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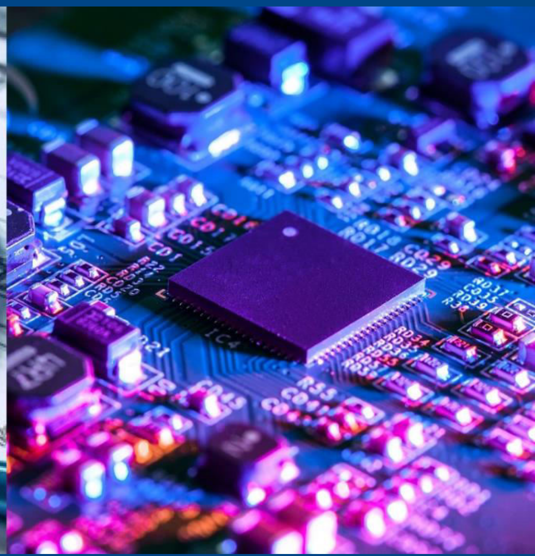

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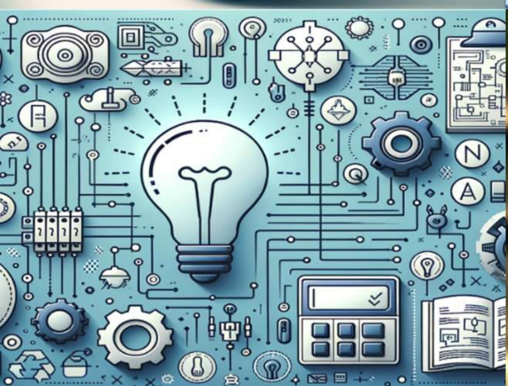

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Review on 5G Wireless Technology

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ABSTRACT: 5G wireless technology is an advancement over 4G, addressing many of the performance limitations that 4G faces, such as poor coverage, interconnectivity issues, low quality of service, and inflexibility. The comparison between 4G and 5G focuses on key aspects such as speed, frequency band, switching design, and forward error correction. 5G offers significant improvements, including higher speeds, greater flexibility, and the ability to support a larger number of devices, which is essential for the increasing demand for faster internet and the growing number of connected devices.

Although 5G has immense potential for future applications, including smart cities and the Internet of Things (IoT), it faces challenges such as low population coverage and performance limitations in real-world scenarios. Current 5G deployments are unlikely to achieve full global coverage before 2028, and smart city applications may rely on a mix of 4G and 5G, which could affect their performance.

This paper evaluates the real-world performance of 5G through a pilot smart city application involving waste collection service trucks. The study shows that while 5G supports mobile video streaming, its performance can vary significantly, making it less suitable for data-intensive or real-time applications. Despite these challenges, 5G remains a promising technology for the future, with its high speed, reliability, and ability to handle massive numbers of connected devices, paving the way for enhanced user experiences and new business models.

KEYWORDS: 5G Technology,Wireless Communication,MIMO Antenna,PIFA Antenna,FR4 Material,Smart Cities,Internet of Things (IoT),Network Performance,Wireless Evolution (1G to 5G),Core Architecture,Advantages and Disadvantages of 5G,Urban Connectivity,Future Communication Systems
These keywords capture the main concepts and technologies discussed in the abstract, focusing on 5G, its components, and its role in future communication and smart cities.

I. INTRODUCTION TO 5G WIRELESS TECHNOLOGY AND ITS IMPACT ON FUTURE NETWORKS

Wireless communication has evolved significantly from the early 1970s, progressing through multiple generations from 1G to 5G. 5G, or fifth-generation wireless technology, is set to revolutionize mobile networks by offering higher speeds, increased bandwidth, and better coverage than its predecessor, 4G. This new generation will deliver speeds over 1 Gbps and support millions of simultaneous device connections, enabling advanced applications like the Internet of Things (IoT) and smart city solutions.

5G is designed to handle high-bandwidth applications such as 4K video streaming and real-time sensor data sharing, which existing 4G networks cannot support. Key technologies like **MIMO (Multiple Input, Multiple Output)** and **OFDM (Orthogonal Frequency Division Multiplexing)** enable 5G networks to deliver higher data throughput, improved spectral efficiency, and enhanced connectivity. However, while 5G offers immense potential, challenges such as limited coverage and the high cost of network deployment remain, especially in early 5G implementations using **Non-Stand Alone (NSA)** technology.

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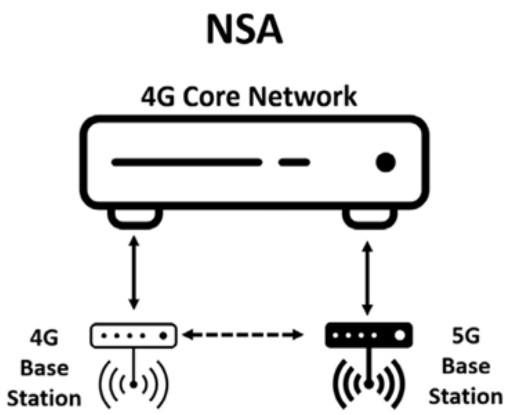

Figure0.1

The most exciting aspects of 5G is its role in smart cities. The high speed, low latency, and large capacity of 5G will support a range of applications, from traffic management to energy efficiency, by connecting a vast number of devices in real time. This will enable efficient sensing and data sharing, significantly improving urban life. However, achieving full global coverage and optimal performance for smart city applications will take time, as current 5G networks are still in the process of expanding.

In this paper, we analyze the real-world performance of 5G networks through a pilot smart city application that tracks road infrastructure maintenance. Our findings highlight both the strengths and limitations of 5G for smart city use cases and offer insights into the challenges and opportunities for future research in 5G network deployment.

This simplified introduction summarizes the key concepts of 5G wireless technology and its potential to transform mobile communication and smart cities.

1. **4G vs. 5G Networks:**
   - 4G LTE is expanding quickly, while 5G is still in research and pilot stages.
   - 4G focuses on bandwidth, but 5G aims to offer stable connections even in tough spots, supporting IoT devices.

2. **5G's Multi-Technology Approach:**
   - 5G integrates various technologies like 2G, 3G, LTE, Wi-Fi, and IoT, supporting applications such as wearables, augmented reality, and gaming.
   - It will provide high-speed connections for HD video and low-speed ones for sensor networks.

3. **Advanced Network Architectures:**
   - New designs like cloud RAN and virtual RAN will improve efficiency through centralized resources and local data centers.

4. **Cognitive Radio in 5G:**
   - 5G will use cognitive radio to adjust to varying conditions, offering flexible service for different applications.

5. **5G and IoT Applications:**
   - 5G will enable autonomous communication between IoT devices, leading to advancements in fields like self-driving cars, healthcare, and energy efficiency.

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6. **Antenna Optimization for 5G:**
   - 5G will require antennas to operate at higher frequencies for faster data rates. Planar Inverted-F Antennas (PIFA) are a potential solution for mobile devices. Research is focusing on optimizing antennas for IoT needs.

II. RELATED WORK

- This section reviews 5G network deployments and performance evaluations in smart cities. 5G uses two frequency ranges: below 6 GHz for higher throughput and 24-71 GHz (millimetre wave) for extreme data speeds and low latency.

Specifications	4G	5G
Full form	Fourth Generation	Fifth Generation
Data Bandwidth	2Mbps to 1Gbps	1Gbps and higher as per need
Frequency Band	2 to 8 GHz	3 to 300 GHz
Standards	Al access convergence including OFDMA,MC-CDMA,network-LMPS	CDMA and BDMA
Technologies	Unified IP, seamless integration of broadband LAN/WAN/PAN and WLAN	Unified IP, seamless integration of broadband LAN/WAN/PAN/WLAN and advanced technologies based on OFDM modulation used in 5G
Service	Dynamic information access, wearable devices, HD streaming, global roaming	Dynamic information access, werable devices, HD streaming, any demand of users
Multiple Access	CDMA	CDMA,BDMA
Core network	All IP network	Flatter IP network, 5G network interfacing(5G-NI)
Handoff	Horizontal and vertical	Horizontal and vertical

Figure0.2

Types of Deployments:

- **Non-Standalone (NSA):** Combines 5G with 4G, offering faster 5G services but with limited throughput and latency.
- **Standalone (SA):** Uses a full 5G core network, enabling lower latency and higher throughput but requiring more investment.
- **Hand-offs:** 5G networks experience hand-offs between base stations due to signal loss, with horizontal (same technology) and vertical (different technology) hand-offs.

5G Performance Evaluation:

- Existing studies mostly rely on simulations or focus on specific aspects like channel behavior and modulation. Real-world evaluations tend to be limited to small areas or controlled scenarios.
- Real-world studies, such as those in the U.S. and China, show variances in performance, but often lack a comprehensive view of 5G's performance in smart city applications.
- **Gap in Research:** Many studies focus on smartphones, whereas the broader potential for smart city applications remains underexplored.

Pilot Smart City Application:

- A pilot testbed was set up in Brimbank, Melbourne, using 5G-enabled waste collection trucks to assess 5G network performance. The trucks were equipped with IoT devices, including cameras, 5G routers, and GNSS.
- The trucks collected data, such as video and location info, which was streamed over the 5G network to cloud-based analytics. This system enabled real-time monitoring of roadside maintenance needs through AI.

III METHODOLOGY FOR 5G PERFORMANCE EVALUATION

- **Application-Specific Testing:** Focused on the performance of the Mobile IoT-RoadBot solution, which uploaded video data from the trucks. Tools like Tcpdump and Wireshark measured network performance metrics such as throughput and latency.
- **Application-Independent Testing:** Used tools like iPerf and Ping to measure general network performance independently of the Mobile IoT-RoadBot application.
- **Key Metrics:** Performance was evaluated based on throughput, latency, and coverage, which are standard metrics for assessing 5G performance.

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This work offers a comprehensive analysis of 5G's real-world performance in a smart city scenario, capturing data from actual deployments in urban settings.

IV. SUMMARY OF 5G NETWORK PERFORMANCE IN BRIMBANK AND EVOLUTION OF WIRELESS TECHNOLOGIES

5G Network Performance Evaluation in Brimbank: This study assessed the performance of the 5G network in the City of Brimbank, Australia, specifically for the Mobile IoT-RoadBot solution, which involves real-time data-intensive applications for smart city technologies. Over two weeks in July 2022, data was collected from 5G routers installed on SmartTrucks, measuring key metrics like network throughput, latency, and signal strength across 25 suburbs.

- **Network Throughput**: Throughput measurements, both for download and upload, showed significant variation across different regions. While some areas experienced download speeds exceeding 20 Mbps, others had much lower speeds. The overall mean download throughput was 19.63 Mbps, while upload throughput was 13.95 Mbps. These variations can be attributed to geographical factors and congestion.
- **Network Latency**: Latency varied by location, with some areas experiencing delays over 600 ms, while others had better latency around 100 ms. These inconsistencies can cause challenges for real-time applications. The lowest latency was observed for Cloudflare DNS servers, whereas higher latency was noted for AWS instances.
- **Geographical Variation**: The performance varied significantly across different suburbs, with better connectivity in certain areas. Some suburbs had very low signal strength, impacting the overall network performance. The signal strength map revealed regions with good coverage but no guaranteed high performance.
- **Impact of Vehicle Speed and Time of Day**: The performance of the 5G network was influenced by factors like vehicle speed and time of day. While vehicle speed had a minimal impact on throughput, network performance was better during times with less congestion, such as early morning hours.

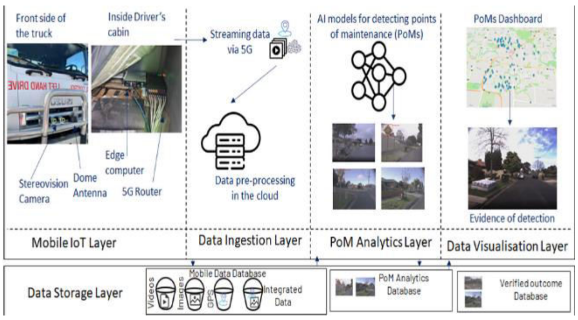

Figure0.3

Mobile Communication Evolution (1G to 5G): The evolution of mobile technology has been rapid, with each generation offering significant improvements in data transfer speeds, coverage, and capabilities.

1. **1G**: Introduced in the 1980s, it supported analog signals and basic voice calls with limited capacity and poor quality.
2. **2G**: Launched in the 1990s, 2G switched to digital signals, enabling SMS and email services. It supported voice communication through TDMA and CDMA.
3. **3G**: In the early 2000s, 3G improved internet speeds and supported video calls and global roaming, shifting from circuit-switched voice to packet-switched data.
4. **4G**: By offering speeds up to 100 Mbps, 4G enhanced multimedia services like mobile TV and video calling, providing an "anytime, anywhere" experience.

5G Technology Overview: 5G, the fifth generation of mobile technology, is designed to provide faster speeds (up to 1 Gbps), lower latency, and improved connectivity for a wide range of applications, including IoT, smart cities, and autonomous vehicles.

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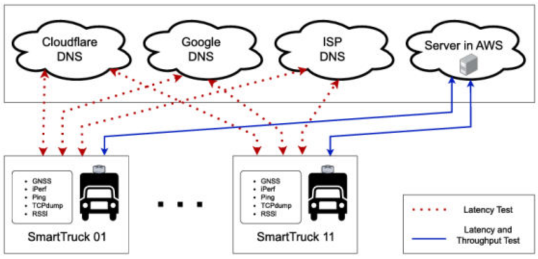

Figure 0.4

Key 5G components include:

- **User Equipment (UE)**: Devices connecting to the 5G network.
- **5G Core**: Manages user sessions, security, and network traffic.
- **MIMO (Multiple Input Multiple Output)**: Improves network efficiency and throughput.

5G supports **device-to-device (D2D)** and **machine-to-machine (M2M)** communications, enabling advanced IoT solutions.

Advantages of 5G:

- Ultra-fast data speeds.
- Better network efficiency with lower power consumption.
- Supports a larger number of connected devices.
- Enhanced network flexibility for diverse applications.

Disadvantages of 5G:

- Limited range due to high-frequency signals.
- High rollout infrastructure costs.
- Rural areas may experience slower adoption.
- Increased battery consumption in devices.

V. CONCLUSION

5G technology promises to revolutionize mobile communications, offering enhanced speed, connectivity, and support for next-gen applications. However, challenges like limited range and high infrastructure costs must be addressed for its full potential to be realized. As 5G becomes more widespread, it will significantly impact smart cities, autonomous vehicles, and IoT systems, paving the way for a more connected and efficient world. 5G promises significant improvements in connectivity and data rates. However, challenges like higher path loss and the need for advanced antennas must be addressed for full IoT integration.

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