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# 5G Mobile Technology and Spatial Analysis for 5G Rollout

Mohamed A. Ismail



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Mohamed A. Ismail
Hazem Hassan Co.
Riyadh, Saudi Arabia
mido.world@outlook.com

**Abstract —** the 5G technologies will revolutionize the way high- bandwidth users access their phones. With 5G technology available on VOIP-enabled devices, users can expect unprecedented levels of call volume and data transmission. The application of 5G technology spans across various services such as Product Engineering, Documentation, and e-Transactions. As consumers become more aware of mobile phone technology, they expect to have access to advanced features in their cellular phones. As a result, leading cell phone manufacturers are constantly searching for new technological advancements to stay ahead of their competitors. For example, Apple's recent launch of the iPhone involved numerous features embedded in such a small device are truly remarkable. In order for 5G to be successfully implemented, it is important to use geographic information systems to access the necessary bandwidth and prevent network obstructions. Due to 5G's higher frequencies, large data flows, and short range, even minor obstructions such as doors or rain can disrupt the network. Therefore, accurate and reliable geospatial data is crucial for implementing these networks.

**Key Words:** 5G, Mobile Technology, Spatial Analysis.

## 1. INTRODUCTION

5G presents a great opportunity for policymakers to empower both citizens and businesses. It can play a crucial role in transforming cities into smart cities, which means that people can participate and benefit from the advanced, data-intensive, digital economy. By providing gigabit speeds, 5G promises to deliver an improved end-user experience, and significantly improved performance and reliability, offering new applications and services. This will enable wireless operators to move beyond providing connectivity services to developing rich solutions and services for consumers and industry across a range of sectors.

5G is expected to increase data rates dramatically and reduce latency to below 1ms, which is ideal for mission-critical services where data are time-sensitive. With its high-speed capability, 5G networks can provide a range of high-speed broadband services, offering an alternative to last-mile access, such as FTTH or copper connections. The 5G standards envisage various types of wireless services, including high-speed links with peak rates of 2 to 20Gbps, low-speed links with high connection density (1 mn/Km2) for sensing and actuating devices (like IoT), and a new class of links that achieve both low latency (less than 1 ms round trip time) and high connection reliability (link outage of 0.99999).

The services offered by 5G have the potential to create a revolutionary class of applications. It will extend the use of wireless technologies, for the first time, across completely new sectors of the economy. 5G will enable both existing and new wireless service providers to develop novel business models to offer innovative applications to

individuals and different economic verticals, including industrial, commercial, educational, healthcare, agricultural, financial, and social sectors.

The upcoming 5G terminals will come equipped with software-defined radio modulation schemes and new error-control schemes that can be downloaded from the Internet while in use. The development focus is on the user terminals for 5G mobile networks. These terminals will have access to different wireless technologies simultaneously, and they will be able to combine different flows from various technologies. Each network will handle user mobility, while the terminal will make the final decision among different wireless or mobile access network providers for a given service. The mobile phone can choose the best connections by considering specific constraints and dynamically changing them during a single end-to-end connection.

## 2. History of Cellular Technologies

To fully comprehend 5G, its implications, and its advantages, it is essential to first have a fundamental understanding of its predecessors. Let's take a quick look at each of the preceding cellular technologies.

- 1G (Analog)

1G, also known as the first generation of wireless communication, was launched in the 1980s. People could make basic calls between their mobile phones with a data transfer speed of 2.4 Kbps.

- 2G (GPRS)

A decade after 1G's introduction, 2G was launched in 1991 as the first-ever digital cellular network. It provided users with internet connectivity, voice calls, and text messages (SMS) at a speed of 50 Kbps.

- 3G (UMTS)

The third generation of telecommunications technology was established in 1998 with a speed of 2 Mbps. 3G initiated the smartphone revolution as users could, for the first time, send pictures and make video calls.

- 4G (LTE)

4G, the present standard of wireless technology, was released in 2008, enabling data-intensive activities like HD live media streaming, gaming, video conferencing, and much more. It has a maximum speed of 100 Mbps.

- 5G Technology

5G is a revolutionary stamp in the history of wireless communications. It's not only an upgraded version of 4G but a discrete technology altogether. The minimum data transfer speed for this new network is 1 Gbps, with potential speeds of up to 50 Gbps. In some test environments, it has even reached speeds of 1 Tbps, which is approximately 65000 times faster than 4G networks. This incredible speed has many potential benefits across different industries, from predicting production lines to reducing the likelihood of road accidents. The launch of this new network has been eagerly anticipated and is set to take place in April 2019.

## 3. The impact of 5G on our lives and Work

What Is the Impact Of 5G Technology in Our Work and Lives?

The impact of 5G on our daily lives and businesses will be enormous. The speed of the internet will increase by an order of magnitude and latency will significantly decrease. These changes alone are game-changing developments. However, the impact of 5G goes beyond that. It will revolutionize our economy, culture, and society by enabling smart cities, connected cars, the Internet of Things (IoT), augmented reality (AR), and more. But what does this mean for entrepreneurs and consumers? It's a huge technological revolution and great features will improve lifestyle and work efficiency.

Fifth-generation wireless broadband, 5G, is the most advanced development in mobile technology. It promises to revolutionize the way we use mobile internet with lightning-fast speeds that can stream immersive videos and download entire movies or games in seconds. This would enable instant connection to high-end gaming sites.

Moreover, 5G technology has the potential to bring a new wave of technologies that could change our daily lives. For instance, autonomous vehicles will be able to communicate, upload, and download real-time information while on the road. Telemedicine will become more common as bandwidth expands. Augmented reality glasses powered by 5G technology could also become an extension of our smartphones, allowing us to bring our digital worlds into reality.

One of the most exciting features of 5G technology is the ability to connect multiple devices over short distances at very high speeds. This means that when a group of people in the same room or office space are connected via 5G networks, they can easily swap files or exchange information without delay. As businesses begin to adopt this technology, it will be interesting to see how employees respond to increased efficiency and productivity.

What Is the Difference Between 5G And 4G?

It's important to note that while 5G has been marketed as being up to 100 times faster than 4G, real-world testing has not yet proven this claim. However, users who have access to 5G can expect significantly faster speeds and more reliable connections compared to those who only have 4G connectivity.

5G is the fifth generation of wireless technology and is designed to provide speeds over 100 times faster than 4G. Theoretically, we should be able to download a 1GB movie in just 3.6 seconds on 5G, compared to six minutes on 4G.

The higher frequencies at which 5G operates allow it to handle more data at once, between 30 GHz and 300 GHz. This massive range of radio waves offers plenty of room for data and speed. In contrast, 4G has less space due to its lower frequency range, so 5G has more capacity and speed.

## 4. EVOLUTION FROM 1G TO 5G

Cell phones are used by millions and billions of users worldwide, but how many of us actually know the technology behind our phones that is used for communication? The generations of wireless telecom connectivity - 1G, 2G, 3G, and 4G ('G' stands for 'Generation') - have evolved over time to provide us with the advanced technology we have today.

1G, the initial wireless telecom network system, used Time Division Multiple Access

and Frequency Division Multiple Access, which is now outdated. The analog 'brick phones' and 'bag phones' were under 1G technology. However, this era marked the beginning of cell phones.

Next came 2G, which took the place of 1G. The leap from 1G to 2G effectively took cell phones from analog to digital, with GSM and CDMA connections. GSM is still the most popular technology, but it doesn't provide internet access. However, GPRS was developed for internet access, and EGPRS was created thereafter, which is more secure and faster than GPRS.

Then, 3G came, providing broadband-speed internet connection on mobile phones. It was specially made to meet the demands of internet usage on smartphones. Further development led to the creation of 3.5G, which provides even faster internet connection speeds, up to 7.2 MBPS. These technologies are ideal for connecting smartphones to PCs to share internet connections. However, as WCDMA technology is not available in all regions, it's not as popular as GSM yet.

Before the major leap from 2G to 3G wireless networks, 2.5G was an interim standard that bridged the gap. Following 2.5G, 3G ushered in faster data transmission speeds, allowing for more data-demanding usage such as streaming videos and audios. Today, cell phone companies are spending a lot of money branding the importance of their 3G network.

The above systems and radio interfaces are based on kindred spread spectrum radio transmission technology. While the GSM EDGE standard ('2.9G'), DECT cordless phones, and Mobile Wi-MAX standards formally fulfill the requirements and are approved as 3G standards by ITU, these are typically not branded as 3G and are based on completely different technologies.

4G, also known as 'beyond 3G' or 'fourth-generation' cell phone technology, refers to the entirely new evolution. Developers are now going for 4G (OFDMA), which will provide internet up to the speed of 1 GBPS! It is said to be able to overcome the problems of weak network strength and should provide a much wider network, making sure that the users get high-speed connectivity anytime, anywhere.

No doubt, 4G will open new doors of revolutionary internet technologies, but for now, 3G and 3.5G are the best. 4G will allow for speeds of up to 100Mbps and promises voice, data, and high-quality multimedia in real-time form all the time and anywhere.

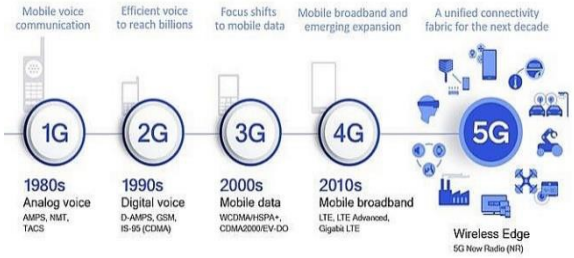


*Figure 2. The evolution of 5G*

*TABLE 1: Features available in 1G to 4 G*

| | |
|---|---|
| 1G | Voice Services |
| 2G | Improved voice and text messaging |
| 3G | Integrated voice and affordable mobile Internet |
| 4G | High-capacity mobile multimedia and LTE |

## 5. 5G TECHNOLOGY AND BENEFITS

5G technology has become the foundation for future communications due to its new network architecture. Below are some of the key features that you should know about:

- Low to Zero Latency: When you need to make quick decisions or operate machines and software in real-time, network

interference and delays can be fatal. 5G has nearly zero latency, reducing 4G's 50-millisecond latency to just one millisecond. This is beneficial for not only quick-loading websites, but also for connected autonomous vehicles, remote surgery, and responsive virtual reality.

- Increased Connection Density: If you've ever tried to connect to mobile data in a crowded public event, you know how important connection density is. 4G can only support up to 2000 devices within a 0.38-mile radius, while 5G can handle up to 1 million devices in the same space.

- Enhanced Precision: 5G is the latest radio technology that uses shorter wavelengths and higher radio frequencies within the 30 GHz to 300 GHz range. As a result, it has much-improved precision capabilities compared to 4G, which makes it highly useful for GPS-enabled devices.

- Improved Battery Life: Reduced latency and increased speed are likely to result in less battery consumption. Eventually, 5G will increase the battery life of smartphones and IoT devices by up to 10 times.

- New Use Cases: The exclusive features of 5G technology, including high bandwidth, near-zero latency, and augmented connection density, have opened up exciting new use cases that were not possible in the age of 4G. These include Cloud AR/VR, Industrial IoT, Connected Automotive, Remote Machinery Control, Smart Cities, and Wireless eHealth.

*TABLE 2. Features Need of 5G*

| |
|---|
| Connectivity (Wireless/Wired) |
| High Speed, Connection Density |
| Low Cost, Low latency, Enhanced Precision |
| Power saving systems, New Use Cases |

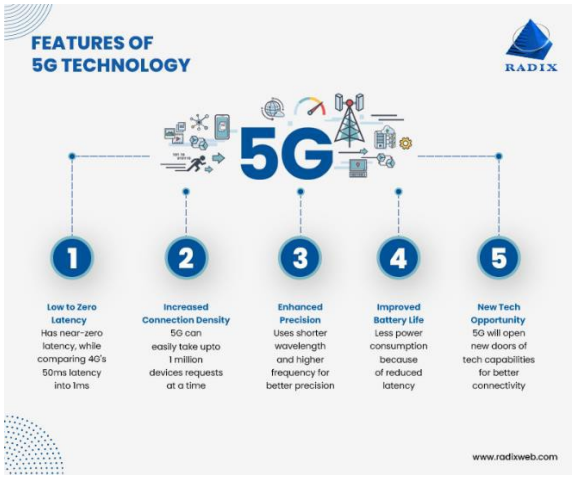


*Figure 3. Feature of 5G technology*


*Figure 4. The three categories of 5G development: EMBB, MMTC, and URLLC.*

## 6. How 5G Technology Works

5G technology operates on three distinct spectrum bands, which are as follows:

1. High Band Spectrum: This spectrum band is responsible for providing the highest performance of 5G with a speed that can reach up to 10 Gbps. However, it has some drawbacks, such as low coverage area and poor building penetration.

2. Mid band Spectrum: This spectrum band lies between the high and low band spectrum and offers a maximum speed of up to 1 Gbps. However, its wall penetration mechanism is not very good.

3. Low Band Spectrum: This is the primary band used by connectivity carriers, offering a high coverage area and impressive wall penetration. It is also known as the 1GHz range.

## 7. CONCEPTS FOR 5G MOBILE NETWORKS

In 5G mobile networks, the focus is on the development of user terminals with software- defined radios and modulation schemes. These terminals will be able to access different wireless technologies simultaneously and combine different flows from various technologies. Additionally, new error-control schemes can be downloaded from the internet. Instead of relying on vertical handovers, which are not feasible with many technologies and operators, each network will handle user mobility. The terminal will make the final choice among different wireless/mobile access network providers for a given service, based on open intelligent middleware in the mobile phone.

The upcoming 5G terminals will come equipped with software-defined radios, modulation schemes, and new error-control systems that can be easily downloaded from the internet. These terminals will also have simultaneous access to different wireless technologies and should be able to combine different data flows from these technologies. In the 5G era, each network will manage user mobility, while the terminal will make the final selection among various wireless and mobile access network providers for a given service. For a better understanding of the 5G mobile terminal design, we will now discuss each OSI layer in detail (as shown in Table 2).

*TABLE 2: Layers in 5G Architecture*

| | |
|---|---|
| Application Layer | Application (Services) |
| Presentation Layer | |
| Session Layer | Open Transport Protocol (OTP) |
| Transport Layer | |
| Network Layer | Upper Network Layer |
| | Lower Network Layer |
| Data Link Layer | Open Wireless Architecture (OWA) |
| Physical Layer | |

- Physical/MAC Layers

The Physical and Medium Access Control layers consist of two parts, namely OSI layer 1 and OSI layer 2, which are designed for the wireless medium. These two layers form the foundation for the 5G network in mobile communications.

- Network Layer

The network layer is built on IP (Internet Protocol) and there are typically two types of IP, namely Ipv4 and Ipv6. Although Ipv4 is more widely used, it has certain limitations such as limited address space and no support for quality of service (QoS). Ipv6, on the other hand, addresses these issues but is not without its own limitations, such as larger packet headers, which makes mobility a challenge. Different mobile networks will use Mobile IP in 5G, with each mobile terminal acting as a Foreign Agent (FA) to keep the Care of Address (CoA) mapping between its fixed Ipv6 address and CoA address for the current wireless network. Additionally, the mobile network will be attached to several other mobile networks or wireless networks at the same time, therefore, maintaining different IP addresses for each interface, with each of these IP addresses serving as a CoA for the foreign agent placed in the mobile

phone. As a result, 5G phone manufacturers will use a fixed IPv6 address in the mobile phone. To accommodate multi-wireless network environments, the network layer in 5G is divided into two sub-layers, namely the Lower network layer and the Upper network layer. The Lower layer network is specific to each interface, while the Upper layer network is specific to the mobile terminal. The middle layer between the Upper and Lower network layer is responsible for maintaining address translation from the Upper network address (Ipv6) to different Lower network IP addresses (Ipv4 or Ipv6).

• Open Transport Protocol (OTA) Layer

The OTA layer works differently for wireless networks as compared to wired networks. In all TCP versions, segments are lost, and it is assumed that segments are lost due to congestion in the network. In wireless networks, however, there will be losses due to high bit error ratios in the radio interface. To address this issue, TCP is used for mobile networks and wireless networks, which allows lost or damaged TCP segments to be retransmitted over the wireless link. 5G mobile terminals are designed to have transport layers that are easy to download and install. In such mobiles, it is possible to download a new version targeted at a specific wireless technology installed at the base stations.

• Application Layer

The 5G mobile terminal is designed to provide excellent quality of services over different and varied networks. Currently, mobile internet users manually select the wireless port for different internet services without the possibility of using QoS history to select the best wireless connection for a given service. A 5G phone will provide the possibility for QoS testing and storage of measured information in the mobile terminal. Different QoS parameters such as delay, jitter, losses, bandwidth, and reliability will be stored in a database in the 5G mobile running on the mobile terminal as system processes. This database will provide the best suitable wireless connection automatically based on the required QoS.

## 8. 5G MOBILE NETWORK ARCHITECTURE

The diagram below illustrates the system model for designing a network architecture that facilitates interoperability between wireless and mobile networks for 5G mobile systems. The proposed model is based on an all-IP architecture. The system comprises a user terminal, which plays a crucial role in the new architecture, and several independent, autonomous radio access technologies. Each radio access technology in the terminal serves as an IP link to the outside Internet world. However, each Radio Access Technology (RAT) requires a different radio interface in the mobile terminal. For example, if we need access to four different RATs, we must have four different accesses specific to each interface in the mobile terminal. All of these interfaces must be active simultaneously for this architecture to be functional.

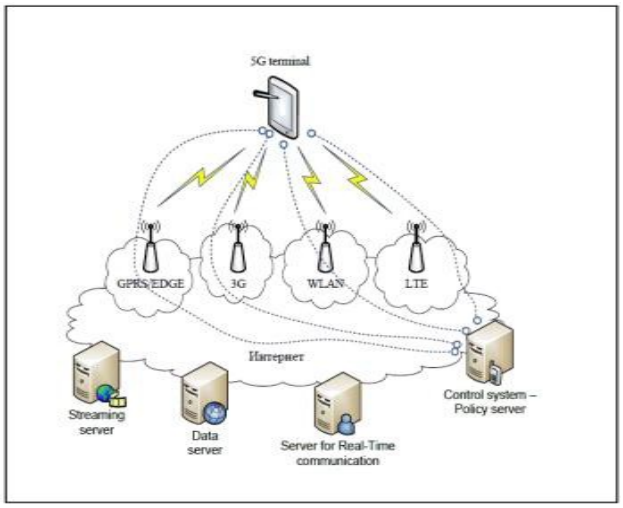


*Figure 5. 5G MOBILE NETWORK ARCHITECTURE*

## 9. FEATURES OF 5G TECHNOLOGY

- 5G technology offer high resolution for cell phone user and bi-directional large bandwidth shaping.
- The advanced billing interfaces of 5G technology make it more attractive and effective.
- 5G technology also provides subscriber supervision tools for fast action.
- The high-quality services of 5G technology based on Policy to avoid error.
- 5G technology is providing large broadcasting of data in Gigabit which supports almost 65,000 connections.
- 5G technology offers a transporter-class gateway with unparalleled consistency.
- The traffic statistics by 5G technology make it more accurate.
- Through remote management offered by 5G technology a user can get better and fast solution.
- The remote diagnostics is also a great feature of 5G technology.
- The 5G technology is providing up to 25 Mbps connectivity speed.
- The 5G technology also support virtual private network.
- The new 5G technology will take all delivery services out of business prospect
- The uploading and downloading speed of 5G technology touching the peak. The 5G technology network offers enhanced and available connectivity to just about the world.

## 10. Geographic Information Systems (GIS) WITH 5G TECHNOLOGY

Spatial analysis refers to the process of analyzing spatial data through the use of mapping software and geographic information systems (GIS). By combining 5G technology with spatial analysis, it would be possible to analyze and visualize data in real-time, enabling faster decision-making and more accurate predictions. For example, 5G mobile technology could be used to collect and analyze real-time traffic data, which could then be used to optimize traffic flow and reduce congestion.

Overall, the combination of 5G mobile technology and spatial analysis has the potential to revolutionize the way we analyze and visualize data, leading to more efficient and effective decision-making processes.

- Merging Geographic Information Systems (GIS) with 5G technology can lead to sustainability in various sectors, such as smart cities, agriculture, healthcare, and environmental conservation. For example, it can revolutionize agriculture and remote healthcare. The partnership between GIS and 5G technology offers a promising path forward in pursuing a more sustainable and inclusive world. It's crucial that telecom companies, governments, and stakeholders acknowledge and harness the potential of this synergy to drive change, not just in emerging markets but worldwide.

Using GIS has many benefits, such as choosing the best location to support the planning of ultra-dense 5G Base Stations (BSs) in indoor and outdoor areas. GIS can also help address the cost challenges facing 5G. By utilizing spatial modeling and visualization approaches, GIS can simulate the signal propagation and service coverage of 5G BSs in urban areas.

- The Importance of Spatial Data for 5G Technology

Spatial datasets, such as topographic (DEM), demographics data, and weather data, are vital for telecom companies to create and implement their networks. By utilizing spatial analytics, companies can make informed

decisions and work with a precise cloud-native mapping solution. This enables them to easily visualize data, make informed decisions, and interact with the information in an efficient manner.

- Three Location Intelligence Uses for 5G Technology Rollout

Let's explore three different approaches for utilizing Location Intelligence in 5G network planning, deployment, and optimization.

1) 5G Network Planning and Deployment

The primary objective of network planning and deployment is to address the requirements of the operator and the customer effectively and efficiently. Using Geographic Information Systems (GIS) in network planning and deployment allows telecom companies to achieve these objectives and also:

- Solve challenges related to service qualification.
- Determine the site selection of network components.
- Discover opportunities for new Identify the best ways to connect network components.
- Markets Enhance service delivery

T-Mobile utilized spatial indexing to simplify its complex data sets and address crucial challenges such as service qualification on a large scale. T-Mobile partnered with CARTO to create a dashboard that enabled them to convert radio frequency propagations into hexbins. This helped their geospatial team visualize and analyze each cell site's coverage in relation to the households to be served.

2) 5G Network Management Optimization and Expansion.

Telecom companies require spatial data science to manage and optimize their network resources and operations effectively.

By using map spatial data, these companies can easily assess the status of their infrastructure and analyze the proximity of network towers and cables to customers. This data can also help them evaluate network suitability for expansion.

Integrating spatial data into their dashboard can assist in troubleshooting network incidents and identifying the location of the strongest signal for the proper installation of customer equipment.

3) Smart Cities & IoT Planning

Smart cities can benefit from the utilization of 5G technology and road traffic data to communicate real-time road conditions to sensors and devices that power transportation and traffic systems. In case of commuter traffic congestion, these devices can quickly and automatically redirect traffic, and also inform the autonomous vehicle systems about the issues on the road. This helps to improve the overall efficiency and safety of the transportation and traffic systems in the smart cities.

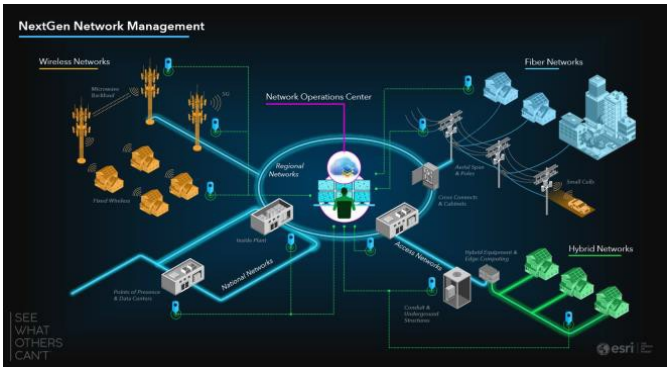


*Figure 6. Network Management in ArcGIS*

Future work, we plan to extend the current work with the 5G and cybersecurity work introduced in [8-87].

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