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Energy Efficient and Environment Friendly 5G Technology

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Abstract: This paper analyse the impact of 5G technology on human health and environment. To enable sustainable 5G networks, new technologies have been proposed to improve the system energy efficiency and alternative energy sources are introduced to reduce our dependence on traditional fossil fuels. In particular, various 5G techniques target the reduction of the energy consumption without sacrificing the quality-of-service. Meanwhile, energy harvesting technologies, which enable communication transceivers to harvest energy from various renewable resources and ambient radio frequency signals for communication, have drawn significant interest from both academia and industry. To fulfil ever increasing demand of high speed internet, 5G wireless communication systems are expected to provide simultaneous broadband services to a large number of users at very high data rate on the order of hundreds of Mbps. Power consumption of current cellular mobile systems is rising day by day at alarming rate. This terrific scenario is ultimately responsible for environmental hazards and human health problems. There is indeed requirement of Green 5G Technology which satisfies both the needs, one is to develop highly advanced technology to serve the demand of society and the other is to minimize the power consumption to reduce electromagnetic radiation in surroundings. It is huge challenge for researchers to develop systems which consumes low power and also radiates low power signal into surroundings to minimize health hazards. The next-generation mobile network is being rolled out across the globe, with promises of super-fast internet going hand-in-hand with claims of massive benefits for the environment. Recently, Massive MIMO (Multiple Input Multiple Output) techniques have been proposed to significantly improve the performance of wireless networks for upcoming 5G technology. Massive MIMO provide huge improvements in throughput as well as radiated energy efficiency is also high. Power saving features such as "sleep modes", whereby components are switched off when they are not being used, and more energy efficient antennae and other hardware are introduced in proposed Green 5G Technology. Some researches Moreover, the manufacturing and maintenance of the new technologies related to 5G technology generates electronic waste, also it consumes important resources that might degrade environmental health. In this paper, positive and negative impacts of massive MIMO technology on human health based on environmental radiations are discussed and future research scope on Green 5G technology is described.

Keywords: *Massive MIMO, 5G Technology, Energy efficiency, Spectral efficiency, Throughput, Green Technology, Health effects, EMF radiation*

1. Introduction

With such tremendously expanding demand for wireless communications in the future, researchers are currently looking for viable solutions to meet the stringent throughput requirement. In this regard, three paradigms have emerged:

• Reduce the transmitter-receiver (Tx-Rx) distance and improve frequency reuse: ultra-dense networks (UDNs) and device-to-device (D2D) communications;

• Exploit unused and unlicensed spectrum: millimeter wave (mmWave) communications and Long Term Evolution (LTE) in unlicensed spectrum (LTE-U);

• Enhance spectral efficiency (SE) by deploying a massive amount of antennas: massive multiple-input multiple-output (M-MIMO).

In general, bandwidth of the signals and frequency of the signal are proportional to each other. So, for higher frequency signals, bandwidth is also high and it can transmit huge amount of data compared to signal of low frequency. There are three challenges faced by wireless communication as follow: (1) Received power of the signal at receiver antenna decreases with increasing frequency. (2) As signal travels through wireless channel signal power decreases and this decrement increases with frequency. (3) As the signal travels long path, loss of the signal increases. Now, how to overcome above challenges? The Friis' transmission formula gives the solution. The first point is to decrease the distance between transmitter and receiver antennas. This is the reason that 5G networks are highly dense cellular networks. Cell size is reduced because of more number of antennas are required to cover given area compared to existing 4G technology. The second point is to deploy advanced beam forming antennas. The final version of the Friis' transmission formula includes extra terms indicating the gain of antennas. Using more number of antennas instead of a single antenna is the attractive manner of increasing the gain. This is why upcoming mobile communication systems use multiple antennas, identified as antenna arrays. In 5G technology, this multiple antenna number reaches to hundreds of antennas, which are deployed at transmitter base station. These massive multiple

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input, multiple output (massive MIMO) antennas will increase channel spectral efficiency and data rate. By using different types of modulations, these massive MIMO antennas will allow wireless communication networks to transmit and receive more than one signal simultaneously over the same radio channel.

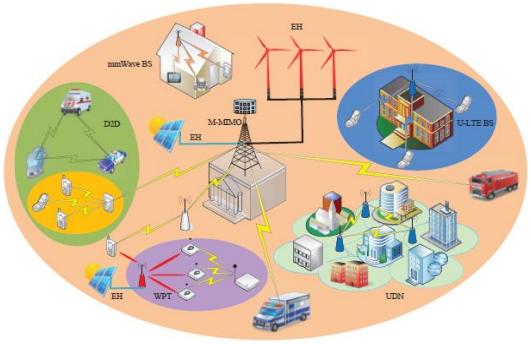

Fig.1. Eco system for disruptive technologies for 5G wireless network

Proposed Eco system for disruptive technologies for 5G wireless network is shown in Fig. 1. We can see that future 5G wireless networks will serve the various fields of society like medical, industry, education, agriculture, infrastructure etc. IoT based technologies will provide connectivity to all the future stakeholders of society. The introduction of 5G technologies urges substantial research work on technical limitations and also reaction of population to deployment. It is expected that the installation large number of antennas and other network components everywhere will be opposed by public and environment conscious people. Conflict may also be stimulated by uncertainties about impacts of exposure to RF even if 5G networks claims that it will generate low radiation exposure as it replaces present 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 such other alloys might be the alternative of production by replacing gallium arsenide. From signal generation, transmission, amplification, filtering, micro component parts made with advanced material will play significant role in upcoming future technologies. Major attraction of 5G communication technology is massive MIMO technique and mm Wave technology which will give drastic improvement in high speed broadband services like video streaming, IoT, secured financial transactions, e- health care services etc. Massive MIMO in 5G will generate pencil narrow radiation beams towards direction of user only by using hundreds of transmitter antennas as shown in Fig. 2. Existing single antenna system generate isotropic radiation while multiple antenna (massive MIMO) system generates radiation beam only when and where receiver terminal is present. So compared to 4G technology radiation in environment will decrease and will less impact health and environment.

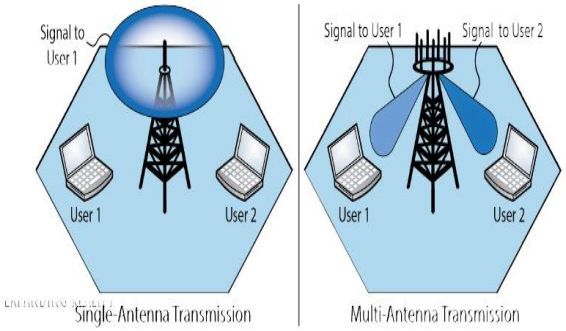

Fig. 2. Radiation difference between single antenna system and massive MIMO system

In massive MIMO system, a base station mounted more than hundred antennas provide simultaneous coverage to multiple users. Massive MIMO (Multiple Input Multiple Output) systems are nowadays emerged as newly designed cellular network architecture with numerous interesting features like achievable capacity can be increased by merely mounting additional antennas to currently active cell sites, more number of antennas significantly reduce uplink and downlink transmit power. Energy conservation is extremely necessary in existing scenario of the world and as per survey done in 2019, 69 Giga Watts power consumed world-wide telecommunication networks. i.e. equivalent to power consumed by 12 New York cities in a year. So massive MIMO is the prominent candidate that can dramatically reduce future power consumption of wireless telecommunication technology and achieve huge energy efficiency. This higher energy efficiency characteristic is not only relevant from an industrial benefit point of view but also environmental as well as safety of health concern related to wireless communications. Another feature is channel reciprocity, in which the overhead associated to channel training scales linearly with user terminals (K) and is independent of the number of base station antennas (N), Due to large number of base station antennas, effect of thermal noise, interference, and channel estimation errors vanish. Another major advantage of massive MIMO systems is that they facilitate us to reduce the transmitted power [2]. On the uplink channel, reducing the transmit power of the user terminals will decrease rate of drain their batteries. The design and analysis of massive MIMO systems is a quite a new concept that is attracting extensive interest. So ultimately massive MIMO technique in 5G technology increases the achievable data rate up to 50 Gbps and more as shown in Fig. 3. In this figure three different communications methods consequently short link communication like USB, WLAN technology having different ITU standards starting from basic 802.11 to 802.11ad and cellular communication technology starting from GSM to advanced 5G technology based on mmWave technology and massive MIMO technology are compared

with respect to achievable data rate [10]. As technology upgrades from 1G towards 5G, we can observe increase in data rate of all kind of wireless communication systems. This is because of advancement in emerging efficient semiconductor devices and fabrication of digital processors in compact size but competent in performance. Mobile phone and internet users also increases day by day across the globe. So to fulfil the ever increasing demand of wireless throughput, environment friendly 5G technology is crucial role player.

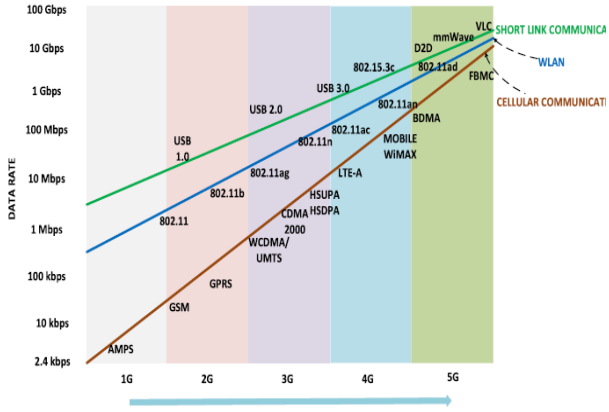

Fig. 3 Data rate comparison and journey from 1G to 5G for WLAN, short link communication and cellular communication technology

2. SURVEY ON IMPACT TO HUMAN HEALTH DUE RADIATION OF 5G COMMUNICATION NETWORK

The tiny cells in 5G intended to install base stations in close areas will transmit low energy radiation compared to existing radiation of base stations. Therefore, at low frequency there will be no much difference in radiation exposure compared to existing network. Nevertheless, for high frequency band exposure to radiation will be much higher. The high frequency band of the 5G network comes in the "millimeter wave" (mmWave) type, its name suggests that wavelength of signal is in the millimetre range. Mm waves are mainly absorbed within 2 milli meters of human skin. Government in all the countries should establish the rules and regulations associated to communication systems radiations and limits of electromagnetic radiation that a device can transmit. According to research carried out, it should not be allowed more than 1.0 mW/cm2 of exposure for the people to protect humankind from severe exposure to thermal radiation. World Health Organization (WHO) has nowadays raised the call for good quality scientific research in this field because of the recent extensive exploitation of 5G technology [1].

In this review paper, analytical survey is carried out to find out whether RF signal radiation by upcoming 5G networks might harmfully affect human health and environment and evaluation of massive MIMO technology which is dominant member of 5G technology on this effect. Various international scientific and government organizations have analyzed epidemiologic, in vivo, and in vitro research of health and genetic concerns with the RF radiation exposures. These agencies have disclosed that the result of these studies do not provide adequate proofs to conclude that RF exposure causes any adverse health effect. Recently research on 5G wave radiation exposure on rats took place by the National Toxicology Program (NTP) mentioned the occurrence of tumours in male rats [1]. Though, the radiation power level and duration of exposure were higher than we are facing currently or what we might face after 5G network rollout. So it cannot be correlated with case of human health because biological structure of human and rat is not comparable as suggested by NTP. So, research is still continue to study the effect of 5G network radiation exposure on human health and adverse effects on animals. However, we have to find a solution by inventing Green 5G technology which minimize the adverse effect of radiation on human and environment. Research suggests that massive MIMO is energy efficient antenna transmission system and consumption of power is less compared to existing base stations. So ultimately it radiates less power in surroundings. But as number of cell sites will increase in 5G network more number of transmitter antennas will be required in same area to provide good coverage. Also manufacturing of large number of network components in 5G network to rollout services in the globe will release terrible amount of carbon in the environment.

Specifically, the exposure levels generated by an 8x8 indoor planar array antenna at 3.7 GHz, is here analyzed in a human computational model [6]. The radiated amount is the specific absorption rate (SAR) in mW/Kg for some specific body part tissues. It demonstrates the first effort to additionally increase the information regarding the exposure levels for the upcoming 5G scenarios. It suggests that position of planar array antenna positioned near to head of a human model is influenced by level of exposure of radiation. Advanced machine learning and other techniques may also be applied in such case to further analyze the effect of upcoming 5G network radiation on human body.

Observed health issues due to existing telecommunication network radiation

- In 2011, IARC mentioned that radiation of mobile phone as one of the possible human carcinogens [11]. An IARC Monographs Working Group analyzed epidemiological proof, cancer bioassays, and mechanistic and other relevant data arrive at conclusion that carcinogenic hazard to humans from exposure to the electromagnetic fields that can occur from mobile handsets as well as from base station radiations.
- The radiation might heat the skin and this heat generation may change the temperature

distribution. Human skin comprises of two layers i.e. outer epidermis and an underlying dermis, with thickness changing from the range of 0.06 to 0.1 mm and 1.2 to 2.8 mm respectively. Relative permittivity of the skin decreases with the increase in the frequency of signal while the conductivity increases [11].

- In the near field radiation of antenna, the tissues of eyes will come in direct contact. Therefore, the probability of cataract will definitely increase. The cataract is a clouding of the lens of the eye which is responsible for decrease in vision.
- Nervous system of the brain is affected by radiation. Due to that minor change in morphological, electrophysiological, and chemical changes can occur. If major changes in these biological systems occur, it will inevitably lead to a change in behaviour of the person.

3. The Impact Of 5g Signal Radiation on Environmental Ecosystem

Some research work suggests that new network devices and technologies to be incorporated with 5G system will be adversely affect the current delicate ecosystems. Recent study suggests that major terrible component is millimetre wave of the 5G system that will influence ecosystems of environment. The millimeter waves will be used in very large scale in upcoming 5G network. Researches mention that millimeter waves are associated with instability in the ecosystems related to birds. As per research article by the Centre for Environment and Vocational Studies of Punjab University, it is observed that past exposure to RF radiation from a 4G mobile base station for duration of around 20 minutes, structure of sparrow's eggs was spoiled [3]. In 5G network highly dense configuration of cell sites to be deployed which might worsen the effect on eggs of birds adversely. And later it might raise questions on survival of birds. Furthermore, a research work carried out in Spain mentioned that breeding, nesting, and roosting harmfully impacts by RF radiation from mobile base station.

Moreover, it is also invented that mobile signal radiations have a harmful impact on survival of bees. In one research, beehives were kept in 900MHz radiation waves for around ten minutes and suddenly colony collapse disorder was observed. In which many bees in the hive left the queen and some worker bees by leaving that hive. Radiation also affected the navigational skills of the bees and bees found it difficult to return back to its original hive. As bees is very much crucial part of the earth's ecosystem, by playing vital role in agriculture. Agriculture is the main food source of more than half of the population of the earth.

All ecosystems of the earth are interrelated with each other. If a single module of the ecosystem is disturbed, it will affect the entire system. 5G network will definitely have dense cell sites, and radiation might also increase. So to develop green technology and prevent our precious ecosystem is the need of the future generation. There are some aspects in 5G technology which prevents harmful effect are also appreciable. In table 1, various features related to environmental health are compared with respect to upgraded generations from 3G to 5G.

Sr. No.	Features	3G	4G	5G
1.	Carbon Dioxide Emission	86 Metric Ton	170 Metric Ton	135 Metric Ton
2.	No. of Base Station sites	3.3 millions	7.6 millions	11.2 millions
3.	Avg. Power consumption per site	1.7 kW	1.3 kW	1.1 kW
4.	Carbon footprints per mobile subscription	20 Kg	23 Kg	31 Kg
5.	Femto cell power consumption	10 W	6 W	5 W
6.	Number of antennas at BS	2	8	Upto 100
7.	Access Technology	WCDMA, CDMA 2000	OFDMA, SC-FDMA	BDMA, FBMC
8.	Type of antenna used	High gain outdoor antenna	Patch and slot antenna	Phased array antenna
9	SAR value	High	Higher	Expected to reduce

Table 1 . comparison of different generation from Green technology point of view

The major environmental issues associated with the deployment of the 5G network arise by the manufacturing process of the many devices of the 5G communications network. Comparison of 3G, 4G and 5G technology from green technology point of view is shown in table 1. Various features like carbon dioxide emission, power consumption per site, green technology used, carbon footprint, RAN electricity consumption, SAR values are compared. From table, it can be observed that though Carbon Dioxide

emission increases from 3G to 4G but decreases in 5G. As shown in table, 86 Metric Ton by 3G , 170 Metric Ton in 4G and 135 Metric Ton in 5G. Hence we can see that 5G is proved to be Green technology compared to 4G. The average power consumption per site decreases from 1.7 kW by 3G to 1.1 kW in 5G. SAR value is also expected to reduce in 5G compared to 3G and 4G because of green technology used like Device to Device transmission, massive MIMO and spectrum sharing in 5G.

4. Role of Massive Mimo On Green Technology

5G network developers have to perform Environmental Impact Assessments initially. This assessment completely estimates the impact of technology to be developed on the environment before production and rollout of network physically [4]. This procedure diminishes and recognizes adverse effect to the environment. To provide safe and sustainable healthy environment to our future generation, it is very much necessary.

Moreover, the process of Life Cycle Assessments of strategy is tremendously advantageous for understanding the impact that 5G will certainly have on the environment [5]. An LCA can be used to measure the effect of network on carbon emissions during their life period, from the manufacturing process of the component to the energy requisite to power the device and eventually the waste created when the device is surplus into a disposal system. By having full understanding of the impact new technology will have on the environment ways to mitigate negative impact to environment.

This method has many advantages such as better energy utilization factor, scope of network, throughput improvement, lessening in latency, and better capacity gain. It can be integrated in three ways: System Massive MIMO, Single Massive MIMO and Distributed Massive MIMO. Based on necessity of the network, these are chosen with respect to energy and power utilization.

In below shown plot massive MIMO system is mentioned with the maximum ratio transmission (MRT) and zero forcing (ZF) method. In this method, the antenna selection is very important. The antennas used are energy efficient to manage the energy efficiency. Antenna muting is a method which can save around half the power. By switching On one port and all other ports are switched OFF in the antenna. The overall performance of the system will increase and good amount of energy will be saved.

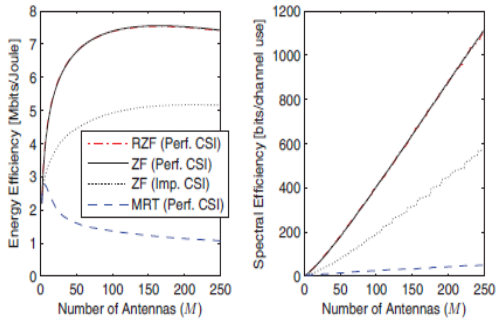

Fig. 4 Energy efficiency and spectral efficiency for different no. of BS antenna with different precoding system in massive MIMO

As shown in Fig. 4, energy efficiency in Mbits/Joule is derived with changing number of Base Station antennas for different precoding techniques like ZF, MRT and RZF. with having knowledge of perfect Channel State Information [8]. It can be observed from plot that by increasing number of BS antennas energy efficiency increases for ZF precoding. Spectral efficiency in bits/channel also increases proportionally with number of BS antennas.

5. Future Research Scope

With the 5G wireless communication network advancement and on its way of standardization, the 5G New Radio (NR) interface standard is also under progress with advanced technologies and higher potentials. The high EM radiation exposure has become an area of concern for the future generation of networks to come. By using Machine learning and other advanced techniques optimization of number of antennas without affecting the performance of communication network to be analyzed. Also power consumption of base station antennas can be utilized by non conventional energy sources like solar energy, wind energy etc. radiation absorbers can be deployed in surroundings to prevent adverse effect of radiations. Some algorithms must be developed to stop unnecessary radiation of energy or currently not in use radiation signal. Efficient EMF radiation neutralizers must be developed to reduce radiation effects. Wearable radiation reduction devices must be developed to prevent Neurotoxic effects on human body.

Electromagnetic radiation is measured in terms of metrics such as power density, temperature elevation, high Specific Absorption Rate (SAR) levels in the human body causing an adverse effect on the health. The same issue has been pointed out with a discussion of some radiation reduction methods and a suggestion to reduce RF radiation in mobile communication systems in the form of “Radiation Reduction (RR)” mode. The radiation reduction effect can be further reduced by incorporating NOMA (Non-Orthogonal Multiple Access). It is the need of the hour to reformulate the regulations and guidelines to ensure safety and reliability for the future generation of networks.

.6 . Conclusion

In this article, we have surveyed the advanced technologies which are expected to enable sustainable green 5G networks. Impact of radiation of 5G network on human health is analysed and 5G exposure scenario in indoor environment is evaluated. In which, effect of high SAR value induced by 8 X 8 planar array at 3.7 GHz on human brain was observed. The impact that the cell towers have on birds and bees is important to understand, because all ecosystems of the earth are interconnected. If one component of an ecosystem is disrupted the whole system will be affected. Various features like carbon dioxide emission, power consumption per site, green technology used, carbon footprint, RAN electricity consumption, SAR values are compared for 3G, 4G and 5G network. From table, it can be observed that though Carbon Dioxide emission increases from 86 Metric Ton by 3G, 170 Metric Ton in 4G and 135 Metric Ton in 5G. Thus lesser Carbon Dioxide emission in 5G compared to 4G. The average power consumption per site decreases from 1.7 kW by 3G to 1.1 kW in 5G. SAR value is also expected to reduce in 5G compared to 3G and 4G because of green technology used like Device to Device transmission, massive MIMO and spectrum sharing in 5G. Various human health issues are also discussed like effect on skin, effect on eyes, carcinogen effect, neurological effects. At last, plot of energy efficiency and spectral efficiency of massive MIMO is presented which shows that as number of base station antennas increases energy efficiency increases and less power consumption occur by network. Future research scope describes some innovative techniques to combat radiations and advance radiation effect can be further reduced by incorporating NOMA (Non-Orthogonal Multiple Access) technology.

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