International Journal of Energy and Environmental Science
2024; Vol. 9, No. 6, pp. 123-129
https://doi.org/10.11648/j.ijees.20240906.11

SciencePG
Science Publishing Group

Research Article

The Double-Edged Sword of 5G: Weighing Its Advantages and Environmental Effects

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Abstract

5G is the fifth-generation technology in which the cellular mobile companies started deploying globally in 2019 to raise speed, decrease latency (the time interval required for any device to demand a request from a server and receive a response), and allow more mobile devices to access the internet simultaneously due to the greater bandwidth 5G provides. When comparing the 5G technology to the previous generation, 4G, the 5G networks are expected to be much faster than 4G to be as close to the real time communication. While taking into consideration the huge benefits of the fifth-generation technology that outweigh the previous generations, are those advantages sufficient for the deployment of the 5G? Are not there any negative influences that may result from the usage of the new technologies in the 5G's development? The fundamental components of the 5G's network are the millimeter (mm) waves because it provides access to the large bandwidth and capacity available in the high frequency band, and the small cells that are located for providing targeted coverage in specific spaces. These newly-used components raise myriad inquiries that are a must to be answered: do those technologies have any negative effects on the individuals, birds, animals, and environment? That's what motivated the researcher to do an extensive research and work on finding answers to these essential inquiries.

Keywords

5G, Latency, MIMO, MM Waves

1. Introduction

The fifth generation mobile network, 5G, is a novel global wireless standard that has been devised after 1G, 2G, 3G, and 4G network standards. It delivers higher data speeds, low latency, more reliability, massive network capacity, increased availability and a more uniform user experience to more users. The 5G technology is faster than 4G according to theoretical and practical calculations, as illustrated in Figure 1. It is shown in [6] that the theoretical peak speed of the 5G is 10 Gigabits per second, Gbps, while that of the 4G is 1 Gbps. As far as the practical network speed of the 5G is concerned, it is also significantly higher than that of 4G. Another aspect that distinguishes 5G over 4G, illustrated in [23], is that 5G uses better spectrum strategy than the one used by the 4G since 5G is designed to highly exploit the spectrum from low bands below 1 GHz, to mid bands from 1 GHz to 6 GHz, to high bands which is the millimeter wave. The 5G technology has a higher capacity than that of the fourth generation as 5G is made to support an almost 100 fold increase in traffic capacity and network efficiency. Finally, in [7], 5G results in lower latency as compared to 4G since it has a little delay in deliv-

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Received: 29 April 2024; **Accepted:** 24 May 2024; **Published:** 30 December 2024

ering more instantaneous, real-time access which approaches a 10 fold decrease in the end-to-end latency down to a millisecond. Despite all of these 5G advantages that outweighs those of 4G, there is a controversy about whether this generation of mobile networks has harmful drawbacks on individuals and the environment. According to the world health organization (WHO), there is no negative outcome anticipated on public health. However, there are other studies conducted which demonstrate that the mmWaves and the small cells of the 5G have negative effects on the ecosystem. Consequently, we investigate in this article whether this generation of mobile networks is harmful to our planet or that the effects are negligible and do not result in severe consequences for the human race and the environment.

Network	Theoretical Peak Speed	Practical Peak Speed
5G	10 Gbps	264.7 Mbps
4G	1 Gbps	45.56 Mbps

Figure 1. *Theoretical and Practical speed of 5G vs. 4G.*

2. What Is 5G and How Does It Work

Historically, mobile technologies have transitioned from one generation to the next over a period of ten years, as manifested in the timeline shown in Figure 2. The Fifth generation provides a wide range of capabilities that outweigh the four previous generations' features such as the enhanced Mobile Broadband (eMBB), Ultra-reliable and Low-latency Communications (URLLC), and the massive Machine Type Communications (mMTC). The eMBB capability provides higher speeds for applications like web browsing, streaming, and video conferencing. The URLLC is used to enable perfect working of the essential applications, industrial automation, and autonomous driving that need a short network traversal time. In [10], the mMTC is used to expand the Long Term Evolution (LTE) Internet of Things (IoT) capabilities to support a huge number of devices with promoted coverage and prolonged battery life. The 5G standard utilizes some novel technologies, demonstrated in [3], such as the hardware that can deal with higher frequencies (millimeter wavelengths), small cells, massive MIMO (multiple input multiple output), beamforming and full duplex, combined together to increase the potential of the devices. Considering the mmWave technique, it is defined as a higher frequency wave than the frequencies of the waves used in the old wireless transmissions. It enables more devices to be connected to the same network at the same time due to the more spectrum available, compared to the used radio waves. The ability of the mmWave to allow myriad devices to be utilized by the consumers lead to a major increase in the energy consumption which subsequently leads to global warming. [3] demonstrates that despite the rise in the energy consumption level, the mmWave has a shortcoming which is weakness in connecting two devices because the waves get absorbed and lose their ability to travel for long distances. To mitigate this defect, the small cells (miniature cell towers) are employed to provide a full, uninterrupted coverage for the locations that have coverage issues. The other technology that distinguishes the fifth generation is the massive MIMO which describes the capacity of the utilized base stations. While the 4G base stations have around eight transmitters and four receivers to direct the flow of data between devices, 5G exceeds this capacity with the MIMO's usage which can handle 22 times more ports. The potential of the MIMO tower is to direct a higher number of connections simultaneously; however, it facilitates the crossing of the signals due to a clashing of the wavelengths during propagation to their respective destinations. To overcome this issue, its solution is mentioned in [3]: beamforming, a manner of directing the wavelengths without interference is necessary, is required which is done by using a variety of antennas to organize signals according to specific properties, such as the magnitude of the signal. The final novel technology that is used is the full duplex transmission, which enables a faster data transmission through sending and receiving data simultaneously. There are some influences that can be predicted because it is known that these technologies will increase the exposure to harmful radiation as well as raising the energy usage. The main 5G environmental concerns have to do with two of these five components, namely, the millimeter waves and the small cells.

2G	3G	4G	5G
1990s	2000s	2010s	2020s

Figure 2. *Mobile telecom evolution.*

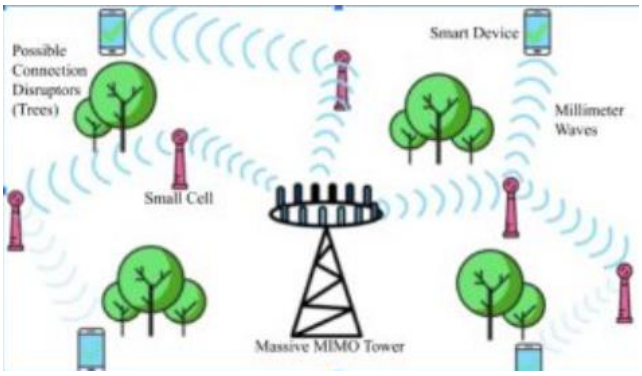

Figure 3. *mmWaves.*

3. Potential 5G issues

3.1. Increased Energy Usage of the 5G Network and the Global Warming

The main goal of the new 5G network is to enable more devices to work at faster rates than ever before. However, this leads to an increase in energy usage which is one of the chief contributors to climate change. The 5G technology operates at a higher frequency portion of the spectrum to create a wider bandwidth which leads to a spike in energy usage for the following two reasons. The first reason is that the technology itself is energy demanding and the second one is the demand for more electronic devices increases. Before the fifth-generation technology, [3] tackles that about 2% of the world's greenhouse gas emissions were attributed to the Information and Communications Technology (ICT) industry, which accounts for around 860 million tons of greenhouse gas emissions. The 5G technology advocates that the small cells use solar or wind energy. However, the issue is not solved completely because of the impact the numerous new devices will have on the amount of energy needed to power them. In [21], it is also estimated that by 2025 nearly 70.2 million small cells will be installed, 500 billion devices will be connected to the internet by 2030, and a 60% increase in the annual production of wireless peripherals such as appliances, and speakers will occur. Moreover, 5G is found to be an energy hog as a hidden menace. Regardless of the fact that 5G delivers up to 1,000 times as much data as previous networks, it consumes up to 1,000 times as much energy as supported in [26]. The energy calculations demonstrate that in 2015, wireless clouds consumed up to 43 Terawatt-hour (TWh) compared to only 9.2 TWh in 2012, an increase of 460% which is equivalent to a rise in carbon footprint from 6 megatonnes of carbon dioxide gas up to 30 megatonnes. About 90% of this consumption is attributable to wireless access network technologies. In [11], it is mentioned that with an increase in energy consumption through technology and the implementation of 5G, it is expected that the climate change issues faced will increase dramatically if no proper actions or limitations are taken. This is due to the fact that European Union researchers in [12] anticipated that to keep the increase in global temperature below 2 ° Celsius a decline in carbon emissions of around 15-30% is mandatory. According to an Ericsson report in [24], by 2040, 5G could generate 14 percent of worldwide greenhouse gas emissions and if the entire system is not energy efficient, 5G will ultimately not be sustainable. Additionally, in 2013, according to the Centre for Energy Efficient Telecommunications, it was discovered, in [27], that wireless access networks are the biggest and most inefficient consumer of energy in the cloud environment.

3.2. The Impact of 5G on Ecosystems

There is some evidence that the new devices and technologies associated with 5G will be harmful to delicate ecosystems when the millimeter wave is the chief component of the 5G network. However, it is also demonstrated in [21] that the millimeter wave which complies with the national non-ionizing radiation safety standard causes no known adverse health effects and are not predicted to produce penetrating effects in the body. The 5G network also has a higher density of small cells where the dangers of these cells all over areas where birds live may cause the entire birds' populations to have mutations that negatively affect their survival. It is shown in a study done in Spain, at [3], that breeding, nesting, and roosting was influenced by microwave radiation emitted by the small cells. Additionally, Warnke, in [19], found that cellular devices had a detrimental impact on bees since when the beehives were exposed for just ten minutes to 900 MHz waves, they suffered from a colony collapse disorder (bees abandonment of the hive leaving the queen, the eggs, and a few worker bees). The radiation also had a disadvantageous effect on the worker bees as their navigational skills worsened, causing them to stop returning to their original hive after about ten days. Bees are an essential part of the earth's ecosystem and without bees, a vast majority of the food would be lost or at the very least highly limited. In [20], research finds bees and pollinators absorb between 3% to 370% more of the higher frequencies of 5G and that the wireless frequencies interfere with birds' navigation systems and circadian rhythms. On the other side, in [23], it is found that the small cells transmit low levels of the radio waves and that the international health authorities have not found any convincing scientific evidence that radiofrequency signals from wireless communications cause negative health influences. In [1], researchers found that 5G does not only affect the birds, but it also has a negative effect on the trees as they can develop some severe mutations, altered growth, thinner cell walls and adverse biochemical changes, just by the standard radiation emissions from antenna equipment. The high-frequency electromagnetic waves emitted by the 5G network could also be harmful to animals as the researchers in Germany states in [26] that there is a single farm where a high number of miscarriages of piglets has been observed and linked to the proximity of a mobile communications transmission installation. The eventual and most important part is the 5G's effects on humans although the higher frequency radiation of the 5G does not penetrate the individuals' bodies as deeply as frequencies from older technologies, the potential effects of 5G technologies are under-researched. However, in [5], there are some crucial biological results that have been reported under the millimeter-wavelength exposure such as oxidative stress, altered gene expression, effects on the skin, and immune function. On the other hand, it is known that the ionizing radiation has been scientifically proven to be harmful to human health, but it is tackled in [1] that for the non-ionising radiation, the type of radiation produced from the 5G, has not been proven to cause any harmful effects. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) states that there is no evidence that the electromagnetic field

(EMF) results in cancer, electrohypersensitivity, infertility, or any other health effects. In October 2020, a report by the American FDA, in [25], came to the same conclusion that there is no scientific evidence of health problems caused by the exposure to the radio frequency energy emitted by the 5G. The ICNIRP took into consideration the possibility of causing any negative health effects, triggering the community to form their basic restrictions as shown in Figure 3 to have margins of safety. Moreover, in [25], according to Rodney Croft, Chair of ICNIRP, the research did not demonstrate any adverse health influences associated with exposures below the ICNIRP restrictions, regardless of the exposure duration.

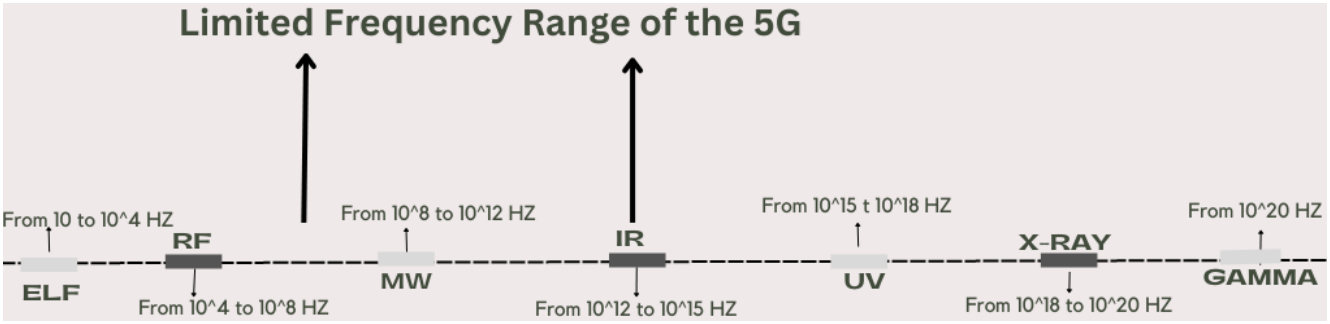

Figure 4. *Limits made by the ICNIRP.*

4. How to Make 5G Safer

There are many large corporations who refuse to deploy 5G not only because of the dramatic increase in energy consumption of the mobile networks but also due to its severe impacts on the environment. An innovative and sustainable approach is needed to break the energy curve. Therefore, in the last few months, Ericsson and Telefónica have carried out joint test pilots on energy efficiency features in an attempt to break the energy curve. Those pilots were initiated with a main focus on attaining maximum sustainability and energy efficiency when evolving towards 5G networks. In this pilot, Ericsson, using Ericsson Radio System (ERS), has proven that by the 5G, there is only 10% consumption of the power of the equivalent 4G (measured in watts per Mbps). These tests, in [27], show that the 5G's technology is about 90% more efficient than 4G in terms of energy consumption per unit of traffic (W/Mbps). There are massive savings by turning on energy-saving software such as MicroSleep Tx and the Low Energy Scheduler Solution which can decrease radio equipment energy consumption by up to 15% while providing the same user experience. There is another measure to limit the negative consequences of 5G by lowering the energy consumption and emissions. International standards have called for 5G to require much less energy to run than 4G. In [24], it is tackled that this would lead to using less power while transmitting more data so that a kilowatt-hour (kWh) of electricity can download 300 high-definition movies in 4G while with 5G, one kWh can download 5,000 ultra-high-definition movies. Moreover, [8] tackles that there are two international bodies that produce exposure guidelines on electromagnetic fields, namely, the International Commission on non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers by the International Committee on Electromagnetic Safety (ICES). According to the ICNIRP and ICES Guidelines of the protection of humans exposed to radiofrequency electromagnetic fields (RF), the frequencies are specified to be from 100 kHz to 300 GHz, covering 5G technologies, WiFi, Bluetooth, and mobile phones which is supported in [25]. Based on Figure 4 which shows the frequencies used by 5G, the frequencies are three types, low band, mid band (C-band), and high band (mmWave). These three categories follow the guidelines provided by the ICNIRP and ICES. With the positive properties of 5G in addition to the assigned guidelines, it is demonstrated that this technology can provide tremendous benefits: greenhouse gasses' emissions reduction, and energy consumption optimization, which is illustrated in Figure 5. Some companies are trying to lower the amount of energy networks consume to cool their base stations. As in Hangzhou, China, new base stations using intelligent voltage boosting and cooling, and solar modules can save 4,310 kWh of power per site each year, thus cutting 1,125 kilograms of CO_2 emissions. A Japanese mobile phone company, NTT DOCOMO, has manufactured Green Base Stations with solar photo-voltaic panels and smart power control, decreasing commercial power consumption by 40 percent. Also, Nokia deployed a liquid-cooled base station in Finland. Using water to cool the station instead of air has resulted in consuming 10% of the energy of traditional air cooling thus reducing carbon emissions by 90% as stated in [24].

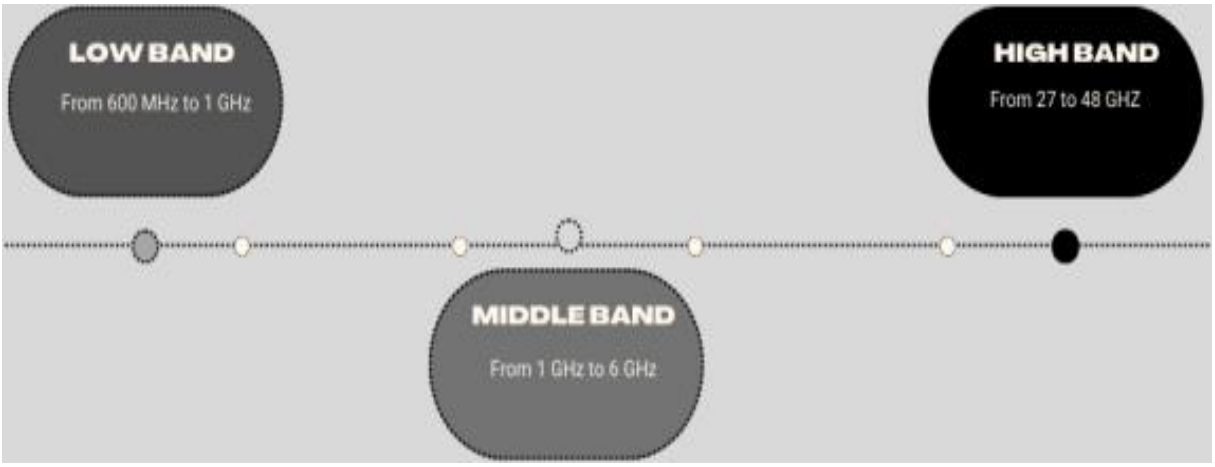

Figure 5. *The frequency bands 5G use.*

5. Conclusion

5G is the fifth-generation of wireless network technology, which is designed to allow customers to stream and browse at much faster speeds than 4G, and low latency connection. The fifth-generation technology introduces development throughout network architecture since the 5G New Radio, the global standard for a more capable 5G wireless air interface, covers new spectrums that were not used in the previous generations. New antennas will incorporate a massive MIMO to enable multiple transmitters and receivers to transfer more data simultaneously. [7] tackles that 5G also supports a converged, heterogeneous network combining licensed and unlicensed wireless technologies, providing a wider range of bandwidth for users. There are myriad concerns about whether 5G is healthy or not, so we made the utmost effort to reach the valid conclusion through tackling many aspects: effects on the ecosystem whether on human beings, animals or even birds, energy consumption, and the influence on climate. It is found that based on the high energy demands of the used network elements like MIMO, energy consumption is expected to increase by 160% between 2020 to 2030 and the power consumption of the 5G network is expected to soar due to active network elements like small cells. In [24], the new used technologies and the new devices have a severe impact on the energy usage since it will cause a 37% increase in overall energy utilization by 2030. The 5G network's radiation may have effects on the birds' nesting, breeding, and roosting as well as harming the bees by suffering from a colony collapse disorder. The high-frequency electromagnetic waves emitted by the 5G network also has a possibility to be harmful to animals as it may alter their nervous systems and body temperatures. Regarding the negative consequences on individuals, the large corporations have made many limitations to eliminate the probability of causing any harmful impacts on the populations. The ICNIRP and ICES determined that radio frequencies will be up to 300 GHz only to get the needed advantages of 5G with the least defects. Additionally, Ericson and Telefónica applied energy-saving softwares to decrease radio equipment energy consumption with the same user experience. There is also another attempt to make the 5G sustainable which is the determined international standards that require the 5G to use much less energy than 4G even by transmitting more data. Additionally, it is found that there is a high possibility that 5G has a role in reducing harmful gasses' emissions, and optimizing energy utilization. The ICNIRP research did not show any harmful health impacts by exposure to radiation below their restrictions, which elucidates that 5G is not a catastrophe as many believe. Combining the 5G's advantages and its assigned sets of limits, the main inquiry still needs to be answered, whether the fifth generation's deployment needs rethinking because of the negative consequences of the 5G or the assigned limitations are enough to trigger the institutions to risk and apply this technology?

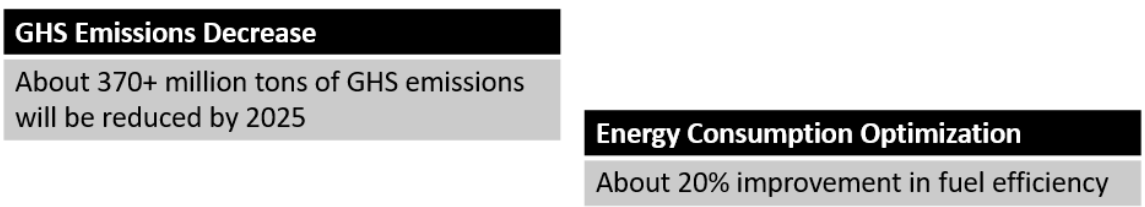

Figure 6. *Benefits of 5G.*

Author Contributions

Aya Ahmed is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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