



## A Review on Telecommunications: Evolution, Current Trends, and Future Prospects - Opportunities and Challenges

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**Abstract:** *The field of telecommunications has undergone a transformative journey from primitive methods of communication to modern, high-speed, and intelligent networks. This paper reviews the historical evolution of telecommunications, highlighting the advancements across various cellular generations, from 1G to 5G, and exploring the prospects of 6G. The study delves into current trends such as the integration of Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), and cloud computing, alongside the pivotal role of fiber optics in meeting the growing demand for data. It examines the opportunities these technologies present, such as enhanced connectivity, operational efficiency, and innovative applications, while addressing inherent challenges such as regulatory constraints, cybersecurity threats, and infrastructural costs. Also, the potential of emerging technologies like quantum computing and satellite internet are discussed as transformative forces shaping the future of telecommunications. The paper emphasizes the need for sustainable practices, including energy-efficient networks and green telecommunication initiatives, to mitigate environmental impacts. This comprehensive review provides valuable insights into the dynamic landscape of telecommunications, offering guidance for stakeholders navigating its complex opportunities and challenges.*

**Key words:** Telecommunications Evolution, 5G Deployment, Internet of Things (IoT), Artificial Intelligence (AI), Sustainable Telecommunications.

### 1 Introduction

The word ‘Tele’ originates from a Greek adjective meaning “far off” (at a distance), and “Communications” meaning exchanging of information (Sapienza et al., 2018). Therefore, Telecommunication is the exchange of information across a great distance. Human desire to send information over a long distance has made history in revolutionizing telecommunications. According to (Yrjölä et al.), right from the ancient era to the current one, many strategies have been developed by humans to facilitate communication across large distances. Ranging from smoke signals, and drumbeats, employing a Horse and carrier Pigeon to the creation of an optical telegraph. The realization and development of electricity in the early 19th century led to the construction of an electrical telegraph which

later evolved into the telephone system that sends and receives voice communications (Yrjölä et al.), (Messerschmit, 1996).

The evolution of Telecommunications has witnessed a series of major changes with the advent of Wireless technology that led to the concept of cellular communications. Successive cellular technology generations have been produced over the past three decades where each generation provides new technology and higher data rate (Agiwal et al., 2016). Introduction of new use cases, enhanced technological capabilities as well as improvement of the use cases of a previous generation(s), are the drivers behind the generations of cellular technology.

1G, introduced in the early 1980s, is the earliest version of a cellular network largely analog-based communication technology using Frequency Division

Multiple Access (FDMA), and) and primarily developed to support voice services. It was later enhanced to provide data bandwidth of up to 2.4 kbps (Wang et al., 2014). It has been characterized by low connection quality, low capacity, insecurity, and inefficient handoff (Lundberg, 2020). The above-mentioned features are the inspiration for 2G which was the next stage in the development of cellular technology after the 1G and developed in the early 1990s. The 2G delivers a digital cellular network, security, higher data rate, high capacity, high transmission quality, lower battery power consumption, and new services, such as SMS, caller ID, roaming, etc (Wang et al., 2014), (Lundberg, 2020). In addition, Global System for Mobile Communication (GSM) was the most popular 2G technology. This is due to its wide acceptability (the same spectrum is assigned across Europe) and easy international roaming. GSM leverages the combination of FDMA and Time Division various Access (TDMA) technologies to boost its capacity by offering various users access to the network. A maximum data transmission rate of 14.4 kbps is accomplished by the GSM and phase transition to achieve higher speed. According to (Lundberg, 2020), 2.5G and 2.75G that have integrated packet switching were created and designated General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE) around the year 2000 to 2003. They have enhanced technology that can raise the achievable data rate to 171 kbps for GPRS and 384 kbps – 470 kbps for the EDGE. The motivation for 3G was that it fulfills the specifications of International Mobile Telecommunications-2000 (IMT-2000), part of which is increased data rates for more demanding applications. A peak data rate of at least 200 kbps is planned by the Universal Mobile Telecommunications System (UMTS) employing Code Division Multiple Access (CDMA) technology, as the successor to GSM (Wang et al., 2014). Based on the IMT criteria, 3G was realized in the year 2000, delivers services at higher speeds and has a larger network capacity than the previous networks. 3G has the capacity to combine high-speed mobile access with Internet Protocol (IP)-based services and is characterized by high-frequency spectrum, adaptive antennas, and wideband radio channels (Lundberg, 2020). Similar to GSM, 3G has been through phase evolution where a protocol known as High-Speed Downlink Packet Access (HSDPA) was implemented as 3.5G in 2003 and provides data rates of roughly 14 Mbps. Also, 3.75G was created in the same year as High-Speed Uplink Packet Access (HSUPA) to support the 3.5G and user-to-user data applications by delivering faster and symmetric data rates (Lundberg, 2020). Increased data demand and the necessity to improve uplink and downlink access rates of a cellular network led to the development and

introduction of Long-Term Evolution (LTE) by the Third Generation Partnership Project (3GPP). LTE is completely a new technology based on IP, fully packet-switched with a maximum speed of 100 Mbps. However, according to the 3GPP 4G standard, LTE is not quite there, so LTE-Advance (LTE-A) is implemented. 4G evolved in 2005 and was finally deployed in 2010 and can bring high speed to mobile and broadband data with the potential to enable VoIP, Video conferencing, HD mobile TV, etc (Lundberg, 2020). Furthermore, 4G will be able to give a maximum speed of up to 1 Gbps, by adopting Orthogonal Frequency Division Multiple Access (OFDMA). 5G is the next generation to 4G and is presently in its infancy with a lot of promises to support vast coverage and enhance bandwidth for larger applications details of which are detailed in the next section. Fig. 1 gives a summary timeline of wireless communications technologies.

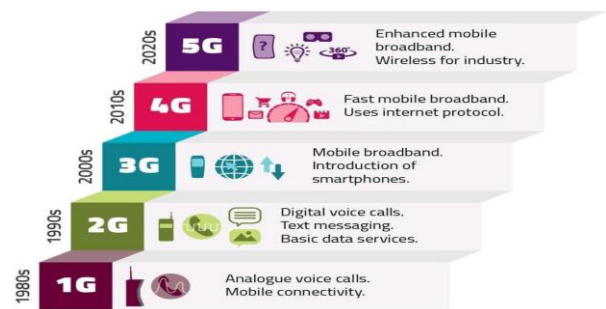


Figure 1: Timeline of Wireless Communication Technologies (Lundberg, 2020)

## 2 Current Trends in Telecommunications

An evolutionary tendency in telecommunications is briefly examined in the background where various generations' features, capabilities, and standards are discussed. It was readily known that each generation gives way to its successor as a result of rising speed needs to support more users and applications. The present trend in the telecoms industry is envisaging convergence of telecommunications, computing, and growing Artificial Intelligence (AI) to allow a huge number of businesses to interoperate and innovate to give cutting-edge solutions in the sector (Costa-Pérez et al.). This results in the expansion of commercial businesses, enabling faster technology, reduced prices, and more functionality. In this section the following significant main components of current trends in telecommunication are discussed: 5G Deployment, Internet of Things (IoT), Artificial Intelligence & Machine Learning, and Fiber optics.

## 2.1 Deployment of 5 G

5G cellular network is also an IP-based model, which has been intended to serve diverse applications, like IoT, offering billions of additional wireless connections as well as applications that were previously not viable and depend on ultra-reliable and low-latency communications. Some of the expected potential uses of 5G include (but are not limited to); Machine to Machine (M2M) or Machine Type Communication (MTC), Internet of Things (IoT), Internet of Vehicles (IoV), Device to Device (D2D) Communication, e-health, etc (Li, 2018). 5G intends to meet multiple user quality of service (QoS) needs, providing improved end-user experience through gigabit speeds under different application situations, and greatly increased performance and reliability (Osseiran et al., 2014), (Phuoc Dai et al., 2021).

According to IMT-2020, 5G is an emerging of creative life-enhancing business model, playing a critical role in aiding governments and policymakers in transforming their cities into smart and realizing a digital economy. As explained in (Attaran, 2021), 5G is being introduced initially as an augmentation of the existing 4G network before evolving to a fully autonomous network. It has been claimed in (Dake and Ofosu, 2019), that the 5G network should accomplish 1000 times the system capacity, 10 times the spectral efficiency, energy efficiency, and data rate compared to the 4G network.

The freestanding 5G network is projected to bring a new radio access network with a greater spectrum in the millimeter wave band (far higher frequency ranges) with a very short connection range and a large increase in the number of base stations to actualize small cells (Baratè et al., 2019). This aims to dramatically increase additional capacity compared to the present mobile technologies. The increased spectrum and more capacity will enable the high speeds and low latency promised by 5G, and the identification of three critical features as characterized by ITU-R, described in (Phuoc Dai et al., 2021) and summarized in Fig. 2:

- Enhanced mobile broadband (eMBB) – this feature will increase indoor and outdoor broadband and supports applications such; virtual reality and ultra-high-definition television (UHDT).

- Massive machine-type communications (mMTC) – will enable IoT, asset tracking, smart agriculture, smart cities, energy monitoring, smart home, remote monitoring etc.
- Ultra-reliable and low-latency communications (URLLC) any delay intolerance application comes inside this category e.g; driverless vehicles, smart grids, remote patient monitoring and telehealth, industrial automation.

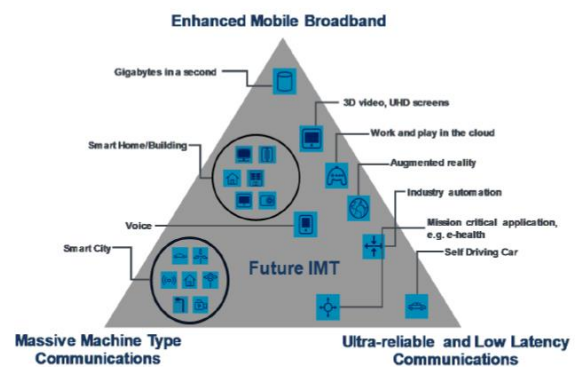


Figure 2: 5G Usage Scenario (Phuoc Dai et al., 2021)

To implement the above features/applications, give wide coverage, and support all planned services, 5G systems would utilize a huge number of tiny base stations, densely concentrated considerably closer to the customers. It is possible to discover multiple indoor micro base stations in a single structure. In view of this, it is proposed in (Attaran, 2021), that the 5G network will be highly diverse with three major frequency ranges:

- Low frequency (less than 1 GHz) – will provide comprehensive coverage across urban, suburban, and rural areas and support low data rate IoT applications.
- Medium frequency (1 – 6 GHz) – offers a nice blend of coverage and capacity benefits.
- High frequency (over 6 GHz) will offer ultra-high broadband speeds envisaged for 5G.

The practical implementation of the 5G system requires base stations (known as gNodeB) equipped with a huge number of antennas (up to 100) that simultaneously serve numerous customers to realize what is called Massive MIMO system (Li, 2019). This permits many messages from several terminals to be broadcast on the same frequency.

Not only that but the increased number of antennas is also projected to boost 5G technologies by delivering what is termed beamforming (Babale et al., 2020, 2022), and beam-tracking ((Ishfaq et al., 2021), ; Baratè et al., 2019), a cell's antenna focuses its signal to reach a specific mobile device and track it as it moves. In addition, since the architecture of the 5G network is intended to separate outdoor and indoor situations (to reduce penetration loss through walls) (Dake and Ofosu, 2019), this can be achieved by utilizing a distributed antenna system (DAS) and huge Multiple Input Multiple Output (MIMO) (Phuoc Dai et al., 2021). The gigantic MIMO system uses large capacity improvements that would result in larger arrays of the antennas.

### 2.1.1 5G Deployment Opportunities

It is believed that 5G will drastically affect the world around us and have economic potential in numerous industries (Shengrong et al., 2012). This is because it has broad technology and capable network built to connect nearly everyone and everything together including machines, items, and devices. This technology has great economic potential as stated in (Shengrong et al., 2012), it is anticipated that by the year 2035, a capital of \$13.2 trillion will be infused worldwide. 5G will support services with high speed and low latency (see Fig. 2) and also advantages numerous aspects including but not limited to; education, healthcare, energy, transportation, industry, automation IoT, etc. In education, for example, the 5G network will support high-quality content, enabling the sharing of diverse resources, and the broadband will provide virtual platforms that enable engagement in real-time and more effective Augmented Reality (AR) apps (Guevara and Cheen, 2020). Also providing a cloud environment for educational purposes by 5G network cuts substantially the cost of application hosting, storage, and delivery. 5G eMBB service is an excellent enabling environment to produce 3D virtualization to enable learners with good understanding via 3D videos (Jovovic et al., 2019).

Healthcare is an excellent example of a sector that is predicted to profit from 5G, as its high bandwidth and URLLC service can offer telemedicine, teleconsultation, and remote surgery. 5G can also provide enabling platforms similar to that of education, to merge virtual and reality health training, boost quality and cheap healthcare, and

promote remote health services (Robinson and Chiorlu, 2019).

Energy and Smart grids are vital components of our life and require a good telecommunications network for efficient performance. 5G using the mMTC described in Fig. 2 can deliver energy efficiency and eliminate needless use remotely. On the other hand, the smart grid also requires 5G help as indicated in (Rahman et al., 2021), efficiency of power systems might be improved with high capacity, high speed real-time, safe and robust telecommunications network. Also, alternative applications can be achieved to combine new technologies in micro-grid and distributed generating. 5G deployment and applications will drastically revolutionize Transportation through better connection, latency, and high data speed. Some of the benefits of 5G proposed in [20] are constructing a reliable and robust network of Internet of vehicles, enabling low latency connectivity for smart cities to increase traffic efficiency, improve road safety, and minimize traffic congestion.

5G is the main enabler of Industry 4.0 i.e., integrating intelligent technologies into manufacturing and industrial processes that rely on fully networked machines based on diverse industrial scenarios. For example, 5G can enable smart manufacturing, a process that employs ubiquitous connection, and real-time control to give flexibility and boost production efficiency (Sahin et al., 2017). When completely networked industries' productions move closer to the end users, factory floors will be altered and enable predictive maintenance. This assists in controlling costs and decreasing downtime.

### 2.1.2 Challenges and Threats of 5G Deployment

It is obvious from the previous discussion that 5G is dominating mobile technology with potential and possibilities. 5G deployment entails processes that require different standards, integrating diverse networks as well as migration from one network to another. Threats and challenges are inherent parts of new advances in technology and 5G looking at its features, the process of deployment and technological diversity will not be unique. Therefore, deployment and execution of 5G come with (but not limited to) the following obstacles and threats:

- **Spectrum Challenges:** Due to its great number of applications and varied use cases on a big scale, 5G will demand high-frequency bands and broader bandwidths. As noted above, the frequency bands are of different kinds; low, medium, and high frequency. However, the frequency spectrum is a significant resource due to its cost and availability, therefore, must be managed efficiently. One of the primary means of spectrum management is its acquisition from the government mostly through auction. The operators must strategize in choosing the frequency bands and change their network and services accordingly. The spectrum cost is a huge worry dependent on the government policy which might lead to increased operational cost and limited spectrum range for some of the 5G services.
- **Cost of Deployment:** In addition to the spectrum challenge, there are other significant factors where managing their expenses is a potential hurdle to the 5G deployment. Deploying 5G involves large financial investments, in creating the essential infrastructure including new small cell towers, antennas (Paracha et-al, 2019), and fiber optics network (Nokia, 2021; Bello, 2023). Sometimes, acquiring the money for a large infrastructure expansion might be tough for the operators, especially in a competitive market. Some infrastructures require routine maintenance while some are difficult to repair or replace when destroyed. In addition, as stated earlier in this research, 5G will use high-frequency bands with low range and poor penetration capabilities. As a result, a dense network of small cells is necessary, and acquiring secured numerous small cell sites, especially in metropolitan locations can be challenging and costly. Finally, most rural locations are less economically viable because of lower population density which could lead to greater costs per user. This will lead to infrastructure gaps and difficult to address digital divide and 5G underserved regions problem.
- **Regulatory policies and Issues:** Regulatory policies play a significant role in the 5G deployment and there is a need for coordination between government, regulatory organizations and industry players to provide and meet them. Building regulatory capability and comprehensive rules by the government of a country is vital to adapt to the complexities of evolving 5G technologies as well as market dynamics and fair playing amongst the operators. The regulatory requirements are mainly related to; spectrum allocation and management, health and safety, international coordination and standardization, privacy and security, etc. However, occasionally meeting regulatory and policy criteria can cause obstacles in the 5G rollout. As mentioned in (Patel and Partel, 2016), many (particularly poor) countries for various reasons find it tough to regularize with the International Telecommunications Union (ITU) policies on 5G. Every part of the regulatory policies is equally significant and a challenge on any might prevent a quick 5G rollout. One notable example is that harmonization of spectrum across varied countries is a complicated process and can represent a large regulatory burden with a serious impact on regional integration and seamless services (Minoli and Occhiogrosso, 2019). Another example is the technique employed by the governments is spectrum allotment, typically auctioning is used and can be competitive and costly. This can affect fair play amongst the operators, potentially leading to poor participation and investment.
- **Security and Privacy:** As discussed 5G implementation will see numerous applications with growing wireless data transfer which could be expensive, sensitive, and vulnerable. This would increase complexity and connection in the network, raise security and privacy concerns, and create ground for a new era of security threats (Patel and Partel, 2016). Some of the security and privacy difficulties are described and briefly discussed here: Telecommunications fraud is a severe challenge that has the impact of slamming cramming toll-free number fraud and bypass problems (Gosh et al., 2015). Network attacks on availability, authentication, and confidentiality are other security concerns described in (Nokia,

2021). User privacy is particularly crucial in 5G networks and might pose a severe issue in; location monitoring, identity, personal data loss, and international mobile subscriber identity (Chen, 2012).

## 2.2 Internet of Things (IoT)

The Internet of Things (IoT) concept was proposed in 1999 by a member of the Radio Frequency Identification (RFID) group, and the current rise of mobile devices due to numerous applications has made IoT more important to the practical world (Brumfiel, 2011). Similar to the evolution of telecommunications provided in the background, IoT is the evolutionary stage of the internet that enables worldwide communications between devices/machines without much human intervention. IoT is converting the conventional internet from a network of computers into a network of various things, like devices, items, machines, cars, animals, humans, etc (Li et al., 2018). IoT may be considered as a system that essentially comprises two elements; the devices (things?) that are smart enough to acquire contextual information from a target source and the technology that enables the devices to process the received information. Therefore, IoT is a technology that enables smart devices to gather and relay information from/to one another, process the information jointly, and automatically take necessary action (Mohanty et al., 2016).

The recent increase in new technologies is the fundamental contributor to the realization and execution of numerous IoT applications. For example, sensors are often the devices used in IoT, and they enable interconnection between the physical things and the network allowing real-time information to be collected and processed. New sorts of sensors are already being realized to boost the detection and collection of information considerably more than human capabilities (Mohanty et al., 2016). In addition, the sensors have the properties to be put in hard-to-access regions for ages without any human intervention. Another example of how innovations will enhance the application of IoT is the domain of robots. A robot can be given strength more than that of a person and also may go where humans cannot. Authors of (Mohammed and Sabahath, 2023) offered an example of such applications where robots were deployed in Japan to examine a nuclear facility (to safeguard humans from radiation) following seismic disasters. Wireless Broadband is another

new technology that will boost the communication capabilities of IoT. Various Applications of IoT will be supported by the mMTC of 5G stated above, which will offer good internet bandwidth. There are several potential and diversified uses of IoT, covering all elements of the day-to-day life of individuals, industries, places, and society in general (Li et al., 2018). Some instances are shown and briefly described below:

**i. Smart Homes:** IoT systems can be used to connect many objects and household gadgets or appliances to enable remote access, monitoring, and controlling of the home. Smart houses automate home activities offering individuals an efficient, comfortable, safe, and convenient living environment (Okot et al., 2023). A smart home has different applications, an example is given in (Mohanty et al., 2016) where energy may be conserved by effective monitoring and managing its usage by the electrical appliances. Another example where smart houses can be used in supporting elderly and disabled individuals living alone is provided in (Li et al., 2018). A variety of health-related information can be captured and delivered to a distant hospital which can be assessed and enhance the health state.

**ii. Smart Cities:** Smart cities are similar to smart houses where intelligence and communications technologies are used by deploying numerous IoT devices in a city for different activities to boost the effectiveness of its operations. Authors of (Khanna and Sharma, 2019) defined a smart city as an innovative city that employs Information and Communication Technologies (ICTs) and other means to increase the quality and efficiency of life in urban operations. Various components as depicted in Fig. 3 with varied applications and solutions are connected to work as a system of smart city.

**iii. Precision Agriculture:** Also termed smart Agriculture is another sector where IoT is used to change traditional agriculture into intelligent and efficient operations. This leads to transformative outcomes in farm management and better production and sustainability. Smart farming enables farmers to optimize their operations and face several issues utilizing equipment that can monitor climate conditions, soil properties, and soil moisture (Elijah et al., 2017; Li et al., 2018). Remote sensors, ground sensors, robots, and drones can be placed and connected to operate autonomously by gathering and analyzing real-time

data. Animal farming is another ideal sector to employ IoT where sensors may be used to track, locate, and identify grazing zones.

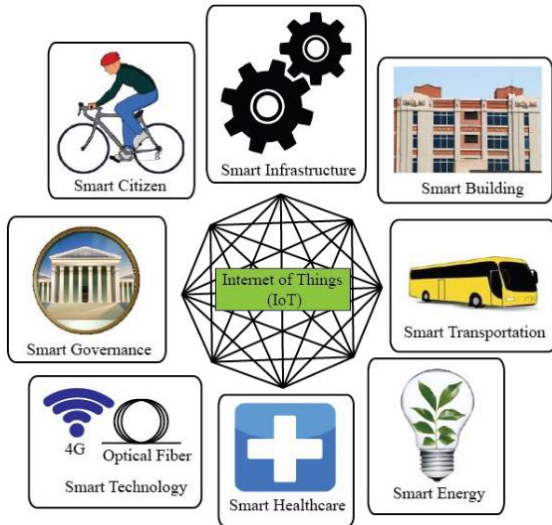


Figure 3: Example of smart city components (Khanna and Sharma, 2019)

### 2.2.1 IoT Opportunities

IoT will support several applications and see widespread use of linked devices that create diverse systems to give real-time monitoring and automation boosting resource utilization. This will provide new opportunities, drive innovation, and produce fresh income sources and company models. The following are some of the opportunities that IoT will provide:

- **Operating Efficiency:** Deployment of IoT technologies in industries can give several benefits like operating cost and time reduction optimizing operational efficiency. IoT allows real-time monitoring, data collecting, and exchange, to help industries make informed decisions, decrease delays and optimize operational efficiency. This can be performed as detailed in (Soori et al., 2023) using predictive maintenance to decrease resource wastage and operational costs. IoT's importance in boosting operational efficiency is not limited to only industry but also in other fields like agriculture. Smart agriculture manages various challenges and offers the capacity to assemble information utilizing sensors to drive more intelligent choices about operational proficiency and business strategies. In general, the rise in operational efficiency results in a higher quality of service, efficient utilization of

both personnel and resources, and subsequently higher productivity.

- **New Business Models:** IoT applications outlined above demonstrate that they can stimulate innovations and generate new business models. Wide adoption of linked devices will improve operations, customer experience, and service offerings to uncover new market opportunities. The enormous quantity of data about customers' behaviour and market trends may be captured and employed to produce more tailored goods and services. Authors of (Russell and Norvig, 2010) suggested how IoT may also promote product differentiation by creating a linkage of smart offerings to cater for customers' needs and preferences.
- **Sustainability:** The capability of IoT technology to connect diverse devices and systems that enable the interchange of information and control, and facilitate resource management, environmental preservation, and sustainability. Technology helps to make better use of resources, cut energy consumption, and improve its distribution as well as minimize carbon footprint. Therefore, according to (Dhokare, 2021), an efficient energy consumption pattern can be attained by people or even communities through IoT-driven applications empowerment. This will give sustainability, waste minimization, and good environmental monitoring.

### 2.2.2 Challenges and Threats in IoT

IoT technology (as discussed) will see deployment of an enormous number of sensors/devices, throughout a wide range of applications that offer multiple options. However, various problems and risks will affect or limit the deployment of IoT technologies. Some of the problems and threats are given and addressed below:

- **Security and Privacy:** IoT technology is subject to security and privacy assaults, this is due to the extensive distribution of linked devices interacting with each other and sharing crucial information. The interactions will generate new security and privacy-related challenges that may lead to

data breaches, hacking, and unwanted access to private information. Authors of (Kühl et al., 2022) presented an example of the security and privacy difficulty of an IoT system as the possibility of compromising the cooling system of a nuclear facility that could lead to a devastating incident. Furthermore, the numerous sensors used in IoT could be subject to authenticity and confidentiality as an attacker could deploy its sensor physically adjacent to sense the same information.

- **Interoperability:** IoT due to its varied area of applications, various devices have their separate domain and different domain devices may not be compatible to connect with one other. In addition, IoT envisages allowing interactions across heterogeneous items and sources of data that require standards to enable communication protocols and a high degree of interoperability. According to (Kühl et al., 2022) the difficulty is absence of the technological standardization and common architecture (due immaturity of the IoT) to enable a seamless integration of the different systems. The interoperability difficulty will affect the end-users by increasing the cost of the products as well as worrying about privacy and security.
- **Data Management:** IoT networks will consist of a high number of devices and objects and consequently make the network grow huge, which can result in data management (scalability) issues. High numbers of devices could overburden the IoT network by requesting a high data bandwidth, which lack of it could cause delays and pose a problem in hindering sensitive applications. Also, there will be an enormous amount of data generated by the increased number of IoT devices and appropriate management and storage of the data will be a scalability challenge. Finally, maintaining, monitoring, setting, and even powering the enormous number of devices are issues that demand answers for successful IoT implementation.
- **Regulatory and Compliance Issue:** IoT comparable to other technologies must have laws and regulations that govern its

deployment and implementation. However, due to the different natures of IoT applications, their technologies are prevalent across various fields, and consequently, policymakers and regulators will also come from various fields of IoT-related applications. Creating regulatory policies for the IoT that have different devices generated from different sectors for varied applications in a heterogeneous network will provide a regulatory and compliance problem. An example is given by the authors of (Kühl et al., 2022) of an application scenario where an IoT involves devices from medical, manufacturing, banking, and food-related applications that require more time and money to go to market. This is because they have to comply with varied regulations from different areas.

### 2.3 Artificial Intelligence and Machine Learning

History demonstrates that Artificial Intelligence (AI) started soon after World War II and its name originated and was coined in 1956 (Ghosh and Thirugnanam, 2021). AI is believed to be one of the most recent, essential, technological advances realized to offer a possibility and capability that would allow machines (computers) to learn. Therefore, as defined in numerous literatures like (Islam et al., 2019), AI is an act of transferring human intelligence to computers to be able to perform cognitive processes connected with human minds. That is, in AI a computer enables a function to reason, learn, see, solve issues, interact with its environment, make a choice, etc. Authors of (Islam et al., 2019) identified AI as a cutting-edge technology that will have an impact on practically every industry including but not limited to, education, health, business, farming, defence, and aerospace. In addition, AI has two primary categories that can be classed based on capabilities or based on functionality (Mihret, 2020).

- i. **AI Based on Capabilities:** This may be further classed into; weak or narrow AI, General AI, and Strong AI. The weak or narrow AI is the most common and extensively used AI which can perform a preset narrow set of instructions without demonstrating any thinking capability. General AI, on the contrary, is meant to

think like humans and is still in its infancy. Lastly, strong AI is believed to have a thinking capacity more than that of humans.

- ii. AI Based on Functionalities: Similarly, the classification of AI here has the following types: reactive machines, limited memory, theory of mind, and self-awareness. For detailed explanations of the sorts of AI based on function classifications see (Mihret, 2020), (Klement and Slany, 1994).

As mentioned before in AI, human intelligence is transferred to computers, letting them perform specialized functions needing human intelligence by designing algorithms and systems. These are divided into several domains and prominent ones are displayed in Fig. 4 and detailed in (Mihret, 2020) as follows:

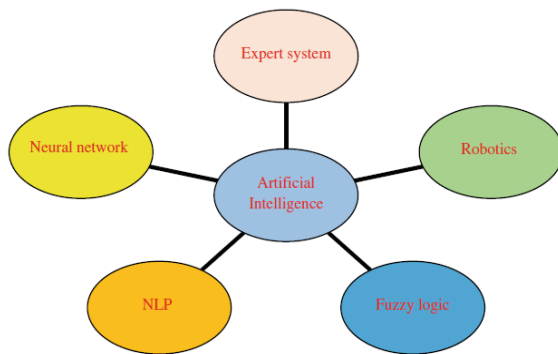


Figure 4: Domains of Artificial Intelligence (Mihret, 2020)

- Neural Networks: This is an AI comprising of algorithms that have the potential to understand relationships between giving data while imitating the way the human brain functions. (Mihret, 2020), (Mahesh, 2020). Neural networks are primarily employed to forecast an event in a network with a huge database by looking at examples of a comparable previous occurrence. It is frequently utilized in AI in the form of machine learning or deep learning to tackle challenges of diverse applications like pattern recognition of face and image identification in medical diagnosis (Mahesh, 2020).
- Robotics: This is the development and use of machines (robots) to carry out a task traditionally done by human beings. According to Webster as provided in (Piran and Suh, 2019) Robot is described as an automatic device that performs functions typically ascribed to people or a machine in the guise of a human. Therefore, robots are programmed in AI to be self-controlled electrical/electronic or mechanical devices and execute a function of intelligence tasks like humans (Piran and Suh, 2019). Robots have feature and features that make them capable of executing a function in place of people. For example, robots never grow weary, have high endurance, can access hard-to-reach and dangerous places, can accomplish routine activities without becoming bored, etc. In general, robotics intelligence is particularly valuable notably in industrial applications, accomplishing automation of robotics operations. Maximizing efficiency and protecting operational processes.
- Expert System (ES): These are systems made by a computer as applications or algorithms that make a choice to tackle complex problems in particular areas with the help of human intelligence and expertise. The concept of ES essentially takes human expertise in a certain field and puts it into a computer program to accomplish a specified activity. This would help if there is a worry of losing an expert or there is a task that requires human knowledge to execute in different parts of the world, ES may be employed without waiting for the expert to go around the areas. ESs can advise, instructing, and supporting human decision-making by interpreting input, diagnosing, and generating a solution. In addition, ESs are characterized by great performance in addressing complicated issues, intelligible, trustworthy, and extremely responsive.
- Fuzzy Logic System: This is another concept in the AI sector intended to allow computers to emulate human thinking by establishing a set of theories for the management of real-world systems (Phillips-Wren, 2012). The theories offered a notion of a degree in validating a condition to permit a state in between true or false, a yes or no. This is to make the computer replicate human judgment that incorporates such a condition state and provide flexibility for reasoning, which

makes it feasible to take into account uncertainties and mistakes.

- Natural Language Processing (NLP): This is another AI domain that overcomes a communication gap between computers and human languages (Mihret, 2020). NLP enables computers to smartly communicate, understand, interpret, and generate human language. Some examples of NLP in AI applications are Google translator, auto-corrects, and predicts in email writing.

Machine Learning (ML) is a subset of AI and is viewed as a technique that assists AI machines (computers) to learn from past experiences utilizing conceptually constructed algorithms that enable the computers to learn from its data taking into account the previous experience (Mihret, 2020). The learning process is initiated by the machine assessing the available data set in what is termed training (Mihret, 2020) and then the algorithms forecast the likely output. For efficient and accurate prediction more data is essential to supply more information for better results. ML is currently applicable practically everywhere from image recognition to navigation, evolving to allow wireless networks to learn and extract knowledge by interacting with a set of data (McKinsey & Company, 2019). Depending on the nature of a problem and its variables, multiple methods may be utilized by ML to find a good model that would suit the best answer (Lemon and Verhoef, 2016). Based on this, as reported in (Mihret, 2020), (Lemon and Verhoef, 2016), ML is classed in the following categories:

i. Supervised Learning: This is an ML category that uses an algorithm that is given labeled training to learn the relationship between the input and the output. As outlined in [39], supervised learning is akin to the approach of a learning pupil under a teacher's observation. Therefore, the algorithms in supervised learning need external aid that infers a function from the labeled training data consisting of a series of training instances (Lemon and Verhoef, 2016). The algorithms are categorized into regression & classification and can be utilized in spam filtering, picture classification, fraud detection, etc. (Mihret, 2020).

ii. Unsupervised Learning: Contrary to the supervised learning here the machine has to train itself without any supervisor, i.e., the algorithms are

left on their own, given unlabeled data, and allowed to uncover patterns without direction or instruction (Mihret, 2020), (Lemon and Verhoef, 2016). The algorithms employed in unsupervised ML are categorized into clustering & association and are utilized in customer segmentation, anomaly detection, picture and video analysis, etc. (Mihret, 2020).

iii. Reinforcement Learning: This is a learning strategy based on trial-and-error and feedback of reward or punishment for every right and wrong action respectively. Therefore, the learning here is a self-learning method done by analyzing its previous performance with the aim of the algorithm to attain maximum reward points at the end (Mihret, 2020). Application examples of this learning are in numerous sectors such as medical diagnosis, image processing, robotics, autonomous vehicles, energy, healthcare, etc.

### 2.3.1 AI/ML Opportunities

- Enhanced decision making: Decision making is a significant and intrinsic human day-to-day activity that has a high impact which is being augmented by computer technology to boost human skills (Ferrara, 2023). AI/ML will considerably boost decision-making through the application of advanced algorithms to give accurate and objective insights, minimizing human mistakes and prejudice. In addition, integrating AI/ML into decision-making will bring several benefits, including (but not limited to) enhanced efficiency, improved accuracy, and advanced predictive analysis (Jain et al., 2024). It also has applications in numerous industries such, as enterprises, healthcare, banking, and government.

- Automation of Repetitive jobs: It is a known truth that machines execute repetitive jobs faster and more efficiently due to their boring character to people. On the other hand, applying AI/ML here will free up human resources from the complicated and strategic routine and monotonous activity by automation that minimizes the likelihood of errors (Jain et al., 2024). This will have the advantage of releasing humans to focus on other professions that need creativity and critical thinking.

- Improved Customer Experiences: This is particularly essential as it can provide distinct and sustainable benefits for industries, enterprises, and business settings. Authors of (Furht and Escalante,

2010) underlined how crucial are the experiences at every touch point of the consumer journey including the pre-buy, purchase, and post-purchase stages. Engaging AI/ML for the customer experience is highly vital and will boost the process to assist businesses meet their expectations. Consequently, enterprises acquire useful information, process automation, right engagement, to have more engaging and seamless experiences for their consumers (Rajeswari, 2019).

### 2.3.2 Challenges and risks in AI/ML

- **Data Privacy and Security:** Most AI/ML apps use vast quantities of data they learn from to make smart conclusions. The enormous data could be heterogeneous, sometimes sensitive and personal, and prone to data breach and identity theft, creating worries about privacy and security (Klement and Slany, 1994). Another potential hazard here is cyber-attacks, electronically stored data could be hacked by people interested in uncovering sensitive information. Abuse of personal data aggregated for the aim of personalized advertisement could be employed for opposing reasons.

- **Bias and Fairness:** AI/ML-created models often exhibit numerous unfair concerns in training datasets which lead to biases and discriminating outputs. Authors of (Odun-Ayo et al., 2017) recognized bias as a major problem in adopting AI/ML systems and defined it as systemic errors that occur in decision-making processes, resulting in unfair outcomes. Bias can originate from several causes such: as data collection, model design, human interpretation, etc.

- **Lack of Transparency:** This is an issue since most of the AI/ML are regarded as sophisticated and offer outcomes without explicitly describing how they are produced. This could pose confidence concerns in the information gained from the output of the models. Proverbially dubbed a “black box” (Berisha et al., 2022), AI/ML algorithms are becoming increasingly sophisticated, making it tough and challenging for users to grasp how conclusions are reached. This reduces openness, and subsequently affects confidence, accountability, and justice in essential applications like; healthcare diagnosis, loan approval, and judicial sentencing (Berisha et al., 2022). Furthermore, lack of openness could have an impact on regulatory, legal, and policymaking, in case of a need to examine a decision process.

## 2.4 Cloud Computing

Cloud computing is an emerging technique in the world of computer applications and Information technology (IT) that instead of spending extensively on databases, allows you to rent what is dubbed “utility computing” (Gewirtz, 2018) offered by a third-party provider. It is an IT infrastructure utilized as a storage device delivering services of data maintenance to remote consumers through the internet (cloud). This allows the users to access and share resources from the database via the internet to accomplish various tasks. Cloud computing is a significant technological development that is being utilized to redefine IT processes and marketplace enabling users to use various devices such as smartphones, laptops, and PDAs to access stored programs, and application platforms over the internet (Keisler et al., 2013). There are three primary types of cloud computing; public cloud, private cloud, and hybrid cloud under which the following four main services are delivered: infrastructure as a service (IaaS), platform as a service (PaaS), software as a service (SaaS), and function as service (FaaS). For the details descriptions of the four services read (Monisha and Venkateshkumar, 2018).

Cloud computing has earned tremendous popularity globally and has the power to host numerous applications some of which are discussed below:

- Data Storage:** This is a form of computer data storage as one of the applications and significant components of cloud computing. It is described by authors of (Abualkishik et al., 2020) as a system that makes several storage devices of different sorts of applications offering data storage and business access. Depending on the demands and requirements, the storage might be for either massive data of an enterprise or a basic one similar to standard data storage utilizing local hard drives (Musumbu and Dioup, 2016). Multiple servers are frequently utilized to deliver services across several geographical regions. The data storage architecture includes a master control server and various storage services (Musumbu and Dioup, 2016), consequently, a data’s actual storage location may alter from time to time as the cloud dynamically manages available storage servers at different locations.

- Big Data Analytics:** According to (Falatah, 2014), big data refers to enormous volume collections of various forms of data that grow

rapidly with time. The datasets are so challenging to store, process, and analyze using a normal management system because of their complexity and bulk. Managing huge data is only achievable with robust analysis approaches, explicit processing, and capable technologies (Falatah, 2014). Another characteristic apart from data volume that needs to be considered in the analysis of big data is what is defined as data velocity (Ashraf et al., 2013). This is the degree to which the data is generated or the pace at which the data must be processed. An example of Facebook users was given in (Ashraf et al., 2013), where the high number of submitted photographs needs to be stored, retrieved, and processed within a second as real-time information. Authors of (Sen, 2015) described two forms of processing: batched and stream. Batch processing is used for blocks of data held over a while, processed as large data, and requires longer time - the big data analytics here is not real-time, i.e. more interested in the volume of the data. On the other hand, stream processing deals with real-time data - analysis is done as the data is generated and the output is retrieved and used quickly.

iii. Disaster Recovery: Disaster has been characterized in (Sajid and Raza, 2013) as unprecedented events in a system lifetime that can be either naturally made by the environment or man-made, e.g., total system failure (hardware/software). Disaster produces major disturbances to the running of a community and results in crucial and devastating harm to a system as well as costly service interruption. Therefore, this is the rationale for many firms choosing cloud computing as a dependable solution to restore data in case of a disaster (Singh, 2017). To lessen the large negative impact of the tragedy, many companies and public services construct a recovery mechanism to protect sensitive data and save critical services. Different ways of disaster recovery and data backup include local Backup, inter-private cloud storage, cloud server central repository, backup repository, etc, for the details of their description see (Sajid and Raza, 2013).

#### 2.4.1 Cloud Computing Opportunities

- **Cost Efficiency:** One of the benefits of cloud computing is modernizing business operations, giving cost-effective solutions compared to conventional processes. Cost efficiency can be achieved by firms managing their spending on essential resources through

optimization using IT (Kaushik et al., 2014). Also, the firms can further cut costs by enhancing usage, reducing infrastructure and operational costs as well as deployment delay.

- **Scalability:** The ability of cloud computing to increase or decrease in performance and cost in reaction to change in the system's process is a highly important metric and is measured here. It is the ability of a system (cloud computing) to respond to an issue independent of its dimension, that is, as the scope of the problem rises the system still replies and delivers a solution (Rezgui, 2021). Therefore, scalability is about holding abrupt change in the number of elements/objects or volume of the workload which as explained in (Rezgui, 2021) depends on system design, kind of data, algorithms, and communications mechanism.

- **Innovations:** Cloud computing is versatile with inherent scalability and power that enables AI adoption to uncover new opportunities and expedite innovations (Fergus and Stephen, 2021). Cloud computing allows organizations to be more productive, collaborative, and imaginative, developing new ideas and expediting their introduction to the market. In addition, it is relatively easy to start a new business using cloud computing since you can provide a service without capital investment in hardware. The cloud provides access to numerous intelligence technologies like AI, ML, and IoT that enable and support enterprises with more efficient and faster product expansions and releases.

- **Remote Work:** Cloud computing allows workers to conveniently access information remotely whenever required and wherever they are using any device. Working remotely will help firms minimize the burden by transferring people from office to home in the cloud without adding hardware or updating individual computers or servers.

#### 2.4.2 Challenges and Threats in Cloud Computing

- **Data Security and Privacy:** As described previously, cloud computing runs using many varied components such as networks, databases, and resource scheduling that have significant security and privacy challenges. An example is presented in (Mane, 2023) for networks that interconnect systems in the cloud and data sets that are accessed or shared, are exposed to security and

privacy risks. Also, resource sharing and memory management algorithms can be hacked if not properly secured. Another security issue stated in (Singh, 2017) is the lack of full control of data in case of disaster since data backup is shared with the service providers there is a chance of data loss with unreliable providers. Also, security concern and a significant chance of data loss is related to centralized storage by the same authors (Singh, 2017).

- **Downtime and Availability:** Technical, operational, or security difficulties in cloud-based services or applications can create downtime or unavailability in cloud computing. It is expected that the infrastructure of cloud computing to be always accessible and cater to unpredictable demands, however, this is a challenge owing to the downtime issue (Miladic-Tesic et al., 2020). Cloud systems might be offline for different reasons ranging from network, hardware, or software faults to planned downtime due to maintenance or upgrades (Miladic-Tesic et al., 2020).

- **Performance Issues:** This is another topic of concern in cloud computing which refers to how well an application, workloads, and database run in a cloud (Wu et al., 2014). Performance difficulty is caused by a lack of adequate resources like; enough cloud space, limited bandwidth, reduced processing speed, memory, network connection, etc (Wu et al., 2014).

## 2.5 Fiber Optics

The high need for expanded capacity in the sector of telecommunications has seen several technological breakthroughs one of which is the implementation of fiber optics. As shown in (Aldossary, 2024), it is one of the most exciting recent advances in the world of telecommunication and data transmission. Fiber optics is in a way comparable to radio waves and microwaves; however, the technology here employs small strands of glass or plastic fiber to carry information across great distances with fast speed and minimum loss (Aldossary, 2024). The technology in fiber optics conveys information in the form of light through transparent fibers. Fiber optics are currently becoming a transmission medium for numerous applications in the field of telecommunications because of its many advantages (Nicoletta, 2024) and some are briefly addressed as follows:

- **Increased Bandwidth:** Compared to other types of wired communications, fiber optics has a huge capacity (bandwidth) to carry high-speed signals over longer distances without repeaters. Fiber optics can attain up to a maximum of 10 gigabytes of speed at over a distance of 40 Km (Aldossary, 2024) permitting the transfer of data at high-speed giving opportunities for numerous applications.
- **Low Signal Loss:** Because of its manner of transmission fiber optics, it has lesser loss of signal intensity (attenuation) compared to copper cables, allowing greater distance transmission with fewer repeaters.
- **Electromagnetic Interference Immunity:** Since communications are transferred in fiber optics as light, the transmission is consequently not sensitive to electromagnetic interference. Fiber optics transmission is described in (Kiminza and Were, 2016) as resistive to electromagnetic force and nearly noise-free.
- **Security:** Signal transmission using fiber optics is highly secured because there is no radiation around the optical fiber and that makes it difficult to tap the signal being transmitted without cutting into the fiber. In addition, cutting the cable may readily be spotted and traced consequently those properties make fiber the most secure media to carry critical data (Kiminza and Were, 2016).

Optical fiber is quickly becoming the ideal transmission medium for many applications in the sphere of telecommunication, such as IoT, medical applications, road transport systems, military applications, etc, (Aldossary, 2024). Optical fiber is classed into two varieties; Single-Mode Fiber (SMF) which has a very tiny core and is also called mono-mode. The second type is Multi-Mode Fiber (MMF) which is bigger (approximately 10 times) than the SMF. For the details description types of optical fiber see (Lawan et- al, 2020; Aldossary, 2024).

### 2.5.1 Fiber Optics Opportunities

- **Expanding Network Connectivity:** Fiber optics will have a big impact on the digital world by providing individuals and organizations with the

fast and reliable connectivity required with higher transmission efficiency. Authors of (Wang et al., 2022) suggested optical fiber as the ideal medium for broadband penetration and its provision will expand network connectivity, for successful high-speed internet services. Fiber optics connectivity will also enable 5G technology adoption meeting the high-speed low latency needs by providing the backbone network needed to connect the cell towers (Banafaa et al., 2023).

- **Smart Cities and IoT:** Fiber optic infrastructure provides the connection and network needs for smart cities and IoT applications. According to (Zhang et al., 2019) optical fiber is the only candidate that can satisfy the capacity demand of smart city and IoT applications. This is because some of the applications have low latency and high speed that demand reliable communication networks with enormous bandwidth, long distances, and improved immunity.

- **Secure Communication:** It is mentioned before in this study that optical fiber transmissions are hard to intercept compared to other ways of wired communications. This is due to the great protection given by the network against many conceivable threats. Some of the techniques used to secure optical fiber transmissions are data confidentiality, optical encryption, optical CDMA, optical key distribution, privacy, and optical stenography, etc, see (Akyildiz et al., 2020) for the specifics. An example of how optical stenography is used to secure user availability is shown in (Akyildiz et al., 2020) where the system assures that a network service is not denied to approved users.

- **Enhanced Cloud Computing:** Fiber technologies are being employed to serve the expanding needs of data centers for cloud computing and big data analytics (Banafaa et al., 2023). Authors of (You et al., 2020) underlined the relevance of fiber infrastructure where it plays a significant part in data center operations that support cloud computing. This is because fiber optics can accommodate the huge data transfer required by cloud services.

### 2.5.2 Challenges and Threats in Fiber Optics

- **High Initial Investment:** This is one of the most important issues because installing fiber optic cables is a capital-intensive operation and investing the initial capital can be discouraging, especially in non-viable places. As stated in (Alsharif et al.,

2020), to build a fiber optic cable there is an initial financial investment of acquiring a license from the government, procurement of infrastructure, and recruiting of workers. In general, the deployment of fiber is expensive notably the initial investment due to numerous variables like (Alsharif et al., 2020); the cost of the fiber cables themselves, the complexity of the installation procedure, and the infrastructure necessary for fiber optics installation.

- **Physical Vulnerability:** Fiber optic cables might be subject to various environmental elements such as temperature, moisture, damage caused by natural disasters, etc. Optical fiber cables are prone to be damaged when there is a calamity like an earthquake or an intentional attack such as a bombing or electromagnetic pulse bomb (Bekaroo and Dawarka, 2023). In addition to damage and loss of essential information as a result of the disaster or attack, there is also the challenge of taking a long time, labor, and resources to find and repair the damaged position of the faulty cable (Bekaroo and Dawarka, 2023). In case of hard-to-reach fault places like subsea, detecting and correcting the fault will be slow taking longer time.

## 2.6 Future Trends in Telecommunications

### 2.6.1 1. 6G Technology

Sixth Generation (6G) cellular technology is repressing the next generation as a successor to the current 5G networks. According to (Zhang et al., 2023) 6G technology is projected to answer the evolving societal needs in the development of emerging use cases that are beyond the capacity of the 5G technology. 6G system is projected to restructure wireless conventional operation to support ubiquitous AI services changing from “connected things” given by the current technology to “connected intelligence” (Nasralla and Alshattarat, 2022). Therefore, 6G is projected to enable numerous smart applications using AI and ML with autonomous networks serving as the backbone of the technology. The authors of (Zhang et al., 2023) characterize 6G as a technology with a greater level of data rate and lower latency compared to 5G. These qualities will enable the 6G to support multiple rising AI applications such as Virtual and Augmented Reality (VAR) which demand data rate in terabits-level and latency in microseconds that cannot be achieved by the 5G (Zhang et al., 2023). This can be achieved as indicated in (Nawaz et al., 2020), by enhancing the

5G system lag using a novel set of technologies like THz and optical frequency bands, ubiquitous AI, network automation, intelligent network environment, Internet of Space Things (IoST), etc. Fig. 5 highlights the crucial enhancement of 6G technology showcasing several important aspects.

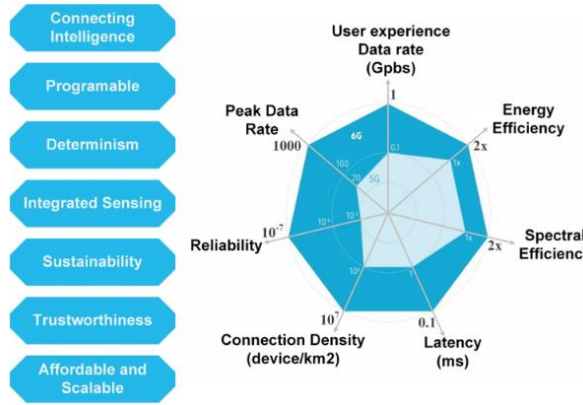


Figure 5: Key improvement of 6G Technology (Nawaz et al., 2020)

Furthermore, 6G technology will improve industrial automation and facilitate migration from Industry 4.0 to Industry X.0 (Zhang et al., 2023), scaling up connectivity density as depicted in Fig. 5 thus boosting energy efficiency. In addition, 6G will demand a real wireless ubiquity recommending nearly 100% geographical coverage, sub-centimeter geo-location accuracy, and millisecond geo-location update rate (Singh et al., 2023) to fulfill various use cases. This must be offered as the 6G technology requirement even in rural, unserved, and underserved locations employing non-terrestrial like satellite communication networks to complement the terrestrial ones. This is because some applications demand smooth and universal service availability to work effectively. Such applications as presented in (Singh et al., 2023) include driverless vehicles, unmanned aerial vehicles, marine communication networks, etc. Fig. 6 offers an overview of 6G wireless networks demonstrating numerous application scenarios, performance indicators, supporting technologies, industry verticals, and new paradigm shifts (Singh et al., 2023).

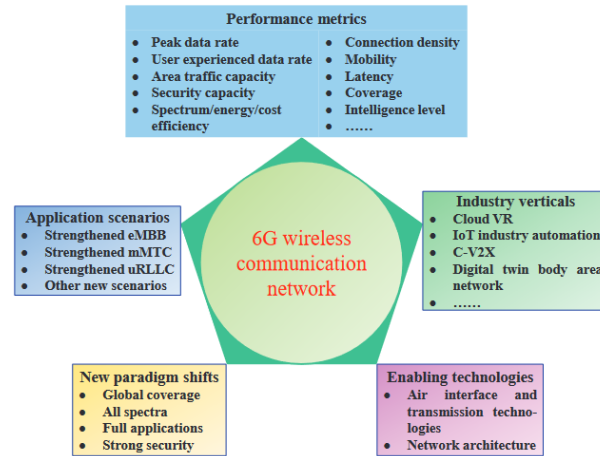


Figure 6: An overview of 6G wireless networks (Singh et al., 2023)

### 2.6.2 6G Opportunities

- Extended Reality (XR) Experiences: One of the prospects of 6G technology is what is called extended reality which is characterized in (Gangyi et al., 2018) as an umbrella word referring to immersive technologies associated with both the actual and virtual environment. XR technologies include Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR). XR applications are developing technologies with ultra-high demands on data rate and latency, ergo they will offer considerable problems to the current 5G networks. 6G technology is considered in (Hossain, 2023) as a perfect contender for the job as well as capable of merging communication and computing using AI for data analytics. Various chances of XR are emerging and its technology can produce unique applications and experiences in different fields such as medical training, travel and tourism, education, and even gaming (Gangyi et al., 2018).

- Holographic Telepresence: This is a developing technology that will be enabled by a 6G network providing a full motion three-dimensional (3D) video conference. This is because holographic telepresence requires a high data rate of close to 5 Tbps and an end-to-end latency of 1 ms both of which according to (Äralikatti, 2021) are hard to achieve with the existing 5G. The device will allow users to project real-time 3D pictures leveraging all five senses – sight, hearing, touch, smell, and taste, to give a completely immersive experience (Zhang et al., 2023). This technology will allow near-real personal communication with digital holographic presence, immersive live models, and a combination of the environment with many digital avatars from different sources (Hasan et al., 2023).

- **Smart Cities and Infrastructure:** The unique and structure of 6G will quicken the realization of smart cities and infrastructure. In addition, providing that 6G is an AI-driven network that will utilize modern telecommunication infrastructure to enable AI-based IoTs and autonomous systems applications that will make a city super smart (Zhang et al., 2023). Authors of (Jiang, 2023) described the convergence of Communications, Computing, Control, Localization, and Sensing (3CLS), as the power of 6G trends that will enable the implementation of smart cities. This will provide a pervasive autonomous system, enabling tactile devices, Internet of Everything (IoE), and ubiquity connectivity throughout the city. Some of the applications in smart cities include smart transportation, smart grid, intelligent transportation systems, intelligent medical diagnosis, shopping recommender systems, etc (Hasan et al., 2023). For the review of numerous use cases exhibiting 6G prospects in (Zhang et al., 2023) see Fig. 7.

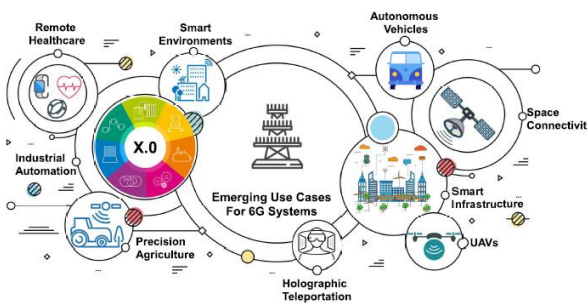


Figure 7: Use cases offering 6G potential (Zhang et al., 2023)

### 2.6.3 6G Challenges

- **Spectrum availability and Regulation:** Higher data rates and greater bandwidth requirements of 6G require access to additional spectrum bands including terahertz (THz) frequencies. However, authors of (Kumar et al., 2024) noted how tough it is to generate THz signals as well as THz communication systems due to a shortage of THz transceivers. This will also present a difficulty for the devices since THz is too high for the ordinary electronic devices that are used to generate microwave signals that are next to the THz (Kumar et al., 2024). Similarly, the THz is near the optical frequency region and too low for photonic-based devices used to generate optical signals. On

the other hand, the problem of the availability and licensing of the THz spectrum is still uncertain providing a substantial impediment. Furthermore, problems on the topic of heterogeneity of high-frequency bands are explored in (Dejpasand and Ghamsar, 2023) that the utilization of mm-wave and THz in 6G will provide a challenge notably on the propagation model. Another difficulty is building a clear and flexible regulatory framework around the full above-mentioned spectrum of challenges.

- **Sustainability and Energy Efficiency:** Due to its many uses involving an enormous number of devices, 6G technology is predicted to be more energy-intensive than the present 5G technology. Therefore, sustaining the 6G will be tough since it demands developing energy-efficient solutions via optimizing network operation. Another concern is the topic of global and climatic changes with the increasing technological growth. There is a concern stated in [80] that 6G technology will have an impact on raising carbon footprint since the number of devices (IoT) as well as antenna placement would be expanded.

- **Interoperability and integration with current Systems:** Various solutions are suggested for 6G by different stakeholders, this would provide a problem in interoperability and easy integration across networks. A similar difficulty is presented in (Nawaz et al., 2020) since the 6G network is AI-driven and various smart devices that may require AI and ML technologies would encounter major challenges in designing the integration mechanism. In addition, 6G is expected to bring together a varied range of technology, applications, and devices, so guaranteeing interoperability for seamless connectivity and compatibility will be tough (Attia, 2021). Finally, there will be a need for collaboration between industry players, standardization organizations, and regulatory agencies to produce common standards and specifications and that would be a challenging effort (Attia, 2021).

- **Security and Privacy:** With growing connections, data interchange, and AI-driven networks maintaining effective security and privacy mechanisms become increasingly complex [89]. New gadgets, usage behavior, and technical advancement will give rise to system vulnerability and expand the security gap (Nawaz et al., 2020).

## 2.7 Quantum Computing and Cryptography

Quantum computing is a multidisciplinary field including features of computer science, physics, and mathematics that employ quantum mechanics to tackle complicated issues faster than classical computers. Its principle follows that of quantum physics respecting the superposition principle which allows the state of a quantum unit to be in a state of superposition of many possibilities (Taleb et al., 2011). This results in quantum information processing being more efficient than classical processing with enormous potential providing a new manner of computing, greater computational power, less energy consumption, and exponential speed above the classical one (Hu and Li, 2001). Contrary to classical computers that employ bits as the smallest unit of data, quantum computers use quantum bits (Qubits) to exist in several states simultaneously due to the principle of superposition (Hu and Li, 2001). Authors of (Hu and Li, 2001) described three important ideas that are the fundamentals of quantum computing:

- i. Superposition: Here contrast to the classical bits that can either be 0 or 1, Qubits exist in a state that is a linear combination of both 0 and 1. This boosts the capacity of quantum computing by processing a tremendous quantity of information concurrently.
- ii. Entanglement: This is done to permit state dependency between one Qubit and another regardless of the distance between them. This increases the speed of quantum computing.
- iii. Quantum interference: This is a strategy used in decreasing mistakes where quantum algorithms leverage the idea of interference to detect correct outcomes and reject incorrect ones using probability.

Cryptography on the other hand is a technique for secure communication by hiding or coding information to safeguard the intended destination (Portillo et al., 2019). The approach is applied in quantum computing as quantum cryptography to give protection against quantum attacks. This is because according to (Portillo et al., 2019), building a quantum computer with computing capacity might potentially weaken many present encryption techniques making sensitive information accessible to assaults.

### 2.7.1 Quantum Computing Opportunities

- Quantum Communications: As explained before that 6G is an AI-based network that demands rapid, dependable, intelligent, and secure, communication requiring great processing power. According to (Nawaz et al., 2020) quantum computing fits the aforementioned characteristics since it can process multi-dimensional large-sized data in parallel. Therefore, quantum communications use photons to transport qubits across remote sites since photons are very well separated from disruption utilizing the idea of superposition (Lee et al., 2010). In addition, quantum communication safe data transfer facilitated by Quantum Key Distribution (QKD) which gave unparalleled degrees of security for transmitting critical information (Portillo et al., 2019).

- Quantum ML (QML): Quantum computing can boost ML by expediting the training and inference of models, enabling the processing of bigger data sets and more sophisticated models (Matar, 2005). QML merges quantum computing and ML techniques to potentially speed up training utilizing quantum algorithms like quantum support vector machines and quantum principal components (Matar, 2005).

- Drugs Discovery and Healthcare: Quantum computing can aid during the drug design stage to precisely anticipate the activity and safety of drug compounds by simulating their interactions. Drug development is a difficult process that encompasses numerous long stages mentioned in (Broadband Commission for Sustainable Development, 2019) and deployment of quantum computing can ease and speed up the process. Authors of (Katona, 2020) described quantum computing as excellent in simulation, predicting drug behavior and properties, and boosting drug understanding during design and production. The significance of quantum computing in drug discovery includes but is not limited to (Katona, 2020): quickening the discovery, cost reduction, increasing collaboration, advancing medical science, etc.

### 2.7.2 Quantum Computing Challenges

- Qubit coherence and error rate: As briefly said previously qubits can be formed from structures like photons, iron, and semiconductor circuits merely to get enough separation in their

binary state. However, qubits are intrinsically error-prone and complex to regulate due to difficulty in maintaining qubits coherence and minimizing error rates (Pachler et al., 2021). Therefore, the precision of quantum computation can be reduced easily because of qubits coherency from environmental interactions and operational mistakes.

- **Scalability issues:** Another hurdle in constructing large-scale error-free quantum computers due restricted number of qubits currently accessible. It is demonstrated in (Portillo et al., 2019) that even if the number of qubits is increasing, it is still much smaller than the number of bits in conventional computers. Scaling up the number will lead to a challenge in maintaining coherence and a low mistake rate. This challenge suggests that due to qubits constraint, quantum computing can only address a restricted number of problems that are beyond the classical computers' capability. Another scalability difficulty as a result of the immaturity of quantum computing produced algorithms that are restricted in number which will therefore limit the types and number of problems that quantum computing can address (Portillo et al., 2019).

- **Hardware and software development:** This is Quantum computing infrastructure and entails hard concerns like technological and financial. Authors of (Portillo et al., 2019) described developing high-quality hardware like qubits and control circuits as a major problem of quantum computing. This is because getting powerful qubit technology to produce a scalable, fault-tolerant qubit is a tough process.

### 3 Satellite Internet

This is a sort of wireless link that employs communication satellites to provide broadband in rural areas, isolated, underserved, and hard-to-access locations (Noorda, 2019). Satellite communication is considered in (Noorda, 2019) as a vital technology that can be used as an alternative to terrestrial connection to bridge a gap between populations that are benefiting from digital technology and others that are not. Sometimes notably in the developed part of the world, satellite networks are not only utilized as an alternative to terrestrial but can interwork as a backbone to offer end-to-end connectivity. Authors of (Aditya et al., 2015) indicated how new telecommunication applications (to be supported by the 5G and 6G mentioned) might potentially reinvent the purpose

of communication systems by enabling the integration of terrestrial and satellite networks. This will boost the performance of mobile broadband as well as addressing the following difficulties impacting terrestrial networks described in (Aditya et al., 2015): Economical and geographical factors will not allow 100% global coverage and thus need the satellite network to supplement. Also, natural disasters like earthquakes that could destroy the terrestrial communication backbone would employ satellites ad hoc for emergencies and quick response for rescue. Authors of (Mehra, 2020) compared favor satellite to terrestrial connectivity for large-scale communications. Their rationale is satellite offers ubiquitous service and robust multi-link transmission ability; it also enables flexible access methods and high-speed connectivity. Satellite has the following three distinct categories each distinguished by distinctive orbital positions and operational attributes (Aditya et al., 2015):

- i. **Geostationary Earth Orbit (GEO):** Also called geosynchronous because it is synchronous with respect to the Earth, appears to be stationary when observed from a fixed point from Earth. It works at 36000 KM orbits, giving vast service regions and decreasing latency by lowering handover time (Aditya et al., 2015). A GEO satellite's footprint can cover up to 1/3rd of the world which means only three of them can sufficiently provide connection throughout the surface of the earth.
- ii. **Medium Earth Orbit (MEO):** This is positioned midway between GEO and Low Earth Orbit (LEO), functioning at an orbit of 10,000 to 20,000 KM [99]. Because its distance from the planet is shorter than that of GEO, a bigger number (around a dozen) of them is necessary to cover the earth's surface. GEOs move more slowly relative to the earth's rotation allowing a simpler system design covering greater populations with fewer handovers (Hamdoun et al., 2016).
- iii. **Low Earth Orbit (LEO):** This satellite is located 500 to 1500 KM above the surface of the earth, characterized by less free attenuation and propagation delay (Aditya et al., 2015). LEOs circle on lower orbit, exhibiting a considerably shorter period with high-quality communications links. However, because of their near to the

planet's surface, they require multiple satellites for global coverage (Aditya et al., 2015).

### 3.1 Opportunities for Satellite Internet

- **Global Coverage:** One of the opportunities of satellite communication is seamless global coverage, especially in future wireless network architecture where it can be leveraged to expand the present terrestrial network to various applications as shown in Fig. 8 (Singh et al., 2023). It shows how multi-beam satellites have been used to give growing wireless data rates. A similar configuration is provided in (Nawaz et al., 2020) where 6G mobile technology is planned to link satellite networks with terrestrial to form ubiquitous worldwide coverage. For example, to actualize the 6G use of space travel space internet is required and that can be achieved by satellite coverage. Satellites can also be utilized to give internet connectivity and access to remote and underserved notably in rural and underdeveloped countries that lack the required infrastructure for dependable connectivity (Maruthi and Rashmi, 2015). In addition, even if there are existing infrastructures satellites may be employed as a complementary to reduce congestion and increase overall performance.

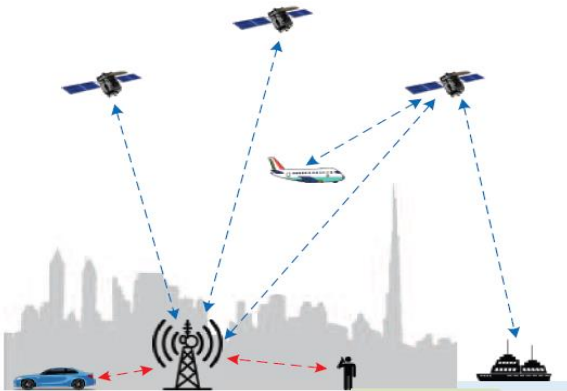


Figure 8: Integration of terrestrial and satellite communication networks (Singh et al., 2023)

- **Disaster Recovery and Emergency Connectivity:** Natural disasters primarily damage or destroy terrestrial telecommunications infrastructure. In a scenario like this satellite network operates as a connecting bridge between the disaster-hit region and the rest of the world (Aditya et al., 2015). The network will provide a stable and on-demand wireless network for recovery and rescue operations. Authors of (Al-anzi et al., 2017) highlighted some of the services that

might be supplied by the satellite networks including point-to-point individual communication, point-to-multipoint IP multicasting, high-speed IP data communication, video transmission, and communication control. Using any of the following applications when required satellite network enables dissemination of information from the catastrophe locations by data transfer of various information. Some of the information as indicated in (Hsu et al., 2024) includes images from the disaster site, flood mapping, early warning, and forest fire mapping, etc.

- **Enabling new Applications and Services:** Satellite-wide coverage will enable a wide range of new innovative applications and services. For example, reference (Hsu et al., 2024) described how satellite connectivity will boost and support the expanding number of IoT devices to realize diverse applications such as smart cities and precision agriculture. Also, satellite communication serving rural places can enhance the distribution of educational content services to impoverished communities. The same applications can be expanded into the health sector to accomplish telemedicine. Here health care practitioners can offer remote consultations, tests, and monitoring services to patients.

#### 3.1.1 Challenges of Satellite Internet

- **High Initial Capital Expenditure:** Satellite deployment, especially big scale has economic issues as it takes a significant initial capital due to production, launch services, and ground infrastructure (Saleh and Hassan, 2024). After the big initial investment, there will be an issue of profit and lengthy sustainability which relies on the ability of the project to create appropriate revenue. This problem has been studied and discussed in (Chen et al., 2011) where the authors look at the likelihood of competition from terrestrial networks that may damage the satellite market. Another difficulty is the limited purchasing power of the end customers, especially in underdeveloped nations, which could lead to the failure of the project.

- **Regulatory and Spectrum Allocation Challenges:** Satellite communications involve substantial coordination at both the national and international levels. First, its functioning requires regulatory permission as well as government policy conformity. Operators must gain permits to be granted specific frequency bands by a regulator which sometimes can be a complex and time-

consuming process (Kulkarni et al., 2020). In addition, the rule for licensing different couriers can provide a problem and produce a delay market to a foreign satellite operator. Sovereignty and privacy concerns are significant legislative and policy challenges that might affect satellite operations. This problem has been discussed in (Ikebe et al., 2007) provided a scenario of a government objecting to the operation of foreign-owned satellites above their land. Also a security and privacy risk of collecting and transmitting data across borders.

### 3.2 Sustainable and Green Telecommunications

Sustainable Green Telecommunication is an area that is centered on minimizing energy usage, lowering emissions, and constructing environmentally friendly infrastructure (Kumar and Rao, 2018). This is important because of the exponential expansion in the demand for communication which would therefore increase the consumption of carbon-based fuel to maintain the rising infrastructure that will cause a major rise in global warming (Kumar and Rao, 2018). Carbon-based fuel is utilized as energy which is obtained partially from the power grid and the remainder burning of fossil fuel, for example, diesel mainly in rural areas and underdeveloped countries (Parenti and Rastelli, 2012). These sources contribute to emissions that are measured using two methodologies (Balbaa and Abdurashidova, 2024): Green House Gas (GHG) emissions and CO<sub>2</sub> emissions. GHG emission is from human activities and a subset of CO<sub>2</sub> emission which constitutes the main gas emitted into the atmosphere including the percentage of methane, nitrous oxide, and fluorocarbons that contribute to the atmosphere impacting the climate (Balbaa and Abdurashidova, 2024). Authors of (Parenti and Rastelli, 2012) presented a study of Indian 5G predicted to raise the usage of the overall network energy by 150-170% by 2026. Also, the telecom towers accounted for 51% volume share of Diesel use in India. Therefore, emerging communications technologies must include sustainability and green telecommunication because of their importance in protecting the environment. Based on the foregoing development, writers of (Balbaa and Abdurashidova, 2024) defined green telecommunication as the process of minimizing the carbon footprint that the telecommunication sector creates or causes to be created. Green

telecommunications have multiple dimensions and can be roughly categorized as stated in (Balbaa and Abdurashidova, 2024): Green telecommunication networks, green production of telecommunication equipment, eco-friendly design of telecommunication buildings, and safe disposal of telecommunication waste.

#### 3.2.1 Opportunities in Sustainable and Green Telecommunications

- **Energy Efficiency in Networks:** This refers to decreasing energy consumption utilizing energy-efficient equipment and innovative technologies (Parenti and Rastelli, 2012). An example of an energy-efficient network employing a smart grid is described in (SES, 2017), where a model is proposed that automatically turns off redundant base stations, and the customers of that network are supplied by a neighboring base station as presented in Fig. 9. The following other solutions were presented in (Parenti and Rastelli, 2012) for energy-efficient cellular networks: Infrastructure sharing, boosting grids supply by expansion to the remote region will save diesel usage lowering carbon footprint emission. Another idea from the same authors is better network planning like; developing a network that employs fewer sites and designing a robust system that monitors and regulates real-time energy consumption.

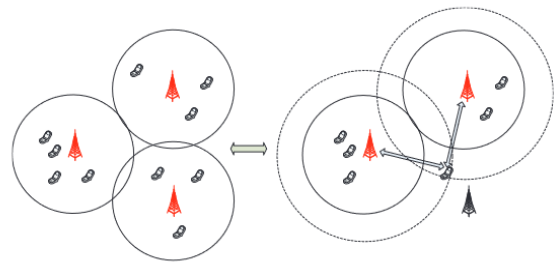


Figure 9: Coverage expansion and energy saving using coordinated multipoint (SES, 2017)

- **Renewable Energy for Telecommunication Infrastructure:** The key aspect of renewable energy is environmental friendliness and cost-effectiveness of energy supplies. Renewable energy sources will lessen the high dependency on fossil fuels and subsequently lower carbon footprint. Telecommunication towers are powered by many renewable energy sources, the following sources are explored and presented in (Parenti and Rastelli, 2012): solar energy is generally utilized as a hybrid,

especially in underdeveloped nations where diesel and solar solutions are supplied. The combination dramatically cuts energy costs as well as carbon pollution. Wind energy - this is another renewable approach provided in the same reference where smaller wind turbine systems are placed on the existing radio masts. Biomass energy and ocean/tidal energy are also renewable energy sources that can help lower energy expenditures and carbon pollution as stated in (Parenti and Rastelli, 2012). Generally, as given in (Infocomm Media Development Authority (IMDA), n.d.), the utilization of renewable energy technologies offers a solution to the scarcity of electricity, supply clean energy, and lower operation and maintenance expenses of the sector.

- **Green Manufacturing of Telecommunication Materials:** These are manufacturing processes that are used to create a system more eco-friendly and eco-efficient employing a green approach (Mushiba, 2024). Green manufacturing is recognized as the sole answer for sustainable development assuring a manufacturing process that does not contaminate the environment and, the safety of employees or other members of the community. This can be achieved if the producers know where their duties end as well as the allowed quantity of hazardous emissions to the environment (Li, 2018). Green manufacturing involves good decision-making, for example, timely decisions on replacing renewable sources for finite ones, and of whether to create or buy products. Another key aspect that must be considered in green manufacturing is waste, which has been defined in (Li, 2018) as anything that does not add value to the product. The waste that needs to be monitored in green manufacturing has been categorized into the following 8 types: over-production, waiting, inventory, transportation, over-processing, motion, defect, and workforce. For the details of their definition and description see (Li, 2018).

### 3.2.2 Challenges in Sustainable and Green Telecommunication

- **Electronic Waste (E-Waste):** Technological advancement creates a high demand for electronic devices and rapid growth of mobile phone industries which make e-waste the most rapidly growing waste in the world (ITU-T, 2017). Telecommunication and electronics infrastructures and equipment contribute to e-waste largely as a result of the disposal of outdated gadgets. The

devices will be abandoned and become obsolete, generating a major problem which results in environmental harm hazardous chemicals, and non-biodegradable materials (ITU-T, 2017). For example, if the waste should be burned instead of being buried or disposed of, it will lead to harmful emissions and environmental contamination (Abdlrazaq and Varol, 2021). One of the issues of e-waste is the problem from both manufacturers and consumers. The former refuse to take responsibility for their product once sold and disposal becomes the headache of the latter (Abdlrazaq and Varol, 2021). Another difficulty stated in (ITU-T, 2017) (Abdlrazaq is standardization and regulation where many nations in the globe do not have clear and effective regulations, and rules to guide or regulate how e-waste is treated. Instead, the e-waste is managed in an ad-hoc manner, employing an unregulated and risky way.

- **Transition to Renewable Energy:** This is not a straightforward undertaking and faces numerous problems including technological, environmental, sociological, economic, and geopolitical. The issues as stated in (Huang and Liu, 2012) essentially involved the following:

- i. **Intermittency:** this is an issue as a result of differences in characteristics of the conventional energy sources that can be regulated and used on demand and renewable energy where its production relies on weather conditions. An example is presented in (Huang and Liu, 2012) of wind-renewable sources relying on wind speeds and solar energy on sunshine.
- ii. **Grid integration:** primarily renewable energy when generated is integrated into existing power systems and that creates a technical difficulty (Huang and Liu, 2012). The challenge is that most of the renewable sources rely on unregulated and unpredictable resources, consequently, there would be an issue of managing the stability due to changeable input.
- iii. **Storage:** The extra electricity generated during periods of peak renewable energy output needs to be stored to be used during the period of low or no output. This process is critical and complex as shown in (Huang and Liu, 2012) because the battery technology utilized for this purpose is still

not cost-effective for storing big quantities of electricity over extended durations.

- iv. **Transmission:** Most of the facilities of renewable energy like wind and solar are created and put in remote places where renewable energy resources are abundant. Therefore, the power generated must be transferred across great distances to towns and industries for consumption and according to (Huang and Liu, 2012) this can be hard. This is because the process demands extensive infrastructure and can result in energy losses.

- **Transmission Bandwidth:** Bandwidth is another difficulty or compromise in green telecommunications. This is because according to (Chen et al., 2011), a bandwidth has a direct link to the transmission rate for a given quantity of transmit power. Bandwidth expansion for a particular transmission rate reduces energy usage [122]. However, there is a considerable barrier here as bandwidth growth demands certain changes in the network and even the possibility of a new scheme as well as the issue of merging with the present scheme. Therefore, the technology highlighted in [122] may not be advantageous to green telecoms.

## 4 Conclusion

This paper analysed Telecommunication's evolutionary tendencies, opportunities or benefits, and challenges that can limit their /applications. The effort started by examining the history of communications as far back as before the realization of electricity, when smoke, drums, horses, and carrier pigeons were used by humans to communicate. It also demonstrated how the field of communications has shown a remarkable shift over the generations. Starting from a simple voice communication system to an IP-based system matching the requirement of high capacity and customer demand, updating the technology to realize multiple cellular network generations from 1G to the present 5G. Features, deployment, applications, capabilities, regulatory and policy, opportunities, and threats were all assessed. The issue of IoT and its numerous uses have been presented as part of the opportunities of current telecommunications. AI and ML have been evaluated also starting from their history down to the applications, indicating their capacity to turn future telecommunication into AI-based networks. In addition, the contribution of cloud computing as

an emerging technology in the field of IT, as well as its challenges and limitations have been given. Fiber optics that can accommodate significant data traffic has been introduced and its features, prospects, and problems have been given and examined.

Feature Telecommunications has been included here and the report surveys 6 G's main enabling techniques, explaining their fundamental use cases, prospects, and problems. The concept of quantum computing and cryptography encompasses 3 basic concepts of quantum computing, applications, and obstacles explained. A satellite network that is expected to be the enabler of future wireless communication is presented in this study. It has been described here as an alternative or supplement to the terrestrial network. Its different varieties, features, uses and challenges have been examined. The telecommunication sector is very significant in human lives and thus must be given sustainable measures, based on that, this research provides a complete review of sustainable and green telecoms. Energy efficient networks, renewable energy sources, E-waste, etc have been highlighted as potential and difficulties of sustainable green telecommunications.

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