Investigation on 5G Networks in terms of Latency

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Abstract:- The growth in traffic and the rise in different requirements provide numerous challenges for the flexibility, scalability, and portability of conventional mobile network architecture. Mobile networks are using service-based design to adapt to the changing needs of the 5G era. In a service-based 5G core network, managing and deploying network services remains a significant difficulty. It is a technological generational leap where everything is brand-new, including the radio, core network, and spectrum frequencies. The architecture of 5G is extremely sophisticated, and its network components and numerous terminals are typically changed to accommodate new circumstance. According to many research organizations, 5G cannot fulfill its requirements without integrating Artificial Intelligence.

Keywords*: 5G, slicing, security, artificial intelligence, Software defined network.*

1. Introduction

In recent years, mobile networks have seen significant developments in both traffic and communication methods [1]. Mobile networks experience an increase in data traffic as a result of the rapid growth of video traffic. New security requirements and challenges are brought about by the sophisticated features of 5G mobile wireless network systems [2]. Beyond the present 4G / International Mobile Telecommunications (IMT) - Advanced Systems, the next generation of mobile wireless telecommunications is known as 5G [3]. "Generation" is what the "G" in 5G stands for. The architecture of 5G technology represents substantial advancements over 4 G Long Term Evolution (LTE) technologies which follows 3G and 2G. For a new generation of mobile apps, 5G technology seeks to provide high bandwidth, low latency, and huge connectivity [4].

The Radio Access Network (RAN), Software Defined Network (SDN), 5G Core, Network Function Virtualization (NFV), Multi-access Edge Computing (MEC), and Cloud are just a few of the technologies it incorporates to accomplish its goal. In order to integrate the legacy networks, such as 4G, the 5G cellular network is being gradually introduced in several countries, mostly in Non-Standalone (NSA) mode. Due to its improved capabilities, such as Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications, and Ultra Reliable Low Latency Communications (URLLC), 5G has brought about previously unheard-of possibilities for use cases in a variety of industries (mMTC) [5]. It has been determined that slicing is a crucial necessity for the 5G network [6] [7]. Slicing is the process of building numerous parallel networks out of a single network infrastructure to serve various 5G application classes, industry verticals, and Mobile Virtual Network Operators (MVNOs). The 5G network is more complicated as a result of the slicing needs [8].

Though 5G fails to bring in a totally new architecture, it has achieved significant advancements over previous generations. On the one hand, service-based architecture (SBA) acceptance and full support for Internet protocols enable 5G to fulfil all of its promises and serve as an infrastructure for both current and future applications. Private industrial networks can be supported, which is a novel feature for 5G networks [9]. The network slicing feature securely divides 5G network resources and simultaneously offers network services to users from various industries and enterprises. The most important difference between 4G and 5G is latency. Although 4G latency vary from 60 to 98 milliseconds, 5G assures low latency of less than 5 milliseconds. Orthogonal frequency-division multiplexing (OFDM), a technique for modulating a digital transmission across numerous channels to reduce interference, is the foundation of 5G. In order to overcome the performance constraints of current deployments and satisfy new application needs, the next 5G mobile networks adopt a variety of novel techniques. 5G, the fifth generation of wireless networks, is more than just a step up from 4G. It's a game-changer with the potential to revolutionize how we live, work, and connect. One of the most significant improvements that 5G brings to the table is its dramatically reduced latency. This feature is crucial for enabling new technologies and enhancing user experiences.

2. Literature Survey

In order to govern the enormous data transmission in the 5G network, the authors in [10] introduce the Multiple Access Protocol Data Unit (MAPDU) session concept and suggest a dynamic anchoring mobility management between various access networks. In [11], function isolation and guaranteeing end to end delay for a slice are the two issues; the authors attempt to answer the query of how to assign a slice in 5G core networks optimally. In order to develop a model that satisfies end-to-end delay constraints plus isolation among mechanisms of a slice for reliability, the authors adopt and expand the work by Dietrich et al. In [12], the authors suggest a brand-new, intelligent 5G core network operating design. Also, the authors talk about the opportunities and confront of understanding an intelligent 5G network. With an emphasis on pertinent Management and Orchestration (MANO) architecture across several domains, [13], offers a study of NS architecture. It also provides a thorough examination and classification of NS algorithmic characteristics. In [14], the authors present a complete discussion on how deep learning will be able to allow numerous applications in wireless systems. Although there is raising interest in deep learning in the field of mobile networking, there are currently few contributions and they are dispersed over several different study fields.

The authors in [15] talk about how machine learning could be used for 5G network applications like huge MIMO and smart grids. This article also identifies various untapped research gaps between ML and 5G. The authors underline the importance of AI in the 5G era and address prospects and difficulties of applying AI into future network architectures [16]. And in [17] the authors presented the benefits and drawbacks of various algorithms, outline many effective ML techniques in Self-Organizing Networks (SONs), and identify potential future study areas. Stand Alone (SA) and Non-Stand Alone (NSA) are the two types of 5G network modes (SA) [18]. By utilizing the 4G network, 5G network introductions can be accomplished swiftly in 5G NSA mode. The brand-new Service-based Architecture is adopted by the 5G SA mode, which also creates the 5G core network independently. The authors in [19] presented the self-healing network concept through Quadratic Probing for fast searching. In [20], the authors presented a Particle Swarm Optimization (PSO) and Probabilistic Neural Network for avoiding interference

3. Architecture of 5G

The numerous access approaches in the network are almost at a standstill and require an immediate improvement when the current 5G network is taken into account. At least for the next 50 years, current technology like OFDMA will be functional. Additionally, there is no need to update the wireless configuration that was created when switching from 1G to 4G. A radical shift in the approach to building the 5G wireless cellular architecture is required to satisfy user requests and address the issues raised by the 5G system. If users inside the building want to interact with the outside base station, the signals must pass through the building's walls, which results in very high penetration loss and decreases the wireless communications' spectrum efficiency, data throughput, and energy efficiency. To address this issue, a fresh concept or design approach has been developed for the 5G cellular architecture, which is to distinguish between outside and interior settings. The penetration loss through the building's walls will be marginally lessened using this method of designing. Massive MIMO technology, which deploys a geographically scattered array of antennas with tens or hundreds of antenna units, will enable this approach.

The heterogeneous 5G cellular architecture necessitates the use of macrocells, microcells, tiny cells, and relays. The 5G wireless cellular network includes a mobile small cell idea, which is made up in part of mobile relay and small cell concepts. It is being adopted to accommodate those with high levels of mobility who are riding in cars and high-speed trains. The radio network and the network cloud are the only two logical layers that make up the 5G wireless cellular network architecture. The 5G cellular network architecture also incorporates the ideas of Device to Device (D2D) communication, small cell access points, and the Internet of Things (IoT). In summary, the design of the 5G cellular network may offer a solid foundation for the 5G standardized networks in the future. Software Defined Network (SDN) is used in 5G architecture. The main goal of using SDN is to divide the control plane outside the switches and offer external data control by means of a logical software component known as the SDN controller. SDN is merely an abstraction for describing the protocols used to manage the forwarding plane and its components. One of the key elements used in the 5G networking design is SDN, which helps to lessen the limits frequently imposed by the usage of hardware.

Beginning with product development to transportation, from agriculture to entertainment, 5G is driving a significant digital transition [19]. The revolutionary potential of 5G is supported by five areas: They are i) Enhanced mobile broadband (eMBB) - High capacity and speeds of up to 10 gigabytes per second provided by 5G enable the transmission of large amounts of data and ultra-high definition video. Applications like extended and virtual reality are made possible by high speed mobile broadband, ii) Massive Internet of Things (mIoT) - 5G can offer up to 1 million connections that are active at once. The implementation of sophisticated large IoT applications depends on this dense connectivity, iii) Mission-Critical services (MCS) - Reliability and performance are essential for mission-critical applications. When a millisecond separates life from death, 5G can transport network traffic with delays as low as that, iv) Private wireless - provides a purpose-built, on-premises network solution that secures mission-critical company processes. Without the limitations of old-school and impromptu wireless networks, a private 5G network facilitates activities both inside and outside, and v) network slicing - Wide area networks can benefit from a network slice as a solution. It enables a connectivity provider to develop a connectivity solution that is appropriate for the customer's needs and gives them access to a "slice" of the public network that is suited to their needs.

4. Network Sclicing in 5G

Latency, in the context of wireless networks, refers to the time it takes for data to travel from one point to another. It's the delay between when you send a request and when you get a response. This can be measured in milliseconds (ms). In simpler terms, lower latency means quicker responses. It is the amount of time between transmissions of a data packet. There are two ways of latency; i) one way latency, and ii) roundtrip latency. The former is the amount of time that passes between sending a packet and when the recipient receives it and the latter is the amount of time that passes between sending a packet and receiving an acknowledgement. Our connections have always had some degree of latency. With a 4G connection, you can watch a live event like a soccer match, but the video you see is actually a little bit behind what is actually happening on the field. Delivery and response times are both impacted by this; the faster the data is transmitted to you, the faster you can respond. One of the key promises of 5G is ultra-low latency. While 4G networks typically offer latency in the range of 50 to 100 milliseconds, 5G aims to reduce this to as low as 1 millisecond. This drastic reduction opens up a plethora of possibilities.

Organizations that are technologically prepared for 5G have been hampered by latency in terms of technologies and application cases. In cloud gaming, in which it continues to be one of the major obstacles to a more fascinating experience, latency also represents a major source of frustration. When playing a first-person shooter game, missing your shot or botching a turn might happen if you take too long to respond. The 5G network is intended to drastically reduce latency. End-to-end latency is predicted to drop 10X with this generation of wireless. This can greatly enhance current consumer experience and create opportunities for new ones. In the context of 5G networks, latency has been drastically reduced compared to previous generations, unlocking a myriad of possibilities and transforming various aspects of modern life. Understanding how low latency benefits 5G networks can provide insights into the future of technology and its applications. Low latency in 5G networks ensures that data transmission is almost instantaneous. This enhancement significantly improves the user experience in everyday applications such as video conferencing, online gaming, and virtual reality. For instance, video calls become smoother and more lifelike, with minimal lag and interruptions, making conversations feel more natural. In gaming, low latency ensures that players can react in real time, creating a seamless and competitive environment. The below figure 1 shows that 5G has lower latency.

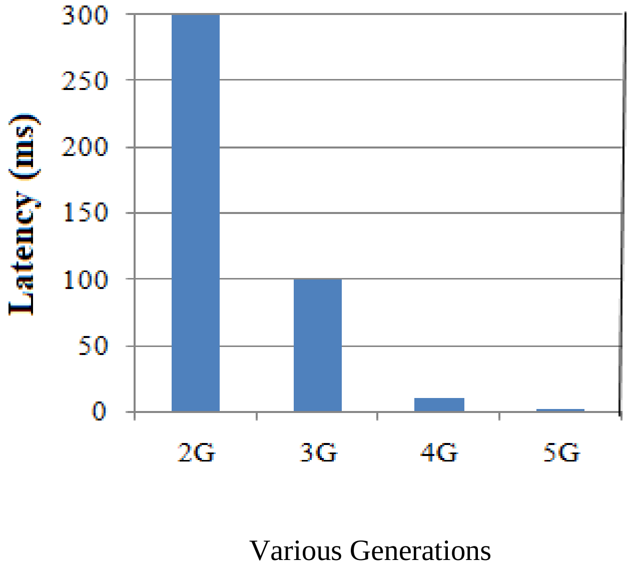

Figure 1 Latency vs Various Generations

A special feature of 5G networks is network slicing [20]. Network slicing is a transformative technology in 5G networks that allows multiple virtual networks to be created on a single physical network infrastructure. Each "slice" can be tailored to meet specific needs, offering different levels of performance, latency, and bandwidth depending on the requirements of various applications or services. Network slicing leverages advanced virtualization technologies such as Software-Defined Networking (SDN) and Network Functions Virtualization (NFV). These technologies enable the dynamic allocation and management of network resources. Each slice operates as an independent end-to-end network, encompassing the core network, transport network, and access network, ensuring that it can function with customized features and isolated performance metrics.

NFV technology is the virtualization element utilized in the network slicing design. This NFV-based architecture design places a strong emphasis on virtualizing every type of network node function. Then, in accordance with the requirements of the use case, these virtualized node functions are linked to build communication services. One or more virtual machines executing various programmes and operations make up a virtualized network function, which is built on top of servers, switches, storage, and cloud infrastructure. Network virtualization is used in 5G network slicing to split up a single network connection into numerous unique virtual connections that offer various amounts of resources to various sorts of traffic. The 5G architectural landscape as a whole has evolved to rely heavily on this configuration. For certain use cases or business models, network slicing combines 5G network functionality with a particular set of configurations. Slicing can occur across a variety of network domains, including software operating on cloud nodes, essential network components, and front haul and backhaul transmission resources.

Each network slice can be customized to meet specific requirements. For instance, one slice can be optimized for ultra-reliable low-latency communications (URLLC), ideal for autonomous driving, while another can focus on massive machine-type communications (mMTC) for IoT devices, and yet another on enhanced mobile broadband (eMBB) for high-speed internet. The ability to support numerous users is a fundamental requirement for the 5G system, and slicing technology is the primary method for accomplishing multiple users, making network slicing a special component of the 5G system architecture. It's one of the traits. Effective network slicing is hampered by 5G transmission slicing, which represents a significant bottleneck. The technical difficulty increases if both the front haul and the backhaul networks collaborate to create a single, adaptable bearer channel for connecting upper-layer mobile network components. Therefore, overcoming the 5G transmission surface with effective slicing technology is a crucial first step in implementing 5G network slicing. The following figure 2 shows a sample for Network Slicing.

Network slicing, a key feature of 5G, involves creating multiple virtual networks on a single physical infrastructure. Each slice can be customized with specific security protocols tailored to its use case. Importantly, slices are isolated from one another, meaning that a security breach in one slice does not affect others. This isolation enhances the overall security posture of the network.

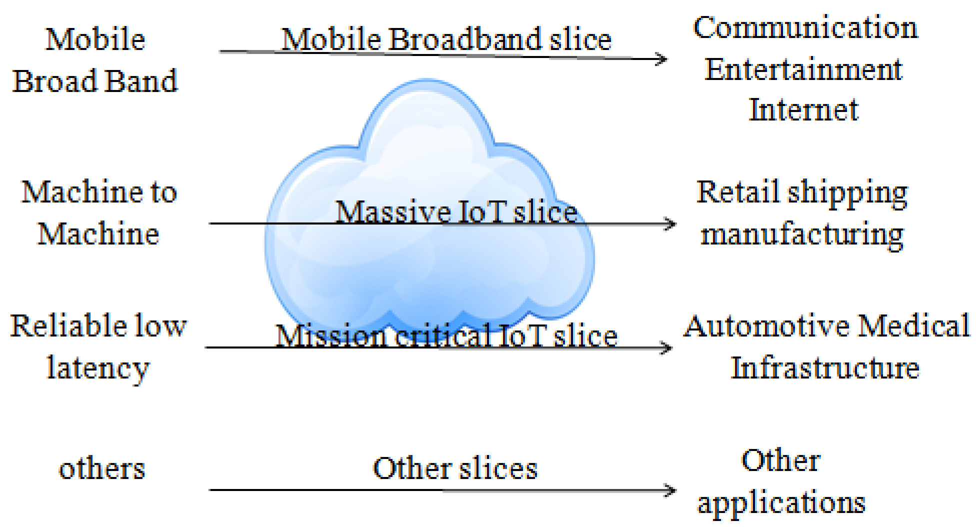

Figure 2. Network Slicing

Through widespread use of cloud-based resources, virtualization, network slicing, and other cutting-edge technologies, the adoption of 5G will produce enormous performance improvements and a variety of applications. These modifications expose more "attack surfaces" in the 5G security architecture and introduce new security threats. Although 5G builds on previous mobile technology generations' security procedures, the trust model has expanded significantly as a result of the involvement of additional parties in the service delivery process. An exponentially better amount of endpoints are created by the IoT and user proliferation, by lots of traffic inputs are not being watched over by humans. Operators will need to continuously monitor and evaluate security performance as 5G deployment progresses and crucial performance nodes become more virtualized. The exponential speed improvements that customers have come to expect from new mobile network generations will undoubtedly be delivered by 5G, but speed is only the beginning. 5G networks leverage artificial intelligence (AI) and machine learning (ML) to enhance threat detection and response. These technologies analyze vast amounts of network data to identify unusual patterns and behaviors that may indicate a security threat. By continuously learning and adapting, AI and ML can detect and mitigate threats more effectively than traditional methods.

5. Discussion

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