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A Comparative Study on 4G and 5G Technology for Wireless Applications

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Abstract: *The 5G wireless technology is based upon modified 4G, which at present is facing many problems to meet its performance goals. The comparison between 4G and 5G wireless technology in relation to its speed, frequency band, switching design basis and forward error correction is studied. The 5G wireless technology helps to solve the problems of poor coverage, bad interconnectivity, poor quality of service and flexibility. An ideal 5G wireless technology to accommodate the challenges and shortfalls of 4G deployments is discussed as well as the significant system improvements on the earlier wireless technologies. The importance of the comparative study is estimated for a speed and effective connection and communication of devices like wireless devices and other hardware.*

Keywords: *5G, MIMO Antenna, Wireless communication, PIFA (Planar Inverted F Antenna), FR4 (Fire Retard 4)*

I. Introduction

Mobile network technology is moving at a relentless pace, and it's being built around not one, but two industry juggernauts: Fourth-generation wireless and fifth-generation wireless. The assimilation of the Internet of Things (IoT) world into both 4G and 5G technologies makes this wireless labyrinth even harder to get around.

5G is the coming fifth-generation wireless broadband technology based on the IEEE 802.11ac standard. 5G will provide better speeds and coverage than the current 4G. 5G operates with a 5 GHz signal and is set to offer speeds of up to 1 Gb/s for tens of connections or tens of Mb/s for tens of thousands of connections.

4G is synonymous with Long Term Evolution (LTE) technology, which is an evolution of the existing 3G wireless standard. In fact, LTE is an advanced form of 3G that marks an audacious shift from hybrid data and voice networks to a data-only IP network.

There are two key technologies that enable LTE to achieve higher data throughput than predecessor 3G networks: MIMO and OFDM. Orthogonal frequency division multiplex (OFDM) is a transmission technique that uses a large number of closely-spaced carriers that are modulated with low data rates. It is a spectral efficiency scheme that enables high data rates and permits multiple users to share a common channel.

Multiple-input multiple-output (MIMO) technique further improves data throughput and spectral efficiency by using multiple antennas at the transmitter and receiver. It uses complex digital signal processing to set up multiple data streams on the same channel..

The LTE standard uses both forms of duplex operations: Frequency division duplex (FDD) and time division duplex (TDD).

Finally, a quick note about the LTE categories. There are different categories of LTE networks, and from a consumer perspective, they mainly differ in terms of theoretical speed under ideal conditions.

LTE-Advanced: The bridge between 4G and 5G

LTE Advanced or LTE-A is the evolution of the original LTE technology toward even higher bandwidths. LTE-A promises nearly three times greater speed than the basic LTE network and comprises of the following five building blocks:

1. Carrier Aggregation
2. Increased MIMO
3. Coordinated Multipoint (CoMP)
4. Relay Station
5. Heterogeneous Network or HetNet
6. s Network or HetNet

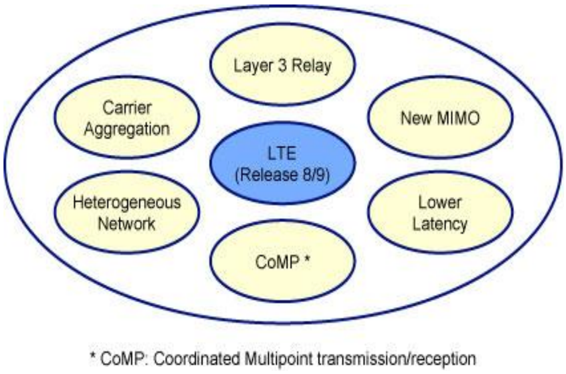

Figure-1. LTE building blocks

Carrier aggregation or channel aggregation is a transmission scheme that allows up to 20 channels from different spectrums to be combined into a single data stream.

Next, LTE-A raises the MIMO bar to 8×8 antenna configurations to increase the number of radio streams using the beamsteering technique.

Third, CoMP or cooperative MIMO, allows mobile devices to send and receive radio signals from multiple cells to reduce interference from other cells and ensure optimum performance at the cell edges.

Fourth, a relay in an LTE-A setting is a base station that uses multi-hop communications at the cell edges; it receives a weak signal and retransmits it with an enhanced quality.

Fifth and the most crucial one is HetNet, a multilayered system of overlapping big and small cells to pump out cheap bandwidth.

HetNet, a gradual evolution of the cellular architecture, is a vastly more complex network as small cells add hundreds or even thousands of entry points into the cellular system. The self-organizing network (SON) concept is one of the key enabling technologies being considered for LTE-A applications.

Here, it's worth noting that while LTE-A standard creates a bridge between 4G and 5G worlds, in many ways, the notion of HetNet is serving as glue between LTE-A and 5G worlds. That's why many wireless industry observers call 5G wireless an enhanced form of LTE-A.

That makes sense because the main concept behind 5G systems is to expand the idea of small cell network to a whole new level and create a super dense network that will put tiny cells in every room.

The Next Generation Mobile Networks (NGMN) Alliance defines 5G as below:

"5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation toward customers and partners, through existing and emerging use cases delivered with consistent experience and enabled by sustainable business models."

Essentially, LTE-A is the foundation of the 5G radio access network (RAN) below 6 GHz while the frequencies from 6 GHz to 100 GHz will explore new technologies in parallel. Take MIMO, for instance, where 5G raises the bar to Massive MIMO technology, a large array of radiating elements that extends the antenna matrix to a new level—16×16 to 256×256 MIMO—and takes a leap of faith in wireless network speed and coverage.

The early blueprint of 5G pilot networks mostly comprises of beam forming technology and small cell base stations. The goals of 5G technology can be summarized in the following value points:

- 1,000x increase in capacity
- Support for 100+ billion connections
- Up to 10Gbit/s speeds
- Below 1ms latency

II. 4g And 5g Difference

a) First and foremost, while the LTE-based 4G networks are going through a rapid deployment, 5G networks mostly comprise of research papers and pilot projects.

b) Wireless networks till 4G mostly focused on the availability of raw bandwidth, while 5G is aiming on providing pervasive connectivity to lay grounds for fast and resilient access to the Internet users, whether they are on a top of a skyscraper or down under a subway station. Although LTE standard is incorporating a variant called machine type communications (MTC) for the IoT traffic, 5G technologies are being designed from grounds up to support MTC-like devices.

c) The 5G networks are not going to be a monolithic network entity and will be built around a combination of technologies: 2G, 3G, LTE, LTE-A, Wi-Fi, M2M, etc. In other words, 5G will be designed to support a variety of applications such as the IoT, connected wearables, augmented reality and immersive gaming. Unlike its 4G counterpart, 5G network will offer the ability to handle a plethora of connected devices and a myriad of traffic types. For example, 5G will provide ultra-high-speed links for HD video streaming as well as low-data-rate speeds for sensor networks.

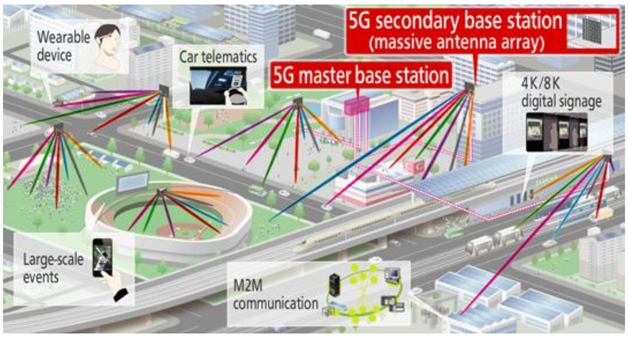

Figure-2. 5G Application architecture.

d) The 5G networks will pioneer new architectures like cloud RAN and virtual RAN to facilitate a more centralized network establishment and make the best use of server farms through localized data centers at the network edges.
e) Finally, 5G will spearhead the use of cognitive radio techniques to allow the infrastructure to automatically decide about the type of channel to be offered, differentiate between mobile and fixed objects, and adapt to conditions at a given time. In other words, 5G networks will be able to serve the industrial Internet and social network apps at the same time.

Table 1. Comparison of 4G and 5G Technologies

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

These 5th generation of systems are driven by OFDM, MC-CDMA, LAS-CDMA, UWB, Network LMDS and IPV6. Table above compares 4G versus 5G technologies and mentions differences between them.

III. The Next Generation Of Mobile Technology:

The Internet Of Things And 5g

A relatively new phenomenon, the *Internet of Things* (IoT), also called the "Industrial Internet" or even the "Internet of Everything", takes these simple automated tasks to the next level by enabling objects to communicate data with connected devices.
Eventually, IoT as we know it will progress from simple home and building automation to more advanced application areas. In the ideal Internet of Things, mobile devices will be able to collect and interpret data such as location and known preferences, and communicate with "smart objects" — without requiring our input at all.
The wide range of possible future applications for the Internet of Things include:

- **Media**
  While driving past a billboard on the highway or watching a commercial on television, data collected by our devices shows that the type of product being advertised and we are automatically messaged with more information.
- **Transportation**

Not only can car parallel park, but it can navigate and drive on its own. Similar improvements to trains and aircraft are just a few of the ways that IoT can help us get around as technology progresses.

- **Healthcare**
  Medical devices automatically administer medications and monitor patients' conditions as well as their overall well-being. Pacemakers, hearing aids, and heart monitors streamline medical care by communicating with doctors and patients.
- **Environment and energy conservation**
  Sensors optimize energy consumption by powering lights and electronics based on a person's activity. On a larger scale, an improved IoT helps monitor water and air quality, among other environmental concerns.
- **Infrastructure**
  IoT sensors monitor the structural stability of bridges, railways, and waste management systems for safety and security.

With the wide use of smart phones in the society, the Internet of Things has an easy way to collect and use our personal data to communicate with objects and smart devices. But to get a jump-start on making IoT possible, we need to create the next generation of mobile technology to optimize smart phones.

IV. When 5g Replaces 4g Lte…

5G is the chosen moniker for the next generation of wireless communication. 5G is currently just a concept, but it is expected to be implemented by 2020 — giving the mobile industry a lot of work to do in a short amount of time.

Most wireless communication professionals agree that when 5G replaces 4G LTE, it should address three key needs:

1. A decreased latency of less than one second.
2. Increased data rates of at least one gigabit per second for tens of thousands of users simultaneously.
3. Increased energy efficiency.

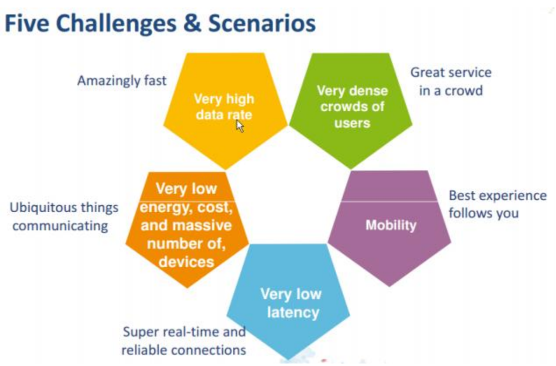

Figure-3. Challenges and Scenarios

Whatever improvements are made to wireless communication by the release of 5G, the main goal is for mobile technology, data collection, and wireless communication to be more seamlessly integrated through speed and efficiency. Without these features, the Internet of Things won't work correctly and will be redundant.

Optimizing Antenna Design For 5g And The Internet Of Things

The Internet of Things, and the next generation of wireless communication, 5G, it's coming soon. First, we need to optimize the performance of existing mobile device antennas.

Among the many developments researchers from across the globe are already working on for 5G, the optimization of mobile device antennas is an important topic to study. Though 5G applications have not been standardized yet and many researchers are developing a range of devices to expand the world of IoT, we can start by looking at a basic introductory model showing how to design a small antenna in a mobile device.

V. Optimizing The Design Of A Mobile Device Antenna

A mobile device antenna must be small and lightweight enough to fit in the limited amount of space allotted for it in a smart phone's design. Planar inverted-F antennas (PIFA) are a good choice for mobile communication because they are small, powerful, and efficient. These antennas can cover multiple frequency bands for cellular devices, WiFi, and Bluetooth® technology — which makes them a great choice for IoT compatible objects and devices.

The mobile device antenna simulated in this paper includes a 4G device made up of a PIFA on a PTFE block with an FR4 circuit board, ABS housing, and glass with a composite silicon substrate. The antenna itself is made up of the PTFE block with a thin copper layer for high conductivity, a lumped port between a perfect electric conductor (PEC) ground plane and feeding strip, as well as another strip shorted to the ground plane and adjacent to the feeding strip for impedance matching purposes. It also includes an impedance matching gap that matches the antenna to the reference impedance of 50 Ω.

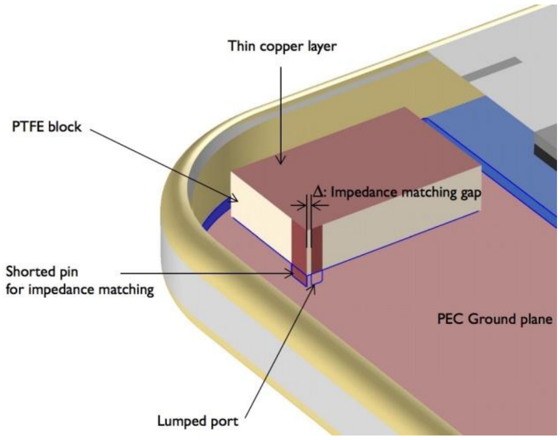

Figure-4. Model geometry of a planar inverted-F antenna in a mobile device.

For the simulation, this antenna can be modeled using PEC boundaries because of the low downlink frequency range. The losses on the metal are inconsequential due to the high conductivity of the copper layer. The PIFA is modeled in a spherical domain that is enclosed by perfectly matched layers (PML) to absorb its outgoing radiation. The lumped port, with a reference impedance of 50 Ω, is used to excite the PIFA and evaluate its input impedance.

Through simulation, we have calculated the field distribution plot for the PIFA. Results show that the field is strong at one end of the metallic surface at the top of the model, far from the feeding strip. These measurements actually resemble those of a quarter wave monopole antenna, a design from which the PIFA is derived.

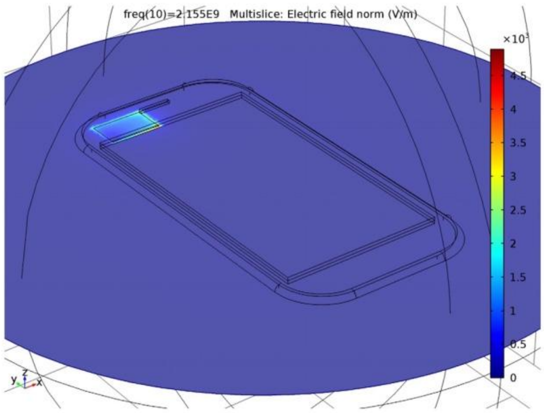

Figure-5. Results plot of the electric field distribution at the top of the PIFA.

The simulation also calculates the polar-formatted far-field radiation pattern. The azimuthal radiation pattern is no longer omni directional since the antenna is now miniaturized and located on only one corner of the ground plane.

From the S-parameters, we can see that the voltage standing wave ratio (VSWR) is less than 2:1. This means that the antenna input impedance is well matched to the reference impedance, which is a typical measurement in network analyzers.

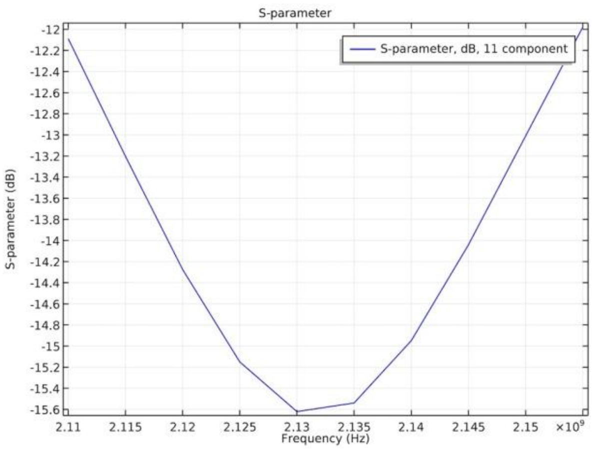

Figure-6. The S-parameters of the given AWS downlink frequency range are calculated.

Going beyond the results of 2D far-field calculations, we are also able to review the simulation in a 3D radiation pattern to show maximum radiation and null.

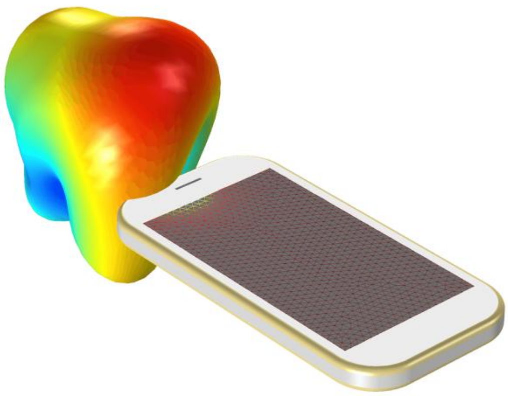

Figure-7 The far-field radiation pattern of the PIFA plotted in 3D.

VI. Conclusion

To address 5G applications, there are many developments to be considered above the introductory model. In order to handle higher data rates, the operating frequency has to be increased to a millimeter range from which we can achieve a wider bandwidth. This will result in higher path loss between transmitters and receivers, so antennas need to provide higher gain to reach a longer distance.

However, this will significantly reduce the covering range in terms of angle because the radiation pattern will be very sharp. Consequently, phased array antennas are required to get over the limit of angular dependency of high-gain antennas using the ability to steer a radiation beam toward wanted directions.

By optimizing the design and performance of mobile device antennas, including those just mentioned, the ideal Internet of Things will be here before we know it, and we will be ready to embrace the new technology.

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