An Analytical Research Study on 5G Network Architecture

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Abstract: -

In today's era the wireless communication is growing day by day with a tremendous rate. Previous communication methods has several shortcomings like the cost of the communication setup was more, errors are more, equipments are less efficient, etc . With the advancement of technology smart phones and mobile phones have taken the place of old land line wired phones. In twenty first century is the data rates and speed are the major concern of mobile communication network. Earlier Long Term Evolution (LTE) is the standard for the fourth generation cellular mobile communication systems. In order to increase the speed and capacity of mobile telephone network LTE is the last step towards fourth generation (4G) technology. This paper is mainly focused on various types of 5G Network Technologies and gives a deep understanding of 5G Network Architecture .

Key Words: - 5G, Core Network, RAN Network, IMT,UE

I.INTRODUCTION:-

5G has been introduced within the release 15 version of the 3GPP specifications, whereas 4G was introduced within release 8UE Power Saving. 5G has been specified based upon the requirements of the following use cases:

- Enhanced Mobile Broadband (eMBB)
- Ultra Reliable and Low Latency Communications (URLLC)
- Massive Machine Type Communications (mMTC)

The Radio Access Network (RAN) belonging to 4G is known as Long Term Evolution (LTE), whereas the RAN belonging to 5G is known as New Radio (NR). NR has been standardized to allow tight interworking with LTE. Tight interworking supports the inter-connection of LTE and NR Base Stations. These Base Stations can then be used in combination to serve the population of User Equipment (UE). 5G network architectures based upon tight interworking between LTE and NR are known as **Non-Standalone (NSA).**

Non-Standalone architectures allow a smooth and relatively simple evolution towards a complete end-to-end 5G System (5GS). Non-Standalone architectures allow re-use of existing LTE Base Stations and existing 4G Core Networks. In general, a software upgrade is sufficient to allow interworking with a set of NR Base Stations.

Standalone (SA) NR Base Stations provide connectivity to a SG Core Network. The combination of NR Base Station and SG Core Network is known as a SG System (SGS). The benefits of 5G are maximized when using a SG System.

NR Base Stations have a flexible architecture which supports a range of deployment options:

- ✓ A 'classical' Base Station architecture can be adopted to keep the hardware within a single cabinet.
- ✓ Alternatively, the Base Station can be split into a Centralized Unit (CU) and a Distributed Unit (DU). The CU accommodates the higher protocol stack layers, while the DU accommodates the lower protocol stack layers. A single CU can host a large number of DU (typically > 100), while each DU can host multiple cells (typically > 6).

In addition, the CU can be split into Control Plane (CP) and User Plane (UP) functions. This allows independent scaling of the CP and UP processing capabilities. It also allows the two functions to be deployed at different geographic locations. UP functions may be located in close proximity to the DU to help reduce user plane latency, while CP functions may be centralized to pool resources. All deployment options can use either passive or active antenna. Passive antenna arc connected to radio modules using RF feeder cables whereas active antenna are connected to baseband processing hardware using high speed fiber. This paper will provide you an outline about various 5G network architectures. It will give a deep understanding about what 5G is all about and will present an overview about the network architecture. The rest of the paper is organized as follows. Section II presents Literature Review about the topic. Section III gives the brief essentials of various 5G Network Technologies. Section IV gives deep understanding of 5G Network Architecture. Then, finally Section V draws concluding remarks which are then followed by the bibliography.

II. LITERATURE REVIEW:-

Huge number of publications is written for 5G technology and vast number of researchers has worked and is working on this research area. Hence literature selected in this section is restricted to very recent level and that to with publications like IEEE magazines, etc. Literature surveyed for this topic is presented below:-

1. Shengli Zhou et al. [2] described zero padded Orthogonal Frequency Division Multiplexing (ZPOFDM) for the illustration of results. CP-OFDM can also be referred for the representation for the better performance of OFDM. It is brought to our notice that while communication is done under water the guard interval can be very long. And that may consume more transmission power in case of CP-OFDM. In ZP-OFDM, it not only saves the transmission power but also decreases the duty cycle of the practical transducer. Along with that when derivations for both are done it was found that the derivation of ZP-OFDM was simpler compared to the CP-OFDM. When windows are incorporated in OFDM, ZP-OFDM found it quite convenient but CP-OFDM does not. The uncoded OFDM was having worse performance under different fading channels.

2. Long Soo Cho et al. [1] tells that in order to communicate with the single carrier transmission we require nyquist bandwidth in order to get the symbol transferred per unit time. These systems have the frequency selectivity issue and it can be eradicated with the usage of multiple carriers for the data transmission. It should be taken into account that the frequency non selectivity of sub channel affects the equalizer that is used in it. If the narrow band channel is frequency non-selective then the equalizer will be less complex. OFDM transmitter maps the messages with the help of PSK and QAM. The guard intervals in case of OFDM can be implemented by two different methods. First one is the usage of zeroes for padding in between the data and the second one is the Cyclic Prefix (CP). If there is any interference obtained between the symbols CP will try to recover the message which the zero pad cannot do.

3. Stefan H. Muller et al. [4] proposed a flexible and distortion free technique for OFDM that is eradicating redundancy that was present in it. This technique may enhance the complexity of the OFDM. It is brought to our notice that the results of PAR reduction obtained from the performed histogram are not good as compared to those which are theoretically found. When the 4-DPSK is implemented in alliance with PTS-OFDM along with the subcarriers, it is found that redundancy is Rap=2(V-1) which was independently of W. V is depicting the number of sub blocks used in PTS and W is depicting the admitted angles for bµv which must not be quite high.

4. E. Del Re et al. [5] compared the OFDM with the direct sequence code division multiple access (DS-CDMA). DS-CDMA is a competent technique in the wireless communication under which every bit of the signal that is needed to be transmitted over the channel is multiplied for the pseudo noise sequence. This pseudo noise sequence's fundamental element which is known as chip is quite short as compared with the information bits. The direct sequence code division multiple access systems provide the better performance as compared to the OFDM. In the proposed system a non-negligible portion of the noise power is focused in narrow band interference. As a result of that under the small values of SNR we obtain better performance.

5. The high peak-to-average power ratio (PARP) is the major issue in all multicarrier communication systems introduced by Hanwang et.al [33]. In past time the methods used to reduce the PARP in OFDM were as: clipping and filtering scheme, SLM (selective mapping scheme), PTS (partial transmit sequence) scheme, and TR (tone reservation) scheme, but due to the different structure of FBMC these schemes were not useful for FBMC. A hybrid scheme for FBMC/OQAM signals to reduce the PARP (peak-to-average ratio) and this is depends upon the multi data block PTS (partial transmit sequence) and TR (tone reservation) approaches. Hybrid PTS scheme the data blocks are divided into segment and this is used to optimize every data block signal for which the optimal phase rotation is needed to choose. To achieve this iterative clipping filtering is used to generate

peak canceling signal for each segment of signal. This operation is very useful to cancel peak of signals.

III. 5G Network Technologies:-

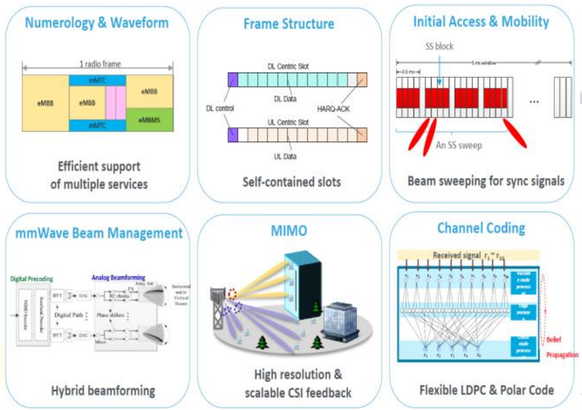

Figure 1: Different types of 5G Network Technologies

There are various 5G Network Technologies which will be used in future. Some of them are shown in Figure 1, The technologies are based on Numerology & Waveform, Frame Structure, MIMO , mmWave Beam Management,etc. Some of the technology is described below

3.1 Waveform and Flexible Numerology

- ❖ OFDM-based waveform continues to be used also in NR

CP-OFDM in DL, both CP-OFDM and DFT-S-OFDM in UL (only DFT-S-OFDM for LTE UL)

- ❖ Diverse numerologies are supported for new spectrum and vertical services

LTE subcarrier spacing is limited to 15 kHz and therefore not suitable for higher frequencies

- ❖ NR supports flexible subcarrier spacing of 2n x 15 kHz, i.e. 15/30/60/120 kHz for data

Multiplexing different numerologies in time or/and frequency domain is possible

- ❖ Removal of CRS (Cell-specific Reference Signal) for forward compatibility

3.2 MIMO and Beam Management

- NR-MIMO: key technology to achieve 3 times the spectral efficiency of LTE-A
- Multi-beam based operation: improve coverage for high frequency band (e.g. 28 GHz) .

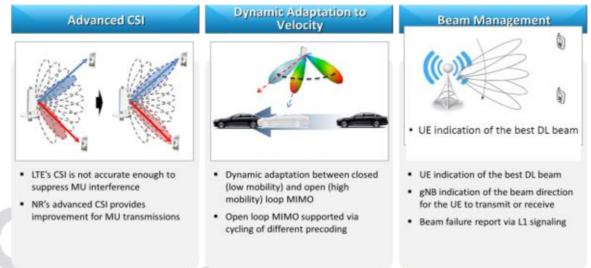

Figure 2: MIMO & Beam Management Network Technologies

3.3 UE Power Saving

In LTE, most UE power is spent on monitoring DL control signaling without being scheduled NR includes mechanisms for improved UE power consumption Bandwidth part (BWP) operation enabling UE to shrink its RF when no immediate data is available Reduction of UE operations for monitoring DL control signaling to reduce UE power consumption when not likely to be scheduled .In figure.3 UE power consumption analysis is shown.

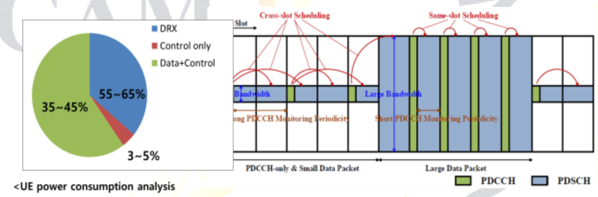

Figure 3 UE power consumption analyses

IV. 5G Network Architecture:-

A resource block is defined as 12 consecutive subcarriers in the frequency domain . Compared to LTE, this Network provides many benefits. Some of the main ones are:

- ➢ Exploitation of much higher-frequency bands as a mean to obtain additional spectra to support very wide transmission bandwidths and the associated high data rates;
- ➢ Ultra-lean design to enhance network energy performance and reduce interference;
- ➢ Forward compatibility to prepare for future, yet unknown, use cases and technologies;
- ➢ Low latency to improve performance and enable new use cases; and
- ➢ A beam-centric design enabling extensive usage of beam forming and a massive number of antenna elements not only for data transmission (which to some extent is possible in LTE) but also for control-plane procedures such as initial access.

The RAN is responsible for all radio-related functionality of the overall network including, for example, scheduling, radio-resource handling, retransmission protocols, coding, and various multi-antenna schemes. The 5G core network is responsible for functions not related to the radio access but needed for providing a complete network. This includes, for example, authentication, charging functionality, and setup of end-to-end connections. It is possible to connect the NR radio-access network also to the legacy LTE (Long-Term Evolution) core network known as the Evolved Packet Core (EPC). In fact, this is the case when operating NR in non-standalone mode, where LTE and EPC handle functionality like connection set-up and paging. Later releases will introduce standalone operation with NR connecting to the 5G core, as well as LTE connecting to the 5G core. Thus, the LTE and NR radio-access schemes and their corresponding core networks are closely related, unlike the transition from 3G to 4G where the 4G LTE radio-access technology cannot connect to a 3G core network.

4.1 5G Core Network

The 5G core network builds upon the EPC with three new areas of enhancement compared to EPC: service-based architecture, support for network slicing, and control-plane/user-plane split. A service-based architecture is the basis for the 5G core. This means that the specification focuses on the services and functionalities provided by the core network, rather than nodes as such. This is natural as the core network today is already often highly virtualized with the core network functionality running on generic computer hardware. Network slicing is a term commonly seen in the context of 5G. A network slice is a logical network serving a certain business or customer need and consists of the necessary functions from the service-based architecture configured together. For example, one network slice can be set up to support mobile broadband applications with full mobility support, similar to what is provided by LTE, and another slice can be set up to support a specific non-mobile, latency-critical industry-automation application. These slices will all run on the same underlying physical core and radio networks, but, from the end-user application perspective, they appear as independent networks. In many aspects it is similar to configuring multiple virtual computers on the same physical computer. Edge computing, where parts of the end-user application run close to the core network edge to provide low latency, can also be part of such a network slice. Control-plane/user-plane split is emphasized in the 5G core network architecture, including independent scaling of the capacity of the two. For example, if more control plane capacity is need, it should be straightforward to add it without affecting the user-plane of the network. The figure uses a service-based representation, where the services and functionalities are in focus. In the specifications there is also an alternative, reference-point description, focusing on the point-to-point interaction between the functions, but that description is not captured in the Figure 4

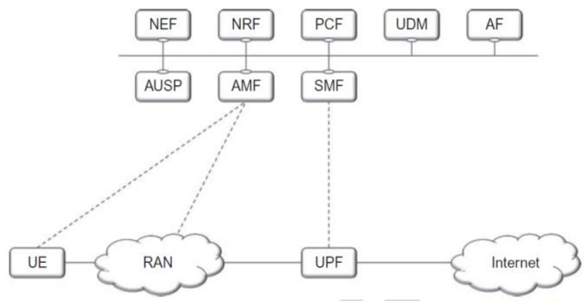

Figure 4. 5G Core Network

5G core network is divided into 3 planes which are described below:

(A) The Access and Mobility Management: Function (AMF) is in charge of control signaling between the core network and the device, security for user data, idle-state mobility, and authentication. The functionality operating between the core network, more specifically the AMF, and the device is sometimes referred to as the Non-Access Stratum (NAS), to separate it from the Access Stratum (AS), which handles functionality operating between the device and the radio-access network.

(B) The control-plane function: The control-plane functions consist of several parts. The Session Management Function (SMF) handles, among other functions, IP address allocation for the device (also known as User Equipment, UE), control of policy enforcement, and general session-management functions.

(C) The user-plane function: The user-plane function consists of the User Plane Function (UPF) which is a gateway between the RAN and external networks such as the Internet. Its responsibilities include packet routing and forwarding, packet inspection, quality-of service handling and packet filtering, and traffic measurements. It also serves as an anchor point for (inter-RAT) mobility when necessary.

4.2 5G RAN Network

The radio-access network can have two types of nodes connected to the 5G core network:

- ✓ A gNB, serving NR devices using the NR user-plane and control-plane protocols; or
- ✓ An ng-eNB, serving LTE devices using the LTE user-plane and control-plane protocols.

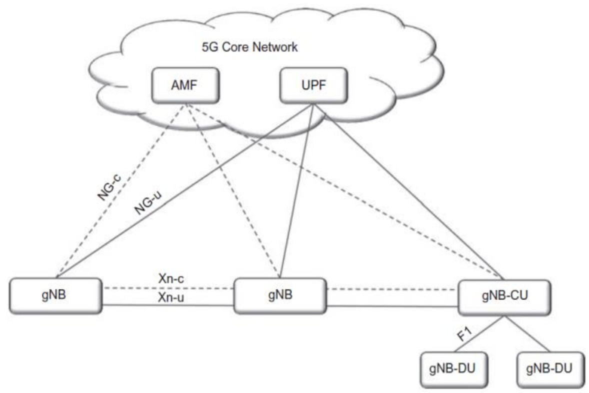

Figure 5. 5G RAN Network

gNB is connected to the 5G core network by means of the NG interface, more specifically to the UPF by means of the NG user-plane part (NG-u), and to the AMF by means of the NG control-plane part (NG-c). One gNB can be connected to multiple UPFs/AMFs for the purpose of load sharing and redundancy. The Xn interface, connecting gNBs to each other, is mainly used to support active-mode mobility and dual connectivity. This interface may also be used for multicell Radio Resource Management (RRM) functions. The Xn interface is also used to support lossless mobility between neighboring cells by means of packet forwarding.

There is also a standardized way to split the gNB into two parts, a central unit (gNB-CU) and one or more distributed units (gNB-DU) using the F1 interface. In the case of a split gNB, the RRC, PDCP, and SDAP protocols, reside in the gNB-CU and the remaining protocol entities (RLC, MAC, PHY) in the gNB-DU. The interface between the gNB (or the gNB-DU) and the device is known as the Uu interface.

The 5G System (5GS) includes the 5G Core Network (CN), the 5G Access Network (AN) and the User Equipment (UE). Figure 5 illustrates these components belong to the 5G System. The 5G Core Network provides connectivity to the internet and to application servers. The 5G Access Network can be a 3GPP Next Generation Radio Access Network (NG RAN), or a non-3GPP Access Network.

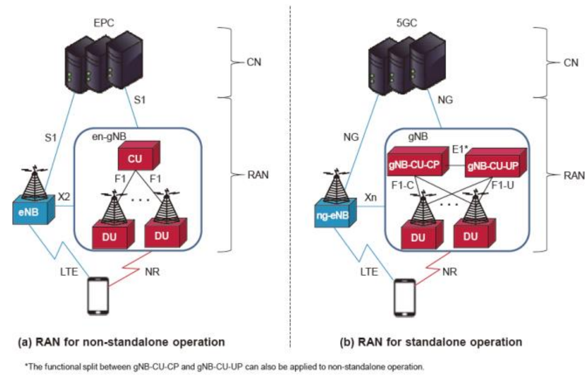

Figure 6. RAN Network Operations

The 5G System (5GS) includes the 5G Core Network (CN), the 5G Access Network (AN) and the User Equipment (UE). Figure below illustrates these components belong to the 5G System. The 5G Core Network provides connectivity to the internet and to application servers. The 5G Access Network can be a 3GPP Next Generation Radio Access Network (NG RAN), or a non-3GPP Access Network

A 3GPP Next Generation Radio Access Network (NG RAN) can be based upon any of the following options:

- Standalone New Radio (NR) Base Station
- Standalone Long Term Evolution (L TE) Base Station upgraded to allow connection to the 5G Core Network
- Non-Standalone Base Station using NR as the anchor and LTE as an extension
- Non-Standalone Base Station using LTE as the anchor and NR as an extension

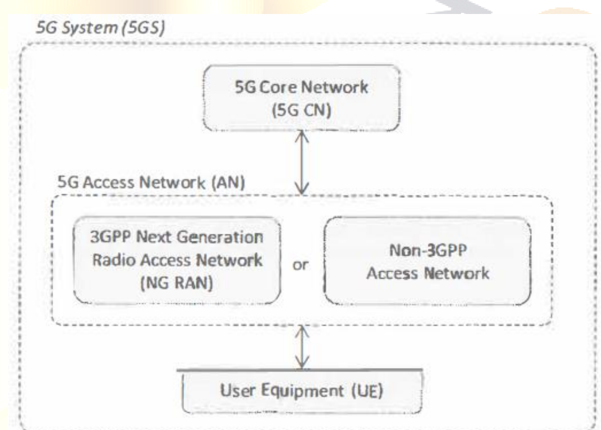

Figure 7. 3GPP Access Network

A New Radio (NR) Base Station is known as a gNode B, whereas an LTE

Base Station which has been upgraded to allow connectivity with the 5G Core Network is known as an enhanced eNode B or a Next Generation eNode B

An example of a non-3GPP Access Network is a Wireless Local Area Network (WLAN) based upon WiFi. Non-3GPP Access Networks use a Non-3GPP Inter working Function (N3IWF) to allow connectivity with the 5G Core Network.

The N3IWF supports 3GPP interfaces towards the 5G Core Network and non-3GPP interfaces towards the non-3GPP Access Network.

V. CONCLUSIONS

5G networks are very fast and reliable, 5G networks are expected to satisfy rapid wireless traffic growth. The 5G mobile phones will be a tablet PC. A new revolution of 5G technology is about to begin because 5G technology is going to give tough competition to normal computer and laptops whose market value will be affected. The development of the mobile and wireless networks is going towards higher data rates and all are based on IP network concept. It offers tremendous data capabilities and unrestricted call volumes and infinite data broadcast together within the latest mobile operating system. This paper gives an overview of different 5G Technologies that will be used all around the world. Massive MIMO and Beam Management, Waveform Numerology are some of the technologies which are presented in this paper. Our special attention is paid on key literature focusing on 5G technology. This paper is mainly focused on the various types of 5G Network Architectures which are going to be deployed all across the world. It gives a deep understanding of 5G Network Architecture and its components.. Further it gives Literature Review about the topic and tells up about the brief essentials of the various ongoing 5G Technologies. Thus the paper provides useful information about the 5G Network Infrastructure and its components which are useful for researchers and Network professionals of the world.

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