Chapter

AI and ML Applications: 5G and 6G

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Abstract

Applications that existed in 4G will become 10 times faster in 5G and 100 faster in 6G in terms of handling uploads and downloads. The key reason is the communication infrastructure which is going to change in the internet backbone. The devices will be upgraded to 5G and 6G soon. In some countries, it is happening now. This will change how the locational intelligence and real-time streaming applications perform and how they are being used. The scalability and reliability of the AI applications and solutions will improve with 5G and 6G implementations. In this article, 5G and 6G roadmap for the applications is discussed in detail. Issues with 5G and 6G are presented with solutions and how new applications will evolved from 4G to 5G to 6G. Different approaches are discussed to solve the lingering issues in 6G using AI/ML.

Keywords: AI, ML, 5G, 6G, cognitive science, conversational AI

1. Introduction

We are now on 4G technology. Looking at changes in our daily life with new applications from 3G days to 4G, there is a huge potential for 5G and 6G applications. 5G deployments are happening across the world and the new 6G technology is the now popular technology. New infrastructure on 6G will have capabilities like 1 Tbps data rates, a latency of 1 ms, and battery life for devices as 20 years. Research is going on in the areas of Terahertz communications, quantum networks, Big Data, Cell-Free Networks, and pervasive AI (Artificial Intelligence) [1]. As shown in **Figure 1**, 5G is already implemented in a connected form where mobile devices, connected cars, IOT (Internet of Things) sensors, RFID, and other computing devices are using this network to communicate and provide services to the consumers.

As the new technology-based networks come into vogue, mobile traffic increases because of new applications and increased network bandwidth. The overall traffic increased as the data downloaded from the cloud or other servers to the device increased. YouTube consumption is around 20 percent of total network bandwidth. Similarly, TikTok is 16%, Facebook is 15%, Instagram 12%, Netflix 4%, and others are consuming 5% of the network bandwidth for video streaming. In the mobile network bandwidth consumption, YouTube, Google, Instagram, and WhatsApp are the key players. iTunes and Google Play are applications from the marketplace that consume network bandwidth for audio and video streaming. Spotify and other podcast applications are in the top category for bandwidth consumption [2].

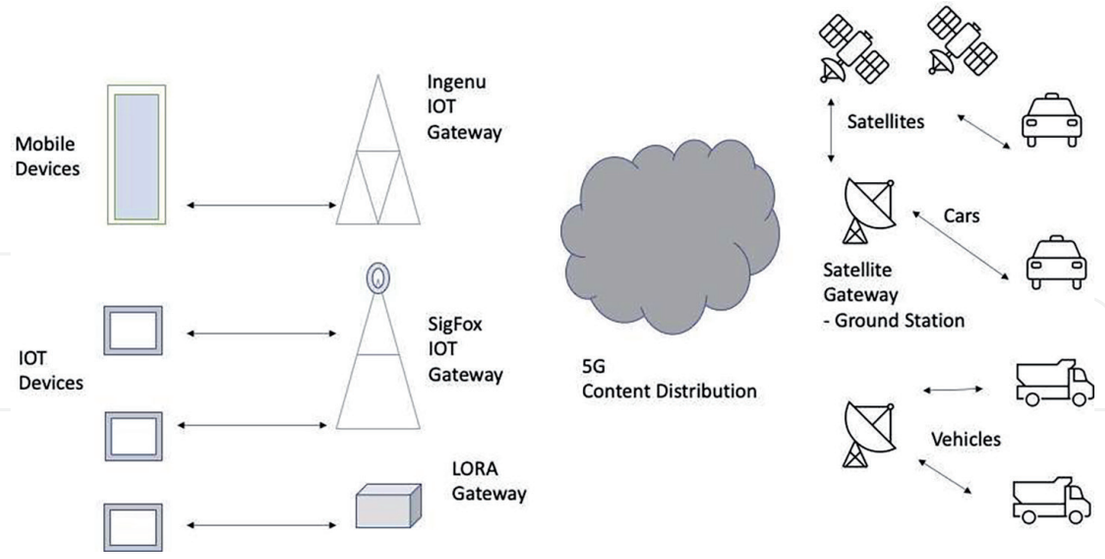

Figure 1.
Inter-device communication in 5G network.

2. Difference between 5G and 6G networks

After 5G implementation across different countries, it is time for 6G. 6G has features to help with immersive technology implementations based on connectivity. In 5G, data transfers happened across the devices in the network. By the time 6G is implemented, you will have fifteen times the current of mobile users in the world. Connected transport is an evolving area that impacts robots, drones, smart home devices, manufacturing devices, and construction machinery. Drones and Unmanned aerial vehicle connectivity have improved with 5G capabilities. New areas of focus like battery power management, energy monitoring, and environmental conditions have emerged after 5G. This paradigm change happened because of Edge AI and sensory networks [3]. Privacy and security concerns [3] have increased with the growing number of devices and applications.

Using 5G, devices can communicate with each other faster as show in the **Figure 2**. 5G applications will have potential to communicate faster and with lesser latency. There

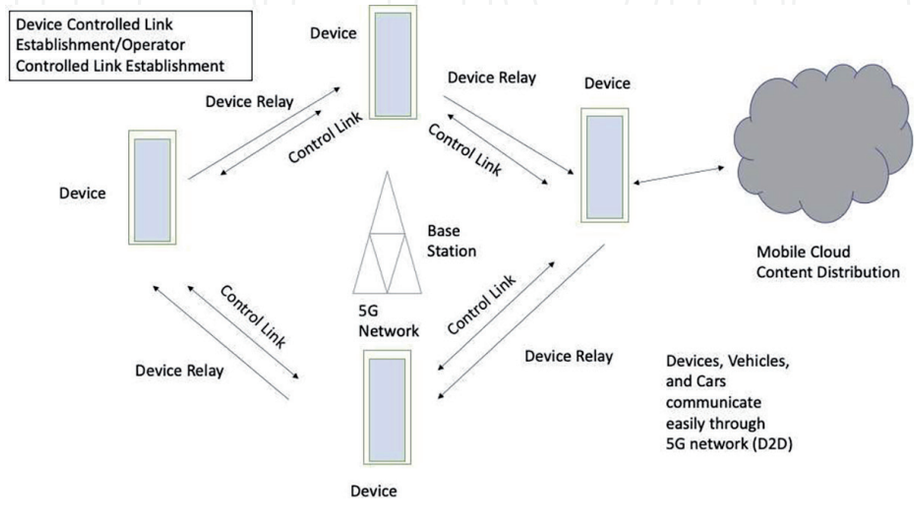

Figure 2.
5G Implementation providing services.

is a huge opportunity for telecom and retail players to work with fintech firms and banks to provide apps for consumers and businesses. This will help build a platform and ecosystem for vendors/partners to provide products and services [3].

Data connections have increased with the number of devices. Most of the offline and online sync-up processes are automated and based on intelligent rules. Robotic agents and bots have simplified monotonous tasks using Robotic process automation. 6G differs from 5G in the areas such as data rates per device, coverage, the number of devices connected, low latency integration, energy consumption, integration of IOT/VR (Virtual Reality) /AR (Augmented Reality) into XR (Extended Reality), distributed MIMO (Multiple-Input Multiple-Output), reliable connections, dynamic analysis, trusted and secure integration mechanisms [3].

In 5G, applications were related to eMBB, URLLC, and mMTC. Moving to 6G, applications will be built based on HTC, tactile internet, VR/AR/XR, and intelligent machine automation. The peak data rates in 5G will be 10 Gps whereas 6G will have 1 Tbps. The frequency of the 5G network will lie between 3 and 300 GHz. 6G network frequency will be 1000 GHz. The latency of a 5G network is 10 ms and in the case of 6G will be less than 1 ms. Mobility support can be up to 500 km/h in 5G networks. 6G network can support up to 1000 km/h. The spectral efficiency of the 5G network is around 30 bps/HZ. In the case of 6G, 100 bps/Hz. The reliability of the 5G network is around 99.9999% and in the case of 6G will be 99.99999% [3].

3. 5G applications

5G has changed the mobile experience as it is on a high-end network compared to 4G. It is delivering speeds up to 20GBps of download rates. It is matching the fiber optic-based network which is accessible by mobile. 5G network can handle high transmission rate, data speeds, and voice. Most of the networks have achieved low latency when they switched to 5G Technology. Many apps related to self-driving vehicles, government, and defense are on 5G networks performing with 0.5-millisecond latency. These networks are based on radio transmission and hence have higher bandwidths for handling big data rates [4].

5G network has given a new responsive customer experience to the mobile users on the network. Users can access cloud storage, and enterprise apps, and execute the jobs with higher processing power. Device makers and app developers are on the 5G ecosystem introducing new devices and applications. Offline scenarios are being supported by these devices and apps to improve the 5G network performance. As the network based on 5G has small cells, it helps in the delivery of high data transfers, low usage of power, and access to cloud providers [4].

AR/VR applications are being used on devices that are on a 5G network. Virtual worlds on metaverse are being experienced using immersive technology-enabled devices on a 5G network. Audio and video on 5G devices are much clearer compared to 4G and LTE networks. Sports events and cultural performances are delivered live on the 5G network with high definition. OTT channels are also enabled on mobile devices with HD TV resolution. Media and entertainment content delivery doubled and might triple by the end of this year after 5G emergence. These networks can deliver 120 Fps (frames per second) with high resolution. The devices can deliver dynamic range streams on video without any breaks. Gaming is getting popular and with an improved experience on the 5G devices [4].

In different verticals such as education, retail, media, healthcare, insurance, banking, finance, and energy, 5 g-based applications and devices are being used by the

consumers and the employees working in these companies. 5G can deliver trillions of revenues by end of this year [4].

In the area of IOT, a 5G network is being used for smart homes, smart buildings, and smart city applications. These networks connect different devices, sensors, appliances, and apps to the cloud for collating data. IOT apps are built using the collated data on the cloud for the consumer's access. The collated data is processed, and analytics are presented in real-time for the user. Smart buildings and cities will be operating on 5 G-based networks with better communication and management of apps. Smart homes and appliances within the home will be connected to the IOT network using 5G communication channels [4].

In the transportation sector, 5 G-based networks will help better asset tracking, managing fleet, data aggregation, scheduling resources, and delivery monitoring. This will help the company's revenue generation and improve customer satisfaction. 5G network helps in providing channels for devices to interact and communicate in a better and scalable way. In transportation, RFID tag usage, supercharged labeling, packing, environment monitoring, location intelligence, dashboard tracking, and autonomous vehicles/drones for delivery have come into existence. Transportation planning is done using AI/ML techniques [4].

In smart cities, 5G based network has impacted in better managing traffic, updating weather, broadcasting, energy, power, lighting, water resources, crowd, emergency notification, and communication to the resources. 5G network has helped in process automation, improved asset maintenance, a secure environment [5], and better transport capabilities. Sensors and devices in the industrial internet of things networks are helping in making the operations secure, smart, lesser cost, and lower energy utilization. AI/ML algorithms are being utilized for traffic management and energy optimization [5].

The agriculture sector has changed because of the network based on 5G. Sensors and GPS devices are being used by agricultural resources for asset and animal tracking. They are also being used for energy monitoring, security, and water resource management. Resource management is easy for tracking devices in fleet management. In health care, professionals and doctors are using the network for operations and surgeries. Patients are using devices and sensors for being monitored for heart and other critical organ problems. Doctors can communicate with patients and access the organ data for detecting the problem and recommending the next steps for the patient. Remote surgery procedure is also feasible on a 5G network which connects the surgeon to the hospital ICU where the patient's surgery is happening. The other technology areas which are impacting the transformation of hospitals are medical devices with sensors, analytics, and imaging technologies. Patients can be monitored with the embedded devices for changes in their condition and alert the doctor to react to the emergency condition. These alerts reach the ambulance management to handle crises to pick up the patient from home. The big data transfer of health data is also feasible on a 5G network. Live events and classes are happening on mobile devices of students and working professionals in various sectors including healthcare [5].

Autonomous cars are a reality today because of the effective communication provided by 5G networks. These networks have low latency and help make driving smoother in autonomous vehicles. New scenarios are being handled well by self-driving cars like traffic signs, detecting obstacles, and other vehicles. As car driving is time-critical, split-second matters and it is doable with the capability of a 5G network. These cars are based on AI/ML algorithms and techniques [6].

Autonomous drones are being used for field operations in the areas of health care, event management, delivery of goods, surveillance & monitoring, media, and entertainment. In the case of pandemics like covid, drones have played an important role in handling the delivery of medicines and food for patients where humans cannot enter and touch or breathe the air in the environment. These drones can help in gathering terrain information and data related to farming and agriculture. Data gathered helps in terrain mapping and improving the location services and transport [5].

Satellite communication has improved with base stations being connected using the 5G-based network [6]. Villages and towns are connected because of the satellite. Satellite communication has helped us in better weather prediction and terrain monitoring. The overall 5G usage and apps have increased and impacted the world economy in a better way [6].

The **Table 1** presents the use cases in different verticals and applied technology in each use case related to 5G implementation.

4. 6G applications

Now let us talk about 6G networks. 6G networks have better eMBB (Enhanced Mobile Broadband Communications), URLLC (Ultrareliable Low Latency

Technology	Vertical/Horizontal	Use Cases
AI	Agriculture	Precision agriculture, Monitoring the environment
AI	Transport	Locational Intelligence, Asset Tracking
IOT, AI	Smart Home	Environment Monitoring, Security
AI, IOT	Remote Operation	Monitoring, Security Alerts
AI, IOT	Health Care	Remote Patient Monitoring, Health care Assistant
AI, IOT	Smart Office	Environment Monitoring, Security
AI, IOT	Smart Devices	Security and monitoring
AI, IOT	Smart Grid	Activation of service, Billing, Metering
AI, IOT	Connected Vehicles	Entertainment, Locational Intelligence
AI, IOT	Smart Sensors	Locational Intelligence, Monitoring of systems
AI, IOT	Retail	Customer behavior Monitoring, Inventory Control, Asset Expiry control
AR, VR, AI, IOT, Wearables	Tourism	Locational Intelligence Intelligent Guide
AI, Chatbots AR, VR	Education	Conversational Assistant, Knowledge Assistant, Metaverse, Immersive Reality
AI, Chatbots, IOT	Fintech	Portfolio management, Customer service assistant
AI, IOT	Automotive	Locational Intelligence, Asset Tracking

Table 1.
5G use cases.

Communications), mMTC (Massive Machine Type Communications), and other capabilities which are better than in 5G networks. The mobile users will have a better experience using VR, AR, and XR applications. AI/ML-based applications will help in quick decision-making. There are challenges in implementing 6G networks which are coverage, capacity, and power related. AI/Ml algorithms like KNN (K-Nearest Neighbor) and Random Forest are used for path loss optimization (PL). New techniques are being proposed and researched related to the allocation of power and association of joint users. GRL (Generalization Representation Learning) approach is being used for power optimization in the 6G-based network. SRL (Specialized Representation Learning) is another approach that can help in bringing power utilization. These approaches are blended with different supervised and unsupervised learning techniques for the prediction of the network's optimal operational parameters. In the **Figure 3**, retail sensors, mobile devices, energy industry devices like smart meters, cloud-based applications, healthcare apps, and low frequency-based sensors (NFC/Bluetooth) are shown as part of the 6G ecosystem.

6G-based networks open up the usage of immersive reality and users interact & communicating with the server for discussion points. New use cases, data types, and scalability scenarios are being proposed for 6 G-based networks. Quantum Communication, THz communication, AI, AR, E-Health, Robotics, Manufacturing based on Industry 4.0, and Holographic telepresence are the emerging use cases. ML (Machine Learning) techniques are being used for the optimization of the quality of service of the 6G networks. These networks will generate data and consumers in the ecosystem read the data as data is the fuel for predictive analytics [7].

The networks based on 6G will change the way networks operate and new research is emerging in the area of network operations. The key areas of research are radiofrequency data analysis, cross-layer wireless optimization, RF(Radio Frequency)-Centric management, massive machine-to-machine communication, and multi-function device coordination. The **Table 2** below presents the use cases in different verticals and applied technology in each use case related to 6G implementation.

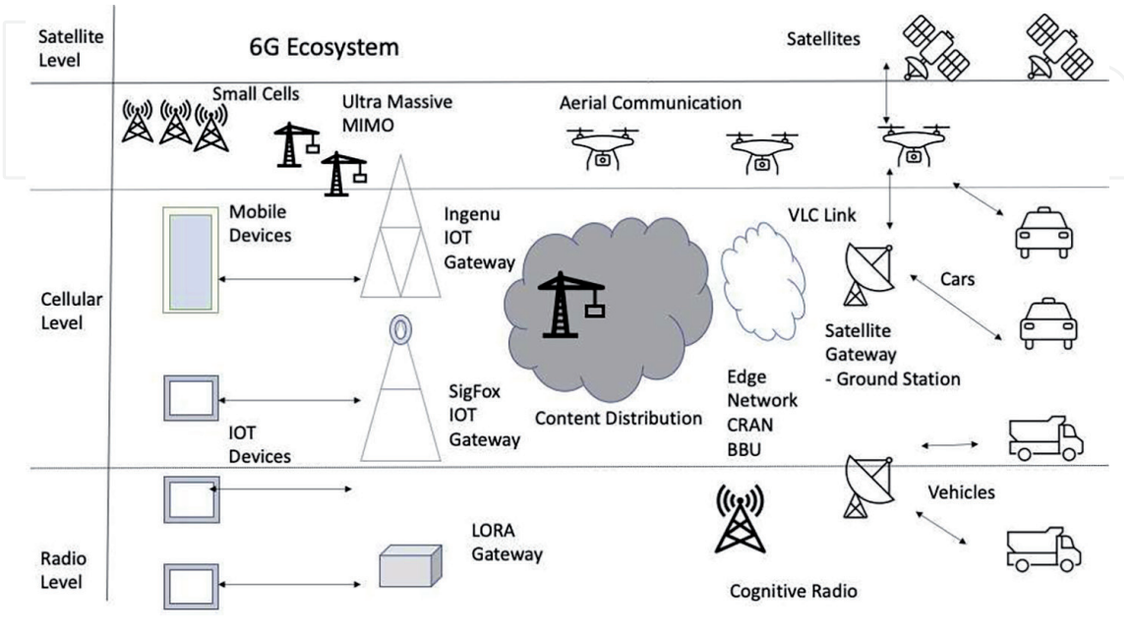

Figure 3.
6G ecosystem.

Technology	Vertical/Horizontal	Usecase
AI, IOT	Transportation	Service Automation, Service Provisioning, Performance evaluation
AI, IOT	Health Care	Distributed Service Deployment, Remote Patient Monitoring, Athlete Monitoring
AI, IOT, NLP	Education	Knowledge Discovery, Knowledge Mining, Knowledge Graphs
AI, IOT, Robotics	Manufacturing	Scheduling, Process Automation, Digital Twin, Autonomous Supply Chain
AR, VR, AI, IOT	Connected Vehicles	Autonomous Vehicles
AI, IOT	Aerospace & Aviation	Communication Networks, Connectivity, UAVs
AR, VR, AI,	Media	Telepresence, Digital Twins,
VR/AR, Immersive technology	Education	Metaverse, Games, Gamification

Table 2.
6G use cases.

5. 6G issues

There are many issues identified with 6G networks. The solution to these issues also will be based on Machine Learning and artificial intelligence. Many researchers are looking at these issues and possible solutions. To start with, the traffic in these networks will reach 5 k exabytes per month by 2030. It was around 7 Exabytes per month back in 2010. This traffic will create problems for the current 5G network. 6G network will come to the rescue as these networks use intelligent reflecting surfaces to manage high-frequency radio bands. This key differentiator will play an important role in networks based on 6G. Typically, a base station sends the signal to an intelligent reflecting surface and the signal is reflected with phase changes that are induced. These phase changes are controlled by the controller. When the receiver gets the signal, the signal can either be in a boosted or attenuated state [7].

The reflected signal is controlled by the elements which are part of the controller. The intelligent reflecting surface is optimized to consume lesser energy and is cheaper in terms of cost compared to traditional relaying/BackCom/mMIMO relaying. In 6G, the network services certainty will be increased to handle different cases in different verticals and sectors. Network slicing, MEC, and AIML techniques are used to improve the 6G service capability. Customized apps and enterprise chosen networks can be a reality in 6G networks. AI/ML in these customized apps will be used for computer vision, voice/speech analysis, translation, and image analysis. Artificial intelligence algorithms are used for transformation and automation in the 6G network. This requires Big Computing power and Big Data handling capabilities [7].

The other important area is space-earth network integration. Base stations on the earth will interact with satellites now. In the 6G network, base stations in the higher stratosphere will be deployed as a mediator between earth and space. This opens up huge opportunities for new apps. This will help solve the lack of internet connectivity for around 3 billion people in the world. The other area which will need investment is

terahertz communication. There is investment needed to overcome issues with terahertz like network deployment, immature terminal ecosystem, and coverage issues. 6G will have new capabilities to provide locational services, tracking, tracing, and environment perception. These capabilities are finding out the posture and gesture using radio signals. Environmental monitoring is another area [7].

Dynamic spectrum will be an interesting area for new technologies to be used for controlling and distributing. To manage the efficiency of the dynamic spectrum, massive input and Massive Output techniques are being researched. For network security in the case of 6G, we will be using QKD and PQC-based techniques. 6G network will have improved stability and reliability. These networks will have the capability of self-healing and adaptive using AI/ML techniques and knowledgebase. Energy-saving using low carbon is another great feature of the upcoming 6G network. These networks will have SLAs to meet using MEC and 6G network slicing algorithms [7].

6G mobile networks [7] will have the capability of handling customizations and configuring dynamically on the fly. Microservices architecture will be used to create service APIs for network configuration and customization. AI networks are another popular technology that is evolving in 6G use cases. AI-based algorithms will run on the engine to deploy, manage, and monitor 6G networks for optimizing the network, handling data, and managing the resources. This will help to bring down the cost and improve the quality of the AI networks. AI/ML services are monitoring the network traffic trends and requirements. They are also looking at customer behavior analysis [7].

6G network [8] might have dead spots where internet connectivity might be an issue. HAPS, LEO, GEO satellites, and other NTN solutions will bring down the dead spots.

These solutions will help provide mobile network connectivity on the ocean, high terrains, and the higher atmosphere. New verticals will come up with flying taxis, self-driving, and delivery drones-based solutions. Regulatory requirements will be a big challenge for 6G networks solutions and apps.

6G networks [9] help in remote sensing, positioning, asset tracking, and remote communications. 6G Networks will interplay with Bluetooth, Wi-Fi, and other channels to improve the overall tracking and monitoring services quality. New power supply solutions like wireless charging and storage batteries will be used for devices that are running on batteries. These devices are sensors, IOT devices, smart meters, audio headsets, and other computing accessories. Multiplexing technologies are being researched to maximize the utilization of the frequency and improve efficiency. DSS and MIMO are popular algorithms. 6G network security will be improved with the emergence of quantum computers and algorithms.

6G networks will be resilient, redundant, and recover based on self-healing services supported by AI and ML algorithms [10] for root cause analysis of network failures. Carbon-free and Net-zero base stations will be another initiative with the emergence of 6G networks. New antenna and new connector technologies are being researched. AI simulation is used for improving 6G networks by creating environment to test out different techniques related to MIMO channel, beam selection, and multimodal data. AI is playing an important role in sensing, data mining, analytics, control network, and 6G application layers. In 6G architecture, these layers related to physical, MAC (Medium Access Control), data link, network, and application layers AI and ML techniques are implemented [9].

Simulation is a powerful tool to analyze the potential issues and solving them through different techniques. Some of the areas like channel modeling for MIMO

wireless orientation, solutions for RNP issues, spatial channel modeling, path loss calculations, propagation conditions, and antenna parameters are being simulated to resolve 5G and potential 6G issues. Simulators are developed at various levels like satellite, cellular, link, and system levels. AI/ML techniques are being applied in the areas of channel estimation, radio resource management, link quality improvements, gains in MIMO, radio network planning, electromagnetic exposure, adaptive modulation and coding, Area spectral efficiency, C/U plane split, and feedback methods. MonteCarlo and probabilistic methods are also used to simulate the network communication to identify the risk areas and solutions. Vehicle to Vehicle communication scenarios are being simulated using edge network simulators.

6. What's next?

The challenges in 6G networks need to be researched and ironed out. The issues [10] are related to remote area backhauling, financing, and emerging countries. The other area which needs research is spectrum regulation and how the u0 model can be the solution to these challenges. The future will tell how the 6G network will emerge. AI and ML will impact the evolution of applications when 6G emerges but also helps in the management of 6G network. AI/ML apps will perform connecting to the services on the Cloud with better performance and latency. In this article, different use cases and the implementation challenges were discussed. This article will be considered as a reference for 6G and 5G [11] AI/ML applications and AI/ML approaches to solve the network issues in 6G.

Acronyms

eMBB	Enhanced Mobile Broadband Communications
URLLC	Ultrareliable Low Latency Communications
mMTC	Massive Machine Type Communications
HTC	Holographic-Type Communication
XR	Extended Reality
VR	Virtual Reality
AR	Augmented Reality
MIMO	Multiple-Input Multiple-Output
DSS	Dynamic Spectrum Sharing
PL	Path Loss
KNN	K-Nearest Neighbor
GRL	Generalization Representation Learning
SRL	Specialization Representation Learning
BackCom	Backscatter Communication
QKD	Quantum Key Distribution
PQC	Post Quantum Cryptography
MEC	Mobile Edge Computing
SLA	Service Level Agreements
LEO	Low Earth Orbit
HAPS	High Altitude Platform Systems
GEO	Geosynchronous Earth Orbits
NTN	Non-Terrestrial Networks

NLP	Natural Language Processing
NLU	Natural Language Understanding
AI	Artificial Intelligence
ML	Machine Learning
XR	Extended Reality
NFC	Near Field Communication

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