FADARE RASAQ OMOTUNDE

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ELECTRICAL/ELECTRONICS ENGINEERING

DEPARTMENT

DIGITAL COMMUNICATIONS – EEE 512

FIRST ASSIGNMENT

AFE BABALOLA UNIVERSITY, ADO-EKITI

Question 1(I)

3G Working principle

1) From 2G to 3G: Public wide-area wireless networks migrated from 2G systems, developed for low-bandwidth circuit-switched services, toward 3G systems, designed to support higher data rates and packet-switched services. Several 3G systems are developed evolving from different 2G roots and with different radio technologies. For the sake of simplicity, we focus here on the Universal Mobile Telecommunication System (UMTS), developed by 3GPP as an evolution of GSM. However, since all 3G systems share the same fundamental structure and functionalities, most of the security concepts presented here are common to other 3G platforms as well. During the migration path from GSM to UMTS, an intermediate phase is General Packet Radio Service (GPRS), a so-called 2.5G technology. With GPRS, the existing GSM Radio Access Network (RAN) is augmented with packet switching capabilities for data services, and a new packet switched core network (PS-CN) is added in parallel to the legacy circuit-switched core network (CS-CN) to carry data traffic. Besides the evolved GSM/GPRS RAN, the PS-CN will eventually connect to the new UMTS RAN (UTRAN) based on WCDMA. It is expected that for many operators GSM/GPRS and UTRAN will coexist for a long while, resulting in a mixture of 2.5G and 3G technologies with a common PS-CN.

2) UMTS Network Architecture: The network structure is depicted in Figure 1.

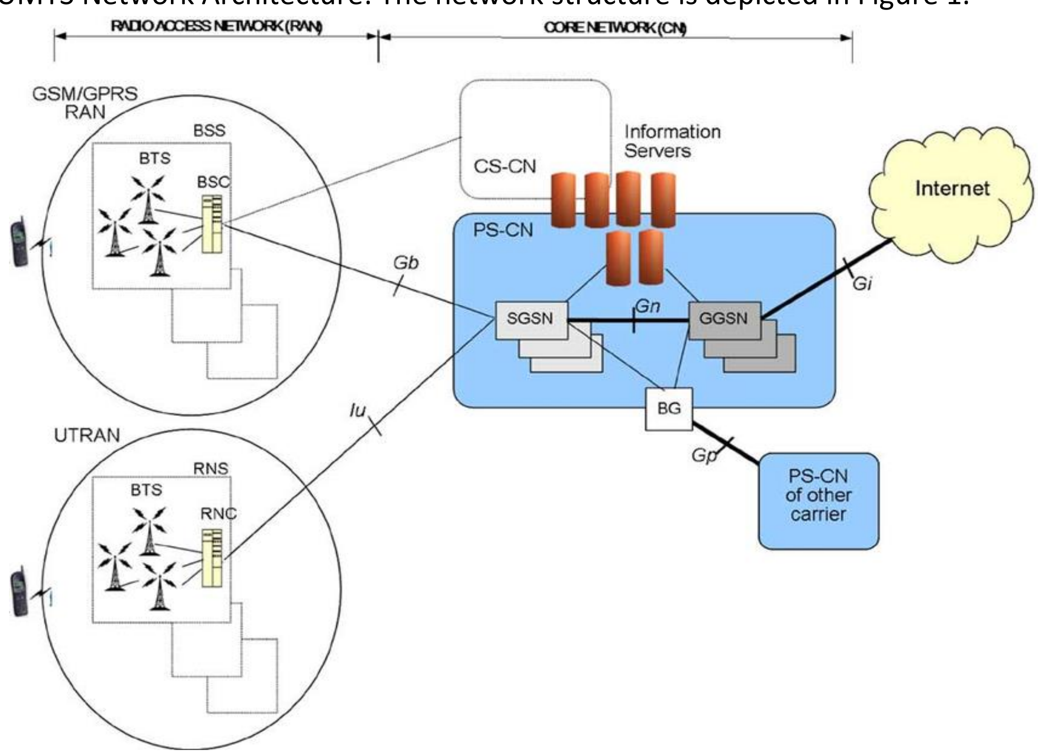

Figure 1: 3G (UMTS) architecture

UTRAN is divided into subsystems, each consisting of one radio network controller (RNC) connected to several base transceiver stations (BTSs). The BTSs maintain the air interface in the cells, while the RNC controls the radio connections with the mobile stations (MSs) and the wired interface to the CN. The GSM/GPRS RAN has a similar structure. The PS-CN embeds several elements: SGSN, GGSN, and multiple information servers.

Each SGSN interconnects one or more RNC to the PS-CN, and performs functions like access control, mobility management, paging, and route management. The GGSN is the logical gateway between PS-CN and any external packet networks (e.g., the Internet, private intranets) and is endowed with a full IP stack. It also handles the IP-level connectivity with the MS. The SGSN and GGSN of the same operator communicate through the Gn interface. In addition, the PS-CNs of different operators are interconnected through the Gp interface to support roaming. The information servers play an important role in the control plane in 2.5G/3G networks. Among them, the home location register (HLR) maintains all subscriber information, including SGSN-level location tracking, while the authentication center (AuC) is responsible for subscriber authentication. Additionally, a number of traditional IP-based servers (e.g., DNS, DHCP, RADIUS) reside in the PS-CN for control and management purposes and interact with the SGSN/ GGSN. Each MS embeds two components that are physically and logically distinct: a software/hardware terminal (e.g., cellphone, smartphone, PDA, laptop) and a subscriber identity module (SIM), which is a tamper-resistant smart card storing a unique identifier and associated secret keys. The UMTS SIM (USIM) is capable of internal processing, and the cryptographic algorithms involved in authentication are executed directly on it. In fact, it is the USIM to be authenticated rather than the terminal. The USIM is issued by the network operator. Its secret keys are known to the home AuC, and a trust relationship is in place between the USIM and the AuC. This makes the administrative separation between the terminals and the network less sharp than in other networks such as public WLANs.

4G Working principle

The 4G Architecture is new architecture developed to provide a higher level of performance in line with the
requirements of LTE. Known as SAE-System Architecture Evolution, the 4G Architecture offers many advantages compared to 2G and 3G architectures such as new routing

techniques, efficient solutions for sharing dedicated frequency band, increases mobility and bandwidth capacity. These requirements are achieved by means of several EPS network elements that have different roles. 3GPP identified in Release 8 the architecture of LTE system that serving as a basis architecture network of 4G Network. The LTE architecture includes the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC) network.

The 4G network architecture consists of the following elements:

- eNodeB
- Mobility Management Entity (MME)
- Serving Gateway (S-GW)
- Packet Data Network Gateway (P-GW)
- Home Subscriber Server (HSS)
- Policy and Charging Rules Function (PCRF)

1) E-UTRAN: Evolution and Architecture

E-UTRAN is a radio access network of 3GPP's Long-Term Evolution (LTE). It is new air interface system, which provides High speed data-rate, lower latency and is optimized for packet data. It uses OFDMA radio access for the downlink and SC-FDMA for the uplink.

In LTE, two duplexing schemes are used, time division duplexing (TDD) and frequency division duplexing(FDD). Using LTE-TDD, a single frequency channel is assigned to both the transmitter and the receiver. LTE-FDD requires paired spectrum with sufficient frequency separation to allow simultaneous transmission and reception.

The E-UTRAN Network require high speed data-rate and reliable transmissions with bandwidth efficiency. To meet these requirements Multiple input multiple-output (MIMO) system have been implemented in which multiple antennas are used in both transmitter and receiver and up to four antennas can be used by a single LTE cell .

The radio access network E-UTRAN achieve many functionalities Including:

- Radio resource management (RRM)
- Provides initial access to the network, registration, and attach/detach to the network
- Mobility Management Functions
- Security Functions
- Terminal state transition
- Flexibility in spectrum usage
- Selection of an MME at UE attachment when no MME information is provided by the UE
- Handover Management—Intra-eNode

2) E-UTRAN architecture: The E-UTRAN architecture consists of eNodeBs that interfaces with the user equipment (UE) and provide user plane (PDCP/RLC/MAC/PHY) and control plane

(RRC) protocol terminations toward the user equipment (UE). eNodeB is a logical element that serving one or more E-UTRAN cells and eNodeBs are normally interconnected with each other by means of an interface known as X2, and are also connected by means of the S1 interface to the Evolved Packet Core (EPC), specifically to the Mobility Management Entity (MME) by means of the S1-MME interface and to the Serving Gateway (SGW) by means of the S1-U interface.

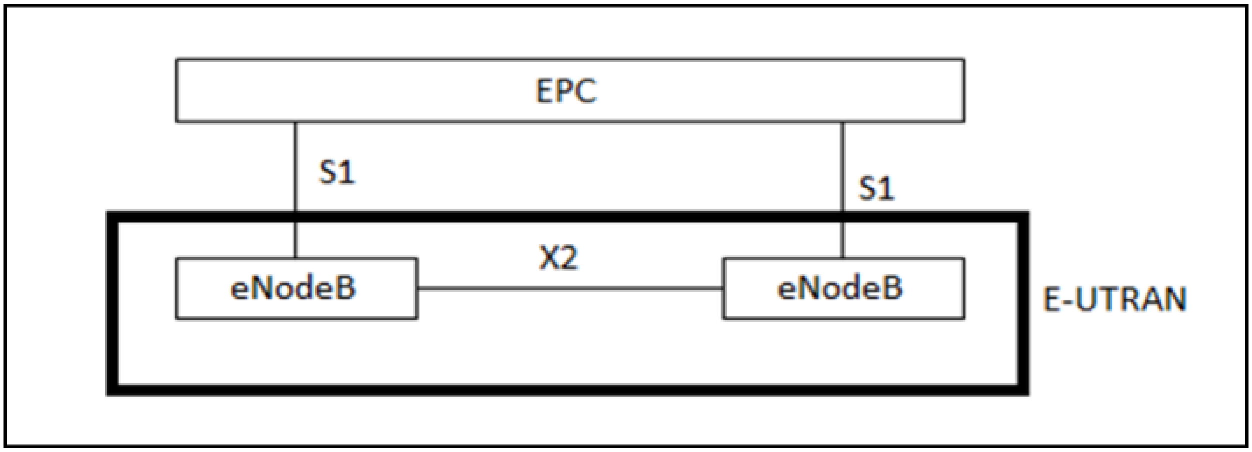

Figure 2: E-UTRAN Architecture

The E-UTRAN in LTE architecture consists of a single node, i.e., the eNodeB that interfaces with the user equipment (UE). The aim of this simplification is to reduce the latency of all radio interface operations. eNodeBs are connected to each other via the X2 interface, and they connect to the PS core network (EPC) by means of the S1 interface. The eNodeBs are normally interconnected with each other by means of an interface known as "X2" and to the EPC by means of the S1 interface. The eNBs are also connected by means of the S1 interface to the Evolved Packet Core (EPC).

3) EPC: Components and Functions
Presented as the latest evolution of the 3GPP core network architecture the Evolved Packet core EPC is a new, all-IP mobile core network developed by 3GPP to allow handover between different technologies. The Evolved packet Core EPC is specified by 3GPP Release 8 standards to improve network performance by the separation of control and data planes and through a IP architecture. The EPC network elements are escribed in more detail in Figure 3.
The EPC Functions include:
- Network Access Control Functions.
- Packet Routing and Transfer Functions.
- Mobility Management Functions.
- Security Functions.
- Radio Resource Management Functions.
- Network Management Functions.
- Charging Functions.

The EPC is composed of several function entities:

- Mobility Management Entity (MME): The MME is the key control node for the LTE access network. It is responsible for idle mode UE tracking and paging procedure including retransmissions. The MME also terminates the S6a interface toward the home HSS for roaming UEs.
- PDN Gateway (P-GW): The P-GW is the anchor point for sessions towards the external Packet Data Networks. The P-GW is responsible for IP management, connection to external data networks; focus on highly scalable data connectivity, QoS enforcement and support online charging using IETF based techniques.
- Serving Gateway (S-GW): Serving a large number of eNodeBs, focus on scalability and security. The S-GW routes and forwards user data packets. It manages and stores UE contexts, e.g. Parameters of the IP bearer service and network internal routing information. The S-GW represent the termination point of the user packet data interface towards E-UTRAN.

The EPC also contains other types of nodes such as Policy and Charging Rules Function (PCRF) responsible for quality of-service (QoS) handling and charging, and the Home Subscriber Service (HSS) node that represent a database containing subscriber information. In more details, Home subscriber server (HSS) is the master database that contains the UE profiles and authentication data used by the MME for authenticating and authorizing UEs. It also stores the location information of the UE which is used for user mobility and inter-technology handovers. The HSS communicates with the MME using diameter protocol.

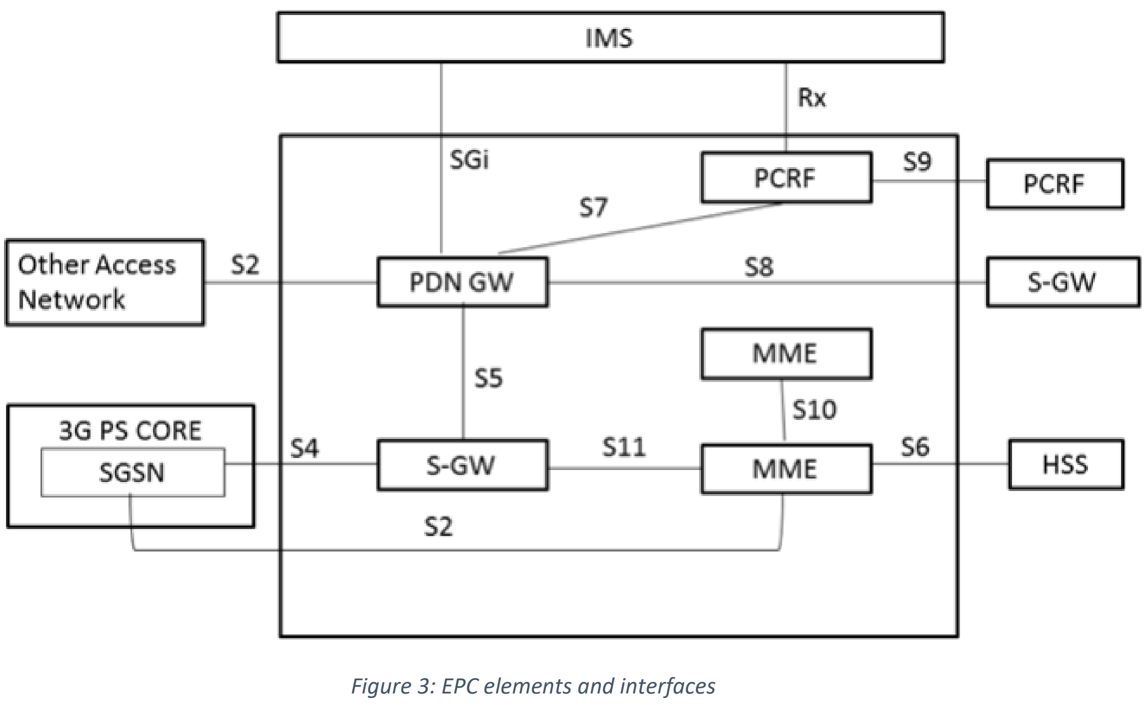

Figure 3: EPC elements and interfaces

5G working principle

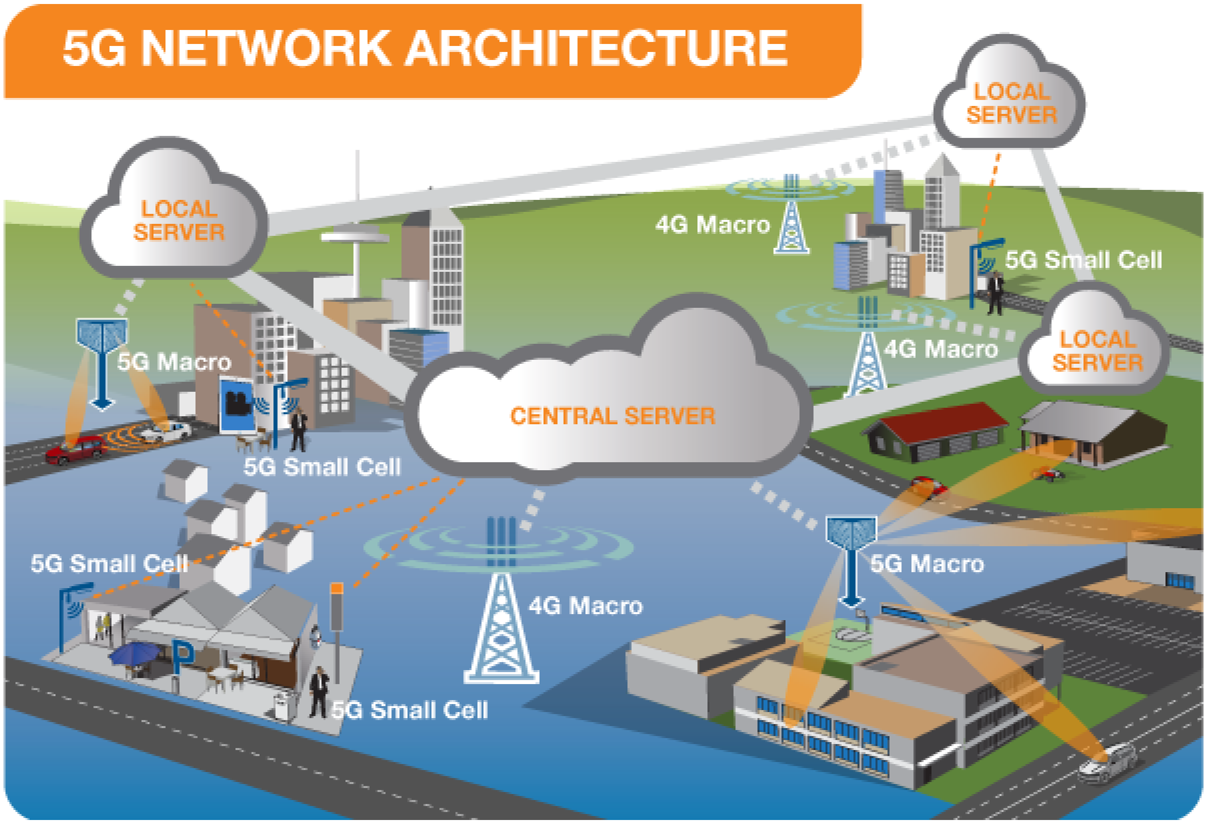

Figure 4: 5G Architecture

5G network architecture illustrating 5G and 4G working together, with central and local servers providing faster content to users and low latency applications.

A mobile network has two main components, the 'Radio Access Network' and the 'Core Network'.

The Radio Access Network - consists of various types of facilities including small cells, towers, masts and dedicated in-building and home systems that connect mobile users and wireless devices to the main core network.

Small cells will be a major feature of 5G networks particularly at the new millimetre wave (mmWave) frequencies where the connection range is very short. To provide a continuous connection, small cells will be distributed in clusters depending on where users require connection which will complement the macro network that provides wide-area coverage.

5G Macro Cells will use MIMO (multiple input, multiple output) antennas that have multiple elements or connections to send and receive more data simultaneously. The benefit to users is that more people can simultaneously connect to the network and maintain high throughput. Where MIMO antennas use very large numbers of antenna elements they are often referred to as ‘massive MIMO’, however, the physical size is similar to existing 3G and 4G base station antennas.

The Core Network - is the mobile exchange and data network that manages all of the mobile voice, data and internet connections. For 5G, the ‘core network’ is being redesigned to better integrate with the internet and cloud based services and also includes distributed servers across the network improving response times (reducing latency).

Many of the advanced features of 5G including network function virtualization and network slicing for different applications and services, will be managed in the core. The following illustration shows examples of local cloud servers providing faster content to users (movie streaming) and low latency applications for vehicle collision avoidance systems.

Network Slicing – enables a smart way to segment the network for a particular industry, business or application. For example, emergency services could operate on a network slice independently from other users.

Network Function Virtualization (NVF) - is the ability to instantiate network functions in real time at any desired location within the operator’s cloud platform. Network functions that used to run on dedicated hardware for example a firewall and encryption at business premises can now operate on software on a virtual machine. NVF is crucial to enable the speed efficiency and agility to support new business applications and is an important technology for a 5G ready core.

5G integration with 4G:

When a 5G connection is established, the User Equipment (or device) will connect to both the 4G network to provide the control signaling and to the 5G network to help provide the fast data connection by adding to the existing 4G capacity.
Where there is limited 5G coverage, the data is carried on the 4G network providing the continuous connection. Essentially with this design, the 5G network is complementing the existing 4G network.

5G networks are designed to work in conjunction with 4G networks using a range of macro cells, small cells and dedicated in-building systems. Small cells are mini base stations designed for very localized coverage typically from 10 metres to a few hundred metres providing in-fill for a larger macro network. Small cells are essential for the 5G networks as the mmWave frequencies have a very short connection range.

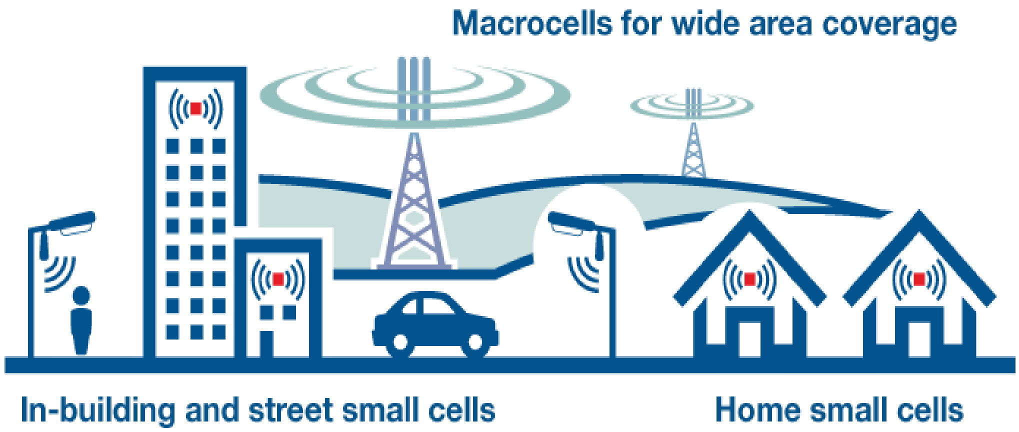

Figure 5: 5G integration

Question 1(II)

Table 1: Advantages and Disadvantages of 3G network

Advantages	Disadvantages
Faster data rates.	Requires 3G compatible handsets.
Support multimedia applications such as video and photography.	The cost of upgrading to 3G device is expensive.
Value added services like mobile television, GPS, video call and video conference.	3G requires closer base stations which is expensive.
High speed mobile internet access.	Power consumption is high.
Increased capacity.	Requires closer base stations.
Always On' Technology	

Table 2: Advantages and Disadvantages of 4G network

Advantages	Disadvantages
Quickly download files over a wireless network	Invasion of privacy is increased
Extremely high voice quality	New frequencies means new components in cell towers.
Easily access Internet, IM, social networks, streaming media, video calling	Higher data prices for consumers

Higher bandwidth	Consumer is forced to buy a new device to support the 4G
4G is 10 times faster than 3G	It is impossible to make your current equipment compatible with the 4G network
Large coverage	Reduced battery life because of increase in power consumption
10 times faster than the 3G network	Not conducive for voice communication because of expensive infrastructure.

Table 3: Advantages and disadvantages of 5G network

Advantages	Disadvantages
High resolution and bi-directional large bandwidth shaping.	Technology is still under process and research on its viability is going on.
Technology to gather all networks on one platform.	The speed, this technology is claiming seems difficult to achieve (in future, it might be) because of the incompetent technological support in most parts of the world.
More effective and efficient.	Many of the old devices would not be competent to 5G, hence, all of them need to be replaced with new one — expensive deal.
Technology to facilitate subscriber supervision tools for the quick action.	Developing infrastructure needs high cost.
Most likely, will provide a huge broadcasting data (in Gigabit), which will support more than 60,000 connections.	Security and privacy issue yet to be solved.
Easily manageable with the previous generations.	Inter-cell interference because of variation in size of macro cells and concurrent small cells.
Technological sound to support heterogeneous services (including private network).	Overload and congestion due to difficult traffic management.
Possible to provide uniform, uninterrupted, and consistent connectivity across the world.	It operates at a high frequency and that leads to a low wavelength which makes the signal coverage small.

Question 2

Table 4: Differences between 2G, 3G, 4G & 5G network

Feature	2G	3G	4G	5G
Year introduced	1990	2001	2010	2015
Technology	GSM	WCDMA	LTE, WiMAX	MIMO, mm Waves
Access system	TDMA, CDMA	CDMA	CDMA	OFDM, BDMA

Switching type	Circuit switching for voice and packet switching for data	Packet switching except for air interference	Packet switching	Packet switching
Internet service	Narrowband	Broadband	Ultra broadband	Wireless World Wide Web
Frequency	850MHz – 1.9GHz	1.6GHz – 2.5GHz	2GHz – 8GHz	3GHz to 30GHz
Bandwidth	14.4Kbps – 64Kbps	2Mbps	2Mbps – 1Gbps	1Gbps and higher
Advantage	SMS, MMs, internet access	High security, international roaming	High speed handoffs, global mobility	Extremely high speeds, low latency
Applications	Voice calls, short messages	Video conferencing, mobile tv, GPS	High speed applications, wearable devices	High res video streaming, remote control of vehicles, robots and medical procedures
Core Network	PSTN packet network	Packet network	All IP network	Flatter IP network and 5G network interfacing

Question 3

i. No, there is no correlation between 5G and corona virus.
ii. No, I do not support the statement

Justification of answers for i & ii

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus. It is propagated through contact with bodily fluids of an infected person.

5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. 5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices.

Corona virus requires contact with infected bodily fluids for it to spread and 5G transmits with millimeter waves which have very high frequency and low penetrating power/wavelength, so it is not possible for corona virus which requires contact with infected bodily fluids to be propagated by the millimeter waves transmitting the 5G network.

Hence 5G evolution does not aid the spread of corona virus (COVID-19) .