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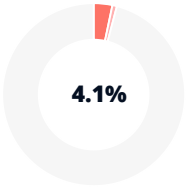

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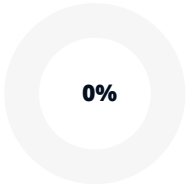

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MOBILE NETWORKING

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***Abstract*—A Review of the entire process of data transfer through various layers from a UE to a Service Provider.Various Performance Indicators have been listed. All levels like User Plane, Control Plane(AN's,Core Network Specifications, Network Slices) and Services Data Flow(Billing Mechanisms,QoS).Instances of various Test Beds for 5G that has been setup. Finally the 6G development models and strategies.major technological breakthrough to achieve 6G. practical guidelines for various uses like blockchain-based secure business models, and holographic based image transmission, and Finally basic information about frequency hopping spread spectrum.**

***Index Terms*—5G,6G, Network Slicing, UE, Control Plane, Key Performance Indicator, QoS, Internet of things, Internet of everything, meta-learning, blockchain, Frequency.**

I. Introduction

In today's fast paced world,one hardly takes time to notice what goes on behind the scenes,for example,when you send a whats-app message.There are various types of devices/terminals/nodes that are present today and they will continue to increase.This also includes the various kinds of devices like Vehicles, Mobiles, Automated Factories, Databases and GPU's.There are about 27 billion interconnected devices as of now[11].As of now 5G is satisfactory but in the following future 5G cannot be served as satisfactory for example next generation of VAR i.e.i.e., holographic teleportation, requires Tbps-level data rates and microsecond-level latency, which cannot be achieved with even the millimeter wave (mmWave) frequency bands within 5G[14].

In this, we try and attempt to give an entire overview of the networks that have brought the emergence of the 5G and soon, 6G networks in this world.

Firstly,we list various Performance Indicators or KPI's (Key Performance Indicators). Then we look at the User Plane and Control Plane levels of the network separately. User Plane consists of various UE's along with a chip called SIM or USIM. Control Plane consists of various levels like AN(Access Networks),Core Networks, and Network Slices. We will take a look at why these are important and how they are created and how AI and ML will soon be integrated into them. Finally, we will take a close look at the level most closest to the Service Provider,i.e.SDF(Service Data Flows) which includes a billing mechanism and QoS mechanism(functions) for different Network Slices. Also,there are some Test Beds setup for testing these new technologies that have been mentioned. Finally a look at advancements made in 6G Technologies and general knowledge of Frequency hopping spread spectrum. Refer figure.1 for Evolution of wireless mobile technology.

Fig. 1: Evolution of wireless mobile technology[15]

Fig. 2: Different Aspect of KPI[3]

II. Results and Discussions

A. Key Performance Indicators(KPI's)

With increasing number of devices, there is a requirement of more and more Data Rate and Bandwidth.5G shall be able to support a minimum user experience with 100 kbps, end-to-end latency of 50 ms, and a lower availability of 95%.In Urban Areas, the focus is on high bit rates and high board rates. In rural areas, focus is on high coverage.

New network requirements, such as high data transmission rates (between 1 to 20 Gbps), massive connections (estimated at 1 million connected devices and cars), low latency ultra-low communications (1ms), and high-speed mobility support (up to 500 km/h), are still awaited. The great identified IoV technology issues were the ones about big data, security, privacy, reliability, mobility, and also standards.

Some UE requires low latency and some UE requires high security.To measure all of that,we have several Indicators such as[6],

- Packet Delay
- Packet Loss Rate
- Packet Drop Rate
- IP Latency

Fig. 3: General flow of data[2]

- Radio resource utilization
- UE (User Equipment) IP (Internet Protocol) throughput (down link and uplink link)
- RRC (Radio Resource Control) connection
- PDU (Protocol Data Unit) Session Management
- Handovers
- Transport Blocks (TB)
- DRB (Data Radio Bearer) Setup Management
- QoS flow management
- UE Context management
- PDCP (Packet Data Convergence Protocol) data volume

All of the above parameters is measured constantly by the MG(Monitor Group) module that sends alerts when the signal rate is larger than the threshold.[6] For more clarification refer figure 2 and 3.

B. 5G(Fifth-Generation Internet)

UP(User Plane):

Types of UE:

1.**eMBB(Enhanced Mobile Broadbands):** Supports stable connections with high peak data rates.

2.**mMTC's(Massive Machines Type Communications):** Supports massive number of IoT devices that are sporadically active and keeps sending small payloads.

3.**URLLC's(Ultra Reliable Low Latency Communications):** Supports low latency transmission of small payloads with very high reliability from a limited set of terminals, which are active according to patterns typically specified by outside events such as alarms.[9]

There are also various types of technologies that are likely to come like DSRC(Dedicated Short Range Communication) in vehicles and C-V2X(Cellular Vehicle to Everything)[12] Functionalities at this level are provided by UICC[10]:

UICC(Universally Integrated Circuit Card): It is a tamper resistant entity to resist software and harware attacks.It has several applications and one of the applications is USIM.

SIM and USIM: It consists a list of PLMN's(Public Land Mobile Network) both for local usage and for roaming when you go to an unvisited place.It also consists of data regarding the Person to which it is belonging.It also provides Network Slice Specific Authentication.

CP(Control Plane):

Mobility Management Entities(MME): The flexible nature of 5G will support different mobility management methods.(refer figure 4) Devices may be[3]:

• stationary during their entire usable life (e.g., sensors embedded in infrastructure)

• stationary during active periods, but nomadic between activations (e.g., fixed access)

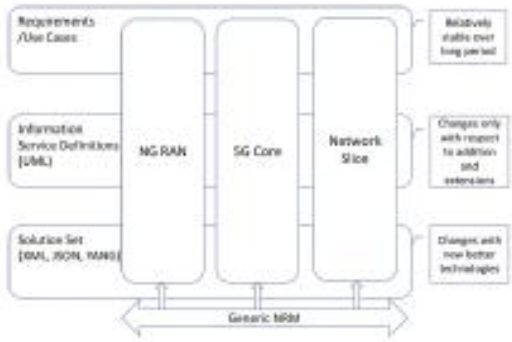

Fig. 4: Network Resource model[5]

• mobile within a constrained and well-defined space (e.g., in a factory), or

• fully mobile.

Access Networks(AN):

RAN: Stands for Radio Access Network.It is a technology that helps your phone to connect to the internet.

PLMN's: It stands for Public Land Mobile Networks.It is a set of networks on land that can be used if we are close enough to it.There is a list of PLMN's in the UICC(USIM) card given by Network Service Provider.

H-NOMA and H-OMA: H-NOMA(Heirarchical Non-orthogonal mutiple access) gives network access *on the basis of whoever asks first to connect.H OMA(Heirarchical Orthogonal Multiple access) gives network bandwidth fairly to all who connects to the network.*

Core Networks[2]:

GPRS(Generic Packet Radio Service):This was used during the time of 2.5G or 2G.Because of this the user plane and the control plane were tightly coupled,hence didn't give room for MME(Mobility management entity).

EPC(Enhanced Packet Core):This allowed for separation between UP and CP and made MME.

5GC:Enhanced the MME(AMF-Access and Mobility Management Function) and providing features for 5G.

Core Networks are separated because we want to achieve higher degree of VoLTE(Voice Over LTE) and IMS(IP Multimedia Subsystems) Services.

Network Slice:

Basically,with newer technologies coming out every day,the same hardware has to been used for different types of UE. Refer figure 5 and 6 ,Previously, in 2.5G and 3G networks,the same hardware was used for all kinds of applications, but majority of them only used 40% of the hardware capabilities.Hence in today's time, we want to provide verticals for different kinds of Application.Now there is 3D,Virtual Reality and High Definition.Soon network requirements will be there for holograms.Instead of developing a different Wireless technology altogether,giving flexible data rates, bandwidth and other NFV(Network Function Virtualisation) by using Slicing is emphasized for different kinds of UE.Network slices are a very significant business for the operators to provide a slice of an instance of the hardware on the network.Charges are applied according to the user's activities per slice.[8]

Fig. 5: Types of network slicing[13]

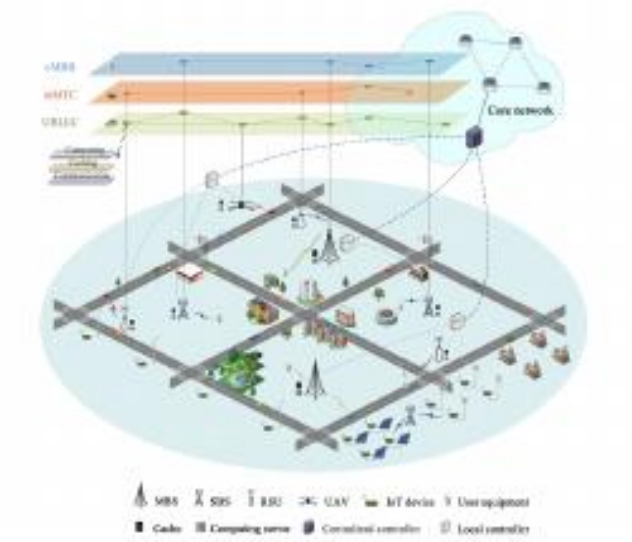

Fig. 6: Network Slicing Visualisation[7]

Network slicing enables the coexistence of multiple isolated and independent virtual (logical) networks,i.e., slices, on the same physical network infrastructure. The advantages of network slicing are multi-fold. First, through the multiplexing of the virtual networks, network slicing supports multi-tenancy, i.e., multiple virtual network operators (VNOs) sharing the same physical network infrastructure. This reduces capital expense in network deployment and operation.

Second, network slicing provides the potential to create customized slices for different service types with various QoS requirements, which can achieve service differentiation and guarantee service level agreement (SLA) for each service type. Third, as slices can be created on-demand and modified or annulled as needed, network slicing increases the flexibility and adaptability in network management[7].

IoC(Information Object Classes)[5]:These are the modules that are used to provide meta data/configuration for different Network Slices.Hence Network slices can be dynamically created and/or destroyed according to the needs.Contains Compute, Storage and Networking Resources.These are the basis of NRM's(Network Resource Models).

AI and DL in Network Slicing[7]: Applications of supervised learning:Traffic classification, smart offloading , sub-6 GHz to millimeter wave (mm Wave) frequency handover, and mm Wave beam alignment.

Applications of Unsupervised Learning:Spectrum sensing and traffic volume prediction.

Applications of Reinforcement Learning:Protocol design and user scheduling with resource allocation .

RDL(Reinforcement Deep Learning):Radio resource based slicing and priority-based core networks slicing is also done.[8]

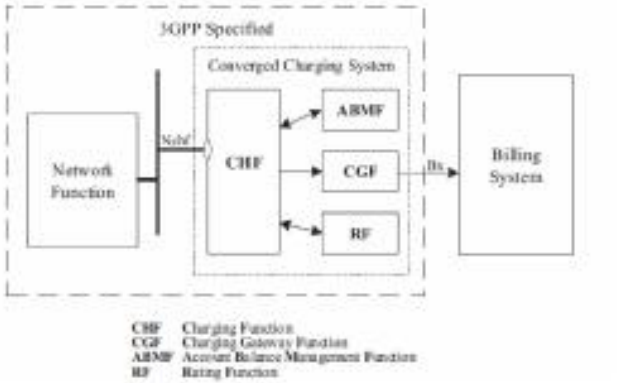

Fig. 7: Billing Function[4]

Service Data Flows(SDF):

Billing Mechanisms[4]: *Refer figure 7, Earlier there was only physical billing,then there was online billing,the one below is used for 5G where both physical and online management is done.[4] Also it is charged according to the network slice being used currently(By using whatever NFV at the Core Network Level).For CGF,it sees the data as coming from the service provider.*

Quality of Services(QoS)[1]: *QoS, or Quality of Service, is about setting rules on your internet to prioritize certain types of data over others. It helps ensure that important stuff like video calls and online gaming gets through quickly and smoothly, even when the internet is busy.*

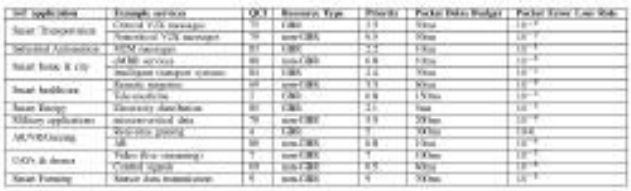

Fig. 7.1 QoS[11]

Test-Beds for Testing these technologies[13]:

1. Alba Eulia Smart City is like a playground for trying out new ideas in how to make cities better. They use things like

smart devices and computers to help save energy and make life easier for people who live there.

2. Hamburg Port is like a big testing area for new ways to move things around on ships. They use special technology to help ships carry cargo more efficiently and make the port run smoother.

3. Bristol is a cool place where they try out smart city stuff, like making transportation better and keeping an eye on the environment. They use smart tech to make living there nicer and greener for everyone.

Challenges for Implementations[12]:

Fig.7.2 Challenges for Implementation

C. 6G(Sixth-Generation):

Key Performance Indicator	5G	6G
System Capacity		
Peak Data Rate (Gbps)	20	1000
Experienced Data Rate (Gbps)	0.1	1
Peak Spectral Efficiency (b/s/Hz)	30	60
Experienced Spectral Efficiency (b/s/Hz)	0.3	3
Maximum Channel Bandwidth (GHz)	1	100
Area Traffic Capacity (Mbps/m^2)	10	1000
Connection Density (devices/km^2)	10^6	10^7
System Latency		
End-to-end Latency (ms)	1	0.1
Delay Jitter (ms)	NA	10^{-3}
System Management		
Energy Efficiency (Tb/J)	NA	1
Reliability (Packet Error Rate)	10^{-5}	10^{-9}
Mobility (km/h)	500	1000

Fig.7.3 Evolution 5G to 6G[14]

Uses of 6G network[14]:

1) ***Multi-Sensory Holographic Teleportation:*** *which is 3D holographic image and we can use that in various field such as Advanced healthcare, surgery, video conference*
2) ***Autonomous Vehicles:*** *In autonomous vehicles ensuring real-time mapping, route optimisation, traffic information, and safety data exchange.*

Fig. 8: OverView of 6G network[15]

3) ***Smart Infrastructure:*** *Increasing the efficiency and management of infrastructure systems through smart technologies and communication networks.*
4) ***Space Connectivity:*** *establishing communication and data exchange in space through technologies like CubeSats and UAVs and gaining knowledge beyond earth.*
5) ***Industrial Automation:*** *Supporting automation processes in industries through reliable and high-speed wireless communication networks.*
6) ***Metaverse:*** *it is presented as potential enabler for 6G. By connecting people, we can get solution to various problem such as skill shortage, global pandemic, etc but it will also increase energy consumption.[18]*

What can we achieve from 6G?

Terahertz Band communication: *it have high data rate and Wide bandwidth. With wide bandwidth it provides very large range of channels and even larger then 5G so we are getting higher frequencies.*

Intelligent communication environment:*it is system with multiple antennas in wireless environment which manipulates network to get better efficiency and performance*

Pervasive AI: *By integrating ai with network, we can achieve network management with ai and also can get solution to that problem which we are not getting with 5G.*

Network automation: *It tells about future unrestricted network wireless access and it provides vision of future 6G and beyond.*

6G Radio: *it represent solution to overcrowding of electromagnetic spectrum. As 6G works with terahertz bandwidth, we can increase data rates of network.*

Ambient backscatter communication: *This method takes radio frequency from the environment and by reflecting and modulating frequency it establish connection with energy efficient for future wireless connection.*

Internet of space things with CubeSats and UAVs: *it represent spacial expansion of IOT in space and it says why*

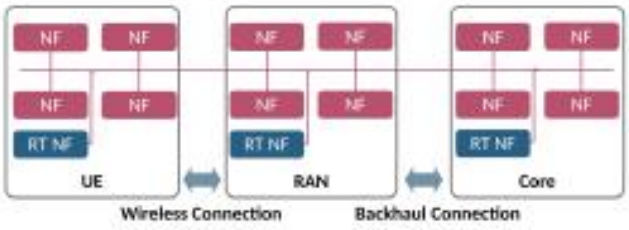

Fig. 9: continuum concept[16] UE(user equipment) RAN(radio access network) NF(network function)

Fig. 10: organic continuum structure[16]

it need to optimal energy in large-scale and IOT's growth.

Cell-free massive MIMO communication: *It eliminates inter-cell interference by distributing densely-packed antenna arrays into smaller sets with fewer elements, serving a similar number of users over a larger area[14].This approach improves network throughput, robustness and overall performance.*

Technologies beyond 6G: *It talks about internet of nano-things, internet of bio-nano-things, quantum communication and represent importance of hostile security solution for future wireless communication system.*

Open Research Challenges:

Fig. 10.1 Open Research Challenges

Organic 6G continuum Architecture concept:

The organic 6G continuum structure uses a less complex structure and has more flexibility than 5G continuum structure. It has one more functionality than 5G continuum which is AI,

Fig. 11: complexity comparison[16]

Fig. 12: flexibility comparison[16]

which enables new services and functionality. Refer figure 9 to 12. This whole organic 6G continuum is just a concept but in the near future, it can be achieved.

Carbon Footprint?

Energy aware backpressure: *it is mechanism and analytic that calculates carbon footprint and energy consumption on overall 6G infrastructure (Vertical Edge refers to customer application)*

Edge agility: *metrics from energy aware back-pressure are used in vertical application and related slices to 6G continuum enables edge agility.*

It decreases carbon footprint by 'scaling to zero' to network functionality and vertical application when and where is not needed.

D. Frequency Hopping Spread Spectrum

In Normal frequency communication, there is only one channel that act as medium of communication between sender

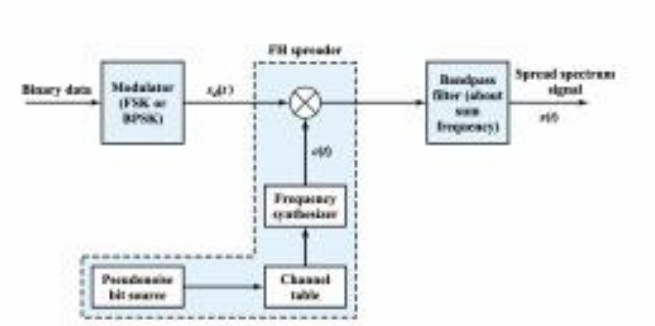

Fig. 13: FHSS Transmitter

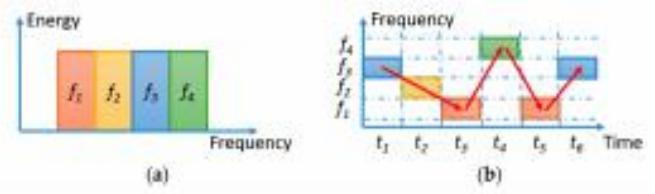

Fig. 14: Frequency Hopping Spread Spectrum

and receiver. but in fact, that is not secure and interferent communication. If frequency is known then, one can easily add some noise and interrupt communication as well as he/she can also use that information. So it can become a threat to sender and receiver. For solution for security and interference FHSS(Frequency Hopping Spread Spectrum) is introduced by Hedy Lamarr and George Antheil.

In FHSS, many frequencies are used for effective communication. Frequencies are sent to receiver and in which one channel that contains information continuously changes its frequency by hopping from one to another. The Pattern of hopping itself is only known to the sender and receiver so no one from outside can spy on the information. IN fig.14 pattern of Hoppig is (f3,f2,f1,f4,f1,f3).

There are two types of FHSS:
1) **Slow FHSS:** In which multiple channel's information are sent together with hopping. It is relatively slow communication.
2) **Fast FHSS:** In which single channel;s information is sent to the reciever with hopping. It is relatively fast communication.

Only FSK or BPSK can be used for FHSS because only these two gives coherent frequencies. ASK,PSK,QSK does not gives coherent frequencies. In fig.13 FSK or BPSK is spreaded by FH spreader. In the result, many frequencies are generated. As following, Frequency synthesizer assigns channel to perticular frequency. Then all frequencies are passed through bandpass Filter and then Spread Spectrum singnal is ready for the receiver. Receiver will take information by hopping pattern that is already known to it.

III. Conclusion

In the above overview, we've delved deep into how the technology has advanced from 2G to 3G to 4G and finally to 5G. We have a long way to go in terms of bit rate and flexibility in networks. Recent advances to bring the NFV(Network Function Virtualisation) into the make of networks definitely made it flexible, but the mathematics behind NFV is relatively very hard to understand and achieve. The concept of Networks Slicing has definitely paved the way for different verticals of applications that can now be developed.

Into the era of 6G, higher speeds, lower latency and better connectivity are bound to be a revolution. 6G wireless network is still in under development and there are many challenges to it but it is achievable in near future.There are many future directions for 6G wireless network system.6G continuum is more efficient than 5G continuum.As well as we are moving toward 6G, so we need to be aware of carbon footprint and balance between energy consumption.

Frequency Hopping Spread Spectrum is used for protection and securing information of communication from unwanted people.

In Conclusion,this review serves as a road map to anyone who wishes to know of the innovations made in the field of Data Communications and Network.

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