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Perspective Article

A Survey on Evolution of Wireless Technologies and The Use of Wireless Technologies in Tele Audiology

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Abstract

The objective of this paper is to know how the evolution of wireless technology is leading to offer services in the area of tele audiology. This paper is a study on different kinds of wireless technologies starting from 1G to 5G and their evolution, and also the study on their Radio access network is done and enhancements made in the latest technology is compared with the legacy technologies. A study was made on how the enhancement in the latest technology helps in delivering the services in tele audiology.

Keywords: 1G, 5G, wireless technology, tele audiology

INTRODUCTION

Evolution of cellular technologies

Technology has become an integral part of our life and has changed our lifestyles. With the advent of smartphones and different kinds of applications, we are now used to book cars, transferring money, ordering food, and book tickets from almost anywhere from a park or a moving train. All of this is made possible by the growth of the wireless network infrastructure Figure 1. The new enhancements and the advancements in the cellular networks and even in Radio access networks have bought a huge advancement in the applications. This paper gives a survey on how the evolution and improvements in the technologies help in promoting tele audiology.

3G Wireless communications-Clinth smith

The first Chapter in this book gives an in depth knowledge of evolution of Cellular technologies starting from 1G to 4G.

First Generation System: The first generation supports Analog voice it used the technology known as Advanced mobile phone service (AMPS), which operates at 800MHz. Later European system used a technology known as Nordic Mobile Telephony (NMT), operating at the 450-MHz band. It was even developed to operate at 900 MHz which was known as NMT900.later the modified version of NMT has come into existence which was known as Total Access Communication System (TACS). It operated at 900MHz frequency.

The basic Attributes of 1G are:

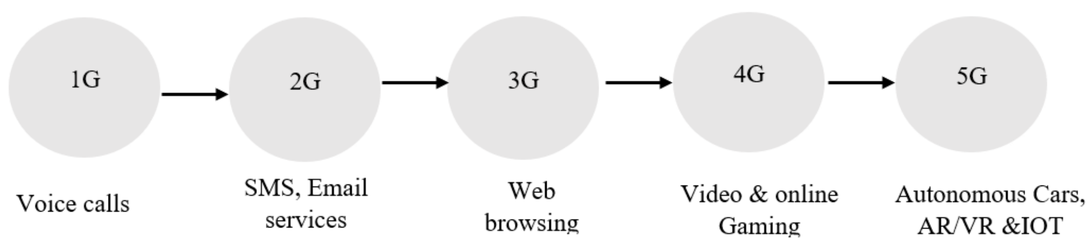

Figure 1: Evolution of wireless technologies.

- It has Speed-2-4 kbps
- It Uses an analog signal
- It has Poor voice quality
- It has Poor battery life
- It has a large phone size
- It has Limited capacity
- It has Poor handoff reliability
- It has Poor security
- It offers a very low level of spectrum efficiency

The Challenges with 2G deployment are as follows:

Capacity: As capacity has increased the number of users serving with required radio resources is one the challenges.

Spectrum utilization: Spectrum is related to the radio frequencies allocated to the mobile industry.

Infrastructure changes: Wireless devices can communicate with each other or can communicate with a wired network.

Subscriber unit upgrades penetration rates: Mobile Phone Penetration refers to the number of SIM cards or mobile phone numbers in a certain country.

Second generation system: The Global System for Mobile Communications (GSM) is a European standard for digital cellular systems operating in the 900 MHz band that has been adopted worldwide.

This technology allows for international roaming, improved speech quality, increased security, and the ability to send and receive text messages.

GSM is made up of the following major components:

- The System of Switching (SS)
- The Subsystem of the Base Station (BSS)
- The Support and Operations System (OSS)

Both the Base Station Controller (BSC) and the Base Transceiver Stations (BTS) make up the BSS. Several BTSs are connected to a BSC. Both the Base Station Controller (BSC) and the Base Transceiver Stations make up the BSS. Several BTSs are connected to a BSC, and then several BSCs are connected to the Mobile Switching Centre (MSC) in a typical configuration. The GSM radio channel has a width of 200 kHz. GSM is available in several frequency bands, including 900 MHz, 1800 MHz, and 1900 MHz However, an analog system called Enhanced Total Access Communication System (ETACS) used the 900-MHz spectrum, occupying a 25-kHz channel. The introduction of GSM into this band necessitated traffic rerouting to accommodate GSM.

TDMA (IS-54/IS-136): IS-136, an improved version of IS-54, is a digital cellular standard based on TDMA technology developed in the United States. TDMA technology uses time division to allow multiple users to share the same channel. IS-136 allows three to six users to share the same physical radio channel at the same time. In the forward and reverse directions, the IS-136 channel offers a total of six-time slots.

IS-136 has several advantages when used in a cellular system: Increased system capacity up to three times over analog. Improved protection against adjacent channel interference Authentication Voice privacy Lower infrastructure capital investment to deploy and provides short message services.

Different radio Communication Technologies Use Code-Division Multiple Access (CDMA) as a channel access spectrum technology and a special coding scheme to allow this without interfering with other users (where each transmitter is assigned a code). Many mobile phone standards use CDMA as the access method. IS-95, also known as "CDMA One," and its 3G evolution, CDMA2000, is often referred as a method. Multiple access is exemplified by CDMA, which allows multiple transmitters to send data over a single communication channel at the same time. This allows multiple users to share the same frequency band.

Third generation system: One of the key factors in the evolution of GSM networks to 3G capabilities was the introduction of General Packet Radio Service (GPRS). The implementation of Enhanced Data Rates for GSM Evolution is the next critical step in this process. Under good RF conditions, GSM operators will be able to offer wireless multimedia Internet Protocol (IP)-based services and applications using existing GSM radio bands at a rate of 384 kbps with a bit rate of 48 kbps per timeslot and up to 69.2 kbps per timeslot using EDGE. The EDGE system is a GSM extension with high-level modulation (HLM). It uses 200kHz carrier spacing, Quaternary-Offset-QAM (QOQAM) [16-QAM], and Binary-Offset-QAM (BOQAM) [16-QAM] (BQAM) [QPSK] modulation, as well as GMSK modulation with eight timeslots per TDMA frame and a set of convolutional channel codes. The data rate determines which modulation technique is used. EDGE meets the following IMT-2000 requirements by using HLM schemes: 144 kbps for high-speed vehicular environment 2 Mbps for indoor office using wide-band 1.6 MHz carrier,384 kbps for pedestrian (microcell) and low-speed vehicular (macro cell) environments.

Fourth generation: Fourth Generation (4G) mobile phones are the successor to 3G mobile networks and provide broadband cellular network services. It offers cellular communications that are purely IP-based. The capabilities provided conform with the International Telecommunication Union’s (ITU) IMT-Advanced specifications. It provides an IP-based packet-switched network for voice, data, and multimedia transmission. It aims to provide high-quality, uninterrupted services to any location at any time. And it provides smooth handoffs across heterogeneous network areas.

4G is categorised into two categories namely Long–Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WIMAX)

Long-Term Evolution (LTE): LTE stands for long-term evolution and is a 3G technology extension. It is a high-speed mobile communication standard that is based on GSM/ EDGE and UMTS/HSPA technologies. The download data rate is 100 Mbps, and the upload data rate is 50 Mbps. The LTE Advanced standard for 4G technology complies with the IMT-Advanced specifications. Its peak downlink and uplink data rates are 1000 Mbps and 500 Mbps, respectively.

Worldwide Interoperability for Microwave Access (WIMAX)– The most recent version of WIMAX is not backward compatible with previous versions, but it is LTE compatible.

Use case of 4G: Advanced mobile web access

- Ip telephony
- High-resolution high-speed gaming services
- Streamed multimedia and data
- High-definition mobile TV
- Video Conferencing

Role of 5G network's: Issues, challenges and applications" Arun Kumar Tripathi, Akash Rajak, Ajay Kumar Shrivastava

This paper explains the evolution of wireless technologies covering from first-generation to fourth generation. Wireless networks of the first generation (1G) were designed primarily for voice communication. It could handle data transfer rates of up to 2.4kbps [1]. Advanced Mobile Phone System (AMPS), Nordic Mobile Phone System (NMTS), Total Access Communication System (TACS), and other 1G-access technologies were the most popular. In 1G, analog signals were responsible for carrying voice. It has several shortcomings, including poor signal quality, low capacity, and insecure and unreliable handoff.

The Second Generation (2G) of wireless networks was primarily designed for voice communication and was capable of data transfer speeds of up to 64kbps. Global Systems for Mobile Communications (GSM), Code Division Multiple Access (CDMA), and IS-95 were the most popular 2G-access technologies. Text messages, picture messages, and Multimedia Messaging Services (MMS) were all possible with 2G technology. It can also provide secure point-to-point communication, which means that the message can only be read and received by the intended recipient. 2G had several serious problems, including a slow data rate, limited cell capacity, and a higher handover time.

Second-Generation Network Expansion (2.5G) It was a development of second-generation wireless technology. It introduces the General Packet Radio Services (GPRS), a packet-based switching technique (GPRS). It can also provide better communication through the use of packet switching and circuit switching techniques, as well as 2G services. It can transfer data at a rate of up to 144kbps. GPRS, Code Division Multiple Access-2000 (CDMA2000), and Enhanced Data Rate for GSM Evolution (EDGE) were the most popular 2.5G-access technologies.

In the year 2000, the third generation (3G) of wireless networks was standardized. The primary goal of 2G was to provide voice communication and high-speed data transfer of up to 2Mbps. Wideband Code Division Multiple Access (WCDMA), CDMA2000, and Universal Mobile Telecommunications Systems (UMTS) were the most popular 3G-access technologies. Specific applications for video calling, online games, email, and social media services such as Facebook and Orkut were developed to take advantage of the benefits of 3G smartphone technology.

Wireless networks of the fourth generation (4G) were standardized in 2010. 4G is designed to handle data transfer speeds of up to 300Mbps while maintaining a high level of quality of service (QoS). Users of 4G can watch high-definition (HD) video online and play online games. Voice over LTE (VoLTE) is the most widely used 4G access technology (use IP packets for voice). Long Term Evolution (LTE) is currently being standardized by the 3G Partnership Project (3GPP). It provides secure mobility and reduces latency for critical applications. It also allows IoT-enabled devices to communicate efficiently. In terms of hardware and implementation, 4G is more expensive than 3G. High-end multifunctional devices that are compatible with 4G technology are required for communication. The delivery of content to mobile devices is the primary focus of 3G and 4G systems, rather than efficient delivery. The 5G wireless network can provide services to billions of devices with near-zero latency. In the year 2020, 5G is expected to be standardized. With QoS, 5G can handle data transfer speeds of up to 10Gbps. Higher speeds enable you to watch Ultra High Definition (UHD) videos online and play online games. The complications and challenges with the development of 5G includes

- High Data Rates and Increased Network Capacity with Energy Optimization
- High Data Rates, Network Capacity Expansion with Energy Optimization Full Duplex Communication Channel
- Environmentally Friendly
- Low Latency and High Reliability
- Network Performance Optimization
- High Mobility and Handover

The Applications of 5G include Environmental Monitoring, Smart Agriculture, Smart metering with 5G network, Smart Health, Internet of Vehicles, Smart Home [2]. All the Applications mentioned above needs very low latency and ultra-high reliability which can be attained through 5G.

5G, 4G LTE, 3G, 2G cellular mobile communications-wireless "Udemy Tutorial"

In this course Author has explained about the cellular technologies and also the architectural overview of the cellular technologies [3]. 3G was much more advanced when compared to 2G/2,5G and offered up to 2 Mbps speed, supporting location-based services and multimedia services. It was ideal for web browsing Figure 2.

The Universal Mobile Telecommunications System (UMTS) is a third-generation cellular system for GSM-based networks. UMTS defines a complete network system that includes the radio access network, core network, and SIM card-based user authentication. Three distinct entities make up the 3G network architecture:

User Equipment (UE): In 2G the handsets were called mobile phones or cell phones as they were predominantly used for making voice calls. However, in 3G, the handsets can support both voice and data services. Hence the term user equipment or UE is used to represent the end-user device, which could be a mobile phone or a data terminal.

Radio Access Network (RAN): The RAN also known as the UMTS Radio Access Network UTRAN is the equivalent of the previous Base station subsystem (BSS) in GSM.RAN includes the NodeB function and the Radio Network Controller (RNC) function. The NodeB function provides the air interface. The RNC managers the air interface for the overall network.

Core Network: The core network, also known as the Network Switching Subsystem or NSS in GSM, is responsible for all of the system's central processing and management.

3G core network consists of the following functions

Home location register (HLR): HLR is a database that contains all of the subscriber's information, including their most recent known location. The HLR maintains a mapping between the international Mobile Subscriber Identity Number (IMSID) and the International Mobile Subscriber Directory Number (MSISDN) and International Mobile Subscriber Identity (IMSI). The MSISDN is a mobile phone number that can be used to make and receive voice calls.

Equipment Identity Register (EIR): The EIR is the function that determines whether or not a piece of the user equipment can connect to the network. It works in combination with the HLR.

Authentication Centre (AuC): AuC is used for storing a shared secret key, which gets generated and burned in the SIM card at the time of manufacturing function is typically collocated with the HLR

Mobile switching center (MSC): MSC is responsible for functions such as routing calls and SMS messages. It interfaces with the HLR for keeping track of subscriber location and does call handovers when the mobile subscriber moves from one location to another Gateway (GMSC) is a function that is present either within or outside of the MSC

Serving GPRS Support Node (SGSN): SGSN is responsible for mobility management and authentication of subscribers in a GPRS network. It performs a role that is similar to the role played by the MSC for voice calls. The SGSN and MSC are often co-located in the network

Gateway GPRS Support Node (GGSN): GGSN acts as a gateway to the internet. It connects the GPRS network with the packet-switched data network. GGSN receives data addressed to a given subscriber, checks if the subscriber is

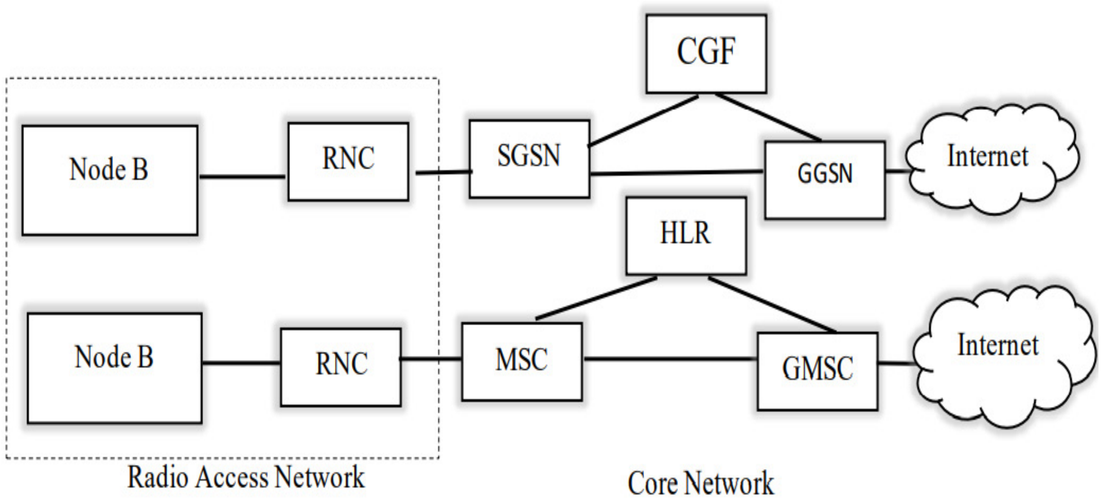

Figure 2: 3G Architecture

active, and then forwards the data to the SGSN serving the particular subscriber

Charging Gateway Function (CGF): CGF handles call detail Records (CDRs) generated by the GGSN in a GPRS network. There are different types of CDRs processed by the CGF based on the network node that generates the CDR

4G Networks: The radio function is based on the Long-Term Evolution (LTE)3GPP standards. The core network is based on the Evolved Packet Core (Figure 3)

In this architecture user plane and control plane are not separated they are collocated

- User plane elements are S-GW AND PDN Gateway
- Control plane elements are MME, HSS, AND PCRF

Here the BTS and BSC combine to form eNodeB on the radio side which is known as E-UTRAN.

4G network consists of the following functions

Evolved Node B (eNB): eNodeB is the entity that manages radio resources and supports the air interface. It performs radio resource management functions such as compression of IP headers, encryption of user data, and routing of user data to the Serving Gateway (SGW).

Home Subscriber Server (HSS): Home Subscriber Server (HSS) is a database for storing the subscriber profile and authentication information, MME downloads subscriber profile information from the HSS, when a user equipment device attaches to the network.

Serving Gateway (SGW): SGW serves as the user plane's mobility anchor. Inter-eNodeB handovers and user equipment (UE) mobility between 3Gpp networks are handled by it. It is in charge of data packet routing between the eNodeB and the Packet Data Network Gateway (PDN GW).

Mobility Management Entity (MME): MME is in charge of UE identities and security settings for mobile devices. It performs functions such as managing session states, authentication, mobility with 3Gpp 2G/3G nodes, and roaming in the control plane.

Policy and Charging Rules Function (PCRF): The Policy and Charging Rules Function (PCRF) is liable for all subscribers' policy and charging-related controls. The PCRF server, for example, records a subscriber's quality of service policy. Each subscriber's QoS policy may differ from service to service.

5G Networks consists of the following functions

In 5G Architecture user plane and control plane elements are separated i.e., CUPS separation.5G Architecture is known as “service-based architecture “as all the network functions interact with each other through service bus so it has got the name as service-based architecture. Here the network elements are not present in the form of hardware instead they are software, virtualized, and orchestrated (Figure 4).

All the network functions are softwarized and virtualized and they run on virtual machines which is referred as Network Function Virtualization (NFV). Basically, in NFV instead of using purpose build hardware, it meant to use generic hardware which means commercially off-the-shelf hardware. All these network functions run on virtual machines or sometimes even on containers. One virtual network function can run by one or more virtual machines.

Authentication Server Function (AUSF): UE authentication is performed by using Extensible Authentication Protocol

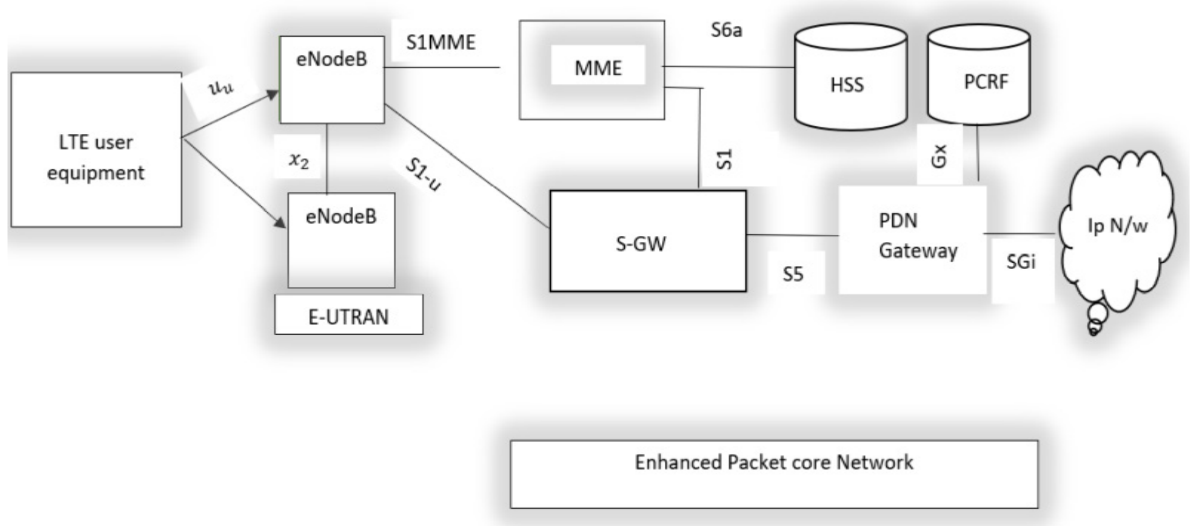

Figure 3: 4G Architecture

(EAP), AUSF behaves as authentication server. AUSF was one of the parts of Home subscriber Server (HSS) in 4G.

Access and Mobility Management Function (AMF): Connection Management, registration management and mobility management are performed by AMF. It is also responsible for authentication and authorization even this is a part of the Mobility Management Entity in 4G.

Data network: Internet services and third-party services are offered by DN

Network Exposure Function (NEF): When an external application accesses the 5G core nodes then it provides security and is an aggregation point. This is a new function in 5G architecture.

Network Repository Function (NRF): Service discovery and profiles of network function instances are maintained by NRF. Even this is one of the new functions in the 5G.

Network Slice Selection Function (NSSF): To serve the user equipment NSSF supports the selection of network slice instances. Based on Network slice selection Assignment Information (NSSAIs) allowed for a given UE. This is also one of the functions introduced in 5G.

Policy Control Function (PCF): A unified policy framework and policy rules to control plane functions are enforced by PCF. It also accesses subscription information relevant for policy decisions from the Unified Data Repository (UDR), PCF was part of the PCRF function in the 4G network.

Session Management Function (SMF): UE Ip address allocation and Session management and DHCP functions are under the control of SMF. It also provides traffic steering configuration for User Plane Function (UPF) for proper traffic routing This was split between the MME and packet gateway (PGW) function in 4G.

Unified Data Management (UDM)

Authentication and Key Agreement (AKA) credentials are provided by UDM. UDM was part of HSS in 4G architecture.

User Plane Function (UPF)

UPF provides packet routing and forwarding functions and also it handles QOS services. UPF was split between the serving gateway and packet gateway in 4G architecture.

User Plane Function (UPF)

UPF provides packet routing and forwarding functions and also it handles QOS services. UPF was split between the serving gateway and packet gateway in 4G architecture.

Application Function (AF)

AF function is similar to the AF function in the 4G network. It interacts with the 5G core to provide services (Figure 5).

KEY ENABLERS TO DELIVER LATENCY-AS-A SERVICE IN 5G NETWORKS" REKHA M DAS, SREE LAKSHMI S, SESHAIAH PONNEKANTI, MILAN PAUNOVIC

All the applications or the use cases of the 5G require low latency and ultra-high reliability. In this paper, the author explains the key enablers which deliver latency as a service [4]. There is a drastic change in the evolution of cellular technology in terms of Architecture, Implementation, and deployment options. And the services offered from legacy technology to contemporary technology have grown more advanced.5G is the one which has developed to address three use cases namely Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), and Ultra-Reliable Low Latency Communication (URLLC). URLLC is one of the key enablers in 5G which supports latency-sensitive applications it means it overcomes one of the serious limitations of the previous technologies. To attain these low latency and higher reliability standards there is a need for enhancements in the Radio Access Network (RAN). As the traditional RAN has proprietary hardware where there exists vendor lock-in and it lacks flexibility. But this is not with 5G RAN which is known as "Open RAN" as the name suggests it has Open capabilities. It uses hardware from one vendor and software from the other vendor. It does not have any kind of vendor lock-in and it overcomes

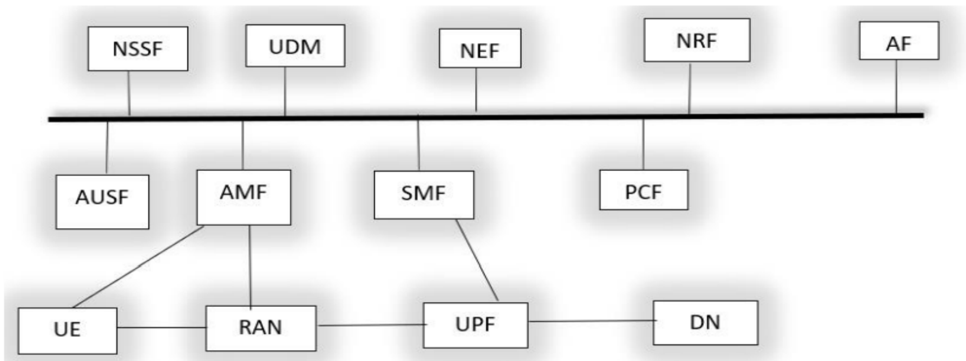

Figure 4: 5G Architecture.

The common network elements in 4G and 5G

AMF	MME	S-GW	P-GW	HSS	PCRF	AF	NEW
SMF	✓		✓				
UPF	✓	✓	✓				
AUSF				✓			
UDM				✓			
AF						✓	
NEF							✓
NRF							✓
NSSF							✓
PCF					✓		

Figure 5: Common network elements.

the limitation of traditional RAN. Here an observation can be made that Open RAN brings more competition among vendors. so obviously decreases the price and improves the performance of the network. It is all possible by making optimum use of virtualized edge infrastructure through Network Function Virtualization (NFV) and Software-Defined Networking (SDN). Both technologies go hand in hand and make 5G service-based Architecture where all the network functions are virtualized and they run on virtual machines or containers. one function can run on one or more virtual machines. And to route, all the functions SDN plays a crucial role.

Here are the key enablers to Realise low latency.

- Mobile Edge Computing (MEC)
- Open RAN
- Ultra-Reliable Low Latency Communication (URLLC)

The very first one i.e., MEC it works with NFV where NFV splits the hardware and software and makes the functions to be virtualized and these functions run on virtual machines or containers and functions run as per the service opted by the customer. Mobile Edge Computing (MEC) has cloud computing capabilities at the edge of the network which can be placed very close to the end-user. Thereby decreasing the latency and can have faithful communication.

The next one is Open RAN. Here we can map between Open RAN and legacy RAN when we do so we can observe that the traditional RAN contains Remote Radio Head (RRH) and Base Band Unit (BBU). These are collocated at the cell site and they lack the flexibility as they have vendor lock-in. With the advent of Open RAN, the vendor lock-in can be resolved.

5G RAN consists of gNodeBs connected to the core network (CN). In open RAN the gNodeB has three functional modules namely

- Radio Unit (RU)
- Distributed Unit (DU) and
- Centralized Unit (CU)

Here the Radio Units are the antennas that are closer to the end-user. Distributed Units are like edge data centres that can be placed at the campus, enterprise, etc. Centralized Units are the Bigger Datacentres. And we can have more split options depending upon the density of users, locality, and service requirements. However, the Edge data centre is the one that helps in maintaining latency. For example, when Biometric Attendance is considered sometimes, it shows a lot of issues concerning the server. As it displays Could not connect to the server at this moment as the server is somewhere away from the host this happens. When we consider having the edge data centre where the fingerprints will be recorded in the edge data centre located in the campus or enterprise itself then there won't be this kind of issue without any latency issue the authentication can be completed.

The Third one is Ultra-reliable low latency communication, The stringent latency and reliability requirement of URLLC can be attained through 5G New Radio (NR). Certain features enable low latency in URLLC like;

- Fast or Hybrid ARQ is moved to PHY: This helps swift retransmissions
- Grant free access: No prior handshakes are required for resource allocation
- Scalable NR slots: Mini slots have 14 symbols; these mini-slots can be accommodated in one slot
- Scalable NR Numerology: Scalable Numerologies are supported by 5G NR to serve a wide range of the spectrum

To provide latency as service certain steps are followed. Network slicing is the one that creates a logical network and customizes the network according to the user service requirements by running appropriate Network Functions (NFs). The lifecycle of Network slicing is depicted in Figure 6.

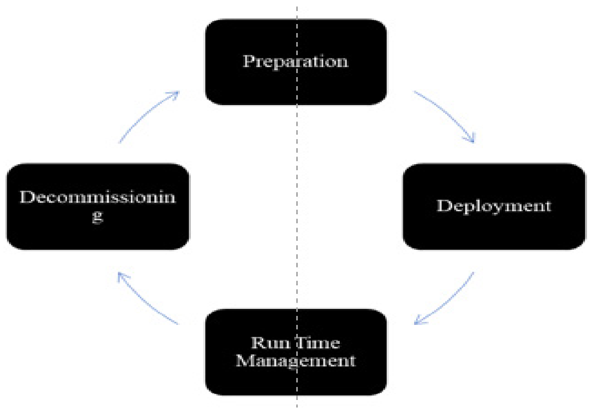

Figure 6: Lifecycle of network slicing.

- In the First stage i.e., preparation Network Service Descriptor (NSD) explains the network service with required VNFs which has to be executed by the NFV orchestrator.
- Deployment: In this stage, the slice is assigned to users thereby performing activation and instantiation.
- Run Time Management: Slices are monitored in real-time to verify whether the VNFs are meeting the service requirements of the customer.

A conclusion can be drawn from the above concept that the 5G RAN and the candidate software technologies help in attaining ultralow latency and high reliability.

USING WIRELESS TELECOMMUNICATION TECHNOLOGY TO PROMOTE TELE-AUDIOLOGY "DAOYUAN YAOL, GREGG GIVENS, LIANCHU YAOL"

This paper explains how wireless technologies i.e. Bluetooth helps in performing tele audiology tests [5]. The design and development of a better tele-audiology assessment system using wireless telecommunication technology are presented in this study. The promoted system will support transmissions of both numeric commands and voice data, integrate communication components such as headsets and web cameras, provide access to audiometers with multiple interfaces, and increase system reliability through software implemented on both the server and console device by designing and developing a smart gateway apparatus called "console device." Voice communication latency and throughput, transmission latency between the server and the audiometer, and so on. There are certain methods discussed in this paper namely.

The Improved System Architecture

- Design of Console Device
- The Typical Test Procedure
- Third Part Communication

Through this survey, we can conclude that through the advancements in the technologies it is easier to perform all these methods as the enhancements in the technologies help in decreasing the latency and have reliable connectivity.

CONCLUSION

This survey gives and detailed view of all the technologies and how these technologies help in performing latency-sensitive applications and also increase reliability which obviously leads to having faithful communication and makes the test complete successfully.

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