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FIFTH GENERATION (5G): SPEED THRILLS BUT KILLS

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ABSTRACT

In **telecommunications**, 5G is the fifth-generation technology standard for **broadband cellular networks**, which **cellular phone companies** began deploying worldwide in 2019, and is the planned successor to the **4G** networks which provide connectivity to most current **cellphones**. 5G networks are predicted to have more than 1.7 billion subscribers worldwide by 2025, according to the **GSM Association**. Like its predecessors, 5G networks are **cellular networks**, in which the service area is divided into small geographical areas called *cells*. All 5G wireless devices in a cell are connected to the **Internet** and **telephone network** by **radio waves** through a local **antenna** in the cell. The main advantage of the new networks is that they will have greater **bandwidth**, giving higher **download speeds**, eventually up to 10 **gigabits per second** (Gbit/s). Due to the increased bandwidth, it is expected the networks will increasingly be used as general **internet service providers** for laptops and desktop computers, competing with existing ISPs such as **cable internet**, and also will make possible new applications in **internet of things** (IoT) and **machine to machine** areas. 4G cellphones are not able to use the new networks, which require 5G enabled wireless devices. The increased speed is achieved partly by using additional higher-frequency radio waves in addition to the low and medium band frequencies used in previous cellular networks. However, higher-frequency radio waves have a shorter useful physical range, requiring smaller geographic cells. For wide service, 5G networks operate on up to three frequency bands – low, medium, and high. A 5G network will be composed of networks consisting of up to three different types of cells, each requiring specific antenna designs as well as providing a different tradeoff of download speed to distance and service area. 5G cellphones and wireless devices connect to the network through the highest speed antenna within range at their location: Low-band 5G uses a similar frequency range to 4G cellphones, 600–850 **MHz**, giving download speeds a little higher than 4G: 30–250 **megabits per second** (Mbit/s). Low-band **cell towers** have a range and coverage area similar to 4G towers. Mid-band 5G uses **microwaves** of 2.5–3.7 **GHz**, allowing speeds of 100–900 Mbit/s, with each cell tower providing service up to several kilometers in radius. This level of service is the most widely deployed, and was deployed in many metropolitan areas in 2020. Some regions are not implementing low-band, making this the minimum service level. High-band 5G uses frequencies of 25–39 GHz, near the bottom of the millimeter wave band, although higher frequencies may be used in the future. It often achieves download speeds in the **gigabit per second** (Gbit/s) range, comparable to cable internet. However, **millimeter waves** (mmWave or mmW) have a more limited range, requiring many small cells. They can be impeded or blocked by materials in walls or windows. Due to their higher cost, plans are to deploy these cells only in dense urban environments and areas where crowds of people congregate such as sports stadiums and convention centers. The above speeds are those achieved in actual tests in 2020, and speeds are expected to increase during rollout. The industry consortium setting standards for 5G is the **3rd Generation Partnership Project** (3GPP). It defines any system using **5G NR** (5G New Radio) software as "5G", a definition that came into general use by late 2018. Minimum standards are set by the **International Telecommunications Union** (ITU). Previously, some reserved the term 5G for systems that deliver download speeds of 20 Gbit/s as specified in the ITU's **IMT-2020** document. Rollout of 5G technology has led to debate over its security and **relationship with Chinese vendors**. It has also been the subject of **health concerns** and misinformation, including **discredited conspiracy theories** that links it to the **COVID-19 pandemic**.

KEYWORDS: 5G, 4G, MHz, GHz, Gbit/s, Mbit/s, 5G NR, ITU, eMBB, URLLC.

Overview: 5G networks are digital cellular networks, for which the service area is divided into small geographical *cells*. The 5G wireless devices in a cell communicate by radio waves with a local antenna array and low power automated transceiver **(**transmitter and receiver) in the cell, over frequency channels assigned by the transceiver from a pool of frequencies that are reused in other cells. The local antennas are connected to transmission electronics connected to switching centers in the telephone network and routers for Internet access by high-bandwidth optical fiber or wireless backhaul connections. As in other cell networks, a mobile device moving from one cell to another is automatically handed off seamlessly to the current cell. 5G can support up to a million devices per square kilometer, while 4G supports only one tenth of that capacity. The new 5G wireless devices also have 4G LTE capability, as the new networks use 4G for initially establishing the connection with the cell, as well as in locations where 5G access is not available.

Figure-1: 5G For better speed and experience.

Several network operators use millimeter waves for additional capacity, as well as higher throughput. Millimeter waves have a shorter range than microwaves**,** therefore the cells are limited to a smaller size. Millimeter waves also have more trouble passing through building walls. Millimeter wave antennas are smaller than the large antennas used in previous cellular networks. Some are only a few centimeters long.[1]

Massive MIMO (multiple-input multiple-output) was deployed in 4G as early as 2016 and typically used 32 to 128 small antennas at each cell. In the right frequencies and configuration, it can increase performance from 4 to 10 times. Multiple bitstreams of data are transmitted simultaneously. In a technique called *beamforming*, the base station computer will continuously calculate the best route for radio waves to reach each wireless device and will organize multiple antennas to work together as phased arrays to create beams of millimeter waves to reach the device.

Application areas: The **ITU-R** has defined three main application areas for the enhanced capabilities of 5G. They are Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine Type Communications (mMTC). Only eMBB is deployed in 2020; URLLC and mMTC are several years away in most locations.

Figure-2: 5G Demons Jiofibre and Airtel Extreme.

Enhanced Mobile Broadband (eMBB) uses 5G as a progression from 4G LTE **mobile broadband** services, with faster connections, higher throughput, and more capacity. This will benefit areas of higher traffic such as stadiums, cities, and concert venues.

Ultra-Reliable Low-Latency Communications (URLLC) refer to using the network for **mission critical** applications that require uninterrupted and robust data exchange. The short-packet data transmission is used to meet both reliability and latency requirements of the wireless communication networks.

Massive Machine-Type Communications (mMTC) would be used to connect to a large number of **devices**. 5G technology will connect some of the 50 billion connected IoT devices. Most will use the less expensive Wi-Fi. Drones, transmitting via 4G or 5G, will aid in disaster recovery efforts, providing real-time data for emergency responders. Most cars will have a 4G or 5G cellular connection for many services. Autonomous cars do not require 5G, as they have to be able to operate where they do not have a network connection. However, most autonomous vehicles also feature teleoperations for mission accomplishment, and these greatly benefit from 5G technology. While remote surgeries have been performed over 5G, most remote surgery will be performed in facilities with a fiber connection, usually faster and more reliable than any wireless connection.

Performance

Speed: 5G speeds will range from ~50 Mbit/s to over a gigabit/s. The fastest 5G is in the mmWave bands and can reach upto 4 Gb/s. Sub-6 GHz 5G (mid-band 5G), by far the most common, will usually deliver between 100 and 400 Mbit/s, but will have a much farther reach than mmWave, especially outdoors. C-Band is expected to be deployed by various operators by the end 2021. Low-band spectrum offers the greatest range, thereby a greater coverage area for a given site, but is slower than the others. 5G NR (New Radio) speed in sub-6 GHz bands can be slightly higher than the 4G with a similar amount of spectrum and antennas, although some 3GPP 5G networks will be slower than some advanced **4G** networks. The 5G specification allows **LAA (License Assisted Access)** as well, but LAA in 5G has not yet been demonstrated.

Figure-3: 5G Dependent Playstation setup.

The similarity in terms of throughput between 4G and 5G in the existing bands is because 4G already approaches the **Shannon limit** on data communication rates. 5G speeds in the less common **millimeter wave** spectrum, with its much more abundant bandwidth and shorter range, and hence greater frequency reusability, can be substantially higher. **Latency:** In 5G, the "air latency" in equipment shipping in 2019 is 8–12 milliseconds. The latency to the server must be added to the "air latency" for most comparisons. Verizon reports the latency on its 5G early deployment is 30 ms: Edge Servers close to the towers can reduce latency to 10–20 ms; 1–4 ms will be extremely rare for years outside the lab. The 5G latency KPIs (key performance indicators) are standardized by 3GPP in TR 28554.[2]

Error Rate: 5G uses adaptive modulation and coding scheme (MCS) to keep the bit error rate extremely low. Whenever the error rate crosses a (very low) threshold the transmitter will switch to a lower MCS, which will be less error prone. This way speed if sacrificed to ensure an almost zero error rate.

Range: The range of 5G depends on many factors. A key factor is the frequency being used. mmWave signals tend to have a range of only a couple of hundred metres whilst low band signals can, in the right circumstances, have a theoretical range of a couple of hundred kilometers. **Standards:** Initially, the term was associated with the **International Telecommunication Union**'s **IMT-2020** standard, which required a theoretical peak download speed of 20 gigabits per second and 10 gigabits per second upload speed, along with other requirements. Then, the industry standards group 3GPP chose the **5G NR** (New Radio) standard together with LTE as their proposal for submission to the IMT-2020 standard. The first phase of 3GPP 5G specifications in Release-15 is scheduled to complete in 2019. The second

phase in Release-16 is due to be completed in 2020. 5G NR can include lower frequencies (**FR1**), below 6 GHz, and higher frequencies (**FR2**), above 24 GHz. However, the speed and latency in early FR1 deployments, using 5G NR software on 4G hardware (**non-standalone**), are only slightly better than new 4G systems, estimated at 15 to 50% better. **IEEE** covers several areas of 5G with a core focus in wireline sections between the Remote Radio Head (RRH) and Base Band Unit (BBU). The 1914.1 standards focus on network architecture and dividing the connection between the RRU and BBU into two key sections. Radio Unit (RU) to the Distributor Unit (DU) being the NGFI-I (Next Generation Fronthaul Interface) and the DU to the Central Unit (CU) being the NGFI-II interface allowing a more diverse and cost-effective network. NGFI-I and NGFI-II have defined performance values which should be compiled to ensure different traffic types defined by the ITU are capable of being carried. 1914.3 standard is creating a new Ethernet frame format capable of carrying IQ data in a much more efficient way depending on the functional split utilized. This is based on the **3GPP** definition of functional splits. Multiple network synchronization standards within the IEEE groups are being updated to ensure network timing accuracy at the RU is maintained to a level required for the traffic carried over it. **5G NR** (New Radio) is a new **air interface** developed for the 5G network. It is supposed to be the global standard for the air interface of 3GPP 5G networks.[3]

Pre-standard implementations

- 5GTF: The 5G network implemented by American carrier **Verizon** for **Fixed Wireless Access** in late 2010s uses a pre-standard specification known as 5GTF (Verizon 5G Technical Forum). The 5G service provided to customers in this standard is incompatible with 5G NR. There are plans to upgrade 5GTF to 5G NR "Once [it] meets our strict specifications for our customers," according to Verizon.
- 5G-SIG: Pre-standard specification of 5G developed by **KT Corporation**. Deployed at Pyeongchang **2018 Winter Olympics**.

Internet of things: In the **Internet of things** (IoT), 3GPP is going to submit evolution of **NB-IoT** and **eMTC** (LTE-M) as 5G technologies for the **LPWA** (Low Power Wide Area) use case.

Deployment

Figure-4: 5G Towers.

Beyond mobile operator networks, 5G is also expected to be used for private networks with applications in industrial IoT, enterprise networking, and critical communications. Initial 5G NR launches depended on pairing with existing LTE (4G) infrastructure in **non-standalone (NSA) mode** (5G NR radio with 4G core), before maturation of the **standalone (SA) mode** with the 5G core network. As of April 2019, the **Global Mobile Suppliers Association** had identified 224 operators in 88 countries that have demonstrated, are testing or trialing, or have been licensed to conduct field trials of 5G technologies, are deploying 5G networks or have announced service launches. The equivalent numbers in November 2018 were 192 operators in 81 countries. The first country to adopt 5G on a large scale was South Korea, in April 2019. Swedish telecoms giant Ericsson predicted that 5G internet will cover up to 65% of the world's population by the end of 2025. Also, it plans to invest 1 billion reals ($238.30 million) in Brazil to add a new assembly line dedicated to fifth-generation technology (5G) for its Latin American operations.[4]

When South Korea launched its 5G network, all carriers used Samsung, Ericsson, and Nokia **base stations** and equipment, except for **LG U Plus**, who also used Huawei equipment. Samsung was the largest supplier for 5G base stations in South Korea at launch, having shipped 53,000 base stations at the time, out of 86,000 base stations installed across the country at the time. The first fairly substantial deployments were in April 2019. In South Korea, **SK Telecom** claimed 38,000 base stations, **KT Corporation** 30,000 and **LG U Plus** 18,000; of which 85% are in six major cities. They are using 3.5 GHz (sub-6) spectrum in **non-standalone (NSA) mode** and tested speeds were from 193 to 430 **Mbit/s** down. 260,000 signed up in the first month and 4.7

million by the end of 2019. Nine companies sell 5G radio hardware and 5G systems for carriers: **Altiostar**, **Cisco Systems**, **Datang Telecom/ Fiberhome**, **Ericsson**, **Huawei**, **Nokia**, **Qualcomm**, **Samsung**, and **ZTE**.

Spectrum: Large quantities of new **radio spectrum** (**5G NR frequency bands**) have been allocated to 5G. For example, in July 2016, the U.S. **Federal Communications Commission** (FCC) freed up vast amounts of bandwidth in underused high-band spectrum for 5G. The Spectrum Frontiers Proposal (SFP) doubled the amount of millimeter-wave unlicensed spectrum to 14 GHz and created four times the amount of flexible, mobile-use spectrum the FCC had licensed to date. In March 2018, **European Union** lawmakers agreed to open up the 3.6 and 26 GHz bands by 2020.[5]

As of March 2019, there are reportedly 52 countries, territories, special administrative regions, disputed territories and dependencies that are formally considering introducing certain spectrum bands for terrestrial 5G services, are holding consultations regarding suitable spectrum allocations for 5G, have reserved spectrum for 5G, have announced plans to **auction frequencies** or have already allocated spectrum for 5G use. **Unlicensed spectrum: MNO's** are increasingly using unlicensed spectrum in the 2.4- and 5-gigahertz (GHz) frequency bands. 4G and 5G networks also use these bands to offload traffic in heavily congested areas and provide connectivity for billions of IoT devices. Advancements in Wi-Fi, LTE in Unlicensed spectrum (LTE-U), License Assisted Access (LAA), and MulteFire use 4G & 5G technologies in these bands.

Blood–brain barrier

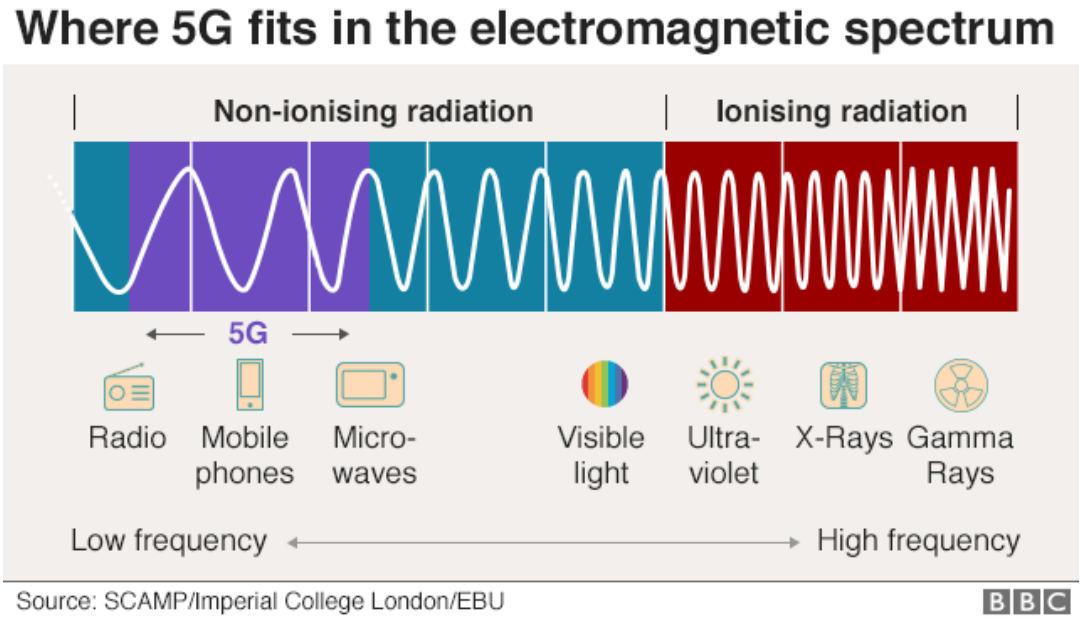

Figure-5: BBB effects from 5G.

A 2010 review stated that "The balance of experimental evidence does not support an effect of 'non-thermal' radio frequency fields" on the permeability of the blood-brain barrier, but noted that research on low frequency effects and effects in humans was sparse. A 2012 study of low-frequency radiation on humans found "no evidence for acute effects of short-term mobile phone radiation on cerebral blood flow".[6]

Cancer: There is no known way in which radiofrequency radiation (in contrast to ionizing radiation) affects DNA and causes cancer, and laboratory research has found no good evidence of any such effect in animal studies. In 2011 the IARC, a World Health Organization working group, classified mobile phone use as "possibly carcinogenic to humans". The IARC summed up their conclusion with: "The human epidemiological evidence was mixed. Several small early case–control studies were considered to be largely uninformative. A large cohort study showed no increase in risk of relevant tumours, but it lacked information on level of mobile-phone use and there were several potential sources of misclassification of exposure. The bulk of evidence came from reports of the INTERPHONE study, a very large international, multicentre case–control study and a separate large case–control study from Sweden on gliomas and meningiomas of the brain and acoustic neuromas. While affected by selection bias and information bias to varying degrees, these studies showed an association between glioma and acoustic neuroma and mobile-phone use; specifically in people with highest cumulative use of mobile phones, in people who had used mobile phones on the same side of the head as that on which their tumour developed, and in people whose tumour was in the temporal lobe of the brain (the area of the brain that is most exposed to RF radiation when a wireless phone is used at the ear)". The CDC states that no scientific evidence definitively answers whether mobile phone use causes cancer. In a 2018 statement, the US Food and Drug Administration

said that "the current safety limits are set to include a 50fold safety margin from observed effects of radiofrequency energy exposure". On 1 November 2018, the US National Toxicology Program published the final version (after peer review that was performed through March 2018) of its "eagerly anticipated" study using rats and mice, conducted over some ten years. This report concludes after the review with an updated statement that "there is clear evidence that male rats exposed to high levels of radio frequency radiation (RFR) like that used in 2G and 3G cell phones developed cancerous heart tumors.... There was also some evidence of tumors in the brain and adrenal gland of exposed male rats. For female rats, and male and female mice, the evidence was equivocal as to whether cancers observed were associated with exposure to RFR".[7]

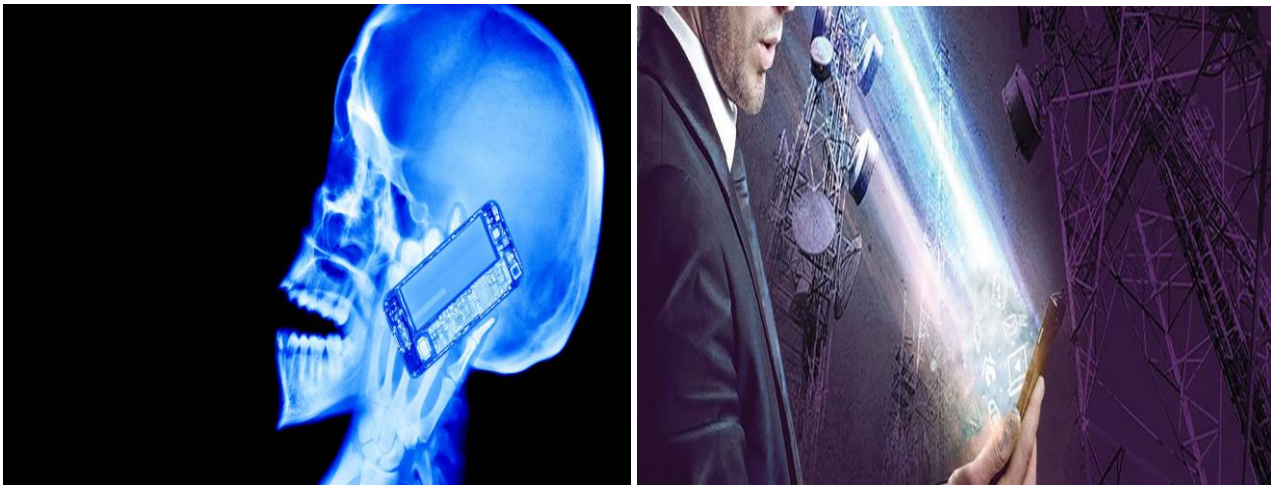

Figure-6: 5G carrier of Cancer.

An early analysis of preliminary results issued by the National Toxicology Program had indicated that due to such issues as the inconsistent appearances of "signals for harm" within and across species and the increased chances of false positives due to the multiplicity of tests, the positive results seen are more likely due to random chance. The full results of the study were released for peer review in February 2018.

Male fertility: A decline in male sperm quality has been observed over several decades. Studies on the impact of mobile radiation on male fertility are conflicting, and the effects of the radio frequency electromagnetic radiation (RF-EMR) emitted by these devices on the reproductive systems are currently under active debate. A 2012 review concluded that "together, the results of these studies have shown that RF-EMR decreases sperm count and motility and increases oxidative stress". A 2017 study of 153 men that attended an academic fertility clinic in Boston, Massachusetts found that self-reported mobile phone use was not related to semen quality, and that carrying a mobile phone in the pants pocket was not related to semen quality.

Figure-7: 5G effects on male fertility.

Electromagnetic hypersensitivity: Some users of mobile phones and similar devices have reported feeling various non-specific symptoms during and after use. Studies have failed to link any of these symptoms to electromagnetic exposure. In addition, EHS is not a recognized medical diagnosis.[8]

Glucose metabolism: According to the National Cancer Institute, two small studies exploring whether and how mobile phone radiation affects brain glucose metabolism showed inconsistent results.

Effects on children: A report from the Australian Government's Radiation Protection and Nuclear Safety Agency (ARPANSA) in June 2017 noted that: The 2010 WHO Research Agenda identified a lack of sufficient evidence relating to children and this is still the case. ... Given that no long-term prospective study has looked at this issue to date this research need remains a high priority. For cancer in particular only one completed case-control study involving four European countries has investigated mobile phone use among children or adolescents and risk of brain tumour; showing no association between the two (Aydin et al. 2011). ... Given this paucity of information regarding children using mobile phones and cancer ... more epidemiological studies are needed.

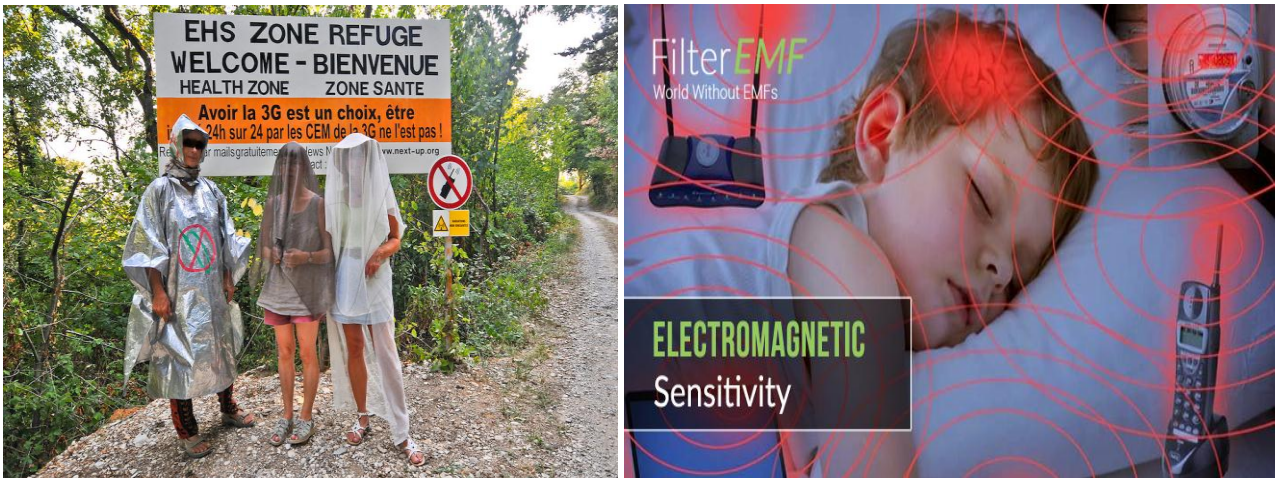

Figure-8: Electromagnetic Hypersensitivity.

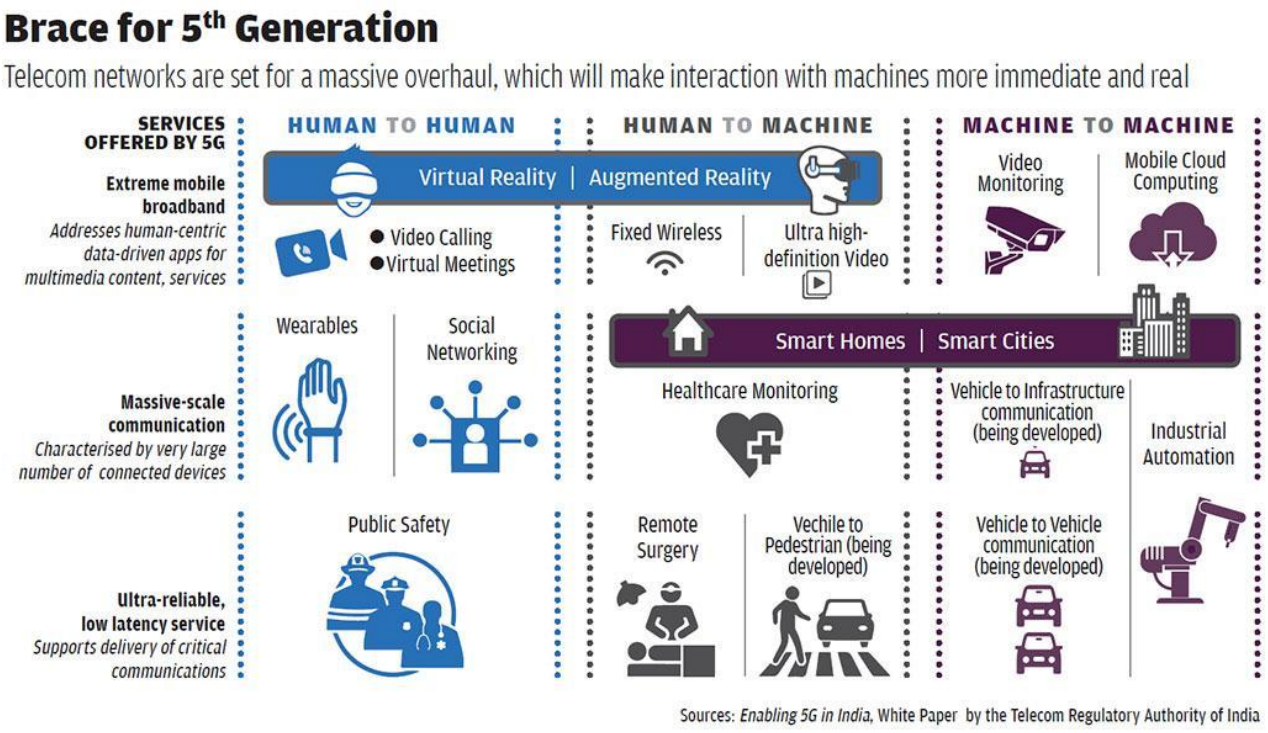

Figure-9: Effect of 5G Over Human Civilization.

CONCLUSION

5G can be significantly faster than 4G, delivering **up to 20 Gigabits-per-second (Gbps) peak data rates** and 100+ Megabits-per-second (Mbps) average data rates. 5G has more capacity than 4G. 5G is designed to support a 100x increase in traffic capacity and network efficiency. In 2000, the World Health Organization (WHO) recommended that the precautionary principle could be voluntarily adopted in this case. It follows the recommendations of the European Community for environmental risks.

According to the WHO, the "precautionary principle" is "a risk management policy applied in circumstances with a high degree of scientific uncertainty, reflecting the need to take action for a potentially serious risk without awaiting the results of scientific research." Other less stringent recommended approaches are prudent avoidance principle and as low as reasonably practicable. Although all of these are problematic in application, due to the widespread use and economic importance of wireless telecommunication systems in modern civilization, there is an increased popularity of such measures in the general public, though also evidence that such approaches may increase concern. They involve recommendations such as the minimization of usage, the limitation of use by at-risk population (e.g., children), the adoption of phones and microcells with as low as reasonably practicable levels of radiation, the wider use of hands-free and earphone technologies such as Bluetooth headsets, the adoption of maximal standards of exposure, RF field intensity and distance of base stations antennas from human habitations, and so forth. Overall, public information remains a challenge as various health consequences are evoked in the literature and by the media, putting populations under chronic exposure to potentially worrying information.

In May 2011, the World Health Organization's International Agency for Research on Cancer announced it was classifying electromagnetic fields from mobile phones and other sources as "possibly carcinogenic to humans" and advised the public to adopt safety measures to reduce exposure, like use of hands-free devices or texting.

Some national radiation advisory authorities, including those of Austria, France, Germany, and Sweden, have recommended measures to minimize exposure to their citizens. Examples of the recommendations are:

- Use hands-free to decrease the radiation to the head.
- Keep the mobile phone away from the body.
- Do not use telephone in a car without an external antenna.

The use of "hands-free" was not recommended by the British Consumers' Association in a statement in November 2000, as they believed that exposure was increased. However, measurements for the (then) UK Department of Trade and Industry and others for the French Agence française de sécurité sanitaire environnementale showed substantial reductions. In 2005, Professor Lawrie Challis and others said clipping a ferrite bead onto hands-free kits stops the radio waves travelling up the wire and into the head.

Several nations have advised moderate use of mobile phones for children. A journal by Gandhi et al. in 2006 states that children receive higher levels of Specific Absorption Rate (SAR). When 5- and 10-year-olds are compared to adults, they receive about 153% higher SAR levels. Also, with the permittivity of the brain decreasing as one gets older and the higher relative volume of the exposed growing brain in children, radiation penetrates far beyond the mid-brain. The FDA is quoted as saying that "...continues to believe that the current safety limits for cellphone radiofrequency energy exposure remain acceptable for protecting the public health." In the beginning of the year 2020 Slovenia stopped the deployment of the 5G technology as a precaution due to health concerns. During the COVID-19 pandemic, misinformation circulated claiming that 5G networks contribute to the spread of COVID-19.

REFERENCES

1. E.J. Violette; R.H. Espeland; R.O. DeBolt; F.K. Schwering (May). "Millimeter-wave propagation at street level in an urban environment". IEEE Transactions on Geoscience and Remote Sensing. IEEE, 1988; 26(3): 368–380.
2. Rappaport, T.S.; Sun, Shu; Mayzus, R.; Zhao, Hang; Azar, Y.; Wang, K.; Wong, G.N.; Schulz, J.K.; Samimi, M. (January 1). "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!". IEEE Access, 2013; 1: 335–349.
3. Yu, Heejung; Lee, Howon; Jeon, Hongbeom (October). "What is 5G? Emerging 5G Mobile Services and Network Requirements". Sustainability, 2017; 9(10): 1848.
4. Meese, James; Frith, Jordan; Wilken, Rowan "COVID-19, 5G conspiracies and infrastructuralfutures". Media International Australia, 2020; 177: 30–46.
5. Witze, Alexandra (November 22). "Global 5G wireless deal threatens weather forecasts". Nature, 2019; 575(7784): 577.
6. Ordonez-Lucena, J.; Ameigeiras, P.; Lopez, D.; Ramos-Munoz, J. J.; Lorca, J.; Folgueira, J. "Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges". IEEE Communications Magazine, 2017; 55(5): 80–87.
7. C.Sunitha; Deepika.G.Krishnan; V.A.Dhanya (January). "Overview of Fifth Generation Networking" (PDF). International Journal of Computer Trends and Technology (IJCTT), 2017; 43(1).
8. Rappaport, T.S.; Sun, Shu; Mayzus, R.; Zhao, Hang; Azar, Y.; Wang, K.; Wong, G.N.; Schulz, J.K.; Samimi, M. (January 1). "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!". IEEE Access, 2013; 1: 335–349.