5G: Challenges, Opportunities, and Health Concerns

Madan Pal Singh[1]
JBIT Dehradun[1]

Ashish Kr. Gupta[2]
SCE Dehradun[2]

Mansi Sharma[3]
SCE Dehradun[3]

***Abstract*:- The mobile communication industry is about to start its latest revolution: fifth-generation (5G) wireless broadband technology. 5G operates at higher frequencies than today's wireless networks and uses new advanced technologies such as massive antenna arrays, to provide better speed and coverage while decreasing latency, the delay before a transfer of data actually begins. With advanced features, 5G will be the backbone of next generation technologies such as driverless cars and the Internet of Things (IoT) while bringing new technological challenges. In this paper we tried to find the way to face the challenges and opportunities while concerning about health. We tried to suggest the best ways to overcome implication caused by high speed (5G) wireless communication.**

Key words: 5G, RF, Antenna array, Health, ITU.

I. INTRODUCTION

The ITU has highlighted 5G networks and artificial intelligence (AI) as fields of innovation necessary for enabling smarter societies. 5G is the next generation of mobile standards and promises to deliver improved end-user experience by offering new applications and services through gigabit speeds, and significantly improved performance and reliability. 5G networks are expected to be enhanced with AI to make sense of data, manage and orchestrate network resources and to provide intelligence to connected and autonomous systems.

This report reviews expectations of 5G and examines the infrastructure and investment requirements on the private and public sectors as they prepare for 5G. It is designed to support emerging use cases and services, and to help all sectors meet the expected performance (gigabit data rates), low latency and high reliability requirements of these services, ensuring that end users reap in full the economic benefit that 5G is expected to offer.

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What is 5G?

5G is the next generation of mobile standards being defined by the ITU. IMT-2020 (5G) is a name for the systems, components, and related elements that support enhanced capabilities beyond those offered by IMT-2000 (3G) and IMT-Advanced (4G) systems.

International Mobile Telecommunication 2020 standards (IMT-2020):

• Set the stage for 5G research activities that are emerging around the world

• Define the framework and overall objectives of the 5G standardization process

• Set out the roadmap to guide this process to its conclusion by 2020 (see Figure 1).

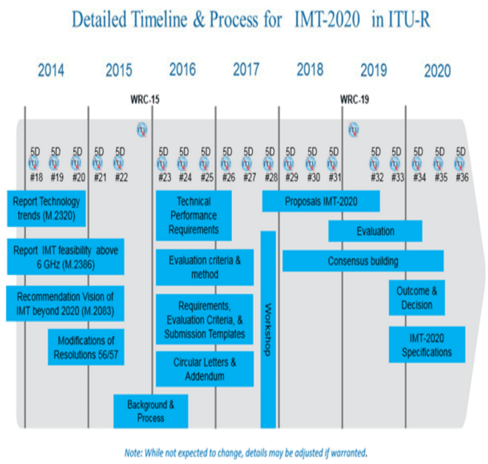


Fig. 1

5G promises to deliver improved end-user experience by offering new applications and services through gigabit speeds, and significantly improved performance and reliability. 5G will build on the successes of 2G, 3G and 4G mobile networks, which have transformed societies, supporting new services and new business models. 5G provides an opportunity for wireless operators to move beyond providing connectivity services, to developing rich solutions and services for consumers and industry across a range of sectors – and at affordable cost. 5G is an opportunity to implement wired and wireless converged networks, and offers in particular opportunities in integrating network management systems.

Commercial 5G networks are expected to start deployment after 2020, as shown in Figure 2, as 5G standards are finalized.1 By 2025, the GSM Association (GSMA) expects 5G connections to reach 1.1 billion, some 12 per cent of total mobile connections. It also forecasts overall operator revenues to grow at a CAGR of 2.5 per cent, to reach USD 1.3 trillion by 2025.

II. CHALLENGES:

Let us review one of the most fundamental equations of the telecommunication engineering: the Friis' transmission equation- $P_r \propto \frac{P_t}{f^2 R^2}$.

The Friis transmission equation describes the RF signal power transmitted from an emitting antenna to a receiving antenna, such as between a 5G base station to a mobile phone or vice versa. The distance between the receiver and transmitter is R, and f is the carrier frequency of the transmitted signal. Friis' equationsays that the power of the signal received by our cell phone (Pr) is proportional to the power emitted by the transmitter (Pt); in our example, the base station is the transmitter. The power also depends on the frequency of the signal and the distance between the receiver and transmitter antennas. However, this dependency is quadratic, meaning, if the frequency is doubled, the power decreases four times; if the distance increases ten times, the power decays one hundred times. We care about the signal power received because weak signal power results in dropped calls and increased susceptibility to interference.

The complete version of the Friis' transmission equation includes additional terms but they are not shown here for the sake of simplicity. Also, here we consider the simplest communication scenario: there are two antennas communicating with each other without any obstruction in the path or a reflector nearby. Despite these simplifications, Friis' equation is very useful to understand the influence of distance and frequency over power received.

A. Key challenges in rolling out 5G:

a) Small cell deployment challenges

In some countries, regulation and local authority policy have slowed the development of small cells through excessive administrative and financial obligations on operators, thus blocking investment. Constraints to deploying small cells include prolonged permitting processes, lengthy procurement exercises, excessive fees and outdated regulations that prevent access. These issues are:-

- Local permitting and planning processes:The time taken by local authorities to approve planning applications for small cell implementations can take 18 to 24 months (Box 7), resulting in delays.
- Lengthy engagement and procurement exercises: Local authorities have used lengthy procurement processes lasting 6 to 18 months to award wireless providers with exclusive rights to deploy small cell equipment onto street furniture, costing time and expense.
- Human exposure to radiofrequency electromagnetic fields (EMF): Exposure limits differ across countries, and in some cases are unduly restrictive. ITU recommend that if radio frequency electromagnetic field (RF EMF) limits do not exist, or if they do not cover the frequencies of interest, then ICNIRP (International Commission on Non-Ionizing Radiation Protection) limits should be used.

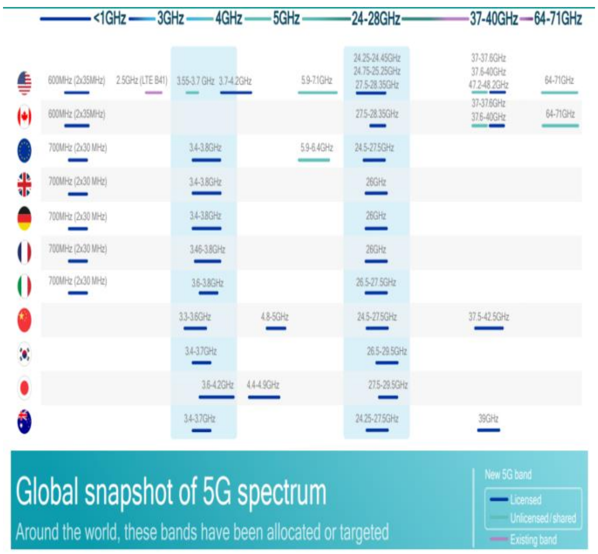
b)Spectrum

The allocation and identification of globally harmonized spectrum across a range of frequencies requires coordination among the global community, regional telecommunication organizations and NRAs. This represents one of the largest challenges for NRAs in the successful deployment of 5G networks. Harmonized allocation has many advantages since it minimizes radio interference along borders, facilitates international roaming and reduces the cost of equipment. This overall coordination is the main objective of the ITU-R in the process of World Radiocommunication Conferences (WRCs).

Consideration should also be given to the sharing of spectrum to make more efficient use of what is available. Traditionally, NRAs have allocated spectrum to mobile operators on an exclusive basis. However, due to growing need, sharing can provide a means to improve the efficient use of existing spectrum.

c) Role of Frequency in 5G

Different countries are considering different electromagnetic frequency bands for 5G. These frequencies range from 600 MHz to 71 GHz. Dividing them into three main groups, i.e. low-band (0.6 GHz - 3.7 GHz), mid-band (3.7 – 24 GHz), and high-band (24 GHz and higher), helps with the frequency related discussions.



In general, bandwidth of the signals increase with frequency. As a result, higher frequency signals can transmit larger amounts of data than lower frequency signals. The bad news is that high frequency signals do not travel as far as low frequency signals, for three reasons. First, the power of the signal received at an antenna decays quadratically with increasing frequency, as previously discussed. Second, the amount of power diminishes as the signal travels through air which increases with frequency, e.g., from low-band to high-band. Third, the longer the path the waves travel, the higher the loss they experience. How can we overcome this challenge? The Friis' transmission equation provides the answer. The first thing is to decrease the distance between receiver and transmitter antennas.This is why 5G networks will be ultra-dense cellular networks meaning that they will have small cells installed every few blocks and closer to the ground than today's tower-top radios scattered every few miles. The second thing we can do is to use better antennas. The complete version of the Friis' transmission equation includes additional terms representing the gain of antennas. Using multiple antennas instead of a single antenna is one simple way of increasing the gain. This is why current mobile communication systems use multiple antennas, also known as antenna arrays. With 5G, the number of these antennas will be increased to hundreds. These massive multiple input, multiple output (MIMO) antennas [3] will boost and multiply signals anywhere 5G is offered. Through various types of modulations, these massive MIMO antennas will enable wireless networks to transmit and receive more than one data signal simultaneously over the same radio channel. The MIMOs' ability to create ultra-narrow beams will be useful to reduce the interference, which limits the capacity of cellular networks, but at the same, it will make it more difficult to handle high-speed mobile users [4].

d) Best Antenna

Despite low-level device-to-device (D2D) communication techniques such as Push-to-Talk, Bluetooth, and WiFi-Direct, most current cellular technologies do not support direct over-the-air communication between end users. A revolutionary aspect of 5G will be enabling D2D communication without or with partial involvement of the network infrastructure, such as mobile access points or mobile base stations. This feature will be the game changer. Hundreds of cars travelling on the same highway or hundreds of devices operating in a manufacturing facility will exchange information directly, without transmitting to a distant base station or through a core network. This will also decrease the overall power consumption of wireless communications: when you use your cell-phone, instead of making a connection with a base station, your device will communicate with a much closer 5G device. That device will pass your data to next nearest device and this will continue until your data reaches to the base station. Let's say; the data exchange is achieved across a chain of ten 5G phones each separated by ten feet. Application of Friis' transmission equation estimates this communication requires just 10 % of the power that would have been used to transmit the 100 feet distance between the first and last antennas. As a result, 5G will enable high-speed data transfer at a lower energy cost. However, this great feature comes with three problems: security/privacy, interference, and pricing [4]. The parties sending and receiving the data must be assured their data is not accessible to the relay, and the relay must be assured the data it is handling is benign. Interference between the cellular network and device tiers and interference among users in the device tier will require novel interference management strategies and resource allocation schemes. The pricing of D2D services is another subject, which requires further study. What incentives should be considered to encourage people to allow their devices to be used as a relay in 5G network? What kind of in-network and out-network pricing schemes should mobile network provides consider to maximize their profit?

III. OPPORTUNITIES

At the highest level, 5G is an opportunity for policy-makers to empower citizens and businesses. 5G will play a key role in supporting governments and policy-makers in transforming their cities into smart cities, allowing citizens and communities to realize and participate in the socio-economic benefits delivered by an advanced, data-intensive, digital economy.

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5G is also expected to increase data rates dramatically and reduce latency compared to 3G and 4G. 5G is expected to significantly reduce latency to below 1ms, suited to mission-critical services where data are time-sensitive. Its high-speed capability means 5G networks can provide a range of high-speed broadband services and offer an alternative to last-mile access such as FTTH or copper connections.

IV. HEALTH CONCERNS

A. RF Signals from Cell Phones

Researchers have conducted studies of many types to find out whether RF fields at levels produced from common devices, principally cellphones, might adversely affect health, including whether they may cause cancer. Numerous national and international scientific and governmental organizations [6-20] have reviewed epidemiologic, in vivo, and in vitro studies of health and biological endpoints in association with the RF exposures that would be encountered in typical environments accessible to the public (i.e., exposures below the level that raises body temperature). These agencies concluded that the outcomes of these studies do not provide sufficient evidence to conclude that RF exposure causes any adverse health effect. Despite this consensus, research continues to test hypotheses, fill in data gaps, and make sure that even a small risk is not overlooked. For example, recent studies on RF exposure in rats and mice conducted by the National Toxicology Program (NTP) [17] at the request of the U.S. Food and Drug Administration (FDA) reported the presence of tumors in male rats. However, the level and duration of exposure were much greater than what humans experience with even the highest level of cell phone use and the NTP has noted that "the results should not be directly extrapolated to humans." The tumors were also observed in only a few animals. Thus, further research will be needed to confirm and explain the results of the NTP studies. As human and rats biologically are not the same, it also is not clear whether these findings have any relevance to our exposures to RF signals at far lower levels. However, we do know what will be different when 5G arrives and what we can do to minimize its health impacts on humans, if it has any.

B. Health Concerns: 5G

The low frequency band of forthcoming 5G networks, where the carrier frequency is less than 3 GHz, is not very different from the frequency bands used in current wireless systems. The small cells planned to be deployed by network providers will be placed in close proximity to urban areas and will be transmitting much less energy compared to today's base stations. Hence, from the spectral point of view, we do not expect a significant difference in exposure to wireless networks' operations at low frequencies. However, exposures will be quite different at higher frequencies, especially in the high-band.

The high-band of the 5G frequencies fall into the "millimeter wave" (mmW) category, i.e. the wavelength of the electromagnetic wave is in the range of millimeters. These waves are mostly absorbed within 1 to 2 millimeters of human skin and in the surface layers of the cornea [20]. In the Unites States, the Federal Communications Commission (FCC) determines the rules and regulations related to communication systems as well as the limits of the electromagnetic energy that a device can transmit. In order to protect humans from acute exposure to thermal levels of radiofrequency radiation, FCC allows a maximum 1.0 mW/cm2 of exposure (averaged over 30 minutes for frequencies that range from 1.5 GHz to 100 GHz) for the general public [21].

While a great deal is known about the interaction of RF signals with materials and the human body, the fact is that because there are few sources of RF fields in the high-frequency band, there is currently little research to point to for confirmation of the current consensus that the adverse effects of RF exposure are caused by tissue heating. Given the concern that some members of the public and some scientists have expressed about exposure to low-band frequencies [18], it is inevitable that concern also will be raised about exposures to 5G signals that have not been as thoroughly studied. In fact, the World Health Organization has already emphasized the need for high quality scientific studies in this area due to the current widespread use of technology, the degree of scientific uncertainty, and the levels of public apprehension [19].

V. CONCLUSION

The introduction of 5G technologies will require considerable research and development on technical issues [4, 5] and also public reaction to deployment. One can expect that the installation of such a large number of antennas everywhere will be challenged by some members of the public, especially if the antennas are large and unsightly. Opposition may also be fueled by fears about exposure to RF even if 5G does lower general exposure as it replaces current low-frequency RF communication systems. Manufacturers of consumer electronics and test & measurement equipment will need solutions to challenges rising from higher ohmic losses at higher frequencies. Silicon-germanium or other types of alloys might be the next choice of industry by replacing gallium arsenide. Plasmonics, controlling electromagnetic wave propagation via micro- and nano-particles, is likely to be used more frequently at higher frequencies. From wave-generation to amplification and filtering, tiny structures made with noble metals will continue to have a significant role in near-future technologies. New composite materials enabling or preventing the transfer of millimeter waves might create new business opportunities in various industries such as automobile, fashion, cosmetics, and paint and coatings.

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