

5g Network Architecture and it's technologies

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Abstract

This articles provides a deep understanding of 5g network architecture and the logical and physical aspects of *gNB* with the functions of its individual elements, This article will also present the key 5g technologies and how is it going to affect modern lifestyle.

Introduction

5g is the 5th generation of broadband cellular network which was first introduced in July 2016 right after the success of 4g, each generation takes nearly a decade to develop which results in a huge performance gap for example - 1G offers 2.4 kbps, 2G offers 64 Kbps and is based on GSM, 3G offers 144 kbps-2 mbps, 4g offers 100 mbps - 1 gbps whereas 5g can go up to 30 gbps and not only speed 5g also provides low latency upto 1ms while 4g latency ranges from 60 to 100ms.

How 5g is better than 4g?

5g introduces three new aspects to the table:

- Bigger channels to speed up data
- Lower Latency
- ability to connect more devices at once.

Based on these three aspects 5g can also be categorised into 3 main types:-

- **Enhanced Mobile Broadband (eMBB):** The main use case of eMBB class is a target to deliver peak download speeds of over 10 Gbps, which is ten times faster if we compare to 4g's peak data transfer rates.
- **Massive Machine Type Communication (mMTC):** In this category 5g networks is a use case for the minimum requirement for 5g to support 1 million low powered, low cost devices per square kilometer with a battery life span up to ten years.
- **Ultra-reliable low Latency Communications (uRLLC):** The aim of this class to offer communication with high reliability and extremely low latency which is considered to be even less than 1ms.

Applications

What are the top applications that can use 5g and why it wasn't possible with 4g? To answer that question below is the list of top 3 promising applications of 5g which will revolutionaries the modern tech-world:

- **Enhanced agricultural productivity** Smart farming is already underway, with enhanced networking power data gathering will be easier and reliable which will lead to better decision-making at lower costs, cut resource consumption which will result in higher yields.
- **Remote Education** Due to Covid-19 Pandemic, digital education was only way to humanity which spotlighted the vulnerabilities of the modern connectivity. 5g should enable better access to remote educational experiences, more importantly educational institutes can develop and deliver new and different types of content which will not only be more easy and can also be interactive to students thanks to high data transfer speed and low latency.
- **Smarter Logistics:** The Logistics department is heavily dependent on the Internet, including transportation, expanding its use of IoT to monitor the packages, autonomous vehicles in warehouses will make package handling a lot easier and convenient.

5G Network architecture

The hardest challenge during the design and planning consideration of 5g was that there is no one-size-all-fits approach, since the the range of applications requires data to travel distances, large data volumes which means 5g architecture must support low, mid and high-band spectrum because high-band spectrum can carry more data and is faster but it's range is limited.

That's why 5g is architect-ed to run on radio frequencies from sub 1GHz to extremely high frequencies which is called 'millimeter wave' (mmW).

Core 5g Network

The new 5g system introduces a cloud-aligned service base architecture to support authentication, security, session management and aggregation of traffic from connected devices, which reacquires complex linkage of functions, The components of 5g core architecture includes the following:

- UPF (User plane function)
- DN (Data networkK)
- Core Access and Mobility function (AMF)
- Authentication Server function (AUSF)
- Session Management Function (SFM)
- Network Slicing (NSF) also known as Network Slice selection Function (NSSF)
- Network Exposure Function (NEF).
- NF Repository Function (NRF)
- Policy Control function (PCF)
- Unified Data Management (UDM)
- Application Function (AF)

All these function work together efficiently to provide a better experience.

gNB - Next Gnereation NodeB

With the advancement of 5g in cellular technologies, RAN (Radio Access Network) have been evolved. In 5G NR (New Radio), it performs various function like packet processing and baseband processing which can also be reffered as **Physical Layer Processing**.

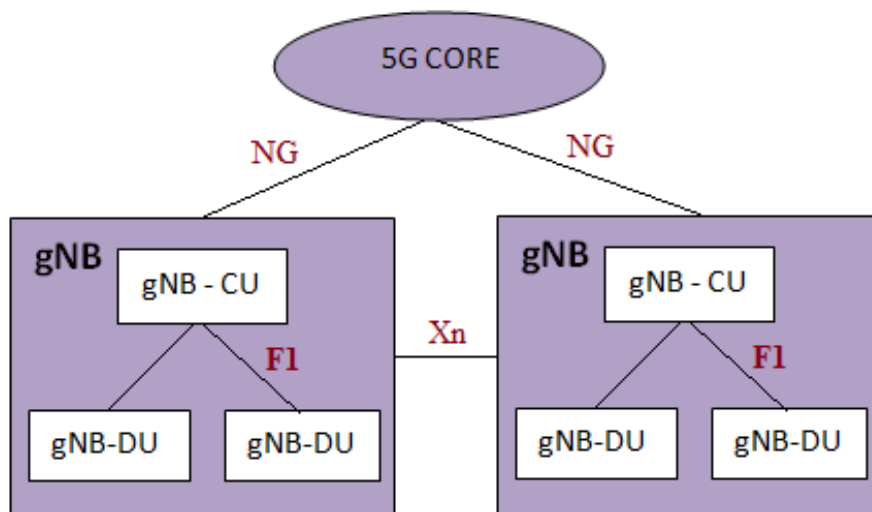
NG configures and scales RAN nodes dynamically with the software. Signalling and data transport are logically separated in NG and are known as control panel and user plane respectively, also NG architecture is flexible and hence nodes are deployed on spectrum efficiency and performance requirements.

The gNB consists of three functional modules:

- Control Unit (CU) takes care of MC (mobility control), RRM (Radio Resource Management) and SM (Session Management).
- Distributed Unit (DU) provides PHY and MAC layer functionalities
- Radio Unit (RU).

The functionality split between CU and DU depends on the implementation.

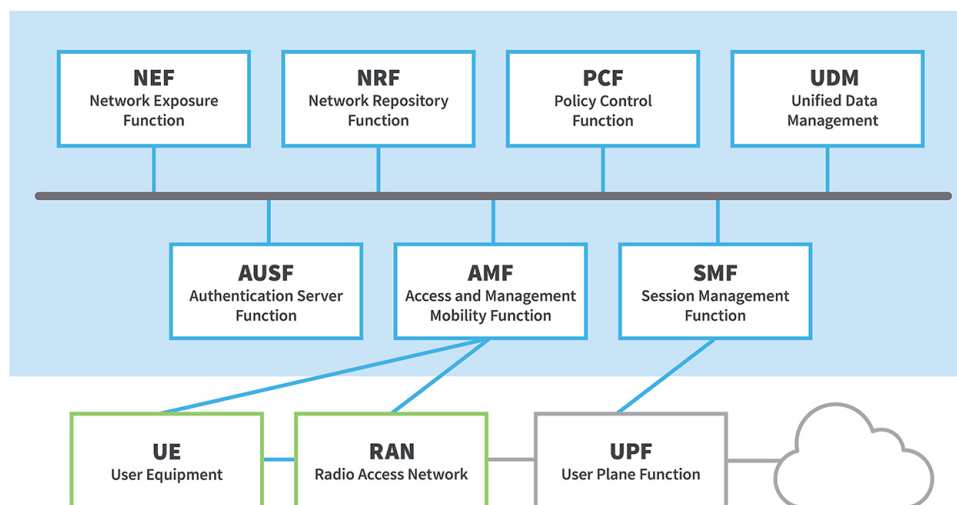
Below is the image which depicts the functionality of gNB



Source: RF Wireless World

5g Network Diagram

Below is a diagram that illustrates the working of 5g Network



Source: Techplayon

As we can notice from the picture above 5g Network looks more complex, Lets try to understand what's these functions do and How it works:

- **User Equipment (UE)** like 5g smartphones or 5g cellular devices.
- **Access and mobility Management Function (AMF)** acts as a single Entry Point for the UE connection.
- Based on the service requested by the UE, the AMF selects the respective Session Management Function or SMF for managing the user session.
- **User Plane Function** It transports the IP data traffic between the user and the external networks.
- **Authentication Server Function** This function allows the mobility function (AMF) to authenticate to the user and access services of 5g.

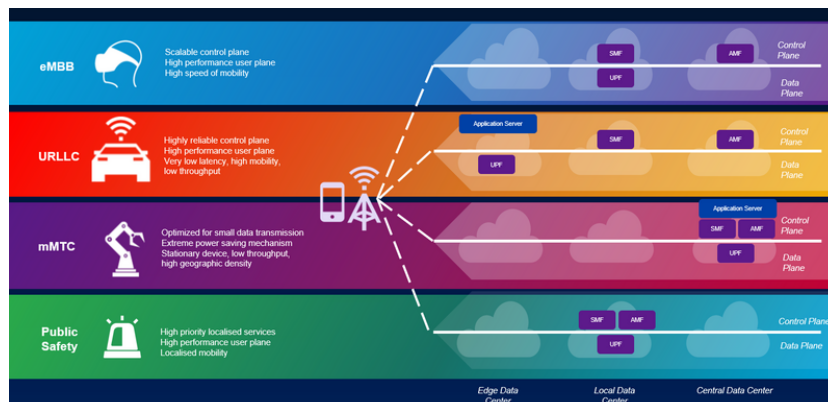
- The rest of the function as **SMF, PCF, AF** and **UDM** provides the policy control framework, applying policy decisions and accessing subscription info. and govern the network behaviour.

all these functions work together to make the best network architecture which is more complex than it looks and there is a lot happening behind the scenes, but it's needed to provide better performance and reliability

5g Network Slicing

Slicing can be defined as the configuration of a network in such a way which allows multiple networks to be created on top of a common physical infrastructure. Each part of the network or slice can be allocated for different needs or use case.

Below is a diagram which helps us understand different parts of 5g network.



Source: Viavi Solutions

Massive MIMO

Massive MIMO (Multiple Input Multiple Output) is an extension of the MIMO system which takes advantage of 5g architecture to expand the legacy systems by adding a much higher number of antennas to the base system which as a result helps to focus energy which introduces dramatic improvements in throughput and efficiency. all these advancements are aimed at achieving peak performance and reliable connection.

MIMO systems capitalizes on three key concepts, which are -

- Spatial diversity - It is one of the fundamental benefits of this technology, In simple terms it improves the reliability of the system by sending the same data across different propagation paths.
- Spatial multiplexing - The working of Spatial multiplexing is like a pipeline through which data is flowing between the base station and on a mobile network, let's consider with one

antenna on the base station and one on the phone – that allows for only so much data to flow. If we install more antennas on either sides with proper spatial separation multiple virtual pipelines can be created which creates multiple paths for more data to flow.

- Beamforming - It utilizes advanced antenna technologies on both mobile and network base to focus a signal in a specific direction. which results in increased data rates and capacity for all users

Advantages of massive MIMO:-

- Increased Network Capacity - Massive MIMO contributes to increased capacity first by enabling 5G NR deployment in the higher frequency range.
- Improved Coverage - users can enjoy a more uniform experience across the network
- User Experience - the above two benefits result in a better overall user experience

References

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