gNB, EPC, etc.) in all standard LTE bands in the country	7
Smart City Solutions	7
Software Defined Radio, Cognitive Radio systems (all bands)	7
2G/ 3G/ 4G LTE/5G Modems	6
4G NIB Small cell	6
Disaster Communication Systems etc., including backpack satellite products	6
IoT based SCADA Devices	6
Telecom Network Management systems (NMS) with its various derivatives	6
5G Edge networking platform	5
mm Wave Systems	5
Other satellite equipment	5
Radio systems (IP/ Hybrid), Mobile Front haul BBU and RRH (CPRI, eCPRI, FlexE, RoE, NGFI)	5
Satellite based IoT Systems including location, resources tracking	5
Satellite Communication- Ground/ Earth Station Antennas	5
Space Communication	5
AAA block(Authentication, Authorization & Accounting)	4
Camera including long range camera, IP camera & Recorders, Night vision cameras	4
Cloud Computing	4
Distributed Unit (DU)	4
Ethernet Switches (L2 and L3)	4
Home Automation based on Wi-Fi or sub-GHz solutions including sensors, remotes	4
IoT Based Customer Feedback Devices	4
IP audio phones / IP video Phones / Analog adaptor	4

Fields	Organisations in R&D
IP based Soft Switches, IMS, Unified Communication Systems	4
Media Gateways	4
NFV/ SDN CPE	4
NG-PON2	4
Outdoor AP (802.11ac - MIMO 2.4 and 5 GHz bands - IP67 Rated	4
Outdoor AP (802.11n/b/g - MIMO 2.4 and 5 GHz bands - IP67 rated	4
Remote Device Management & Data Acquisition	4
Telecom Consultancy	4
Telecom Network Management systems (NMS) with its various derivatives including Operation Support System (OSS), Billing Support System (BSS), Trouble Ticketing System (TTS)	4
Unified Communications and IP Telephony	4
VoIP and SIP Phones (User Terminals Phones)	4
VSAT Systems	4
Wi-Fi based broadband wireless access systems indoor & Outdoor (Including Access Point, Aggregation Block, Core Block)	4
Wireline PABXs / IP PBX	4
XGS-PON,	4
5G CPE	3
Drone Communication	3
Encryption/ UTM platforms (TDM and IP) (Unified threat management)	3
EPC (Enterprise class)	3
Gateways: GSM, V0IP, Signalling,	3
GNSS based Time Servers (including navIC) NTP. IEEE 1588/PTP for Time Synchronisation and Standalone GNSS receiver for location information	3
GPON equipment (including ONT and OLT)	3
Mesh network of Hardware, Cloud, analytics and Software	3
NB-IoT Geo Satellite Systems	3
Quantum Key Distribution (QKD)	3
Remote management platforms for SIM, Subscription and Device enablement	3
SIM Applets for Subscription Management & Control	3
Telecom Billing Support System (BSS) with all its derivatives	3
Telecom OSS with its various derivatives	3
Terrestrial Communication	3
Two-way MSS Data Terminals (Satellite Receivers with location data)	3
Video Conferencing Applications	3
VSAT terminal Subsystem - IDUs	3
VSAT Terminal Subsystem - ODUs	3
Over-the-Air Technology	2
Secure Element based Identity and Encryption Systems	2

A.4. External Presentations

“NextG Alliance” Presentation by Dr. Farrokh Khatibi (Qualcomm)

Next G Alliance.pdf

“EU’s 6G Smart Networks and Services (SNS) Joint Undertaking” presentation by Dr. Colin Willcock.

EU 6G-IA
Presentation to TSDSI

सत्यमेव जयते

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