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The Health Effects of the Fifth Generation (5G) of Cellular Mobile Communications

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Abstract

The fifth-generation (5G) of cellular mobile communications network will support revolutionary services ranging from autonomous transportation systems, smart grid, connected devices, smart manufacturing, autonomous vehicles, telesurgery, and many more. However, these advancements are limited by the public fear of the safety of 5G and a lot of controversies between the researchers, regulatory agencies, and governments. This work surveyed the ongoing debate about the safety of the network by evaluating the safety of 5G enabling technologies and their applications. We suggest that it is not a good idea to use higher frequencies to support the 5G network without enough evidence of their safety. Instead, technologies like cognitive radio and non-orthogonal multiple access can be used to increase the capacity and spectral efficiencies of the existing lower frequencies to support 5G. We also suggest the adoption of some health tips to lessen the effects of the lower doses of the daily exposures to non-ionizing radiation.
Keywords: *5G, mmWave, Specific absorption rate (SAR), massive MIMO, Network densification, beamforming*

1. Introduction

Wireless communications happen when a source creates a message which is modulated by a transmitter and radiated by an antenna over a wireless medium: the transmitted message by the medium is received by a receiving antenna and demodulated by a receiver to make out meaning from the transmitted signal. The signal radiated by the antenna is conveyed by electromagnetic waves which can be characterized by wavelength and frequency.

Wireless communications technologies are classified based on their area of coverage. Thus, we have Wireless Personal Local Area Network (WPAN), like Bluetooth, Wireless Local Area Network (WLAN) like Wi-Fi, Wireless Metropolitan Area Network (WMAN) like cellular mobile communications, and Wireless Regional Local Area Network (WRAN) like the satellite communications [1].

Cellular mobile networks have been undergoing revolutions and evolutions from the First Generation (1G) which only supported analog voice communications to Fourth Generation (4G) Long Term Evolution LTE which supports digital multimedia communications. The 5G mobile network revolution is enabled by technologies which include: small cells, massive Multiple Input Multiple Output (massive MIMO), millimeter wave (mmWave), cognitive radio, heterogeneous networks (HetNets), network slicing, network densification, and much more [2].

The Fifth Generation (5G) of cellular mobile communications network will bring forth diverse technological advancements. This radical revolution will shift cellular mobile communications from supporting only man-machine communications to include machine-machine communications [3]. These diverse services include autonomous transportation systems, smart grid, connected devices, smart manufacturing, autonomous vehicles, telesurgery, and many more [4].

The rising public fears and concerns, which climaxed with the speculation that 5G is responsible for the outbreak of Coronavirus Disease (COVID-19) pandemic, and the enormous controversies amongst the researchers, 5G vendors, and governments concerning the safety of 5G network, calls for critical evaluations and further investigations about the public safety of this revolutionary technology before its full deployment.
This work aimed at surveying the ongoing discussion about the safety of the network, evaluating the evidence about the safety of the 5G enabling technologies, and suggesting future research directions.

2. Ionizing and Non-ionizing Radiations

Based on the frequency of the radiation, electromagnetic waves can be divided into ionizing and non-ionizing radiations (World Health Organization, 2020). Ionizing radiations (like gamma rays and x-rays) are high-frequency radiations with

high energy that can ionize atoms they come in contact with. If this radiation interacts with human cells, it can harm human deoxyribonucleic acid (DNA) and can cause denaturation of proteins [6]. On the other hand, non-ionizing radiations (like radio frequency and microwave) are the lower frequency and low energy radiations that do not ionize atoms but rather transmit energy to them which can manifest in the form of thermal agitations of the atoms thereby, raising their temperatures [6]. The non-ionizing radiation is the part of electromagnetic spectrum that is used for wireless communications.

There are a lot of debates concerning the safety of non-ionizing radiations used for wireless communications. On one hand, governments and regulatory agencies like the National Institute of Environmental Health Sciences (NIEHS), United States Food and Drug Administration (FDA), United States Centers for Disease Control and Prevention (CDC), United States Federal Communications Commission (FCC), etc. are of the opinion that wireless communications are safe [7]. Similarly, other researchers affiliated or sponsored by telecommunication vendors concluded that these radiations are safe. For instance, [8] concluded that there was no correlation between Extremely Low Frequency (ELF) and acoustic neuroma. The studies of [9] also hinted that exposure to mobile phone radiations doesn't lead to genotoxicity and chromosomal instability. Also [7] claimed that higher frequencies are safer due to skin shielding effects. However, it might be interesting to note here that ionizing radiations are all higher frequency waves and they are very dangerous to the skin and human tissue [10] as such electromagnetic penetration shouldn't be the sole parameter in evaluating the safety of radiations.

On the other hand, International Agency for Research on Cancer, (2011) [11] indicated the possibility of radio frequency electromagnetic waves being carcinogenic. A. Karimi *et.al.* (2020) [12] extensively reviewed a good number of recent literature concluded that depending on intensity and length of exposure, there is a correlation between ELF-EMF and childhood cancer incidence, Alzheimer's disease (AD), and miscarriage. Although, there are not enough proofs to establish the same with adult cancer and cardiovascular diseases. Hao, Zhao, & Peng, (2015) [13] also pointed out that the health effects of microwave radiations do not only depend on energy but also on the duration and frequency of the wave. Similarly, Kivrak *et al.*, (2017) hinted about the damaging effects of heating effects of non-ionizing radiation one of which is the carcinogenic effects on the brain and immune system impairments, oxidative stress due to free radicals formation, and oxidative tissue damage. According to them, these effects are accompanied by symptoms such as fatigue, headaches, and hypertension and they concluded that electromagnetic fields (EMF) have harmful effects on the hippocampus and cerebellum.

Kostoff, *et. al.*, (2020) [15] cautioned that the safety of 4G and 5G was not established in realistic environments before deployment. They pointed out that the detrimental effects of non-ionizing radiations might be underreported since parameters such as message signals and other toxic stimulus that might be present in humans are not considered in the majority of the laboratory studies. From their extensive literature reviews, they portrayed the correlation between these radiations and carcinogenicity, genotoxicity, mutagenicity, neurodegenerative diseases, neurobehavioral problems, and many more adverse health effects. They finally called for more realistic epidemiological studies that will consider all the important parameters usually omitted in the laboratory studies.

From the foregoing discussions, we can say that majority of vendors, governments, and regulatory agencies are of the opinion that non-ionizing radiations are safe in a small dose. Whereas, most of the independent researchers are of the opinion that the duration of radiation exposure is also a factor to reckon with when discussing the safety of the radiation. It could also be inferred that the danger of electromagnetic radiation increases with frequency. This points out that 5G may have more adverse health effects than the previous generations since it will use higher mmWave frequencies. There is also a need for more epidemiological researches to identify the actual safety of these radiations.

3. Specific Absorption Rate (SAR)

In recognition of the harmfulness of non-ionizing radiations at a higher intensity, regulatory bodies, like FCC and International Commission on Non-Ionizing Radiation Protection (ICNIRP), use specific absorption rate (SAR) of radio frequency (RF) radiations to prescribe safer thresholds of radiations. SAR refers to the rate of radio frequency (RF) energy absorption per unit mass of human body tissue and its unit is watt/kilogram (W/kg) [16].

The threshold for the whole body SAR is based on 4 watts per kilogram (4 W/kg). According to FCC, SAR threshold is 1.6 watts per kilogram (W/kg), per one gram of tissue [17]**.** Whereas, ICNIRP SAR limit is 2 watts per kilogram (W/kg) per 10 grams of tissue. These two thresholds are the major thresholds adopted by other regulating bodies worldwide.

FCC's SAR is based on radiation between 300 kHz and 100 GH. It was noted by FCC that most of the body absorption occurred at the frequency range of 30-300 MHz [18] as such they provide the SAR of this range of frequencies. It was also noted that for devices operating at frequencies higher than 6 GHz, SAR is an ineffective parameter in determining the safety of the radiations. A better parameter called power density, measured in milliwatts per centimeter square (mW/cm^2), is therefore used. It is imperative to note that 5G will use mmWaves which range up to 300 GHz thus, these regulations are insufficient to ascertain the safety of 5G using mmWaves technology.

4. 5G Technologies

5G will support three use cases, namely: ultra-reliable low latency communications (URLLC), enhanced mobile broadband (eMBB), and massive machine-type communications (mMTC) [19]. These use cases have more stringent requirements like extreme low latency, very high reliability, energy efficiency, high data rates, etc [20]. These requirements are more than what is obtainable with the current 4G network. To meet these requirements technologies like mmWave, hetnets, small cells, MIMO, beamforming, etc. are employed [21]. In this section, we briefly introduce these technologies and evaluate their health effects.

4.1 MmWave

This is electromagnetic radiation within the range of 30-300GHz [22]. MmWave will be used to cater for higher bandwidth need of 5G which is proportional to data rate. This is because the RF wave is nominally occupied. However, the use of mmWave can be detrimental to health since considering the fact that ionizing radiations are very high-frequency waves, we can say that the danger of radiation increases with frequencies. Moreover, SAR is ineffective in determining the safety of mmWave and power density was only specified for frequencies up to 100 GHz by FCC which is less than the range of frequencies of mmWave. One solution to this problem is cognitive radio. This based on the fact that most of the purported scarce frequencies are actually scarce due to the static allocation of bandwidths by regulatory bodies. Similarly, non-orthogonal multiple access (NOMA) can be deployed since it provides better spectral efficiency than orthogonal multiple access (OMA) at the expense of tolerating a percentage of interference. It is better we maximize spectral utilization at lower frequencies than to exploit the higher ones since they are more detrimental to our health.

4.2 Network densification

Network densification is the introduction of smaller cells, namely: picocells, femtocells, microcells within the radius of a macrocell to improve spectral efficiency, throughput, and connectivity by increasing frequency reuse [22]. The forgoing overlap of networks is called a heterogeneous network (HetNet). Massive MIMO involves the use of many antennas per transceiver system, especially the base station. The antenna array focuses energy using a technology known as beamforming and can be used along with network densification to achieve spectrum efficiency and enhanced data rates [23]. Although beamforming will not permeate the space with omni-directional radiations, the concentration of radiation energy on the transceiver of the intended user means more energy is exposed to the user and can be more detrimental to his health.

However, these improvements in desirable quality of service promised by mmWave, network densification and massive MIMO come at the expense of increased power consumption by the 5G base stations [24]. A 5G macro base station can consume three or more times the power consumption of a base station supporting a combination of 1G-4G networks [25]. This is not to mention the energy consumption of the low powered small cell base stations in the HetNet.

It might be interesting to note that 5G applications like autonomous driving, intelligent transport system, home automation, teleconferencing, etc. could reduce energy consumption by improving the energy efficiency of systems and reducing the need for transportation. These applications might also trigger some sort of increase in energy consumption since they are more convenient than consuming fossil fuels.

According to [26] about 65% percent of world electricity generated in 2017 was powered by fossil fuels. This implies that 5G will either increase air pollution and global warming if its power consumption is more than the power savings from its applications or decrease air pollution and global warming if its power consumption is less than the power savings from its applications. Thus 5G can either be detrimental to our health or enhancer of our health depending on its net energy consumption. Therefore, there is a need for further studies to ascertain the actual energy savings or otherwise that 5G will bring to our society.

5. 5G Applications

Some of the services which 5G will support like home automation, telecommuting, virtual and augmented realities, drone deliveries, etc. will encourage a sedentary lifestyle which can cause overweight and obesity. And according to [27] overweight and obesity can cause diseases like cardiovascular diseases, diabetes, and some types of cancer. A sedentary lifestyle is also associated with vitamin D deficiency [28]. Vitamin D reduces the risk of osteoporosis, autoimmune disease, cancer, and hypertension [29].
Other applications like the Internet of Things (IoT) which is a network of low powered devices (mostly battery-powered) can increase environmental pollution especially when their dead batteries are not properly disposed of.

6. Conclusions and Recommendations

5G will transform our way of living but at the expense of potential health risks such as cancer, cardiovascular diseases, Alzheimer's disease, hypertension, etc. We can conclude that the higher frequencies that 5G will use are most likely to be more detrimental to our health compared to lower frequencies as such we recommend the use of lower frequencies to support 5G. Cognitive radio can be exploited to detect and use white spaces for data transmissions of unused allocated frequencies by the regulatory bodies. The regulatory bodies can consider changing from the current static to dynamic spectrum allocation. NOMA can also be used to enhance the spectral efficiency of the lower frequencies. There is a need for further epidemiological research and standardization to ascertain the safety of mmWaves before using it to support communications. For instance, we need a comparison between the energy consumption of 5G and the energy savings by 5G applications.
Since RF radiations can be harmful, the following measures should be adopted in minimizing RF exposure: avoiding long calls or make hands-free calls, turning on flight mode when the networks of the devices are not in use, regulatory bodies should regularly check for adherence to the maximum SAR by the network equipment vendors and network providers.

Other health tips to lessen the effects of our daily exposure to small doses of radiations include regular exercise, eating food rich in vitamin C which can boost immunity and vitamin D which can prevent cancer, diabetes, hypertension etc. and taking dietary antioxidants like foods rich in vitamin E and C to relief oxidative stress.

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