Health Concerns of Wireless Networks & Technologies

Computer Networks Group - 19 Project

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I. Abstract

Wireless Networks and Technologies are a large part of humans lives especially in the western hemisphere, but yet many people don't know very much about them. A majority of people don't understand how they work or how they pose a negative health impact. This paper seeks to deliver the truth about wireless communications and their impact on human beings, through examining the history of wireless technology, their cause-and-effect relationship with human health, and the future of this technology. At the end of the day humans will always need wireless communication to help with productivity and connection, but everybody should realize the health risks that are associated with these networks.

II. Introduction

In most geographies around the world the digital transformation, replacing old technologies with new ones, is well under way. The rapid innovation of new technologies, especially in the wireless networks sector, is driven by humans needing to consume more and more data at faster speeds. A prime example of this is 5G. 5G has promised to increase speeds (i.e. how fast data can be transmitted, also known as throughput), and bandwidth, (i.e. the amount of data that can be transmitted at a given time). 5G increases bandwidth by increasing the size of the channel from 1-20 MHZ, for 4G LTE, to 1-100MHZ, for 5G[1]. 5G networks are expected to be 10x current 4G LTE speeds, with hopes of eventually being greater than 100x faster[2]. New innovations, like 5G, are helping humans increase their productivity, but at what cost. Is it at the cost of human's health? There are many scientific studies that are now proving wireless networks and communication technologies, like WLANs and Cellular networks, have a detrimental effect on the human body[3]. This paper will discuss the negative health effects associated with current wireless communication, as well as the possible health concerns that should be considered before implementing new higher frequency and higher bandwidth wireless networks. Over the next 9 pages this topic will be elaborated further. Starting off by discussing the history of wireless communications including how they were discovered and by whom, how it's developed over the years, what past health hazards have been associated with them, etc. Next this study will describe the relation of work in literature and from there it will transition into the main body of work. The main body will thoroughly examine the different health effects that can occur in humans and nature, and the aspects that drive these negative impacts. Finally, this paper will walk through the future technological advancements in wireless networks and what health implications these new innovations may

pose. This research paper will end with the conclusions that were found and references that were used to find them.

III. History

The first ever wireless communications to take place, dates as far back as the pre industrial era. Humans used smoke signals and flares to send complex messages and to transmit information over long stretches of land. Fast forward to 1895, ten years after Thomas Edison first patented an electrostatic induced system of wireless systems, Guglielmo Marconi sent and received the first ever wireless electronic telegram. It wasn't too long until this new and unique technology was being developed and utilized on land for everyday purposes[4]. In 1927, the first ever commercial radio telephone service which operated between Britain and the US, was created. This paved the way for the first car based mobile telephone technology using a push to talk feature. Since then, the trajectory of wireless technologies and networks has been rising at an exponential rate.

Now digging a little deeper into the origin and timeline of the resurgence of pure wireless networks. The first ever network to use radio waves to transmit digital signals was developed at the University of Hawaii in 1971. This network of electromagnetic transmissions was called ALOHA and allowed different campuses of the university to communicate with each other via radio transmission. However the popular demand amongst consumers and companies was still the Ethernet based technology due to its unparalleled transmission speeds at the time [5]. Even though the gap in transmission speeds and security between the two technologies has drastically decreased over time, the question still remains whether a user is ready to sacrifice performance over enhanced mobility

The biggest breakthrough in wireless network technology has been the development of cellular networks. With over 200 millions users of cellular networks worldwide they have become a very important aspect of human life. After the establishment of commercial telephone services that used radio technology, it was discovered that the use of this radio technology was extremely inefficient due to the use of a central metropolitan transmitter. Some facts and figures that brought this matter to the forefront was the problem that the New York Metropolitan system could only support 543 users at that time. The concept of cellular networks was developed to combat this dilemma which basically divided a geographical area into adjacent, non overlapping “cells” with each cell consisting of a centralized transmitter and receiver (called a base station). Each cell then communicates with the mobile units in that cell.[6] The original cellular system design was finalized in the late 1960s and deployed in the early 1980s, with cellular networks enjoying an exponential rise in popularity ever since!

IV. Relation of Work in Literature

As concerns around wireless networks continue to rise, so too has the need to address the public regarding these concerns. Literature is one of the most widely used platforms for people to gather and research information and this is especially true for information regarding wireless networks. Peer-reviewed studies, journals, reports and articles are giving people more information on wireless networks and their effects on the human bodies. Thanks to these free high quality sources, people are able to educate and form their own opinions. This is extremely important when discussing a controversial topic like the health effects of wireless networks. Peer-reviewed studies like “Potential Health Risks of Radiofrequency Fields from Wireless Telecommunication Devices” written by 7 university graduates, provide a scientific understanding of how wireless networks and radio frequencies affect

human health. Whether this information was gathered through testing or through extensive research, peer reviewed reports are very accurate and non-political. These works of literature allow people to learn for themselves as well as educating others by passing on the information they've absorbed. This ripple effect will help create more critical thinkers which society as a whole will benefit from. This is why works of literature are not only vital in understanding the health risks associated with wireless networks but also why literature is so important to humanity.

V. Main Body of Research

Health Risk Causes

Wireless Networks are known to use electromagnetic fields (EMF's), more specifically radio frequencies, to transmit information and data from one user to another. Further discussion will primarily revolve around the transmission of these EMFs from technologies such as cellular networks, in our mobile phones, WLANs and both of their respective base stations.

A. Electromagnetic Fields (EMF's)

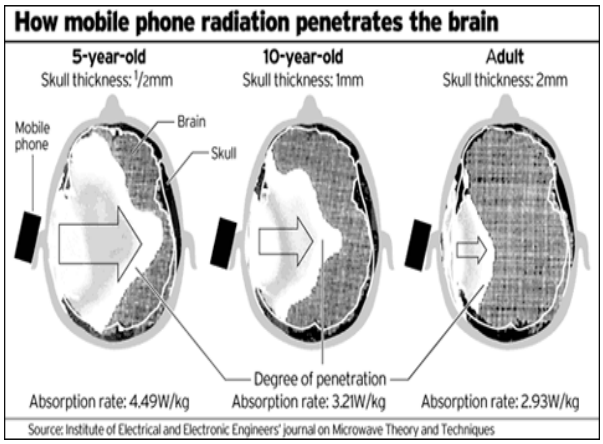
Since a focal point of this report is centred around the transmission of EMF's by wireless networks, it is vital to get a clearer understanding of these frequencies. Electromagnetic fields (EMFs) are oscillating waves generated when an electric current flows through an electric field. They can be categorized into two different classes:

- Ionizing EMF's: Higher frequency EMFs, for example X rays and Gamma rays. Exposure to Ionizing EMFs are especially dangerous to the human body due to their ability to break chemical bonds which in turn cause ill fated side effects such as burns and organ damage.
- Non - Ionizing EMFs: Long wavelength and low frequency waves that lie on the end of the electromagnetic spectrum that contains radio waves, microwaves, etc. Used for data transmission in wireless networks due to their inability to break chemical bonds.

Exposure to non ionizing radiation is not strong enough to affect the structure of our atoms. However non ionizing EMF's do cause our atoms to vibrate abnormally which heats them up. This in turn has led to numerous health concerns associated with wireless networks.[7]

B. EMFs in Wireless Cellular Networks

Cell phones transmit non ionizing radiation (radio frequencies RF) through their built in antennas which are used to transmit data to and from their base stations. The amount of non ionizing exposure a person is subjected to is also dependent on a few other factors. These include how long a person converses on their device, how close they hold their phones to their heads and how close they are to the base station (further discussed below). Numerous studies conducted over the years have shown that EMF exposure from mobile phones can potentially have a negative impact on human beings' health. The main health concern raised by experts in this domain is whether this radiation can cause tumors in the facial region specifically around the brain.



An article by John Tuohy (2000) published in USA Today stated that Dr. George Carlo of the Cellular Telecommunications Industry Association has found three studies confirming that people who use cell phones are more likely to get tumors on the outside of their brains[8] . Another study found that people who use cell phones for more than six years are 50% more likely to get benign tumors behind their ears. It was surprisingly to discover that the 20-minute EMF exposure during a single mobile phone conversation is equal to a whole year of exposure to Wi-Fi. [9]

C. EMF's in WLANs (WiFi)

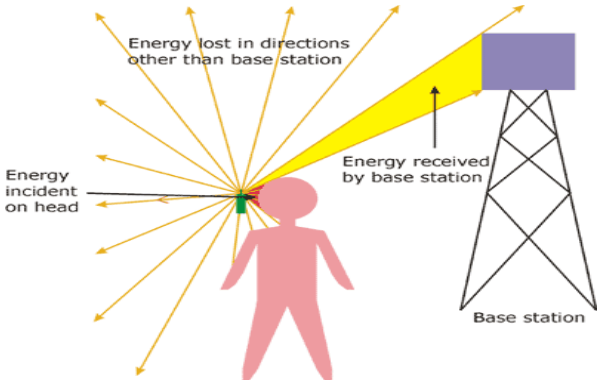
With Wi-Fi exposures becoming more common, there is much concern about possible Wi-Fi health effects. Just like cell phones, routers use radio frequency (RF) energy, which is a form of non ionizing EMF. However as compared to mobile phones, the research into Wi-Fi RF signals is more preliminary, making it harder for scientists to determine a linkage to specific health risks.

According to Leeka Kheifets, Ph.D. and a professor of epidemiology at the UCLA School of Public Health, researchers can still make some judgments about the potential harm to humans based on how WiFi and similar technologies work. As mentioned before, your phone receives and sends RF signals between its antenna and base station. The radiation from WiFi devices also falls into the same electromagnetic range as the RF signals transmitted from cell phones. However since the distance travelled by the RF signals between WiFi devices (example: laptop to WiFi router) is much shorter than the distance between a cell phone and its base station, the RF can be transmitted at a much lower strength. Thus the effects of radiation from the non ionizing EMFs is much lower and less harmful in comparison. [10]

Even though the exposure to non ionizing EMF's is less harmful in comparison, one should not forget that they are still being exposed to radiation. Even Though users of WLANS are exposed to lower powered signals, their exposure to EMFs is of longer durations than people using cellular phones. David Carpenter, M.D. and director of the Institute for Health and the Environment at the University at Albany, says that "while exposure from a single router in your home may be small, the risks could be greater in places that have dozens of laptops and routers working at the same time—such as school classrooms". Phillips notes that children's developing bodies may be more vulnerable to all forms of radiation. [10]

D. EMF's in Base Stations

Base stations are required to enable mobile phone communication and wireless connections, which include calls, data transfer and WiFi. The antennas of base stations are said to be the most dominant source of EMF exposure for homes in the surrounding area. However, radiofrequency (RF) emissions from wireless transmission antennas have exposure levels that are typically thousands of times less than safety limits. These safety limits were adopted by the Federal Communications Commission (FCC) based on the recommendations of expert organizations and endorsed by agencies of the federal government. [11]



These measures however do not completely ensure that living things are not negatively affected while being near a base

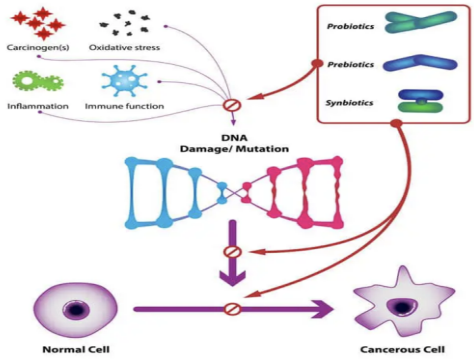
station. A study by Italy's Ramazzini Institute has evaluated the lifespan of rodents exposed to RFR (radio frequency radiation), as generated by cell phone radio base stations. Even though exposure rates were 60 to 6,000 times lower than general safety guidelines, there were still statistically important findings. The study showed significant increases in Schwannomas of the heart in male rodents, and Schwann-cell hyperplasia in the heart in male and female rodents. Male and females both reported an increase in the number of brain and heart tumors, which is the same histological type of tumour that's observed in the epidemiological studies on cell phone users. [12]

Human Health Effects

Many research studies are now proving that even low-level exposure to electromagnetic frequencies (EMF's) released by wireless LANs, cell phones, base stations, disturb the body's natural energy field and may be a leading cause in many different illnesses. Some severe illnesses that can be caused by EMF exposure include weakened immune system, reduction of humans' ability to reproduce, affect DNA integrity and cell growth, create anxiety, depression and other mental illness disorders, and magnifies intracellular calcium buildup[13]. Further discussion will focus on the ladder four impacts as they've been proven to have the strongest correlation between EMF exposure from wireless networks and health deterioration.

A. Intracellular Calcium Overload

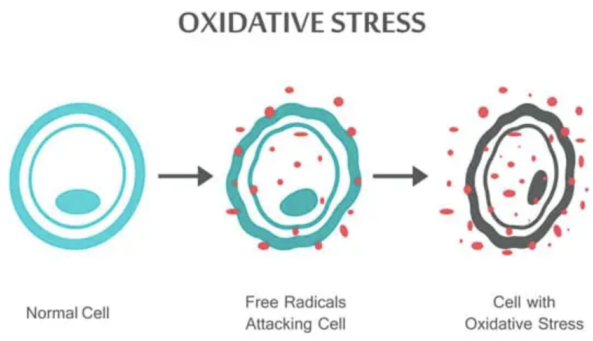
According to Bethan Lang Ph.D., voltage gated calcium channels (VGCCs) are a family of multimeric transmembrane proteins involved in calcium homeostasis, gene expression and neurotransmitter release[13]. VGCCs are located in the cell membrane and control the flow of calcium ions called intracellular Ca2+. VGCCs are extremely sensitive to electric pulses like EMFs. Electric pulses force the voltage sensor to open the channel allowing calcium ions to flood into the cell. An imbalance in intracellular calcium can turn healthy functioning cells into cancerous ones, which can lead imbalances in neurotransmitters and can be linked to many chronic diseases [15].



F2. DNA Mutation turning a normal cell to cancerous cell [15]

B. DNA Damage and Cell Integrity

Not only can EMFs cause intracellular calcium overload but they can also negatively impact DNA integrity and cell development. A human cell is built by design to protect DNA, RNA and protein macromolecules. EMF's can negatively impact a cell's function by penetrating the cell's membrane and creating toxic free radicals. Once created free radicals attack the nucleus causing breaks in DNA strands, which puts oxidative stress on the entire cell. Excessive oxidative stress results in cancerous cells which is a precursor to tumors and cancer [15].



F1. Healthy cell transitioning into a cell with oxidative stress [15]

C. Depression, Anxiety and Mental Illness

1) As stated above EMF's can activate voltage gated calcium channels (VGCCs) which have a critical impact on a human's emotions. Activated VGCC's cause an imbalance in the release of neurotransmitters, like dopamine, serotonin and norepinephrine, that the human body uses to control mood and emotional behaviour. An improper balance of these chemicals in the human body can lead to anxiety disorders, bipolar disorders and depression[16].

2) Another reason why EMFs are correlated to anxiety, depression and stress is because of their link to sleep deprivation and insomnia. A lack of sleep can affect mood and emotional behaviour and ultimately create anxiety disorders and depression[17]. In a 2007 study, scientists researched the impact of low frequency modulation from cellphones on the people's sleep. Participants in the test group were exposed to electromagnetic signals from real cell phones, whereas the control group had fake cell phones with no signals. The study showed that participants in the test group experienced changes in brainwave patterns which hindered their ability to fall asleep [13]. Not only that but it's been established that EMF exposure suppresses the creation of melatonin by the brain's pineal gland [16]. Melatonin is a hormone that is naturally produced by your body to help you fall asleep, also referred to as the hormone that regulates your internal clock [18]. Without the production of melatonin, it is extremely difficult to fall asleep and reduces the quality of the sleep (i.e. less REM sleep) [18].

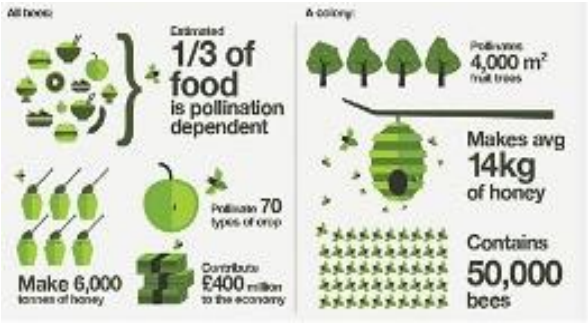
D) Male and Female Reproductive Systems

There have been many studies that have shown a link between EMF exposure and a reduction in men's reproductive system functionality. A recent study concludes that men with erectile dysfunction (ED) on average carried a turned-on cell phone, which is EMF emitting, in their front pocket 2.5 times more than men without ED. EMF exposure produces increases in testicular proteins, which in turn increase the probability of having testicular cancer and other reproductive issues. Many areas of men's reproductive systems can be negatively impacted by EMF exposure including reducing sperm count and motility, damaging sperm DNA and increasing the likelihood of ED[20]. Not only are men's reproductive systems damaged by EMF's but also females. An increase in oxidative stress levels (previously discussed) from EMF exposure can increase the possibility of an abnormal pregnancy or a failure of the egg to implant [13].

Environmental Risks

EMF's emitted from wireless networks have a direct negative impact on humans but there is also an indirect impact to humans that is quite often overlooked, the effect of EMFs on plants, animals and the broader environment. Humans rely on the environment for their survival, so if the environment is negatively affected humans are indirectly negatively impacted. EMFs are now all over the world and even though they are not seen by the human eye they still cause a great threat to the natural world.

Many animals in the world use the earth's magnetic field to orient themselves, including birds, bugs, insects and many others. As the world becomes more polluted with wireless networks, EMFs will increasingly interfere with earth's magnetic field making it extremely difficult for animals to gain their orientation. Lack of orientation will ultimately lead to these animals' death [20]. If this cycle continues, we will see more and more important animals become endangered or extinct. This will have a catastrophic ripple effect throughout the entire ecosystem. A prime example of this is the honeybee. Honeybees rely on the earth's magnetic field to search, gather and retrieve pollen from flowers. If they lose their orientation, they will no longer be able to return home after finding pollen, which will lead to their inevitable death. If honey bees were to go extinct, 1/3 mouthfuls of food humans consume would be directly eliminated [21].



F3. Importance of honeybees

The extinction of animals caused by EMFs will have a huge impact on plants, but that's not the only way they will be negatively affected. Studies have shown that EMF radiation damages plant cells very similar to the way it damages human cells. Plants exposed to EMFs from wireless networks have thinner cell walls and smaller mitochondria, in simple terms they are less healthy than plants not exposed to EMFs[20].

Limiting the Health Effects

There are numerous ways to counter the effects caused by EMFs emitted by wireless networks and mobile devices. However the sole most important practice to reduce EMF exposure is to make sure you are using your cell phones and wireless connected devices with proper care and precaution. Practices such as keeping these devices away from your head and body. This is particularly true in areas where the cellular signal from the base stations is considerably weak for example when your phone has only one bar, since phones with poorer reception may increase their power to compensate. Another useful practice might be to choose devices with lower SAR values. The specific absorption rate (SAR) is the amount of RF energy from the device absorbed by the user's body. Furthermore, in order to limit the health effects caused by wireless network devices, the FCC also recommends placing more distance between your body and the source of EMF, since the exposure drops drastically through distance

VI. Future of Wireless Networks

As technology continues to evolve in the wireless network space, new networks like 5G have already started to phase out old, and now obsolete, technologies. 5G will remain dominant over the next 5-10 years, and will see many improvements over the years, such as a potential increase from 10x to 100x faster speeds when compared against 4G LTE. However, even though 5G is very new and just beginning to roll out, 6G networks are already in development and are planned for commercial use in the next 10 years. Projected speeds can top out around 100GBps (nearly 100x that of current 5G speeds), and will operate at frequencies of 1THz (1 Terahertz). It is safe to assume that 6G networks will be close to 10x more harmful to the human body than 5G networks are currently[22].

With respect to Wi-Fi there is potential for a healthier alternative. Researchers are working on a new technology called LiFi, which would use visible light waves to transmit data, rather than radio waves. Visible light waves are known to be harmless to humans and other forms of life. On top of this, LiFi would offer incredibly fast speeds of up to 224GBps, and the visible light spectrum is 10,000x broader than the radio spectrum, providing greater bandwidth than Wi-Fi[23]. 6G and LiFi are replacements for current technologies, but there is a new technology that has never been as prevalent as it is now.

Wireless charging has recently been popping up everywhere, and although it is fairly safe where it is now (just a charging pad plugged into the wall, and a wireless device is placed on pad to charge inductively, which emit very minimal EMFs), companies are working on mega wireless chargers that would go into the walls, floor and ceiling of rooms and be able to charge multiple devices from over 15ft away. This would cause an unreasonable amount of EMFs exposure and would be very dangerous to humans and other forms of life.

VII. Conclusions

It's very evident that wireless technologies are here to stay, so trying to phase them out is not an option. Due to the EMFs emitted by these wireless technologies, they are known to be quite harmful to humans and other forms of life. We could continue to live with these current technologies and see some side effects, but as time goes on, and technology keeps growing at an exponential rate, so will the negative health risks. 6G is being developed right now, and wireless charging could potentially pose a new risk every time you're in a room. Thankfully there is some hope, as some researchers have found ways to not only improve current technology in terms of speed and bandwidth, but to make them much safer. For example, in the near future we could potentially see WiFi be replaced by LiFi, which would use harmless light waves in place of radio waves to transmit data. If research can continue to go this way, and find safer alternatives to what we currently use while also improving performance and efficiency, then the future of wireless networking is looking bright. But for the time being, EMFs pose multiple human health risks. With excessive use of mobile devices, and the current trajectory of future development EMF related illnesses will continue to increase.

VIII. References - IEEE Format

[1] B. O'Donnell, "How Fast Will 5G Really Be?," *Forbes*, Nov. 19, 2019. https://www.forbes.com/sites/bobodonnell/2019/11/19/how-fast-will-5g-really-be/?sh=7423c0225cf3 (accessed Mar. 16, 2021).

[2] Clare Duffy, "5G explained: What it is, who has 5G, and how much faster is it really?," *CNN - Breaking News, Latest News and Videos*, Mar. 06, 2020. https://www.cnn.com/interactive/2020/03/business/what-is-5g/ (accessed Mar. 16, 2021).

[3]S. S. D. Jennifer Ph. D. Reviewed by Dr., "Does WiFi Affect the Brain?," *News-Medical.net*, Apr. 30, 2020. https://www.news-medical.net/health/Does-WiFi-Affect-the-Brain.aspx#:~:text=There%20are%20many%20scientific%20studies,proteins%2C%20lipids%2C%20and%20DNA. (accessed Mar. 16, 2021).

[4] E. Pat Hindle, "History of Wireless Communications," *Microwave Journal*, 20-Jan-2021. [Online]. Available: https://www.microwavejournal.com/articles/

24759-history-of-wireless-communications#:~:text=1885%20%E2%80%93%20Thomas%20Edison%20patented%20a,published%20his%20results%20in%201888. [Accessed: 06-Apr-2021].

[5] "A History of Wireless Technologies," *Wireless Data Technologies*, pp. 1–6.

[6] J. R. Vacca, *Computer and information security handbook*. Amsterdam: Morgan Kaufmann, 2009.

[7] "Cellular (Cell) Phones," *American Cancer Society*. [Online]. Available: https://www.cancer.org/cancer/cancer-causes/radiation-exposure/cellular-phones.html. [Accessed: 06-Apr-2021].

[8] D. S. ZafarAhmed and Q.-ul-A. ZafarAhmed , Minnesota State University, Mankato , Mankato , MN, rep., 2003.

[9] C. Roberts, "Do I Need to Worry About Radiation From WiFi and Bluetooth Devices?," *Consumer Reports*. [Online]. Available:https://www.consumerreports.org/radiation/do-i-need-to-worry-about-radiation-from-wifi-and-bluetooth-devices/. [Accessed: 06-Apr-2021].

[10] "Public Debate on the use of the wireless network (Wi-Fi) in schools," *Tnuda*, 22-Oct-2019. [Online]. Available: https://www.tnuda.org.il/en/public-debate-use-wireless-network-wi-fi-schools. [Accessed: 06-Apr-2021].

[11] "RF Safety FAQ," *Federal Communications Commission*, 13-Oct-2020. [Online]. Available: https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety. [Accessed: 06-Apr-2021].

[12] Miller AB;Sears ME;Morgan LL;Davis DL;Hardell L;Oremus M;Soskolne CL; "Risks to Health and Well-Being From Radio-Frequency Radiation Emitted by Cell Phones and Other Wireless Devices," *Frontiers in public health*. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/31457001/. [Accessed: 06-Apr-2021].

[13] "10 Shocking Facts about the Health Dangers of Wi-Fi," *Dr. Group's Healthy Living Articles*, Apr. 02, 2014. https://globalhealing.com/natural-health/10-shocking-facts-health-dangers-wifi/ (accessed Mar. 18, 2021).

[14] B. Lang PhD, "Voltage Gated Calcium Channel - an overview | ScienceDirect Topics," *ScienceDirect.com | Science, health and medical journals, full text articles and books.* https://www.sciencedirect.com/topics/neuroscience/voltage-gated-calcium-channel (accessed Mar. 18, 2021).

[15] "How EMFs Biologically Impact the Body's Cells and Damage DNA | DefenderShield," *DefenderShield*, Oct. 19, 2020. https://www.defendershield.com/emf-biological-impact-cells-damage-dna (accessed Mar. 18, 2021).

[16]"How EMF Exposure May Cause Depression, Anxiety & Other Mental Health Issues | DefenderShield," *DefenderShield*, Oct.

19, 2020. https://www.defendershield.com/emf-exposure-depression-anxiety-mental-health-issues (accessed Mar. 18, 2021).

[17] E. Suni, “Anxiety and Sleep | Sleep Foundation,” *Sleep Foundation*. https://www.sleepfoundation.org/mental-health/anxiety-and-sleep (accessed Mar. 18, 2021).

[18] “Melatonin - Mayo Clinic,” *Mayo Clinic*, Mar. 03, 2021. https://www.mayoclinic.org/drugs-supplements-melatonin/art-20363071 (accessed Mar. 18, 2021).

[19] “Men’s Reproductive Health: Cell Phones, Sperm and Fertility,” *Environmental Health Trust*. https://ehtrust.org/key-issues/cell-phoneswireless/mens-reproductive-health/ (accessed Mar. 18, 2021).

[20]“Environmental Impact of Wireless Devices: How EMF Radiation is Endangering the Planet | DefenderShield,” *DefenderShield*, Oct. 19, 2020. https://www.defendershield.com/environmental-impacts-emf-wireless-devices/ (accessed Mar. 18, 2021).

[21]“Top 10 facts about bees | WWF,” *WWF*. https://www.wwf.org.uk/learn/fascinating-facts/bees (accessed Mar. 18, 2021).

[22] “Upcoming Wireless Network Technology | Worldwide Supply,” Worldwide Supply, Nov. 08, 2018. https://worldwidesupply.net/blog/blogupcoming-wireless-network-technology/ (accessed Apr. 05, 2021).

[23] “LiFi the healthier alternative to WiFi - en.geovital.com [EN],” en.geovital.com [EN], Feb. 02, 2016. https://en.geovital.com/lifi-the-healthier-alternative-to-wifi/ (accessed Apr. 05, 2021).