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5G Applications in Heterogeneous Network Issues and Challenges

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***Abstract:** This paper x rays an overall overview of 5G mobile communication technology and its application in a heterogeneous network. 5G (5th generation of mobile network technology) is a trade of from 4GLTE, it has better and improved performance matrix ranging from, high capacity, network segmentation and slicing, low data rate and latency, maximum throughput and network virtualization. From the evolution of 1G to 5G several advancement in technology has been recorded in mobile communication technology. With the rapid change and advancement in technology over the years human/manual intervention in communication has reduced, thus creating functionality for systems to be more specialized and intelligent. This paper also discusses in-depth 5G architecture, its ionizing effect, spectrum band in the Electromagnetic spectrum and 5G enabled-devices.*

5G is a mobile and wireless communications technology that has been developed to meet the ever growing need for improved standard of living, ease of work & play, global village connectivity, and smart things connected to their owners - YOU. 5G communication technology is for the good of humanity, as with all previous generations of communication

systems like 4G, 3G, 2G, 1G, and POTS (old telephone wires, booths, and desk phones used in offices and homes). The world is better with 5G, embrace it and enjoy the reality of being in control of your domain with the Internet of Things, Smart City, and Virtual/Augmented Reality.

5G networks n support a wide range of applications such as smart home, autonomous driving, drone operations, health and mission critical applications, Industrial IoT (IIoT), and entertainment and multimedia. Based on end users' experience, several 5G services are categorized into immersive 5G services, intelligent 5G services, omnipresent 5G services, autonomous 5G services, and public 5G services

Keywords: 5G, Virtualization, Heterogeneous, QoS

1.1 Introduction

The quest for a better communication system has lead to the evolutionary trend in mobile communications over the last few decades. The revolution and advancement from 1G-4G LTE has given rise to boundless areas to be tapped and harnessed in mobile communication, several functionalities have been put in place over the years to incorporate quality of service(QoS), high efficiency, low latency, low data rate and maximum throughput thus paving the way for 5G and other generation of mobile technology that will surface in the posterity. 5G technology is simply a transition from the 4G LTE since it leverages on the features of 4G with better performance matrix. The 5G technology implements the structural separation of hardware and software, as well as the programmability offered by SDN (Software Defined Networking) and NFV (Network Function Virtualization). With the concept of Network slices in 5G, software running on various hardware devices in each network slice can be able to communicate using API calls thereby making it possible for device-to-device (D2D) communication between different slices. With the virtualization of network in 5G, security and storage of information is guaranteed with high fidelity since information can be stored in the cloud and be accessed at anytime anywhere.

5G networks operates on up to three (3) frequency bands, low, medium, and high [1 ,2], these bands contain three different antennas, and as such 5G enabled devices are able connect to the network through the highest speed antenna within range at their location. With the segmentation of bigger cells into smaller cells in 5G, network connectivity to even remote area becomes possible and the rise of these smaller cells such as pico-cell, femto-cells gives rise to a heterogeneous network. 5G has found application in many areas spanning across medicine, manufacturing (automobile, wearable devices), education, military and government due to its interfacing with sensors forming a well of IoTs which creates boundless opportunities. For a full implementation of 5G, creation of multiple cells with close proximity to each other for efficient network coverage, high frequency and bandwidth demand with implementation of new infrastructure to facilitate the stay of 5G has formed a mythology among researchers and individual. This paper explain the features and the application of 5G as well as the effect of its radiation to human health.

1.2. Evolution of Mobile Technology

Mobile communication has become more popular in last couple of years due to fast revolution in mobile technology. This revolution is due to very high increase in telecommunication customers [3] scouting for high efficiency, low data rate and latency, maximum throughput for the services offered to them. This revolution is from 1G- the first generation, 2G- the second generation, 3G- the third generation, 4G- the forth generation, and then the 5G-the fifth generation. Based on the rapid advancement in telecommunication in years to come 6G will definitely surface.

Table 1. *Table of previous Evolution on Mobile Technology [3] [4] [19].*

S/N	Generation of Mobile Technology	Period/ Era	Distinctive Features
1	First Generation – 1G	Early 1980s	The devices (phones) used then were analogue devices and the phones were called cell phones [3]. Mobile technologies such as mobile and Advanced mobile telephone systems (AMTS/MTS), and push to talk were implemented in 1G [3]. FDMA modulation technique was employed for voice call modulation, it is operated at a frequency of 150MHz. It has low capacity, low reliability during hand-off, poor voice links and poor fidelity in the voice call since third party eavesdropping was inherent in the system [3].
2	Second Generation - 2G	1998	It operates at a speed of 64kbps and it utilizes digital signal for voice transmission [3] Using a bandwidth of 30-200KHz it enabled facility for short message service (SMS) [3]. 2.5G system which was an advancement of 2G employed packet switching and circuit switching method for data transfer at a rate of 144kbps e.g. GPRS, CDMA and EDGE [3]. 2.5G had better spectrum efficiency and security as opposed to the 2G. Introduced new feature for text message and low data rate
3.	Third Generation - 3G	2001	Circuit switching and packet switching were used respectively for voice calls and data transfer [3] It had extensive capabilities for global roaming, It operates at a range of 2100MHz and has a bandwidth of 15-20MHz used for High-speed internet service, video chatting [3] With the use of wide band voice channel 3G succeeded in making the world a little village [3]. Utilizes either circuit or packet switching, with Turbo codes for error correction [19]

4.	Fourth Generation - 4G	2008	The modulation technique employed for IEEE 802.11a is BPSK, QPSK [19]. The concept of 4G necessitate the use of high speed wireless network for the transfer of data [19] employing packet switching method for message transfer. 4G offers a downloading speed of 100Mbps [3]. 4G provides same feature as 3G and additional services with much more advanced functionality with better speed than 3G [3]. LTE (Long Term Evolution) is considered as 4G technology. 4G is being developed to accommodate the QoS (Quality of service) and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth. [3] 4G utilizes a frequency range of 2-8GHz [19] with bandwidth same as 3G (5-20MHz), while supporting data rate more than 20Mbps [19] It employs the use of multi-carrier that is either CDMA or OFDM (TDMA) with enhanced capability of integrating wireless LAN and WAN. 4G employs concatenated codes for error correction [19].

1.3. 5G Mobile Technology

5G-and-beyond communication systems not only will be more advanced but also are expected to be more complex in comparison with legacy systems. To achieve the goals of 5G-and-beyond communication systems, convergence of the heterogeneous wireless technologies has emerged as one of the key solutions. with faster response of time, virtually zero latency, very high capacity, more improved platform compatibility accommodating 100 times more devices, ubiquitous connectivity, with a wide range of application, more options to upgrade, in addition to cell splitting (wide coverage area) to improve efficiency for communication with speed up to 10Gbit/s [5]. Its first standards-based deployments began in 2018, and deployments will accelerate in 2019 and the 2020s.

A. 5G Architecture

The 5G network architecture embraces two (2) logical network layers viz; a radio network (RN) with a minimum set of layer1/layer2 functionalities and a network cloud with all higher layer functionalities [6]. Based on the design principles, NGMN (Next Generation Mobile Network) envisions an architecture that leverages the structural separation of hardware and software, as well as the programmability offered by SDN (Software Defined Networking) and NFV (Network Function Virtualization) [21]. As such, the 5G architecture is a native SDN/ NFV architecture covering aspects ranging from devices, (mobile/ fixed) infrastructure, network functions, value enabling capabilities and all the management functions to orchestrate the 5G system. APIs (Application Programming Interfaces) are provided on the relevant reference points to support multiple use cases, value creation and business models [21]. This architecture is illustrated in Figure 1.

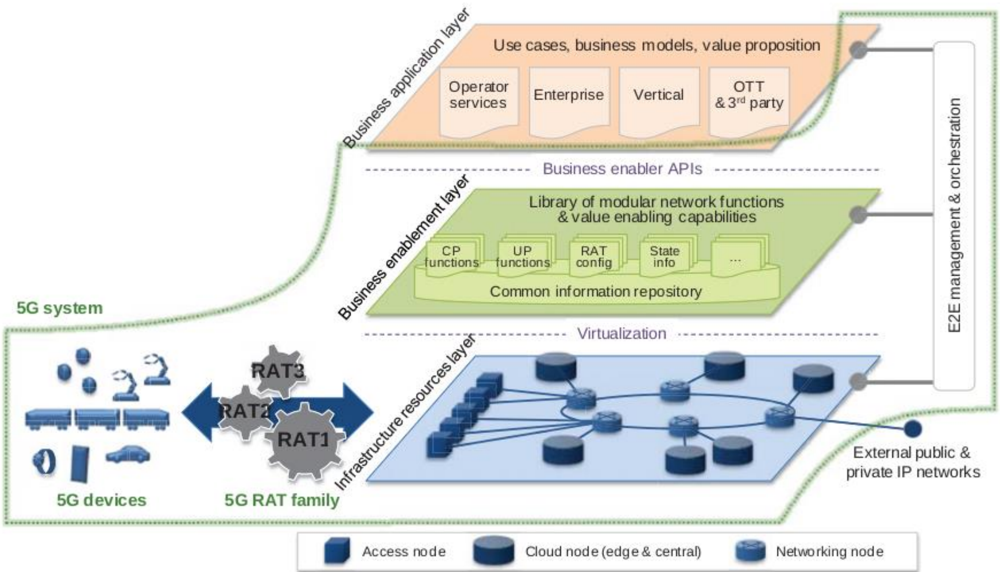

Figure 1. *5G Architecture [21].*

The architecture comprises three layers and an E2E management and orchestration entity.

The infrastructure resource layer consists of the physical resources of a fixed-mobile converged network, comprising access nodes, cloud nodes (which can be processing or storage resources), 5G devices (in the form of (smart) phones, wearables, CPEs (Customer Premises Equipment), machine type modules and others), networking nodes and associated links [21]. 5G devices may have multiple configurable capabilities and may act as a relay/ hub or a computing/ storage resource, depending on the context. Hence, 5G devices are also considered as part of the configurable infrastructure resource. The resources are exposed to higher layers and to the end-to-end management and orchestration entity through relevant APIs. Performance and status monitoring as well as configurations are intrinsic part of such an API [21].

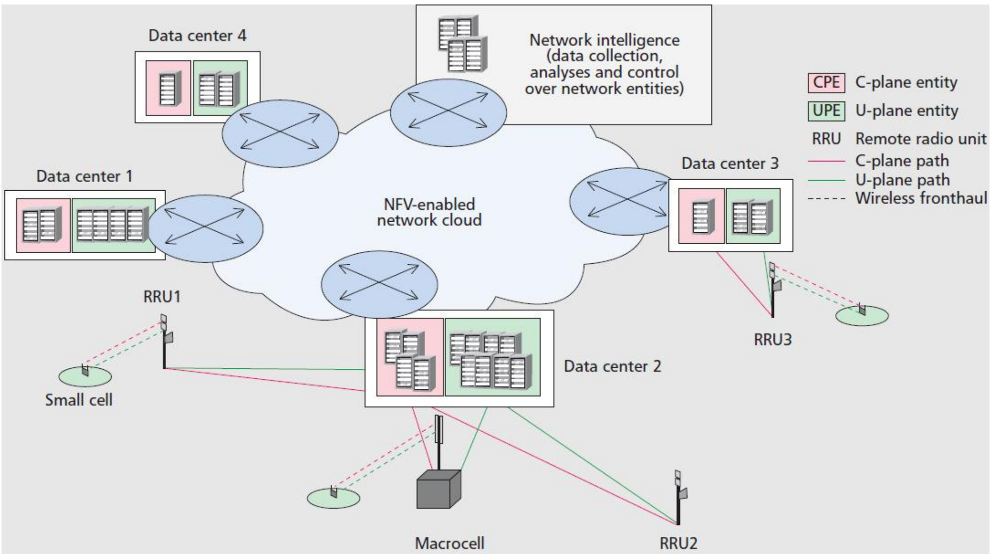

Figure 2. *5G Network Cloud [6].*

The business enablement layer is a library of all functions required within a converged network in the form of modular architecture building blocks, including functions realized by software modules that can be retrieved from the repository to the desired location, and a set of configuration parameters for certain parts of the network, e.g., radio access [21]. The functions and capabilities are called upon request by the orchestration entity, through relevant APIs. For certain functions, multiple variants might exist, e.g., different implementations of the same functionality which have different performance or characteristics. The different levels of performance and capabilities offered could be utilized to differentiate the network functionality much more than in today's networks (e.g., to offer as mobility function nomadic mobility, vehicular mobility, or aviation mobility, depending on specific needs) [21].

The business application layer contains specific applications and services of the operator, enterprise, verticals or third parties that utilize the 5G network. The interface to the end-to-end management and orchestration entity allows, for example, to build dedicated network slices for an application, or to map an application to existing network slices [21].

The E2E management and orchestration entity is the contact point to translate the use cases and business models into actual network functions and slices [21]. It defines the network slices for a given application scenario, chains the relevant modular network functions, assigns the relevant performance configurations, and finally maps all of this onto the infrastructure resources [21]. It also manages scaling of the capacity of those functions as well as their geographic distribution. In certain business models, it could also possess capabilities to allow for third parties (e.g., MVNOs and verticals) to create and manage their own network slices, through APIs and XaaS principles. Due to the various tasks of the management and orchestration entity, it will not be a monolithic piece of functionality. Rather it will be realized as a collection of modular functions that integrates advances made in different domains like NFV, SDN or SON. Furthermore, it will use data-aided intelligence to optimize all aspects of service composition and delivery [21].

Network Slicing Concept in 5G Architecture

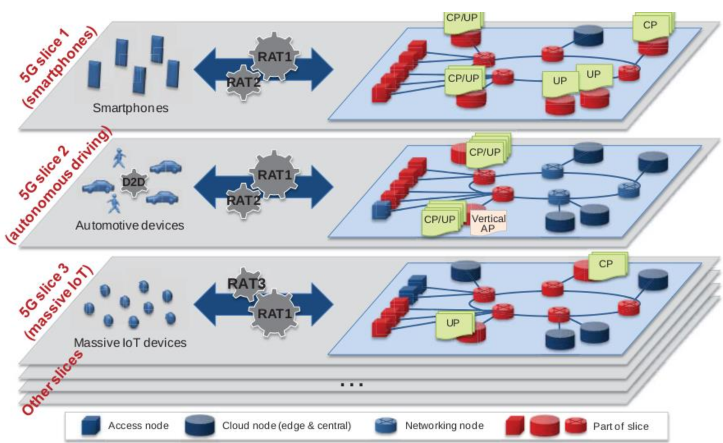

Figure 3. *5G Network Slicing [21].*

A network slice, namely "5G slice", supports the communication service of a particular connection type with a specific way of handling the C- and U-plane for this service [21]. To this end, a 5G slice is composed of a collection of 5G network functions and specific RAT settings that are combined together for the specific use case or business model. Thus, a 5G slice can span all domains of the network: software modules running on cloud nodes, specific configurations of the transport network supporting flexible location of functions, a dedicated radio configuration or even a specific RAT, as well as configuration of the 5G device [21]. Not all slices contain the same functions, and some functions that today seem essential for a mobile network might even be missing in some of the slices. The intention of a 5G slice is to provide only the traffic treatment that is necessary for the use case, and avoid all other unnecessary functionality. The flexibility behind the slice concept is a key enabler to both expand existing businesses and create new businesses. Third-party entities can be given permission to control certain aspects of slicing via a suitable API, in order to provide tailored services [21]. The 5G network should contain functionality that ensures controlled and secure operation of the network end-to-end and at any circumstance.

1. Frequency Range/ Band of 5G Network

5G networks operates on up to three (3) frequency bands, low, medium, and high [1][2]. A 5G network will composed of networks of up to 3 different antennas, each type giving a different trade off of download speed with respect to the distance and service area. 5G cell phones and wireless devices will connect to network through the highest speed antenna within range at their location.

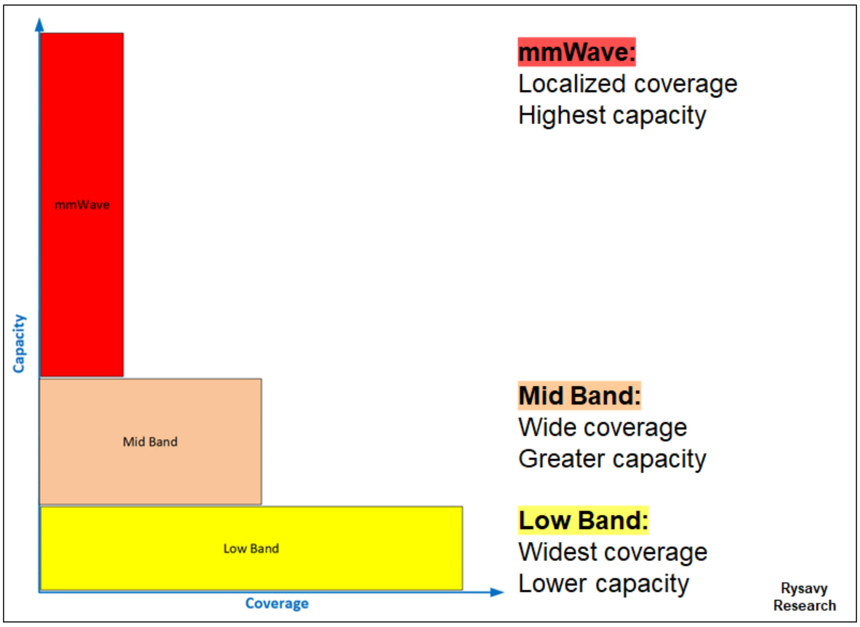

Figure 4. *Three-Tier Spectrum Usage for 5G [7*5].*

Table 2 *Showing the frequency bands accessed with 5G network [1].*

S/N	Frequency-Range	Features
1.	Low-band frequency	Uses similar frequency range as current 4G cellphones of 600-700MHz, giving a download speeds a little higher than 4G: 30-250Mbps [1]. Its coverage will depend on the location.
2.	Mid-band frequency	Uses microwaves of 2.5-3.7GHz, currently allowing speeds of 100-900Mbps, with each cell tower providing service up to several miles radius. This level of service is the most widely deployed, and should be available in most metropolitan areas in 2020.
3.	High-band frequency (mmWave band)	Uses frequency of 25-39GHz, it is near the bottom of the millimeter wave band to achieve download speeds of 1-3Gbps, comparable to cable internet. The mmWave or mmW only have a range of about 1 mile (1.6Km), requiring many small cells, and have trouble passing through some types of building walls. Millimeter Wave operates at a frequency of 26GHz [1].

2. 5G Network in Heterogeneous Network [8]

The concept of heterogeneous network spans across small cell utilization, new carrier type, long term evolution (LTE) and WiFi coexistence, device-to-device communication.

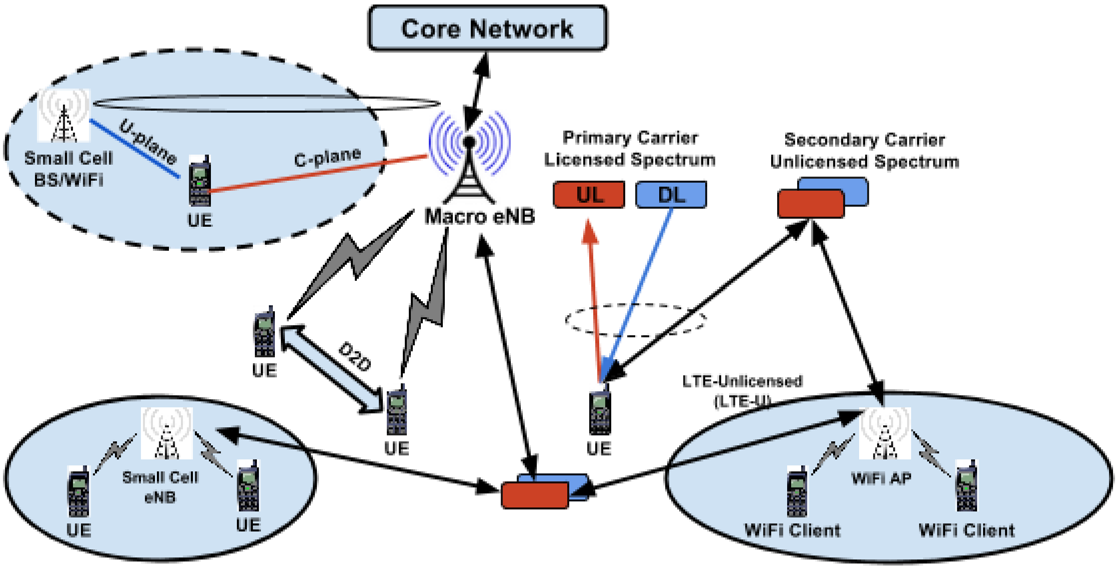

Figure 5. *5G Heterogeneous Network [8].*

Small Cells

Next generation 5G wireless networks will run applications requiring high demand for data rates. One of the solution to solve the data rate requirement is to allow densification of network by deploying small cells. Such densification results in higher spectral efficiency and can also reduce the power consumption of mobile due to its communication with nearby pico-cell. This solution significantly improves network coverage. However, this solution requires innovation in hardware miniaturization and cost reduction in the design of small cell base-station. Such small cell base-stations can be deployed as low powered femto-cells typically used in enterprise/residential deployments or higher powered pico-cells for improving outdoor coverage of macro cells. The concurrent operation of Macro-, micro-, pico- and femto-cells is termed as heterogeneous networks (HetNets). Interference management is one of the most critical challenges due to the uncoordinated nature of HetNet deployments. However, 3GPP has identified various scenarios and requirements in for the enhancements of small cells.

New Carrier Type

There has been recent push from both the academia and industry (3GPP) to enhance the operation of small cells by splitting control and data plane. The main idea here is that control plane provides connectivity and mobility, whereas user plane provides the data transport. This results in the fact that user equipment (UE) is connected to multiple base-stations, viz. macro and small cell. Such a definition of new carrier type in 3GPP (Rel 8-10), results in improved spectral efficiency as data transport is handled by small cell. There is also significant gain in energy efficiency of network infrastructure as small cells can be switched off in case of lightly loaded scenarios.

Long Term Evolution (LTE) and WiFi Coexistence

5G wireless network design will see lot of convergence happening between LTE/WiFi networks. There has already been push from the industry to operate LTE in unlicensed bands. Such an approach will allow easier offloading of traffic from LTE to unlicensed bands. However, such offloading poses quality of service (QoS) issues for end users due to unmanaged and over-crowded nature of today's WiFi deployments. IEEE 802.11 Working group has also initiated a study group on High Efficiency WLANs (HEW) to address the densification of access points and terminals.

Device to Device (D2D) communications

Device to Device (D2D) communications is an approach where terminals close by discover themselves automatically and interact with each other without the base-station. Such an approach is highly efficient from power control standpoint and can also reduce interference in unlicensed frequency bands.

Conventional cellular architecture does not allow for user equipments (UEs) to communicate directly. However, when the devices are close by, this can be very inefficient and D2D can be especially useful in machine-type-communication (MTC) scenarios where there are large number of devices operating closely with each other. D2D when combined with the fact that it can be coordinated with base-stations can bring significant advantages to the existing cellular architecture in terms of both energy efficiency and spectral efficiency. D2D is currently an active topic of discussion within 3GPP

3. Applications of 5G Network [7][18][20]

5G completely increases the number of use cases and potential areas of applications for wireless connectivity and they include:

1) Fixed wireless access. 5G will provide a possible alternative to wire-line broadband networks [7]. Since wired communication will run simultaneously with wireless, thus relieving wired services.
2) Augmented reality (AR) and virtual reality (VR). Higher throughput, lower latency, and edge computing will make AR

and VR over 5G mainstream [7].

3) Ultra-high definition video. Extremely high-resolution video streaming and downloads, including 4K, 8K, and 3D, will be possible over 5G, although such usage may only be feasible on a wide scale in higher capacity mm Wave bands [7].
4) Healthcare. 5G will support applications such as health monitoring through wearable/implanted devices, telemedicine, and robotic surgery [7].
5) Cloud gaming. High throughputs and low latency will enable games to be hosted in the cloud [20].
6) Automotive and smart traffic management system.. Sensors in roadways, communications between infrastructure and cars, and communications between cars, will make driving safer and more efficient, and will also support autonomous cars [20] [7]. Other automotive applications, some already possible with 4G, include vehicular internet and infotainment [7].
7) Video surveillance. Video cameras coupled with AI will become ubiquitous, improving safety and supporting many IoT applications [7].
8) Education. Many forms of connected-education will be enhanced, including high-resolution, telepresence-based distance learning. AR/VR will also play a role [7].
9) Smart cities. 5G will support high densities of sensors, surveillance, smart infrastructure, smart lighting, and safety enhancements [7].
10) Wearable computing. Low-power operation in 5G will enable cellular-network connectivity with long battery life for health and fitness [7].
11) Monitoring of infrastructure. Low-latency and long-battery-life sensors will allow rapid responses to critical events [7].
12) Manufacturing and other industrial applications. High reliability, precision timing, and low latency, as well as private-network options in 5G, will hugely expand use in industry [7].
13) Green Communication. With 5G deployment power consumption will definitely have a phase shift towards information and communication technology, which will result in the deployment of chip-sets.
14) Industrial Automation. 5Gwireless communication deployed on robots can efficiently be used for industrial automation, thereby producing smart factories [18].
15) Drones. 5G will extend the reach of controllers beyond a few kilometers or miles in the application of drones with extensive capability to be viewed above the line of site. This then can be deployed for border security, surveillance and drone delivery services [18].

1. Issues and Challenges of 5G Base Station

Microwave and millimeter wavelength radiation is non-ionizing.

1. 5G Technology and its wireless radiation is safe. This includes radiation from Transmitting Stations (aka Base Station) and User Equipment (aka Mobile Phones/Devices) that enable the communication between you and other persons on the telecommunication networks.

2. There is absolutely no correlation between 5G Technology and the novel Corona Virus Disease (COVID-19). Many cities affected by Corona Virus disease do not have 5G deployed at all.

3. 5G Technology can operate in the multiple frequency bands which falls within: a. 600MHz to 6000MHz known as sub-6GHz band;

b. 24GHz to 38GHz called mmWave band.

Both wireless radiation bands fall under the frequency spectrum range known as Non Ionising (meaning they do not affect biological cells because the power levels cannot change atomic or molecular structures). Wireless equipment radiation Power Density does not exceed 9W/m2 [based on EIRP (carrier power & antenna gain) versus Antenna sizes/area]. The radiation levels comply with the International Electrotechnical Commission (IEC) – IEC 62209-1&2 with respect to radiation exposure limit

4. 5G mobile and wireless communication products complies with the following Electromagnetic Compatibility (EMC) standards:

a. International - 3GPP TS38.113;
b. Europe - ETSI EN 301 489-1 & ETSI EN 301 489-50;
c. North America - FCC CFR 47 Part 15 B & IC ICES-003 B.

[9]. With higher frequencies and shortened ranges, base stations will be more closely packed into an area, to provide complete coverage and avoid 'not-spots'. This could mean possible ranges of 20-150 meters with smaller coverage areas per 'small cell [9] A cell radius of 20 meters would imply about 800 base stations per square kilometer (or 'small area wireless access points' (SAWAPs), the term used in the EECC). This contrasts with 3G and 4G technologies, which use large or 'macro' cells, offering ranges of 2-15 kilometers or more, and therefore covering a larger area but allowing fewer simultaneous users

since they have fewer individual channels [9]Furthermore, 5G will employ higher frequencies [11] than previous 'G' networks and greater bandwidth which will enable users to transfer wireless data faster.

2. Ionizing and Non-Ionizing Frequencies

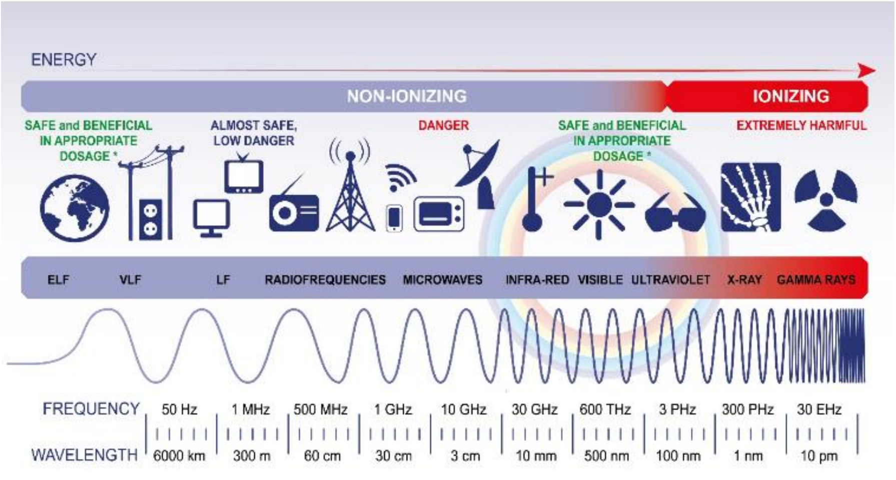

Figure 6. *Electromagnetic Radiation: Ionizing and Non-Ionizing Radiation [9] [16].*

Ionizing Radiation and its Effect on Human Body

Ionizing radiation (ionizing radiation) is radiation, traveling as a particle or electromagnetic waves, that carries sufficient energy to detach electrons from atoms or molecules, thereby ionizing an atom or a molecule [10]. Ionizing radiation is made up of energetic subatomic particles, ions or atoms moving at high speeds (usually greater than 1% of the speed of light), and electromagnetic waves on the high-energy end of the electromagnetic spectrum. The higher frequencies of EM radiation, consisting of x-rays and gamma rays, and the higher part of the ultraviolet are types of ionizing radiation. These radiation are characterized by their extremely higher frequencies with lower wavelength. Ionizing radiation can be a serious health hazard; exposure to it can cause burns, radiation sickness, cancer, and genetic damage. Using ionizing radiation requires elaborate radiological protection measures, which in general are not required with non-ionizing radiation.

Non-Ionizing Radiation and its Effect on Human Body

Non-ionizing (or non-ionising) radiation refers to any type of electromagnetic radiation that does not carry enough energy per quantum (photon energy) to ionize atoms or molecules that is, to completely remove an electron from an atom or molecule [11]. Instead of producing charged ions when passing through matter, non-ionizing electromagnetic radiation has sufficient energy only for excitation, the movement of an electron to a higher energy state. The non-ionization radiation covers two main regions, namely optical radiation (ultraviolet (UV), visible and infrared) and electromagnetic fields (EMFs) (power frequencies, microwaves and radio frequencies) [12]. The energy of particles of non-ionizing radiation is low, and instead of producing charged ions when passing through matter, non-ionizing electromagnetic radiation has only sufficient energy to change the rotational, vibrational or electronic valence configurations of molecules and atoms. This produces thermal effects. The possible non-thermal effects of non-ionizing forms of radiation on living tissue have only recently been studied. Much of the current debate is about relatively low levels of exposure to radio frequency (RF) radiation from mobile phones and base stations producing "non-thermal" effects. Some experiments have suggested that there may be biological effects at non-thermal exposure levels, but the evidence for production of health hazard is contradictory and unproven thus the consensus is that there is no consistent and convincing scientific evidence of adverse health effects caused by RF radiation at powers sufficiently low that no thermal health effects are produced [13][14]. Exposure to low levels of radiation encountered in the environment does not cause immediate health effects, but is a minor contributor to our overall cancer risk [15]. the risk of cancer increases as the dose increases: the higher the dose, the greater the risk. Conversely, cancer risk from radiation exposure declines as the dose falls: the lower the dose, the lower the risk.

3. Devices in 5G Network

With the roll out of 5G network, chipset vendors like: Huawei, Mediatek, Qualcomm and Samsung have embraced the technology in making different innovations to existing devices. Report from the Global mobile Suppliers Association (GSA) helps to paint a picture of the 5G device situation. In its latest monthly report on the 5G device landscape, the firm counted a total of 48 announced 5G devices from 26 different vendors, covering eight form factors: phones, hotspots, indoor modems, outdoor modems, modules, snap-on dongles/adapters, IoT routers and USB terminals [16].

Conclusion

5G in a heterogeneous network will be awesome, Thus main purpose of any mobile industry is to intelligently connect everyone and everything to a better future and 5G is the next major step in delivering on this goal. 5G building upon and working together with 4G, provides the ability to connect people and things faster and more efficiently as part of a 5G era. The applications, challenges and issues of 5G network are many from public acceptance, deployment, health related issues etc 5G will drive new innovation and growth, it will be an evolutionary step with a revolutionary impact delivering greater societal benefits than any other previous mobile generation. The technology will fundamentally improve the way we live and work, enabling new digital application services and business models to thrive in heterogeneous network

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