ISSN No:-2456-2165

Reducing Latency in 5G networks

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Abstract:- One of the most significant challenges in fulfilling the essential requirements for a 5G system is achieving lower latency, which is the most dominant aspect in 5G. Unlike previous generations, where there was sufficient bandwidth for daily uses, today's applications, such as VANET and online gaming, demand low latency. Control and location update information depend more on latency than on throughput. In this research, our focus will be on understanding and addressing this crucial aspect. To begin, we will explore the evolution to 5G NR (New Radio) based on the needs of humans and how technology has strived to accomplish its mission. A key aspect will be understanding the Key Performance Indicators (KPIs) for evaluating a cellular system's performance. In-depth analysis will then be conducted on the technical aspects related to latency. Specifically, we will divide latency into different parts of the network and concentrate on Radio Access Network (RAN) latency. This will involve studying the impact of waveform and frame flexibility structures, channels, and duplex modes on latency, along with the role of numerologies. By investigating these technical aspects, we aim to contribute to the advancement of 5G systems, ensuring they meet the stringent latency requirements of modern applications. Ultimately, this research will pave the way for better 5G implementations, benefiting various industries and improving user experiences in critical areas like VANET and online gaming.

Keywords:- *5G, Latency, Frame Structure, 5G NR, KPI,LTE,VANET, Simulation.*

I. INTRODUCTION

Latency is becoming one of the most significant aspect in telecommunications nowadays ,as The evolution of communication systems ,some applications need a very critical latency in other Hand, we have learnt in our college education career that a telecom system should fulfil the Three aspects which are: the availability, integrity and the confidentiality. Thus, the absolute Importance of the power of telecom always brings up the quote "the power of a country is Measured by two factors: the army, and the telecom infrastructure"

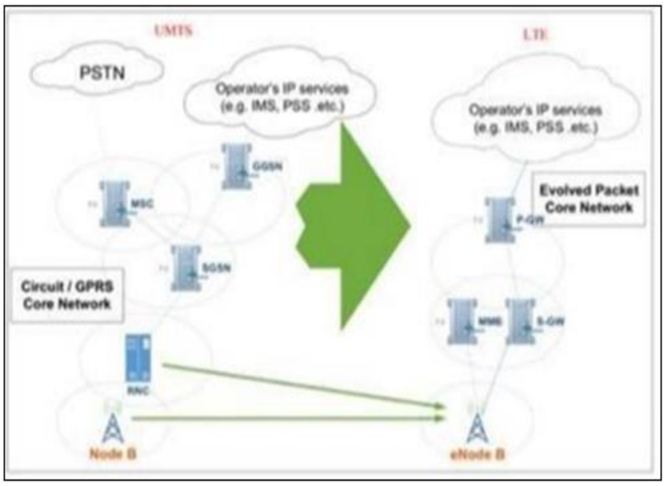

Fig 1 GSM Access Network Vs LTE Access Network

Since telecom infrastructure has many fields, from a daily basis use to the industrial Applications, due to the telecom, our lives are made even more comfortable. We can access our Web services from any place in the world, we can communicate with our families, friends, co-Workers without any boundaries, thus, in an industrial section, we can monitor and acquire data From the machine in the fields and do the different operations on this data. Mobile or cellular network is the most telecom application that plays a significant role in our Lives, basically, glad to the mobility that it provides us, However, this did not end here, starting From analog phone or the 1G which was not so popular, the 2G provided us with the mobility And many voice services which were the critical requirement of the cellular network back then, Such as texting, call onhold, MMS … ,the human lives isn't only based on talking all the Time ,especially after the big evolution of the internet, the realizes of the 2G didn't fulfil the Requirements and that can be to the old access technology which was TDMA ,the throughput Provided wasn't sufficient for a user to watch videos or to browse with ease ,the 3G came up With a solution for giving the accessibility to the web ,which was the next goal for the cellular Communication system ,glad to the CDMA technology and separation of packet switching From the voice ,3G system had a long journey since everyone could access internet with Reasonable throughput ,many people were fine with the service provided by this generation, but The world of technology isn't only for telecom ,the revolution in other technologies made 3G Embarrassed ,such as HD videos, Online gaming , "the big war is telecom and informatics Already settled ,we no longer depend on the circuit switching in the voice communication ,the Packet switching is doing the job. That made The 4G the first full IP-based system, a sufficient throughput and latency for the evolution of Digitalization, by introduction the OFDM approach which played the hero role in 4G systems, But the war of technology did not end here, the world is growing fast and one year of human Lives equals four years of technology, a new concept of other technologies was introduced and Forced the 4G system to seem old, but rather than throughput problem which was the big Concern in the previous generations, now the latency has climbed the stairs and forced itself to Be the most critical aspect, which was the primary focus of the 5G, achieving a 1ms latency in Our communication system rather than 25ms in 4G, with a reliable link, it is the hardest Challenge that the telecom infrastructure has ever seen, the VANET, D2D, tactile internet, Telemedicine, internet of things .. And all the promised fictional applications are becoming real In the 5G cellular communication system.

II. LATENCY IN 5G

➢ *To Achieve Low Latency in the Network Design, Several Improvements and Technologies can be Implemented:*

- Mobile Edge Computing (MEC) and Caching: By deploying MEC nodes closer to the edge of the network, computing resources and cached content can be brought closer to end-users. This reduces the round-trip time for data requests, leading to lower latency.
- Network Function Virtualization (NFV): Implementing NFV allows network functions to run on virtualized infrastructure, leading to faster deployment and flexibility in managing network resources, ultimately reducing latency.
- New Physical Air-Interface: Research and development in areas such as small packet transmission, different waveforms, short time intervals for delivery, and advanced coding and modulation schemes can significantly reduce the time taken for data transmission and reception.
- Optimization of Radio Resources: Technologies like Massive Multiple-Input Multiple-Output (mMIMO) can efficiently allocate radio resources, prioritize data transmission, and enhance spectral efficiency, thus reducing latency.
- Carrier Aggregation in Millimeter Waves: Utilizing carrier aggregation techniques in the millimeter wave frequency bands can increase data rates and capacity, leading to lower latency for users.
- Integration and Convergence with LTE: Ensuring stable and effective integration of 5G networks with existing LTE services allows for smoother
- and quicker transitions, enabling faster and more efficient 5G technologies for customer use.
- Revolutionary Network Architecture: A welldesigned and innovative network architecture will be essential for accommodating the unique requirements of 5G services and facilitating lowlatency communication.
- Evolution from LTE: 5G broadband communication networks should build upon the existing LTE infrastructure, making the transition seamless while leveraging new radio technologies and revolutionary architecture for improved performance.

By combining these improvements and technologies, network designers can effectively minimize latency and provide a seamless and efficient experience for users in the 5G era.

➢ *QoS Parameters*

In designing next-generation networks, the quality of different service parameters holds significant importance. These networks cater to data-hungry applications, and ensuring QoS guarantees for high-density services is a primary objective.

III. FRAME STRUCTURE ENABLES LATENCY IN 5G

To achieve low latency, various aspects of the Radio Area Network need to be optimized and modified. This chapter primarily focuses on the physical layer technologies and air interface technologies. Here is an overview:

Mobile broadband demands high performance and low latency, which can be achieved through a combination of little cells operating at lofty carrier frequencies (mmwave) and larger cells at lower carrier frequencies.

However, in the case of uplink transmissions in large cell deployments, the power available to User Equipment (UEs) at the cell edge or maximum distance from the base station (BS) may be limited. In such scenarios, optimizing the power efficiency of the waveform becomes crucial to maintain reliable communication. For small cells, the distance between the UEs and the BS is significantly reduced, which opens up opportunities to enhance overall network performance and minimize latency. By addressing these aspects and optimizing the Radio Area Network, it becomes possible to achieve the desired low latency for mobile broadband services.

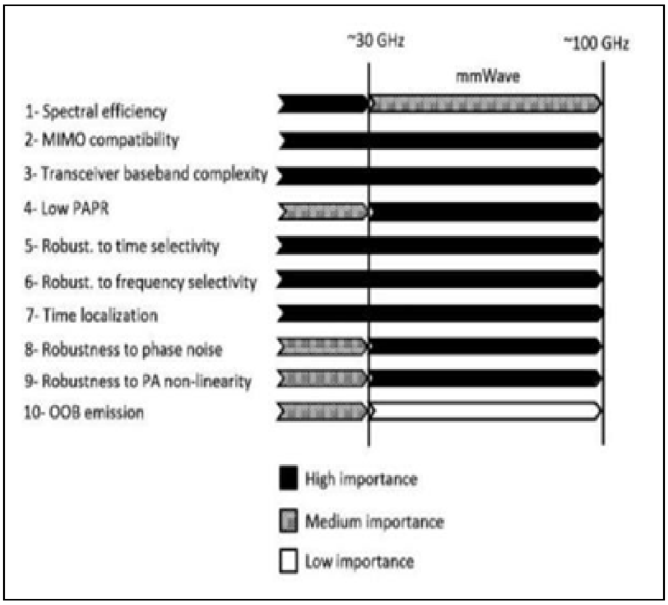

Fig 2 Importance of Waveform Performance Indicators Especially for Low Latency

ISSN No:-2456-2165

➢ *Key Performance Indicators (KPIs)*

Are crucial for 5G NR wave form design. 5G NR exhibits extreme data rates, large channel bandwidths, URLLC requirements, small-sized base stations with a massive number of antennas, and TDD deployments. The identified KPIs for waveform design by 3GPP are as follows:

- *Spectral Efficiency:*

Supporting requirements on traffic densities, data rates, and user connections is of utmost importance. Lower carrier frequencies have a greater impact on spectral efficiency than higher frequencies.

- *MIMO Compatibility:*

As carrier frequency increases, both base stations (BS) and user equipment (UEs) require more antenna elements. Using different MIMO schemes improves spectral efficiency and enables beamforming for better coverage.

- *Low PAPR (Peak-to-Average-Power-Ratio):*

Power-efficient transmissions are vital, especially for the uplink side (UEs). Icing low PAPR(Peak- to-Average Power rate) is critical, especially at veritably high frequentness. This is particularly important for small- sized, cost-effective base stations operating at high frequentness, and it can also upgrade downlink transmissions.

- *Robustness to Channel Time Selectivity*

High speed scripts are current in large cells, but at veritably high frequentness, surge obstacles might limit content. Small cell deployments are anticipated at high frequentness, where mobility isn't a major concern.

- *Transceiver Baseband Complexity*

Baseband complexity is particularly critical from the receiver's perspective. For NR, it's a major consideration for BSs since small- sized access bumps with limited processing capability are common at high frequentness

➢ *Power Efficiency*

The major debit participated by all multicarrier waveforms is their high Peak- to-Average Power rate(PAPR) and low power effectiveness. In Figure3.2, we compare the PAPR of colorful waveforms, similar as CP- OFDM, W-OFDM, UFOFDM, FBMC- OQAM, and DFTS- OFDM(assuming 16 QAM and 1200 subcarriers). We observe that utmost multicarrier waveforms parade analogous PAPR, with the exception of UF- OFDM, which has a advanced PAPR. Still, the DFT- grounded precoding in OFDM(DFTSOFDM) effectively reduces the PAPR and achieves advanced power effectiveness compared to standard OFDM.

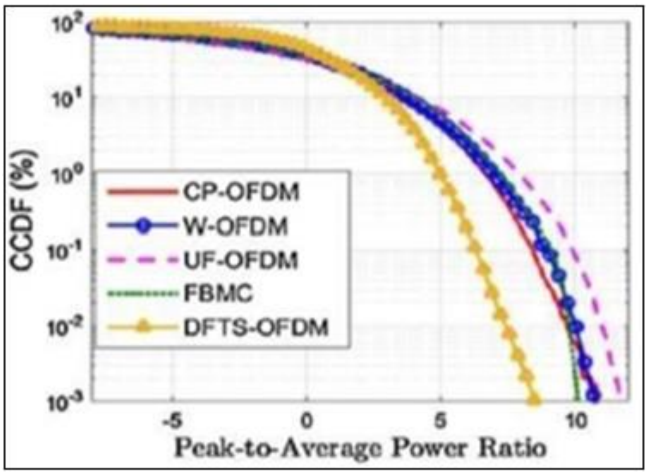

Fig 3 A Comparison of PAPR of Multicarrier Wave forms and Single Carrier DFTS- OFDM Wave form

IV. SIMULATION OF FRAME STRUCTURE OF 5G

5G frame structure ability to enable URLLC is due to the several modification in the physical Layer ,one of the most significant modification is the frame structure flexibility as we have Shown in chapter 03 and evaluated the waveform using the required KPIs for the work ,in the Simulation we will use the MATLAB as its strong ability for studying signal processing as well As its library for 5G and also its accuracy in term of results ,in the first step we will simulate The burst time of most significant waveforms and see how it affects the latency ,in the second Part we will focus on simulating the numerologies of 5G and how to manage high bandwidth Decoding for small devices using the bandwidth-part technique

➢ *Result and Comments*

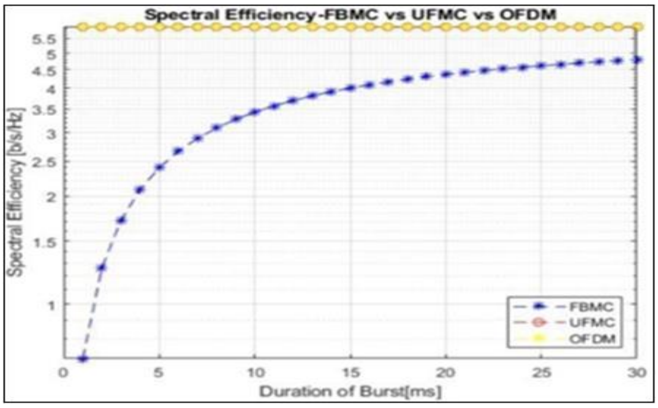

Fig 4 Spectral Efficiency and Burst Duration for 5G Highlighted Candidates

ISSN No:-2456-2165

UFMC offers several advantages compared to OFDM. It exhibits higher spectral efficiency due to its ability to filter sub-bands, which reduces the need for guard-bands.

The graph above illustrates how the spectral efficiency depends on the burst duration of the highlighted waveform candidates. Both OFDM and FBMC have the same CPnumber and filter length, causing them to overlap during the burst. However, FBMC increases its spectral efficiency with longer burst durations, which makes it unsuitable for low latency applications that rely on shorter burst durations. In contrast, UFMC's filtering capabilities and higher spectral efficiency make it a more attractive option for such scenarios.

V. CONCLUSION

5G requirements are still a promise in 2020, reaching all the requirements necessity is still a Long road, for 1ms total latency and 10Gbps, as well as the deployment of the 5G around the Globe.

Fulfilling the world needs in the telecom in general or in the cellular network in particular is Based on valuing the work and the collaboration of each individual person, a small modification Or optimization whether in latency optimization or in throughput or any entity could really Makes the different in reaching the theoretical requirement of 5G system, we believe that the Key to innovation journey starts with understanding the technology, in our work we focused on Giving the most details of how latency works and the significant aspects of it, from the RAN to The transport as explained in the chapter three, the latency is a divided to many section each Part has the necessity to be optimized as well as making it much more reliable, many Technologies are now possible due to the other works in the different industries, such as LDPC Coding which was an old system but glad to the hardware technology ,now its possible to use

Its features in the 5G ,same goes for the beamforming which was already discovered in the Analog and have been used in many old technologies, also, SDN and NFV are now possible Due to the vast capacity and processing speed, which made the software tasks as fast as Hardware, with this concepts, we no longer have to make Application specific integrated-Circuits (ASIC) and throw / recycle them after few years, the software made it easier for us to Build any type of network architecture and monitor/control our system with much more Precision with a lower cost.

The frame structure has a significant impact on the latency in 5G was brought by the flows Made in the 4G as well as the new capability of utilizing the resources we have, such as Mmwave massive bandwidth, the idea of variable numerologies made its fingerprint on the Latency aspect, since there is a reciprocal relation between high frequencies and thus made the Symbol duration smaller. However, due to higher frequencies we face a lot of other problems Especially the possibility for an IoT or low power device to decode the whole bandwidth, here Where it comes the idea of the Bandwidth part, the UE receives only a part of the bandwidth Then decode it with ease, another aspect is the mini-slot, where we send 2,4 or 7 symbols for a User rather than 14 OFDM symbol, this would help the applications which depends on latency More than the throughput.

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