

# STRATEGIC IMPLICATIONS OF 6G TECHNOLOGY DEVELOPMENT ON INDIAN DEFENCE ARENA

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## **Abstract**

Future wars; both kinetic and cognitive, will be shaped by wireless communications. The wide scale use of communication networks and digital space in ongoing conflicts; Russian-Ukrainian and Israel-Hamas are testimony of the fact that not only the control of spectrum but also its intelligent and innovative use that will play a decisive role in times to come. The perceived military benefits of faster, widely available networks have accelerated the race for networks like 6G. Ubiquity is the unique features of 6G i.e availability on land, space and underwater. AI will be integral part of 6G technology and will revolutionise human-to-human, human-to-machine and machine-to-machine interactions. Amid all these fast emerging wireless technologies, militaries around the world need to adapt, innovate and re-design their strategies. With widening user base, increased data-centric applications, and Industry 4.0 requirements, 5G network is expected to saturate and eventually making way for 6G. To achieve the milestone of 6G rollout by 2030, a well funded research, government support and user participation is essential. Many countries have already made considerable investments in development of 6G infrastructure and components. 6G development should be top priority of India as the country not only has the potential to be a leader in 6G technology development but also can be a leading manufacturer of its

components. Indian defence forces must capitalise on the benefits of 6G in war-fighting and should associate from the inception stage to develop defence specific applications of 6G. The article covers the limitations of 5G network, the AI entanglement in 6G, applications of 6G, joint military applications and the development story of 6G so far.

## **Introduction**

Wireless mobile networks have seen significant revolutions in last three decades. Countries like China have taken leap steps in adding 'intelligence'<sup>1</sup> to the networks. Emerging niche technologies like Internet of everything (IoE), Edge computing, Quantum computing, Virtual reality, 3D media, AI and Machine Language (ML), which were originally designed for civil world, have found impacting applications in military world. By end of year 2025, 65% of the world's population is expected to have access to 5G network. While 5G is fully deployed, research has already begun on 6G networks also known B5G, 5G++ etc.<sup>2</sup> In wireless tech domain, it is believed that after every 10 years the next technology takes over. Going by this, by 2030, 6G technology should be fully implemented and standardised. Most of the niche technologies being developed need wireless networks and considering this fact, a strategic competition is being build up in the world to take lead in these wireless network technologies.

In the ongoing Russian - Ukrainian war, Russian forces used the tactics of blending cyber and physical attacks on Ukrainian C4ISR networks. On the other hand, Ukrainian forces extensively relied upon satellite public telecommunication and Cloud Computing as backup for its continued operations with the help of web based solution providers like Microsoft, Google and Amazon. Indian defence forces may face similar attacks from its adversaries and might have to resort to 'intelligent' strategies in future.

We have already witnessed extensive use of UAVs, UCAVs, Underwater drones in Russian-Ukrainian war. Warfare henceforth will definitely include use of 6G driven intelligence swarms, Cross domain mobile warfare, Cognitive control operations and AI based space confrontations. 6G has also revolutionised hypersonic missile communication

technology. USA, UK, China and Finland are already patenting 6G technologies. India, has also taken some initiatives, albeit late, for nurturing 6G Technology. A 6G alliance (6GA) has been set up and research and development centres are being formed up in government and privately funded laboratories. Considering the implications of 6G on security, it's imperative for Indian defence forces to take a lead in steering faster development of 6G and associated niche technologies.

### Evolution of 6G

Last three decades have witnessed revolutionary changes in mobile communication and exciting applications like Internet of Everything (IoE), Virtual Reality (VR), 3D media, Artificial Intelligence (AI), enhanced mobile broadband (eMBB)<sup>3</sup> have seen rapid growth. 5G network was expected to strengthen the Internet of everything. However, due to inherent limitations of 5G network, it is not able to create a fully automatic and intelligent network that enables high mobility service. 4G and 5G network also exhibit issues such as high mobility, Doppler Shift and lack of coverage in some zones. Table 1 gives a brief comparison of 4G 5G and 6G Technologies.<sup>4</sup>

KPIs	4G	5G	6G
Peak data rate /device	1 Gbps	10 Gbps	1 Tbps
latency	100 ms	1 ms	0.1 ms
Max. spectral efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Connection density	2000 devices/Km <sup>2</sup>	1 million devices/Km <sup>2</sup>	>10 million devices/Km <sup>2</sup>
Coverage percent	< 70 %	80%	>99 %
Positioning precision	Meters precision (50 m)	Meters precision (20 m)	Centimeter precision
End-to-end reliability	99.90%	100.00%	100.00%
Receiver sensitivity	Around –100dBm	Around –120dBm	< –130dBm
Mobility support	350 km/h	500 km/h	≥1000 km/h
Satellite integration AI	No	Partial	Fully

KPIs	4G	5G	6G
Autonomous vehicle	No	Partial	Fully
Extended Reality	No	Partial	Fully
Haptic Communication	No	Partial	Fully
THz communication	No	Massive MIMO 90 GHz	Widely
Service level	Video	VR, AR	Tactile
Architecture	MIMO 6 GHz	Massive MIMO 90 GHz	Intelligent surface 10 THz
Max. frequency	Video	VR, AR	Tactile

**Table 1: Comparison of 4G, 5G & 6G Technologies**

6G architecture is being designed in a way to resolve these issues and provide high speed ubiquitous network. This network will be enabled through meshing of Satellite, Air and Terrestrial Communications. 6G Network will also cover underwater communication, giving vital coverage to under water vessels including submarines. 6G data coverage would be accomplished through hybrid networking of device to device, low Earth orbit satellites and satellite communication. 6G ultimately intends to amalgamate computation, navigation and sensing within the communication network. The expected technical features of 6G include a high data rate of 1 Tbps, operating frequency of at least 1 THz, end to end delay of not more than 1ms, reliability rate of  $10^{-9}$ , high mobility of at least 1000/h and a frequency range up to 300 $\mu$ m.<sup>5</sup>

### **Role of AI in Enhancing 6G Technology**

AI would play an important role in enhancing the 6G network structure and will help 'intelligentise' 6G applications and functions for domains like architecture, computing storage etc. AI will enhance the speed of 6G networks.<sup>6</sup> AI may also be used for data analysis of the 6G network and identify the places where improvements are required. This will help reducing latency and improve overall network performance. AI will also help to optimise the network requirements while streaming videos or large files like real-time

battlefield picture. One of the important aspects of use AI is the ability to detect and prevent suspicious activities on the network, identify them and block potential threats. This can help in improving security of 6G networks. AI will also help in detecting and preventing data breaches which will keep users safe and help protect their data. AI optimised 6G networks will ensure that user get the best possible digital experience.

### **General Application Domains of 6G**

AI will change the way human life will behave after the year 2030. In fact, 6G will be the driver of broader AI applications. Some of the general applications of 6G in terms of emergence of niche technologies are<sup>7</sup>

- Bio-implants, wearable devices, skin patches, brain sensors with natural and intuitive interfaces.
- Typing will be replaced by gesturing and speaking.
- Cameras and Sensors will be deployed en masse due to rapid advances in AI, 6G and computer vision.
- Many of the human tasks will be replaced by Service robots.
- In-body devices and 24x7 parameter monitoring will forever change the healthcare fundamentals.
- Dynamic Digital twins will augment human intelligence and holographic telepresence (appearance of entity at multiple locations at same time) will be a reality with the help of 6G networks.
- Smart cities leveraging 6G technologies, AI enabled autonomous vehicles, sensors, cameras for traffic control, cashless transactions, environmental data and weather data for public assistance and much more will be a reality by 2030.
- The multi-sensory XR experience will be further enhanced using dynamic VA/VR.

## **Development of 6G and Associated Military Applications**

Modern military forces by 2030 would be potentially based on industries standards 4IR or IR 4.0 (4th Industrial Revolution). These militaries will emerge as powerful 6G device forces and would be harnessing niche technologies like AI, ML, Big data, Cloud computing, AR, Quantum computing, Cognitive computing and IoT wave. 6G technology would make military operations highly digitized and intelligent and further would serve both as weapon of war and tool of deterrence. 6G would be the core technology of any net-centric strategy consisting of large number of assets that could operate from space, near space, fly in the air, on surface and deep into underwater to conduct large scale ISR missions and exploration. A wide network of sensors, vehicles and robots would operate with the help of 6G communication and using AI will highly influence the missions, which will be faster, deadlier and autonomous. At the tactical level, the 6G and AI interplay will further shrink the OODA loop and will help Tactical Commanders take faster decisions. The likely uses of 6G by military are as follows:

- Rapid data exchange between sensor and analytics will significantly improve ISR capabilities. More devices can be connected on different frequencies. For Indian defence forces 6G will be a big enabler for Theatre Commands and Theatre Commanders based on rapid real-time field picture and ISR can play a decisive role in guiding the forces and taking critical decisions like defence mobilization etc.
- 6G will enhance battlefield communication and make it more secure.
- UCAVs/UAVs/AVs/Drones will be the largest beneficiary of 6G communication. 6G will provide devices (surface space and underwater) with seamless connectivity, precise tracking and improving their speed and range.
- 6G communication is going to play major role in providing communication links for hypersonic weapons.
- Net-centric Warfare and Joint war fighting, wherein all three defence forces would be deploying their assets and execute effect based operations, would be enhanced using 6G.

- As discussed, precise, high rate of real-time data available would help in theatre monitoring easy.
- 6G will enhance training of soldiers, providing them with real-time experience using VR and AR and would help them formulate their own tactics and strategies using the vast data available.
- Undertaking remote medical procedures using 6G framework will help military doctors in treating battlefield injuries in field areas itself.
- Armed robots operating on autonomous 6G network using brain machine interface (BMI) of 6G will be an effective alternative to soldier on ground during critical operations.

## **6G Technology Challenges**

### **Coverage in Mountains and Power Infra**

So far, the focus of 6G development is on high data rates rather than connecting the remote areas; hilly terrains, the places where wars are likely to be fought. However, research has begun on challenges in connectivity; especially backhaul connection, the link between the internet and local access points. Coverage in hills can be demanding, in terms of range and power infra requirements. Recently, a research team from the University of Stuttgart<sup>8</sup> has succeeded in establishing a broadband connection in the mountains between the valley and the summit for the first time in Austrian Alps, at an altitude of 2334 meters over a length of 2 x 10.5 kilometers and transmitted data at a speed of 25 gigabits per second. In absence of fiber network, laying of which may not be viable in mountainous terrain, satellite constellations like Starlink by SpaceX and the systems by OneWeb and Telesat can be game-changers.<sup>9</sup> The forthcoming 6G networks are expected to leverage the power of flying platforms [e.g., unmanned aerial vehicles (UAVs) and high-altitude platform stations (HAPSs)] in different network segments including the backhaul part, especially in harsh terrains or if terrestrial deployments have collapsed or not been set up. To achieve this goal, non-terrestrial networks need to address a number of technical impediments

related to their integration with terrestrial infrastructure, their placement in three-dimensional space, and their energy efficiency concerns, thus calling for further research.

Use of low-power Power Amplifiers is being explored to minimize the power requirements of 6G networks. Use of alternative power sources like Solar and Wind to power Base Stations is also been in works. There is also room for developing low-power beamforming hardware and software in 6G which will help to increase data rates or range and adjust radiation patterns based on need. On the other hand, intelligent reflecting surfaces (IRSs) are among the latest breakthrough technologies of the 6G ecosystem, used to passively reflect the signal without amplification. Since solar power is not always available, solar power can be supplemented by other off-grid energy sources, such as wind energy, hydrogen cells, and others. One way to reduce the number of towers and their heights is to utilize diffraction, wherein a signal propagates beyond LoS obstacles. The problem is how this phenomenon can be efficiently utilized. Network planning and propagation estimation tools are needed for simple and cost-effective planning.

### **Security and Cyber Challenges**

6G applications also have specific vulnerabilities. The robotics and autonomous systems typically rely on the AI and the VLC (visible light technology) where malicious behavior, encryption and data transmission can be compromised.<sup>10</sup> The multi-sensory XR applications use the molecular communication technology, the THz technology and the quantum communication technology, which means they are susceptible to access control attacks, malicious behavior, and data transmission exposure. Wireless Human-Machine interface use the same techniques as the multi-sensory XR application, but have their own unique security and privacy issues. Essentially, 6G technology components are prone to five main types of security and privacy issues: authentication, access control, malicious behavior, encryption and data transmission.

The Cat and Mouse game of vulnerabilities and counter-measures will continue in 6G technology also. However, parallel tech is being developed to mitigate the possible security and cyber threats. For different phases of cyber security protection and defense in 6G, concept of distributed AI/ML can be used. The utility of AI/ML driven cyber security lies



on the advantages in terms of autonomy, higher accuracy and predictive capabilities for security analytics.<sup>11</sup> There is hope of research in introducing ML based cyber-security and quantum encryption in communication links in 6G networks. Quantum ML algorithms may enhance security and privacy in 6G communication networks. There are promising 6G applications where there are potentials in applying quantum security mechanisms. PLS (Physical Layer Security) methods will be leveraged by 6G to provide an adaptive additional layer of protection in the context of new enabling technologies.

### **6G Development Scenario in Other Countries**

6G developments at present are in a free competitive stage, focusing primarily on profitable avenues for 6G applications, the technology and associated requirements. The parent organisation for global wireless telecommunication standard setting activities, the 3GPP (the Third Generation Partnership Project) embodies the multinational nature of this technology. The group has partnering organisations from USA, Europe and Asia. Statistically 3GPP includes 439 companies from Europe, 171 from China, 145 from India, 95 from USA, 46 from Japan, 15 from Finland, 18 from Singapore, Nine from Taiwan and Two from Russia. These players are actively involved in designing 6G component technology, acquiring patents, anticipating standardisation and commercialisation in coming few years. Research is the current activity these organisations are at present involved in due to capital intensive and technical complexity of the technology. The major companies involved in 3GPP are Europe (Nokia, Ericsson, Orange), USA (Cisco, AT&T, Qualcomm, Verizon), China (Huawei, ZTE), South Korea (Samsung, LG), Japan (Fujitsu, NTT, Docomo).

### **Battlefield 6G: How USA And China are Shaping the Technology for Military Use**

USA and China, both view 6G and associated disruptive technologies as key areas of competition for technological domination in the Civil and Defence sectors.<sup>12</sup> Beijing's efforts to combat intelligent warfare and system confrontation are progressing in sync with the 6G technological maturity. Chinese scientists recently developed a device that could effectively use 6G technology for hypersonic communication and target detection, overcoming previous problems of signal blocking that occurs at these speeds. Chinese

defence in year 2020 had laid down the vision for how 6G could be used in future operations.<sup>13</sup> This include cross domain communication networks enabled by Satellite, Drone and Optical technologies. PLA may use 6G for enhancing ISR capabilities, especially of space. US Department of Defence, on the other hand is focusing on development of 6G in four major areas; contested logistics, joint fires across all domains and services, joint command and control of all domains (in both permissive and contested environments), and information advantage. DoD is putting emphasis on the downstream challenges post by improved data-centric warfare and future warfare concepts namely training and decision making requirements and security related strategies. As USA witnesses a great leap being made by China in 6G and AI, the DoD is pushing for increasing need for war fighters to better understand the strategy and get prepared and trained to be disruptive and becoming innovative soldiers who can make impact in contested and chaotic environments.

### **Bharat 6G - India's Road to 6G Network**

Indian government is making all out efforts in driving 6G research and innovation with an aim to promote India as a global lead in 6G technology and becoming its mainstream manufacturing hub. The country has adopted a nationwide approach involving industry, start-ups, academia and research laboratories, standards bodies in not only achieving the self-reliance but also making useful contributions to the world.<sup>14</sup> In the year 2021, the Department of Telecommunications under Government of India (GoI) has formed a Technology Innovation Group (TIG) for 6G with members from various ministries/departments, research and development institutions, academia, standards bodies, telecommunication service providers and industry. The aim of the group was to develop vision, mission and goals for 6G and also develop a broad road map and draw plans for 6G development in the country. Based on the recommendations of this TIG, the GoI have prepared and issued a comprehensive Bharat 6G Vision Document.

### **The Bharat 6G Vision and Mission**

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

India<sup>15</sup> is based on principles of Affordability, Sustainability, and Ubiquity. The document envisions that India takes its legitimate place in the world order as a leading manufacturer, supplier of next-gen telecom technologies and possesses capabilities to offer solutions that are affordable and contribute to the overall global growth. As per the vision document, India plans to achieve 6G mission in two phases; Phase I from 2023-2025 (Ideation); Phase II from 2025-2030 (Conceptualization and delivery).

### **Bharat 6G Alliance - B6GA**

The Bharat 6G Alliance is conceptualized to be an alliance of domestic industry, academia, national research institutes and standards organizations, sponsored by GoI. The B6GA is guided by broader guidelines of Bharat 6G Vision Document and have the authority to draw its further course of action. Strengthening its efforts on 6G, on 09 Sep 23, during the G20 Summit at New Delhi, Next G Alliance of North America networks and the Bharat 6G Alliance announced that they had signed a Memorandum of Understanding<sup>16</sup> (MoU) to further explore opportunities for joint collaboration on 6G wireless technologies.

### **Implications of 6G Developments for India and Joint Military Applications**

Addressing the nation from New Delhi's Red Fort on India's 77<sup>th</sup> Independence Day, Prime Minister Narendra Modi said that the country is prepping to enter the 6G era soon. "We have formed a 6G task force," he said during his Independence speech at the Red Fort.

India today has more than 30 Crore smart phone users. As India approaches 'Swarnim Bharat' dream in 2047, the next two decades are a crucial period of growth. Technological advancements and manufacturing capacity will determine the country's future. It is critical to take advantage of the opportunity presented by the 6G, even if the technology is in nascent stage. As the second largest telecommunications market in the world, India must evolve and project itself into a global provider and manufacturer of network technology. It should be the country's endeavor to actively participate in defining the contours of 6G and drive tech innovation to meet the urgent needs of not only India, but also of global world. India's early participation and lead in 6G technology development will help reduce differences in regional and social infrastructure. The impending

integration of space and terrestrial networks into a seamless, unified India offers the opportunity to leverage its space technology capabilities to fill the gaps in the coverage of its vast rural hinterland and ensure that all Indians, regardless of their location have broadband connections.

Militarily, 6G and AI will help India modernize its forces, help optimize the forces and keep its deterrence high especially w.r.t China. The country is poised to grow at fast pace economically and is been seen as Global smart power. Space and underwater are two domains where Indian armed forces see huge potential to grow. Both these domains will be enormously benefited by 6G technology. India is also fast becoming a 'Drone hub' of the world. 6G technology will enable next generation of drones and robotics and can further establish India as a global supplier of these disruptive war fighting elements. In a nutshell, 6G and AI can propel the missing Indian quest for military exports besides strengthening its own boundaries.

### **Key Recommendations**

Taking into consideration China's advances in AI and investments in 6G, the Indian security space needs to take definite steps to counter China's technological edge in 6G and AI. Limitations in the semiconductor industry, manufacturing and technology development must be prevailed over to position us at the starting line of this competition. Based on this paper, the recommendations for the military use of 6G in India are as follows:

- Keeping in mind the future wars, AI enabled equipment and changing tactics, there is a need for including military specific representatives in 6G Apex Body and Directorate. These representatives along with experts from academia, R&D labs and Private consortium will focus on developing 6G technology components for enhancing country's security infrastructure.
- R&D Labs, be envisioned as 'Military 6G & AI Clusters' and funded for 6G development based on competencies for orchestrating new generation equipments. The Labs should be agile and quickly adaptable to evolving military needs. *Formation of STEAG (Signals Technology Evaluation and Adaptation Group) by Indian Army and AI cell*

*under UDAAN (Unit for Digitisation, Automation, Artificial Intelligence and App Networking) of IAF is a positive step in this regard.*

- Dedicate funding for R&D in 6G and AI for developing military specific hardware and software. Use of 6G enabled ISR with AI technologies to assist the Local Commander at remote borders in war fighting must be the key priority of any 6G development project. Similarly, AI enabled Robotics, having high processing powers, propelled by 6G communication would be a revolutionary change for any military.
- Alliances with friendly nations to develop critical 6G technologies for defence and further commercialization of the same needs to be made.
- Government special funding for key 6G applications such as Drone communication, Human-Machine interfaces, Low Orbit Satellites (LEOs), Hypersonic Missile communication, Extended Reality, Digital Twins etc.
- While reviewing Spectrum requirements for 5G+/6G, the Military requirements must be taken into account.
- With an eye on Indo Pacific region and to secure our sea lines of communication, development of key 6G technologies for deep sea water and under water communication must be facilitated.

## **Conclusion**

‘Intelligent’ warfare, driven by 6G and AI demands absolute integration of military and civil domains as we witness blurred lines between peacetime and wartime. The outcome of a war will be determined not by who destroys the other in a kinetic sense, but by who derives the greatest political benefit out of it, as is being seen in recent conflicts in Russia-Ukraine. Intelligent warfare integrates human and machine intelligence. Soldiers will eventually no longer be the first line of battle and wars will be fought under the overall gambit of intelligent systems, ultimately the war becoming a machine-on-man or machine-on-machine oriented. Strategically and tactically, human fighters, including the commanders will comprehensively enhance their inherent cognitive and physiological capabilities using 6G and AI. Cross-domain warfare and asymmetric combat in military

operations will be new normal in future conflicts. Unmanned operations will reset the rules of engagement and redefine the support process. To protect our growing economy from these immediate future threats, India must keep accelerating efforts to develop 6G and its assisted niche technologies. The Bharat 6G vision document and the 6G Alliance, as well as recent collaborations with friendly nations, are steps in the right direction, but allocating more funds for research and development is the need of the hour. The overall objective for India as a nation remains to become global 6G technology provider for human good while maintaining strategic deterrence for its military.

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