

EVOLUTION OF 5G NETWORK TECHNOLOGY, USE CASES AND IMPACTS ON APPLICATIONS & SOCIETY

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Abstract:

The evolution of 5G network technology has been a pivotal advancement in the realm of telecommunications, promising unparalleled speed, connectivity, and innovation. This paper provides a comprehensive overview of the evolution of 5G technology, highlighting its technical underpinnings, architectural advancements, and deployment strategies. Additionally, it delves into the diverse array of use cases facilitated by 5G networks, ranging from enhanced mobile broadband to massive machine-type communications and ultra-reliable low-latency communications.

Furthermore, the paper examines the profound impact of 5G on various applications and industries, including healthcare, transportation, manufacturing, and entertainment. It explores how 5G enables transformative capabilities such as augmented reality, virtual reality, autonomous vehicles, and remote surgery, revolutionizing the way we work, communicate, and interact with the world around us.

Moreover, this research investigates the societal implications of widespread 5G adoption, discussing the potential benefits such as economic growth, job creation, and enhanced quality of life, as well as the challenges related to privacy, security, and digital divide. Through a thorough analysis of technological advancements, use cases, and societal impacts, this paper aims to provide valuable insights into the evolution of 5G network technology and its profound implications for applications and society.

Keywords —Evolution of 5G Network Technology, Use Cases, Impacts on applications, Impact on Society, Identification of problem, issues and Implementation Steps, discussion, and Conclusions.

I. INTRODUCTION

The evolution of 5G network technology marks a transformative milestone in the realm of telecommunications, promising to revolutionize the way we connect and interact with the world. Emerging as the fifth generation of wireless technology, 5G is designed to surpass its predecessors—1G through 4G—in terms of speed, capacity, and connectivity. While 1G introduced basic analog voice communication, and 2G brought digital voice and text messaging, 3G and 4G expanded capabilities with mobile internet and enhanced data speeds. However, 5G is set to

redefine the boundaries of digital communication, offering unprecedented data rates, ultra-low latency, and massive device connectivity.

The development of 5G is driven by the increasing demand for faster, more reliable internet services, and the proliferation of connected devices in the Internet of Things (IoT). Unlike previous generations, 5G leverages advanced technologies such as millimeter waves, small cells, massive MIMO (multiple-input multiple-output), and beamforming to deliver its enhanced performance. These innovations enable 5G to support new applications and services, from autonomous

vehicles and smart cities to augmented reality (AR) and virtual reality (VR), which require high bandwidth and real-time data transmission.

As countries worldwide race to deploy 5G networks, the technology's potential to spur economic growth, enhance digital inclusion, and drive innovation in various sectors is becoming increasingly evident. However, the journey to widespread 5G adoption involves overcoming significant challenges, including infrastructure development, regulatory hurdles, and cybersecurity concerns. Despite these obstacles, the evolution of 5G network technology heralds a new era of connectivity, poised to unlock transformative possibilities and reshape the digital landscape.

II. EVOLUTION OF NETWORK TECHNOLOGY

The evolution of network technology from 1G to 5G represents a remarkable journey of innovation and advancement in telecommunications, marked by significant milestones in each generation.

1G: The Birth of Mobile Communication Introduction in the 1980s

1G, or the first generation of mobile networks, was introduced in the 1980s. It marked the beginning of wireless communication with analog transmission. The primary feature of 1G was the ability to transmit voice calls, making mobile phones a novel but luxury item. The Advanced Mobile Phone System (AMPS) was one of the most popular 1G standards. However, 1G networks had significant limitations, including poor voice quality, limited coverage, and lack of security.

2G: The Digital Revolution Introduction in the 1990s

The 1990s saw the advent of 2G networks, which transitioned from analog to digital signals. This generation introduced significant improvements, including better voice quality, encryption for secure communication, and the ability to send text messages (SMS). Global System for Mobile Communications (GSM) became the dominant 2G standard. Enhanced Data Rates for GSM Evolution

(EDGE) later extended the capabilities of 2G, allowing for basic internet access.

3G: The Dawn of Mobile Internet Introduction in the 2000s

The launch of 3G networks in the early 2000s brought mobile internet access to the forefront. 3G technologies, such as Universal Mobile Telecommunications System (UMTS), provided higher data transfer rates, enabling web browsing, email, and video streaming on mobile devices. This generation supported multimedia messaging (MMS) and was crucial for the growth of mobile applications and services. The introduction of High-Speed Packet Access (HSPA) further enhanced data speeds, making mobile internet more practical and widespread.

4G: The Era of Broadband Connectivity Introduction in the 2010s

4G networks, rolled out in the 2010s, represented a significant leap forward with broadband-like speeds and improved network reliability. Long-Term Evolution (LTE) became the cornerstone of 4G, offering data rates up to 100 Mbps and reduced latency. This generation enabled high-definition video streaming, advanced gaming, and the proliferation of mobile apps that required robust internet connectivity. LTE-Advanced further pushed the boundaries with even higher speeds and capacity.

5G: The Next-Gen Network Introduction in the 2020s

The emergence of 5G in the 2020s marks the latest and most advanced phase in mobile network evolution. Designed to support a massive increase in connected devices, 5G offers data speeds up to 10 Gbps, ultra-low latency, and enhanced reliability. Key technologies driving 5G include millimeter waves, small cells, massive MIMO, and beamforming. These innovations allow 5G to support new and emerging applications such as autonomous vehicles, smart cities, augmented reality (AR), virtual reality (VR), and the Internet of Things (IoT). 5G is poised to drive the next wave of digital transformation, enabling unprecedented

levels of connectivity and integration across various sectors.

III. USE CASES OF 5G NETWORK TECHNOLOGY

The use cases of 5G network technology span across various sectors, each benefiting from its enhanced capabilities. From improving everyday mobile experiences to transforming industries with IoT, smart cities, and autonomous systems, 5G is set to drive significant advancements and innovations, leading to a more connected and efficient world. 5G network technology, with its high-speed connectivity, low latency, and massive device support, is set to revolutionize numerous industries and create a wide range of innovative use cases. Here are some of the most promising and impactful applications of 5G:

1. Enhanced Mobile Broadband (eMBB)

High-speed internet on mobile devices

5G provides significantly faster data rates compared to previous generations, enabling seamless high-definition video streaming, augmented reality (AR), virtual reality (VR), and other data-intensive applications on mobile devices. Users can enjoy ultra-high-definition content and more immersive experiences on the go.

2. Internet of Things (IoT)

Connecting billions of devices

5G's ability to support a massive number of connected devices is critical for the IoT ecosystem. Smart homes, wearables, industrial sensors, and connected appliances can communicate efficiently, facilitating advanced automation and real-time monitoring across various sectors. This connectivity enhances everything from personal fitness tracking to complex industrial automation.

3. Autonomous Vehicles

Safety and efficiency in transportation

Autonomous vehicles rely on real-time data to navigate and make decisions. 5G's ultra-low latency and high reliability ensure that self-driving cars can communicate with each other and with traffic

infrastructure instantly, improving safety and efficiency. This real-time communication is essential for coordinating traffic flow, reducing accidents, and optimizing route planning.

4. Smart Cities

Improving urban living

5G technology can transform urban environments into smart cities by enabling efficient management of resources and services. Applications include intelligent traffic management, energy-efficient buildings, smart lighting, waste management, and enhanced public safety through real-time surveillance and emergency response systems.

5. Remote Healthcare

Telemedicine and remote surgery

5G's high-speed and low-latency capabilities are crucial for telemedicine applications. Doctors can perform remote consultations with high-definition video, monitor patients in real time, and even conduct remote surgeries using robotic systems. This improves healthcare access, particularly in remote or underserved areas.

6. Industrial Automation

Smart manufacturing and logistics

In manufacturing, 5G supports the deployment of smart factories where machines, robots, and sensors communicate seamlessly to optimize production processes. This enables real-time monitoring, predictive maintenance, and more efficient supply chain management. Logistics can also benefit from real-time tracking of goods and automated warehouse operations.

7. Enhanced Entertainment and Gaming

Immersive experiences

The gaming industry stands to benefit enormously from 5G. With its low latency, gamers can enjoy cloud-based gaming with minimal lag, enhancing multiplayer experiences. Additionally, AR and VR applications will become more immersive and responsive, opening up new possibilities for interactive entertainment and virtual events.

8. Remote Work and Collaboration

Boosting productivity

The shift towards remote work, accelerated by the COVID-19 pandemic, can be further supported by 5G technology. High-speed and reliable connections enable smoother video conferencing, virtual collaboration tools, and cloud-based applications, enhancing productivity and connectivity for remote teams.

9. Agriculture

Precision farming

5G can revolutionize agriculture by enabling precision farming techniques. Farmers can use connected sensors and drones to monitor crop health, soil conditions, and weather patterns in real time. This data-driven approach can optimize irrigation, reduce pesticide use, and increase crop yields, leading to more sustainable farming practices.

10. Public Safety and Disaster Response

Enhanced emergency services

5G can improve public safety by enabling real-time communication and coordination among emergency responders. Drones equipped with cameras can provide live video feeds from disaster sites, and connected sensors can detect and report hazardous conditions immediately, facilitating quicker and more effective responses to emergencies. The entire document should be in Times New Roman or Times font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.

IV. IMPACTS ON APPLICATIONS

The deployment of 5G network technology is expected to bring a multitude of positive impacts across various applications, but it also comes with potential downsides. While 5G technology promises substantial benefits, including faster connectivity, enhanced IoT applications, and transformative impacts on industries like healthcare and transportation, it also poses challenges. These include high infrastructure costs, security risks,

potential health and environmental concerns, and the risk of exacerbating the digital divide. Addressing these challenges will be crucial to maximizing the positive impacts of 5G while mitigating its downsides. Here is an overview of the good and bad impacts of 5G technology on applications:

Positive Impacts

1. Enhanced Mobile Broadband

- **Faster Speeds:** 5G offers significantly higher data rates, allowing for seamless streaming of high-definition video, faster downloads, and a more responsive internet experience on mobile devices.
- **Improved User Experience:** Applications such as augmented reality (AR) and virtual reality (VR) will benefit from low latency and high bandwidth, providing smoother and more immersive experiences.

2. Internet of Things (IoT)

- **Massive Connectivity:** 5G can support a vast number of connected devices simultaneously, enabling the expansion of IoT applications in smart homes, cities, and industries.
- **Real-Time Data:** Enhanced connectivity and low latency allow for real-time data collection and analysis, improving automation and decision-making processes.

3. Autonomous Vehicles

- **Safety:** Ultra-low latency communication is crucial for autonomous vehicles, enabling real-time decision-making and reducing the risk of accidents.
- **Efficiency:** Improved communication between vehicles and infrastructure can lead to better traffic management and more efficient transportation systems.

4. Remote Healthcare

- **Access:** Telemedicine can be more widely accessible with 5G, providing high-quality video consultations and remote monitoring for patients in remote or underserved areas.
- **Innovation:** Advanced medical applications, such as remote surgeries using robotic systems, become feasible with reliable, low-latency connections.

5. Industrial Automation

- **Productivity:** Smart factories and automated systems can operate more efficiently with real-time monitoring and control, leading to higher productivity and lower operational costs.
- **Predictive Maintenance:** 5G enables continuous monitoring of equipment, allowing for predictive maintenance and reducing downtime.

Negative Impacts

1. Infrastructure Costs

- **High Deployment Costs:** Building the infrastructure for 5G, including new base stations and small cells, is expensive and resource-intensive.
- **Maintenance:** The complexity and density of 5G infrastructure require ongoing maintenance, which can be costly.

2. Security Concerns

- **Increased Attack Surface:** The vast number of connected devices and the complexity of 5G networks create more opportunities for cyber-attacks.
- **Privacy Issues:** Enhanced data collection capabilities can lead to privacy concerns if data is not properly managed and secured.

3. Health and Environmental Concerns

- **Health Risks:** There are ongoing debates about the potential health risks associated with increased exposure to radiofrequency radiation from 5G infrastructure, although current evidence is inconclusive.

- **Environmental Impact:** The deployment and operation of 5G networks require significant energy consumption, which could have environmental implications.

4. Digital Divide

- **Inequitable Access:** The rollout of 5G technology may be faster in urban areas, potentially exacerbating the digital divide by leaving rural and underserved communities with slower connectivity.
- **Cost Barrier:** The high cost of 5G-enabled devices and services may prevent some individuals and small businesses from accessing the benefits of the technology.

5. Compatibility and Transition Issues

- **Device Upgrades:** Consumers and businesses may need to upgrade their devices to be compatible with 5G, which can be costly and inconvenient.
- **Network Transition:** The transition from 4G to 5G may involve interoperability issues and require significant changes in network management and operations.

V. IMPACTS ON SOCIETY

5G network technology is poised to revolutionize various aspects of society, bringing about significant positive impacts while also introducing potential negative consequences. 5G network technology holds the potential to drive substantial positive changes in society, from boosting economic growth and enhancing healthcare and education to creating smart cities and improving consumer experiences. However, these benefits come with significant challenges, including the risk of exacerbating the digital divide, privacy and security concerns, potential health and environmental impacts, and economic disruption. Addressing these challenges will be crucial to ensuring that the positive impacts of 5G are widely and equitably distributed across society. Here's an overview of the effects 5G could have on society:

Positive Impacts

1. Economic Growth

- **Job Creation:** The deployment of 5G infrastructure and the development of related technologies and applications are expected to create numerous jobs in engineering, construction, and IT sectors.
- **Innovation and Startups:** 5G can spur innovation, leading to the emergence of new startups and business models, particularly in sectors like IoT, healthcare, and smart cities.

2. Improved Healthcare

- **Telemedicine:** High-speed, low-latency 5G networks enable high-quality video consultations and remote monitoring, improving healthcare access for people in remote or underserved areas.
- **Advanced Medical Procedures:** 5G facilitates the use of advanced technologies such as remote robotic surgeries and real-time data sharing between medical professionals, enhancing patient care and outcomes.

3. Enhanced Education

- **Remote Learning:** 5G supports high-quality video streaming and interactive applications, making remote learning more effective and accessible.
- **Educational Tools:** Augmented reality (AR) and virtual reality (VR) applications can provide immersive educational experiences, enhancing learning and engagement.

4. Smart Cities and Improved Infrastructure

- **Efficient Resource Management:** 5G enables the development of smart cities, where connected sensors and devices optimize traffic management, energy usage, waste management, and public safety.
- **Environmental Monitoring:** Real-time data from connected devices can help monitor environmental conditions and manage natural resources more effectively.

5. Enhanced Consumer Experience

- **Entertainment:** 5G enables high-quality, lag-free streaming of 4K and 8K videos, cloud gaming, and immersive VR experiences.
- **Smart Homes:** Enhanced connectivity supports a wide range of smart home devices, improving convenience and energy efficiency.

Negative Impacts

1. Digital Divide

- **Access Inequality:** The deployment of 5G infrastructure may be concentrated in urban and affluent areas, potentially exacerbating the digital divide by leaving rural and low-income communities with slower connectivity.
- **Cost Barrier:** The high cost of 5G-enabled devices and services may prevent some individuals and small businesses from accessing the benefits of the technology.

2. Privacy and Security Concerns

- **Increased Vulnerabilities:** The vast number of connected devices in a 5G network can create more entry points for cyber-attacks, posing significant security challenges.
- **Data Privacy:** Enhanced data collection capabilities raise concerns about user privacy and the potential for misuse of personal information.

3. Health and Environmental Concerns

- **Health Risks:** There is ongoing debate about the potential health effects of increased exposure to radiofrequency radiation from 5G infrastructure, although current scientific evidence is inconclusive.
- **Environmental Impact:** The deployment and operation of 5G networks require significant energy consumption, which could have environmental implications, particularly if the energy comes from non-renewable sources.

4. Economic Disruption

- **Industry Shifts:** Some industries may face disruption due to the introduction of 5G, leading to job losses in sectors that are slow to adapt to new technologies.
- **Infrastructure Costs:** The high costs associated with building and maintaining 5G infrastructure may strain public and private budgets, especially in less developed regions.

VI. IDENTIFICATION OF PROBLEM AND ISSUES IN 5G NETWORK TECHNOLOGY

***Problem Statement:** Enhancing Smart Cities with 5G Technology.

***Presentation of the problem**

Urban areas face numerous challenges, including traffic congestion, inefficient energy use, pollution, and inadequate public safety. Current network infrastructures often struggle to support the data-intensive and latency-sensitive applications needed to address these issues. 5G technology offers the potential to significantly enhance the functionality and efficiency of smart cities by enabling advanced applications in transportation, energy management, environmental monitoring, and public safety.

Solution approach: 5G-Enabled Smart City Applications

5G technology, with its high-speed, low-latency, and massive connectivity capabilities, can support a wide range of smart city applications. These applications can improve urban living by enhancing transportation systems, optimizing energy use, monitoring environmental conditions, and increasing public safety.

Key Concepts:

1. Intelligent Transportation Systems (ITS):

- Use 5G to enable real-time communication between vehicles (Vehicle-to-Vehicle, V2V) and between vehicles and infrastructure (Vehicle-to-

Infrastructure, V2I) for safer and more efficient transportation.

2. Smart Energy Management:

- Integrate 5G with smart grids to optimize energy consumption, enable real-time energy distribution, and facilitate the use of renewable energy sources.

3. Environmental Monitoring:

- Deploy 5G-connected sensors across the city to monitor air quality, noise levels, and other environmental parameters in real-time, providing valuable data for managing urban environments.

4. Enhanced Public Safety:

- Utilize 5G for real-time surveillance, emergency response coordination, and communication between public safety officials to improve the effectiveness of law enforcement and emergency services.

***Implementation Steps, discussion, and Conclusions**

1. Infrastructure Development:

- Build and upgrade 5G infrastructure, including small cells, base stations, and IoT devices, throughout urban areas to support smart city applications.

2. Data Integration and Management:

- Develop platforms for collecting, integrating, and analyzing data from various 5G-enabled devices and sensors. Ensure data interoperability and security.

3. Collaborative Planning:

- Engage city planners, technology providers, public agencies, and community stakeholders in the planning and deployment process to ensure that smart city solutions meet local needs.

4. Regulatory Framework:

- Establish regulatory frameworks that support the deployment of 5G technology and ensure compliance with data privacy and security standards.

5. Pilot Programs and Scaling:

- Launch pilot programs to test and refine 5G-enabled smart city applications. Use the insights gained to scale successful solutions across the city.

Benefits of 5G in Smart Cities:

- Improved Urban Mobility:

- ITS can reduce traffic congestion, lower accident rates, and enhance public transportation efficiency through real-time data and communication.

- Energy Efficiency:

- Smart energy management systems optimize energy consumption, reduce wastage, and promote the use of renewable energy, contributing to sustainable urban development.

- Environmental Protection:

- Continuous environmental monitoring allows for proactive measures to mitigate pollution and manage urban ecosystems effectively.

- Public Safety:

- Enhanced surveillance, real-time communication, and coordinated emergency responses improve the safety and security of urban residents.

- Quality of Life:

- By addressing critical urban challenges, 5G-enabled smart city applications can enhance the overall quality of life for residents, making cities more livable and resilient.

Conclusions:

5G technology has the potential to transform urban living by enabling advanced smart city applications that address key challenges in transportation, energy management, environmental monitoring, and public safety. Through strategic infrastructure development, data integration, collaborative planning, and regulatory support, cities can harness the benefits of 5G to become smarter, more efficient, and more sustainable.

***Problem Statement:**Enhancing Healthcare through 5G Technology

***Presentation of the problem:**

The healthcare industry faces significant challenges such as limited access to specialized care in remote areas, delayed diagnostics, and the need for real-time patient monitoring. The existing network infrastructure often cannot support the high data rates, low latency, and reliability required for advanced healthcare applications like telemedicine, remote surgery, and continuous patient monitoring.

Solution approach:

5G technology, leveraging 5G for Advanced Healthcare Applications with its high speed, low latency, and enhanced connectivity, can revolutionize healthcare by enabling a wide range of advanced applications. These include real-time telemedicine, remote robotic surgery, continuous health monitoring, and augmented reality (AR)-based diagnostics.

Key Concepts:

1. Telemedicine:

- 5G enables high-definition video consultations and real-time data sharing between patients and healthcare providers, improving access to healthcare services in remote and underserved areas.

2. Remote Surgery:

- The ultra-low latency of 5G allows surgeons to perform complex procedures remotely using robotic systems, making specialized care accessible globally.

3. Continuous Health Monitoring:

- Wearable devices and IoT sensors connected via 5G can continuously monitor patients' vital signs and transmit data in real-time to healthcare providers, enabling early detection of medical conditions and timely interventions.

4. Augmented Reality (AR) in Diagnostics and Training:

- 5G supports AR applications that provide healthcare professionals with enhanced diagnostic tools and training simulations, improving accuracy and outcomes.

***Implementation Steps, discussion, and Conclusions**

1. Infrastructure Development:

- Upgrade healthcare facilities with 5G infrastructure, including 5G-enabled devices and IoT sensors, to support advanced applications. Ensure robust and secure network connectivity within hospitals and clinics.

2. Regulatory Compliance:

- Ensure all 5G healthcare applications comply with regulatory standards and data privacy laws. Implement strong cybersecurity measures to protect sensitive patient data.

3. Integration with Existing Systems:

- Integrate 5G technology with existing healthcare IT systems, electronic health records (EHRs), and diagnostic equipment to ensure seamless operation and data exchange.

4. Training and Adoption:

- Provide training for healthcare professionals on the use of 5G-enabled tools and applications. Encourage the adoption of new technologies through demonstrations and pilot programs.

5. Collaboration and Partnerships:

- Foster collaboration between telecom providers, healthcare institutions, technology companies, and regulatory bodies to drive innovation and deployment of 5G healthcare solutions.

Benefits of 5G in Healthcare:

- Improved Access to Care:

- Telemedicine and remote consultations reduce the need for travel, making healthcare more

accessible, especially for patients in rural and remote areas.

- Enhanced Patient Outcomes:

- Real-time monitoring and early detection of health issues enable prompt medical interventions, improving patient outcomes and reducing hospital readmissions.

- Cost Efficiency:

- Reduced need for physical consultations and hospital visits can lower healthcare costs for patients and providers.

- Advanced Medical Training:

- AR and VR applications provide immersive training experiences for medical professionals, enhancing their skills and knowledge.

- Global Reach of Expertise:

- Remote surgery and teleconsultations allow patients to access specialized medical expertise regardless of geographic location.

***Conclusion**

5G technology holds the potential to transform healthcare by enabling advanced applications that improve patient care, accessibility, and outcomes. Through the deployment of 5G infrastructure, compliance with regulatory standards, and collaboration among stakeholders, the healthcare industry can harness the full potential of 5G.

VII. CONCLUSIONS

The evolution of 5G network technology marks a significant milestone in the telecommunications industry, bringing transformative changes across various sectors and profoundly impacting both applications and society at large. This research paper has explored the journey of 5G from its inception to its current state, delving into the technological advancements, diverse use cases, and the extensive societal implications it entails.

5G technology, with its unparalleled speed, ultra-low latency, and massive connectivity, is set to

revolutionize multiple domains, including healthcare, transportation, entertainment, and smart cities. The enhanced capabilities of 5G networks enable the deployment of advanced applications such as telemedicine, autonomous vehicles, immersive virtual reality experiences, and the Internet of Things (IoT) at a scale previously unimaginable.

The societal impacts of 5G are profound and multifaceted. On one hand, 5G promises to bridge the digital divide, offering high-speed internet access to underserved and remote areas, thus fostering digital inclusion. It also catalyzes economic growth by driving innovation, creating new business models, and enhancing productivity across industries. On the other hand, the deployment of 5G raises concerns about cybersecurity, data privacy, and the potential environmental impact of increased electronic waste and energy consumption.

As we stand on the cusp of widespread 5G adoption, it is imperative for stakeholders, including policymakers, industry leaders, and technologists, to collaboratively address these challenges. Ensuring robust security frameworks, developing sustainable practices, and fostering inclusive policies will be critical to maximizing the benefits of 5G while mitigating its potential drawbacks.

In conclusion, the evolution of 5G network technology is not merely a technological upgrade but a pivotal enabler of future innovations and societal advancements. Its successful implementation holds the promise of a more connected, efficient, and equitable world. Continued research and adaptive strategies will be essential to harnessing the full potential of 5G, ensuring that its transformative impact is both positive and far-reaching.

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