Ubiquitous Computing (CS60055)

Autumn Semester (2021-2022)

4G, 5G and 6G

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4G

Introduction

- The 4G wireless cellular standard was defined by the International Telecommunication Union (ITU) and specifies the key characteristics of the standard, including transmission technology and data speeds.
  - Support for interactive multimedia, voice, streaming video, Internet, and other broadband services.
  - IP based mobile system.
  - High speed, high capacity, and low cost per bit.
  - Global access, service portability, and scalable mobile services.
  - Seamless switching, and a variety of Quality of Service driven services.

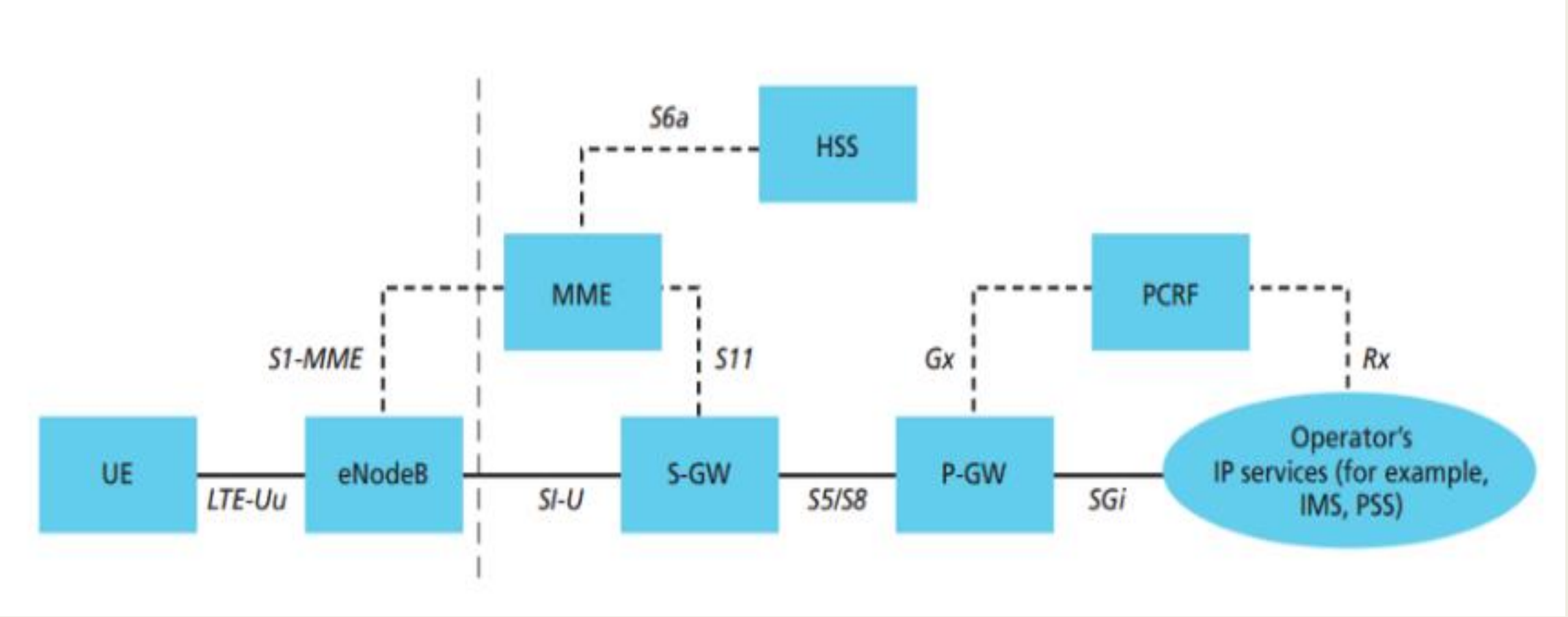
Introduction

- Better scheduling and call admission control techniques.
- Ad hoc and multi hop networks (the strict delay requirements of voice make multi hop network service a difficult problem).
- Better spectral efficiency.
- Seamless network of multiple protocols and air interfaces (since 4G will be all] IP, look for 4G systems to be compatible with all common network technologies, including 802.11, WCDMA, Blue tooth, and Hyper LAN).
- An infrastructure to handle pre existing 3G systems along with other wireless technologies, some of which are currently under development.

Various Parameters

Parameters	Description
Frequency Band	2 - 8 GHz
Bandwidth	5-20 MHz
Data rate	Up to 20 Mbps or more
Access	Multi-carrier - CDMA or OFDM(TDMA)
FEC	Concatenated codes
Switching	Packet
Mobile top speeds	200 kmph

Network Architecture



https://medium.com/@sarpkoksal/core-network-evolution-3g-vs-4g-vs-5g-7738267503c7

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Mobility Management Entity (MME):

- It is responsible for providing the Mobility and Session management to User Equipment.
- It is the control node that manages the signaling between UE and CN.
- The protocol running between UE and CN is know as NAS protocols.
- MME has 2 main functions which are bearer management and connection management.
- Bearer management is related with establishment and maintenance of bearers.
- Connection management is related with establishment of connection and security between network and UE.

Cont…

Serving Gateway(S-GW):

- It is responsible for exchanging the traffic between P-GW and 4G RAN.
- IP packets that are coming from user is passed from S-GW.
- It is like a local mobility anchor for the data bearers when UE devices moves between base stations (eNodeBs).
- S-GW is responsible for some administrative functions like collecting information about charging from networks.

Cont...

PDN Gateway (P-GW):

- It is also responsible for data traffic between S-GW and other networks like IMS or internet.
- One of main responsibility of P-GW is to assigning the IP to UE.
- It is responsible for the filtering of downlink user IP packets into the different QoS-based bearers.

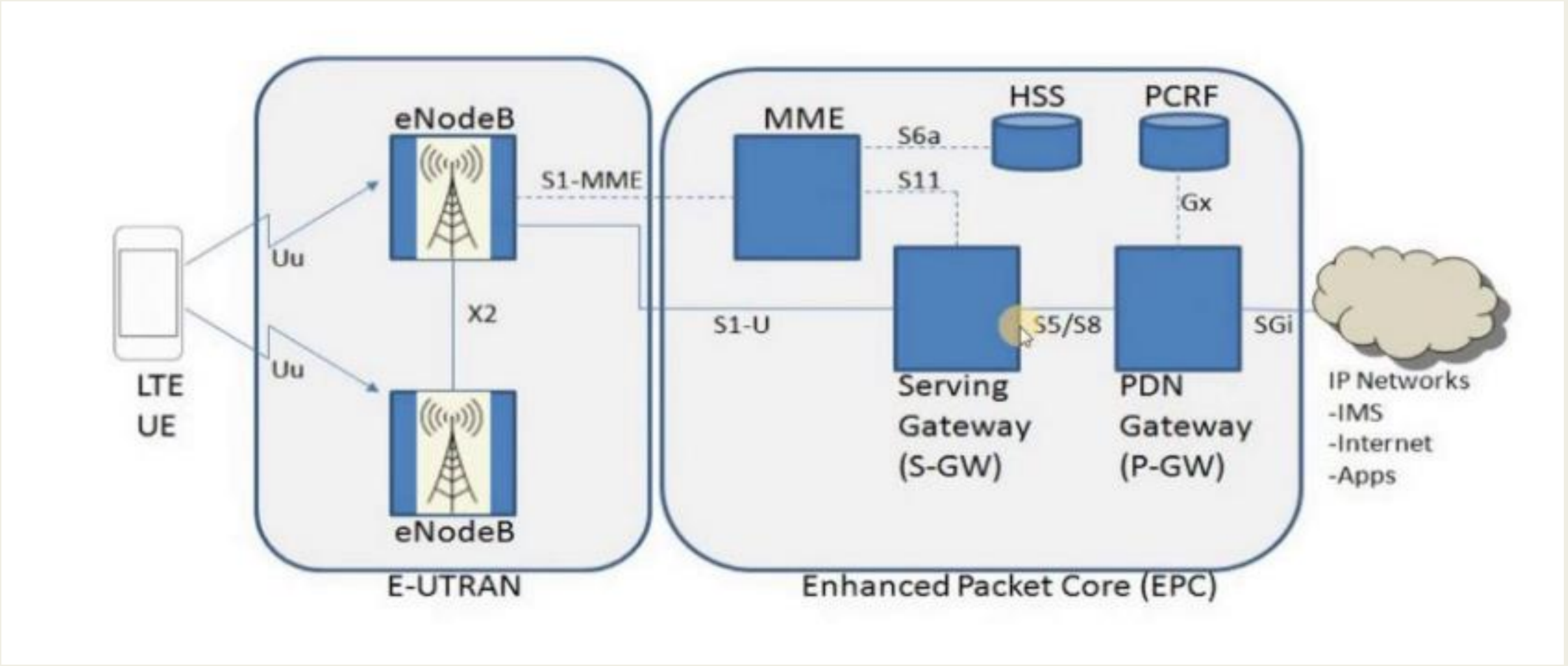
Policy and Charging Rules Functions (PCRF):

- It is responsible for providing the information of QoS to P-GW.
- This information may include charging rules, flow control rules and traffic priority.

LTE

- “LTE” stands for “Long Term Evolution.”
- LTE is a 4G wireless broadband standard.
- It is an open, interoperable standard used by virtually all carriers.
- Self-organizing network.
- Assign priorities to customers.
- Provides high speed mobile and broadband data, telephone service, and supports public safety functions.

4G/LTE Architecture



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E-UTRAN

- The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called **eNodeB** or **eNB**.
- Each eNB is a base station that controls the mobiles in one or more cells.
- The base station that is communicating with a mobile is known as its serving eNB.

EPC

EPC contains following components:

- **The Home Subscriber Server (HSS)** component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.

- **The Packet Data Network (PDN) Gateway (P-GW)** communicates with the outside world. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.

Cont…

- **The serving gateway (S-GW)** acts as a router, and forwards data between the base station and the PDN gateway.
- **The mobility management entity (MME)** controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).
- **The Policy Control and Charging Rules Function (PCRF)** is a component which is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW.

Advantages

- Better spectral efficiency
- High speed
- High capacity
- High bandwidth
- Tight network security
- High usability: any time, anywhere and any with technology
- Support for multimedia services low transmission cost
- Low cost per bit
- Affordable communication system
- Have easier access to services and application
- Increases the level of use of synchronization
- Machine to machine communication provided
- Global access, service portability, and a variety of quality of services provided
- A seamless network of multiple protocols and air interface

Disadvantages

- The battery uses is more
- Hard to implement
- Need complected hardware
- It needed to avail services of 4G technology
- The equipment required for a next-generation network is still very expensive
- The network has more problem has security issues
- High data prize for consumers
- Need different handsets
- Power consumption is high
- Roaming and data or voice work together has not yet been implemented
- Require closer base station and are expensive
- Network protocol and standardization have not to be defined
- Not many areas of 4G services yet

5G

Introduction

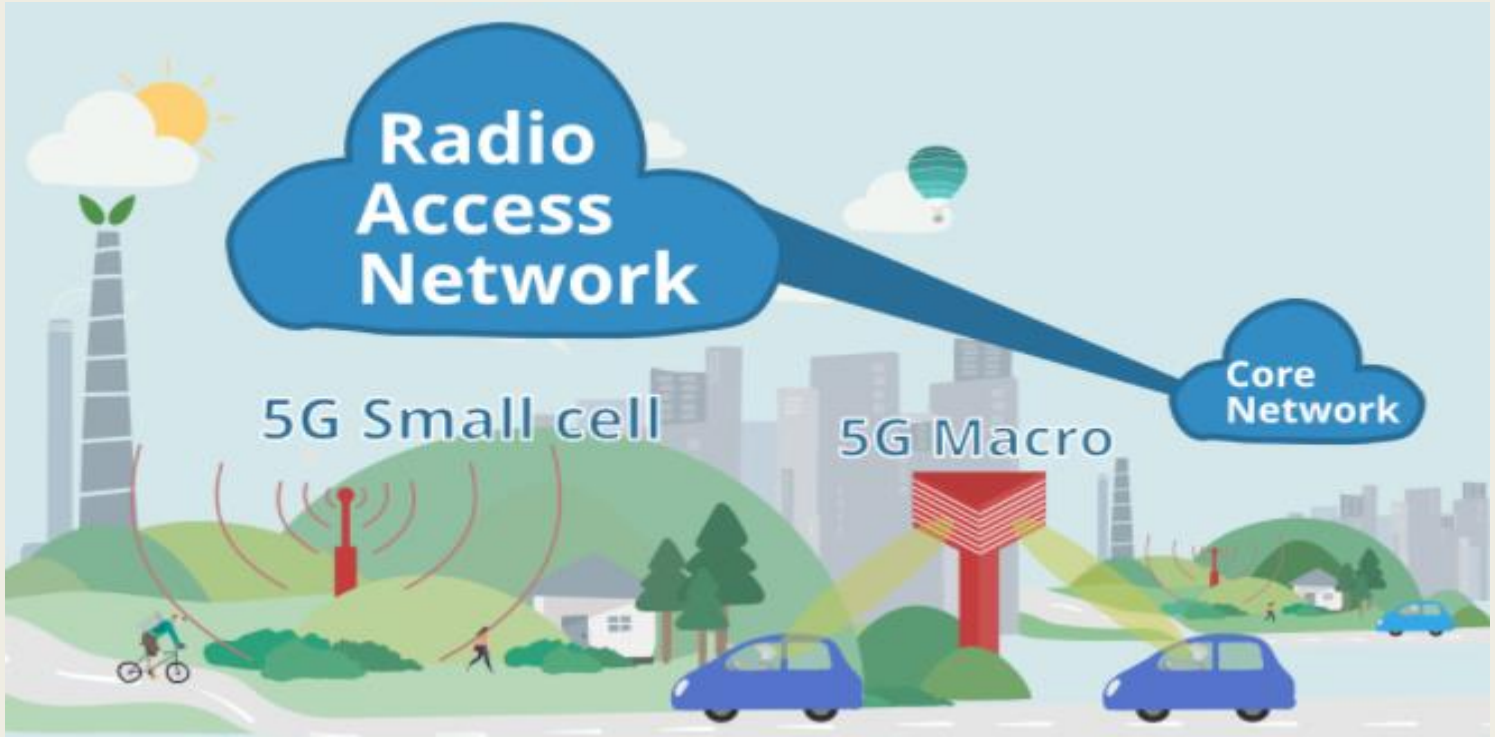
- 5G Wireless Technology is the 5th generation of mobile networks
- An evolution from the 4G LTE networks.
- Fulfill the demands of current technological trends, which includes a large growth in data and almost global connectivity along with the increasing interest in the Internet of Things.
- Data speed would be at a maximum of around **20 Gbps**.

What does it offers?

- Worldwide cellular phones
- Extraordinary data capabilities
- High connectivity
- More power & features in hand held phones
- Large phone memory, more dialing speed, more clarity in audio & video

Working

- There are basically 2 main components in the 5G Wireless Technology systems:
  - Radio Access Network
  - Core Network



https://www.geeksforgeeks.org/what-is-5g-wireless-technology-and-how-it-works/

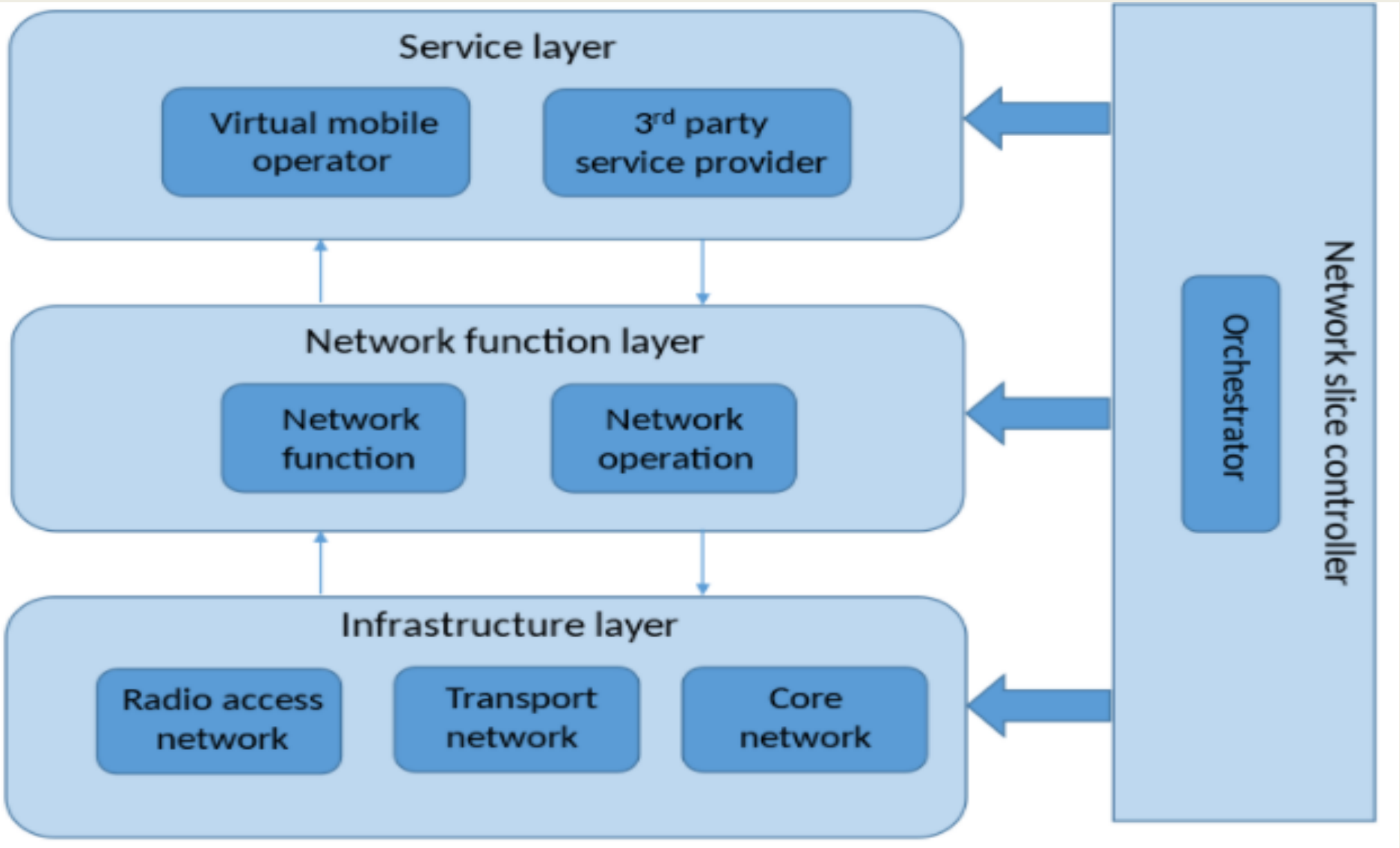
Radio Access Network

- The Radio Access Network mainly includes 5G **Small Cells** and **Macro Cells** that form the crux of 5G Wireless Technology .
- The 5G Small Cells are located in big clusters because the millimeter wave spectrum can only travel over short distances.
- These Small Cells complement the Macro Cells that are used to provide more wide-area coverage.
- Macro Cells use **MIMO** (Multiple Inputs, Multiple Outputs) antennas which have multiple connections to send and receive large amounts of data simultaneously.
- More users can connect to the network simultaneously.

Core Network

- The Core Network manages all the data and internet connections for the 5G Wireless Technology.
- It can integrate with the internet much more efficiently and it also provides additional services like *cloud-based services, distributed servers* that improve response times, etc.
- Another advanced feature of the Core Network is *network slicing.*
- **5G network slicing** is a network architecture that enables the multiplexing of virtualized and independent logical networks on the same physical network infrastructure.

5G Network Slicing Framework



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- **Service layer**
  - The service layer interfaces directly with the network business entities that share the underlying physical network and it provides a unified vision of the service requirements.
- **Network function layer**
  - The network function layer is in charge of the creation of each network slice according to service instance requests coming from the upper layer.
  - It is composed by a set of *network functions* that embody well-defined behaviors and interfaces.
- **Infrastructure layer**
  - The infrastructure layer represents the actual physical network topology upon which every network slice is multiplexed and it provides the physical network resources to host the several network functions composing each slice.

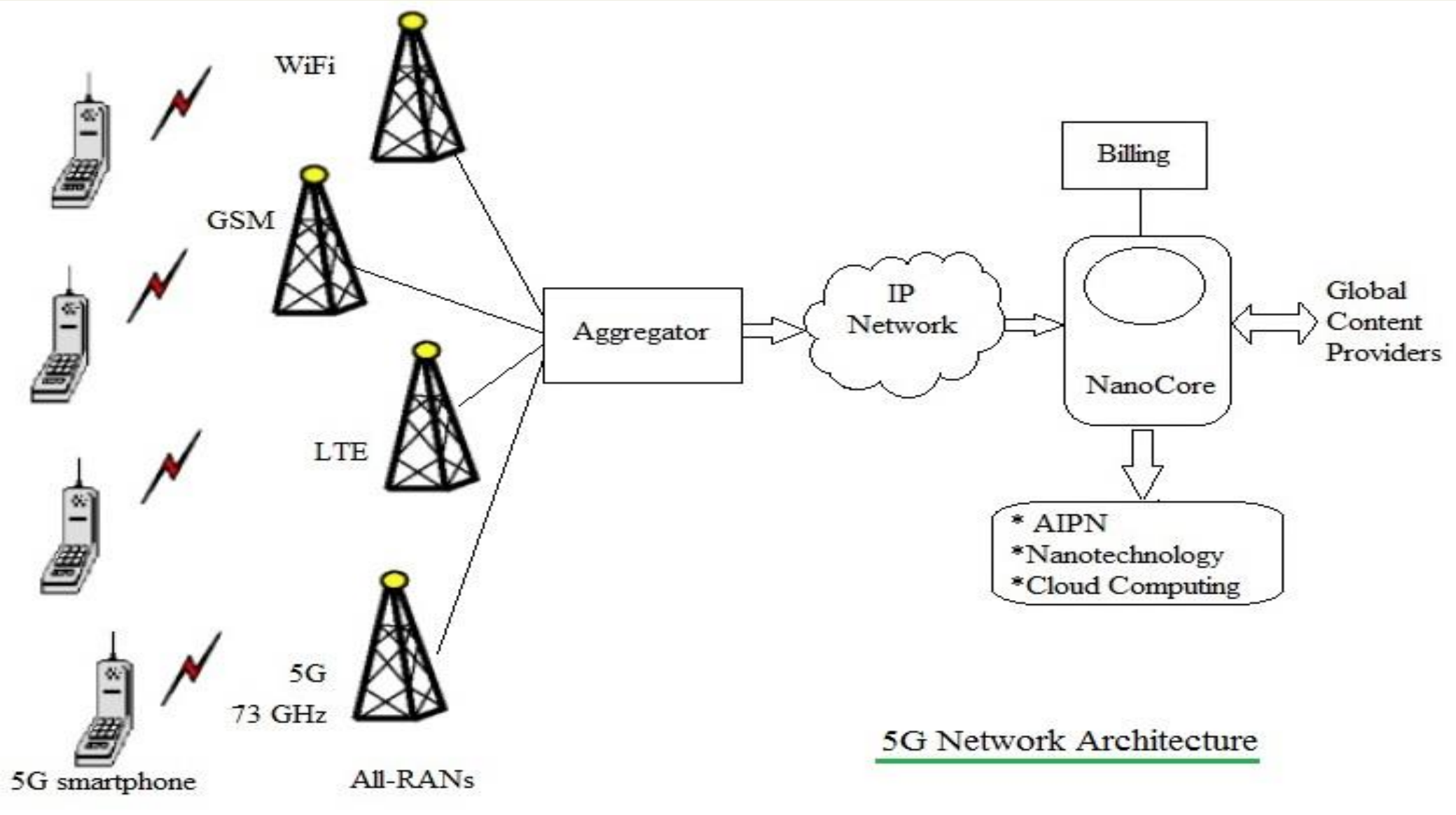
Cont...

- **Network slice controller**
  - The network slice controller is defined as a network orchestrator, which interfaces with the various functionalities performed by each layer to coherently manage each slice request.
  - **Responsible for:**
    - **End-to-end service management**: mapping of the various service instances expressed in terms of SLA requirements with suitable network functions capable of satisfying the service constraints.
    - **Virtual resources definition**: virtualization of the physical network resources in order to simplify the resources management operations performed to allocate network functions.
    - **Slice life-cycle management**: slice performance monitoring across all the three layers in order to dynamically reconfigure each slice to accommodate possible SLA requirements modifications.

Parameters of 5G technology

Peak data rate	At least 20Gbps downlink and 10Gbps uplink per mobile base station.
Real-world data rate	Download speed of 100Mbps and upload speed of 50Mbps.
Spectral efficiency	30bits/Hz downlink and 15 bits/Hz uplink. This assumes 8×4 MIMO
Latency	Maximum latency of just 4ms (compared to 20ms for LTE)
Connection density	At least 1 million connected devices per square kilometre (to enable IoT support)

5G Network Architecture



https://telecomnewsrf.wordpress.com/2017/04/25/5g-network-architecture/

5G Network Architecture

- Uses flat IP concept so that different RANs (Radio Access Networks) can use the same single Nanocore for communication.
- Flat IP architecture identify devices using symbolic names unlike hierarchical architecture where in normal IP addresses are used.
- 5G aggregator aggregates all the RAN traffics and route it to gateway. 5G aggregator is located at BSC/RNC place.
- 5G mobile terminal houses different radio interfaces for each RAT in order to provide support for all the spectrum access and wireless technologies.
- 5G nano core consists of nanotechnology, cloud computing and all IP architecture.
- Cloud computing utilizes internet as well as central remote servers to maintain data and applications of the users.
- Global content service providers support following applications:
  • Search engine, education, public portal, private portal, government, medical, transportation, banking etc.

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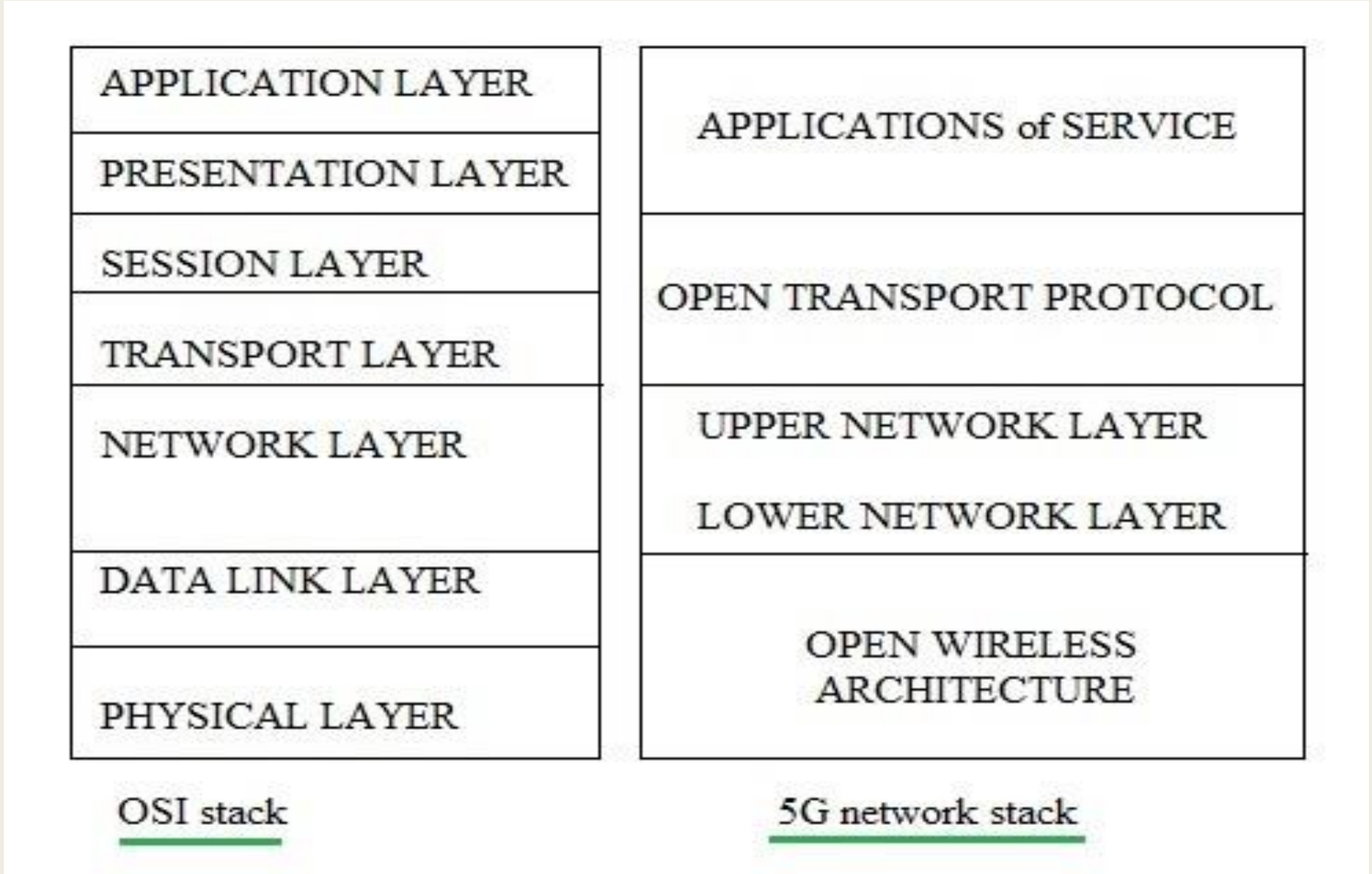
Network Stack of 5G



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Network Stack of 5G

- **OWA Layer:** OWA layer is the short form of Open Wireless Architecture layer. It functions as physical layer and data link layer of OSI stack.
- **Network Layer:** It is used to route data from source IP device to the destination IP device/system. It is divided into lower and upper network layers.
- **Open Transport Layer:** It combines functionality of both transport layer and session layer.
- **Application Layer:** It marks the data as per proper format required. It also does encryption and decryption of the data. It selects the best wireless connection for given service.

https://telecomnewsrf.wordpress.com/2017/04/25/5g-network-architecture/

Hardware & Software of 5G

- **5G Hardware:**
  - Uses UWB (Ultra Wide Band) networks with higher BW at low energy levels
  - BW is of 4000 Mbps, which is 400 times faster than today's wireless networks
  - Uses smart antenna
  - Uses CDMA (Code Division Multiple Access)

- **5G Software:**
  - 5G will be single unified standard of different wireless networks, including LAN technologies, LAN/WAN, WWWW- World Wide Wireless Web, unified IP & seamless combination of broadband
  - Software defined radio, encryption, flexibility, Anti-Virus

Advantages of 5G

- Data BW of 1 Gbps or higher
- Globally accessible
- Dynamic information access
- Available at low cost

Applications of 5G

- Wearable devices with AI (Artificial Intelligence) capabilities
- Pervasive (Global) networks
- Media independent handover
- Radio resource management
- VoIP (Voice over IP) enabled devices
- With 6^{th} sense technology

Comparison between 4G and 5G

BASIS OF COMPARISON	4G	5G
Connection Density	Supports less devices per unit area when compared to 5G.	5G is expected to support many more connected devices than 4G. The standard states that 5G network map should be able to support 1 million connected devices per square kilometer.
Speed	Has low speed when compared to 5G.	Greater speed, enough to download a full-length HD movie in few seconds.
Application	Application Is still limited to internet access.	5G technology is anticipated to be utilized widely for applications such as smart logistics, driverless cars and other such smart applications which demand high-speed internet.
Coverage	4G has a limited coverage area.	5G is expected to have a better coverage area and high data rate at the edge of the cell.
Multiple Data Transfer Rate	No multiple data transfer rate.	Availability of multiple data transfer rate.

6G

Introduction

- 6G technology refers to the sixth generation technology.
- It is proposed to integrate 5G technology for a global coverage.
- For resource monitoring and weather information multimedia video and high-speed Internet connectivity and the Earth imaging satellite networks are used.
- To integrate these three kinds of satellite like telecommunication, navigation, multimedia networks which provide global positions, internet connectivity with high speed and for mobile user's weather information services are major three objectives for 6G technology.

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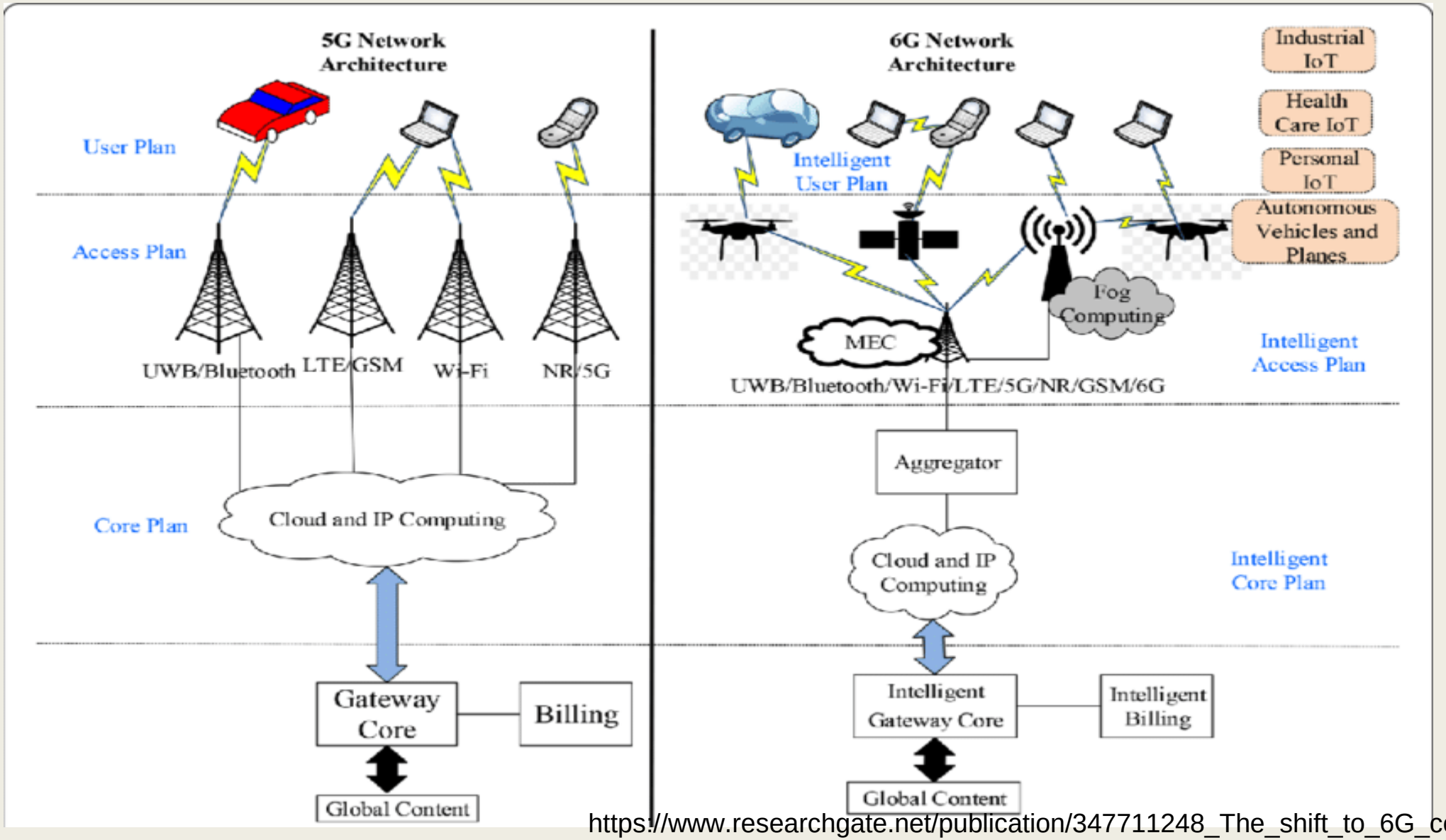


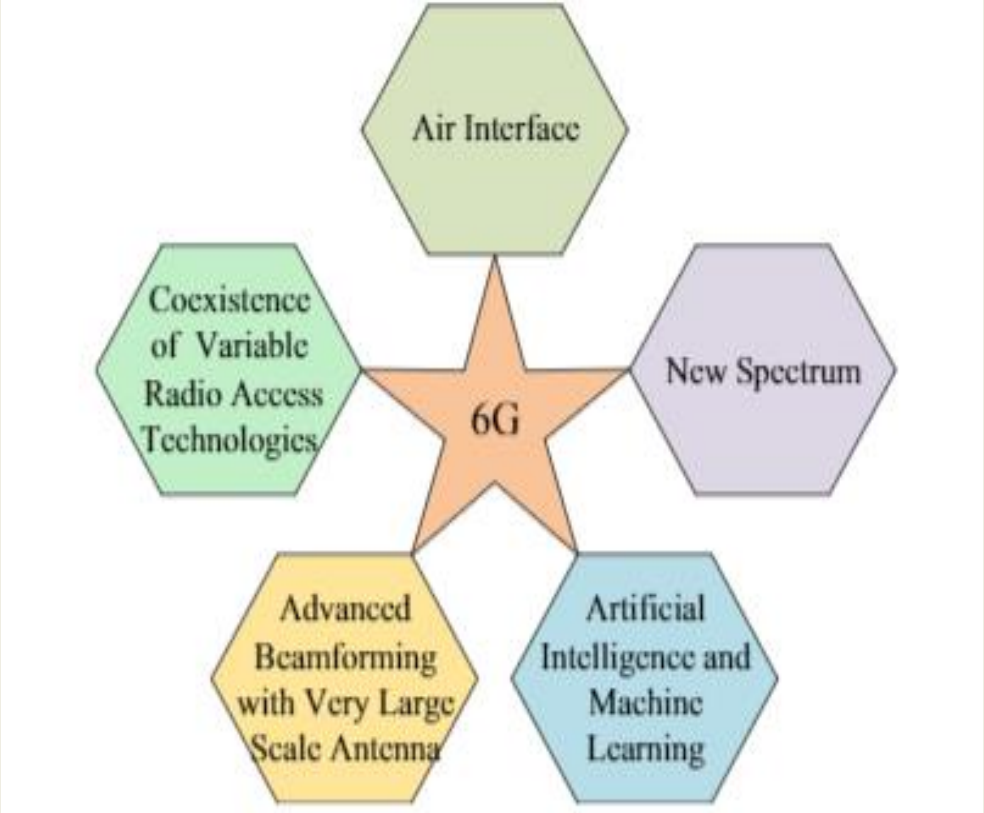
https://www.researchgate.net/publication/347711248_The_shift_to_6G_communications_vision_and_requirements

Architecture

Air interface: 6G concentrate on the current terahertz frequency range with extremely wide bandwidths available, it will bring up new obstacles to interact efficiently at these frequencies.

New spectrum: The idea of using an unlicensed spectrum is proposed, i.e., to use the mmWave, THz band, and visible light spectrum, simultaneously.

Artificial intelligence/machine learning: B5G/6G wireless networks have increased complexity, requiring smarter methods for handling any losses and handling network features, detecting anomalies, and understanding KPI trends. This can be done by introducing solutions for ML and SDN.



Architecture

Advanced beamforming with very large scale antenna (VLSA):

- The idea of beamforming is to steer the beam to only the desired direction or user.
- Since energy is not spread in all directions, the transmission range is thus improved by concentrating the beam in one direction.

Intelligent Reflecting Surfaces (IRSs) :

- IRSs can be the potential area for beamforming in 6G.
- IRSs are composed of thin electromagnetic materials, which can reflect/configure the incoming electromagnetic rays in an intelligent way by configuring the phase of reflected rays by a software.

Orbital angular momentum (OAM)-aided MIMO:

- OAM can have an unlimited number of orthogonal modes, which allows the EW to multiplex multiple data streams over the same spatial channel, thereby, enhancing the spectral efficiency and transmission capacity.
- OAM support a high number of user in mode division multiple access (MDMA) scheme without utilizing extra resources (i.e., frequency, time, and power).

Advantages

- Ultra fast to access Internet.
- Data rates up to 10-11 Gbps.
- Home automation and other related applications.
- Smart Homes, Cities and Villages.
- Used in the production of Energy from galactic world.
- Space technology and Defense applications will be modified with 6G networks.
- Home based ATM systems.
- Satellite to Satellite Communication for the development of mankind.
- Natural Calamities will be controlled with 6G networks.
- Sea to Space Communication

Challenges

- Wireless Big Data
- Portable and Low-Latency Algorithm
- Hardware Co-Design
- Power Supply
- Network Security Issue

Comparison between 5G and 6G

Features	5G	6G
Year	2015	After 5G onwards
Speed	1Gbps and Higher	10 to 11Gbps
Technology	4G+WWW	5G+Satellite
Standards	WiMAX LAS CDMA, OFDM, MC-CDMA, UWB, Network-LMDS, IPv6	GPS, COMPASS, GLONASS, Galileo systems
Core Network	Internet	Internet
Handoff	Horizontal & Vertical	Horizontal & Vertical

Thank you!!!