Energy Efficiency Techniques in Green Mobile Communications

Md Sabbir Hosen[1], Sidratul Montaha Silmee[2]

[1]Department of Information & Communication Engineering, University of Science & Technology Beijing, China
[2]Department of Electrical & Electronics Engineering, Daffodil International University, Bangladesh

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Abstract - *Energy efficiency is a key concern of proposing next-generation wireless communications since it has a significant impact on human existence on the earth's surface due to two causes, namely global warming caused by CO2 emissions and rising sea levels. Additionally, this challenge has become more concerning as the high demand for data rates, spectral efficiency, and QoS integrated with massive IoT communications. As a result, it is necessary to implement green mobile communications technologies that may decrease energy consumption while increasing battery life, as well as improved capacity to allow the fast development of small cell integrated base stations. So previously mentioned, feature-enabled wireless communication networks is known as 5G green cellular communication networks. To achieve the green cellular communication, several techniques have been proposed and discussed in this article like as small cell, wireless power and data transmission, mm Wave, massive MIMO, and beamforming.*

Key Words: **5G, Massive MIMO, Millimeter Wave, Energy Efficiency, Green Communication.**

1. INTRODUCTION

Providing broadband wireless services has been a massive achievement in ICT (Information & Communication Technology). Until now, the wireless technology revolution has been focused on increasing the network coverage & capacity while maintaining a high standard of service quality for users. At this moment, around half of the world's population uses mobile phones. As a result, energy consumption is growing on a daily basis, resulting in a rise in carbon dioxide (CO2) emissions across the world, as well as increasing the number of difficult jobs for researchers and scientists. Efficient Energy Management is a major consideration for developing the green wireless networks. This is the key reason for analyzing solutions that will significantly increase energy efficiency as well as decrease the operating costs and environmental effects of cellular communications. The surveys predict that wireless and cellular communications would emit about 400 million tons of carbon emission in upcoming years. This article discusses energy impact in current cellular communications. This article is an overview of several technologies that will be implemented in 5G networks to increase energy efficiency.

2. THE DEVELOPMENT OF CELLULAR COMMUNICATIONS

S. Morse invented the telegraph, the first device for communicating via electricity. Additionally, it is used to transmit voice signals. Maxwell suggested the possibility of wireless energy transmission in the mid-1880s. Hertz later established this fact. In 1876, scientist Alexander Graham Bell had invented the telephone. After that, the transformation of wireless communication has gone through generations and years. This part of the article covers the distinguishing characteristics of different cellular generations in a concise manner (1G to 5G).

A. 1G (First generation)

In the early 1980's when the first-generation systems, which are analog technology in nature, were developed and implemented. These offer data transfer rates up to 2.5kbps but have several disadvantages in terms of security, data transfer & call dropping. Essentially, it was the first technology developed specifically to improve coverage area and worldwide connection at the expense of network energy optimization.

B. 2G (Second Generation)

2G system was mainly designed for voice transmission also included power control mechanisms that allowed for a consistent data transfer rate of up to 72kbps while maintaining an acceptable Quality of Service. The second-generation system provides services such as Short Message Service(SMS) & Electronic Mail (E-mail). The primary standards in 2G systems include the GSM, Interim Standard - 95 & Interim Standard - 136. The 2G supported mobile devices have a long battery life due to the low power radio signals. The upgrade version of the second-generation system is 2.5G. The working principle of the 2.5G system is similar to the 2G System. Circuit Switching & Packet Switching both techniques are employed in this system. This system supports data transfer rates of up to 150kbps.General Packet Radio Service (GPRS), Enhanced Data rates for GSM Evolution(EDGE) & Code Division Multiple Access(CDMA-2000) are the three most widely used technologies in 2.5G. There is no difference in power levels between 2G and 2.5G.

C. 3G (Third Generation)

Along with 2.5Mbps data transfer rates, the 3G technology also provides improved Quality of Service (QoS). IMT-2000 is the 3G technology standard developed by International Telecommunication Union which is based on Wideband Code Division Multiple Access (WCDMA). The Universal Mobile Telecommunications System (UMTS) is one of the standards established by 3G, which is an alternative for GSM, and it is recognized by the 3GPP. Third generation (3G) systems offer new features such as global roaming and enhanced call quality. the major disadvantage of 3G technology is that it consumes significantly more power than 2G technology.

D. 4G (Fourth Generation)

The fourth generation(4G) wireless technology is the successor of the 3G wireless systems in terms of broadband mobile communications. 4G is also known as LTE standard(Long Term Evolution). Carriers are transformed orthogonally, and multiplexing utilized a frequency division technique in this technology. The data transmission rates of 4G can reach up to 1Gbps for stationary users and up to 100Mbps for users with high mobility. The fourth generation(4G) system delivers voice, data & multimedia services faster than previous generations. Multimedia Messaging Service(MMS), GPS, Mobile HDTV, Digital Video Broadcasting(DVB), Video Call & Conference are some features of 4G. Some of the standards that are being developed will help to solve the problem of coverage area while also enabling the development of networks that are significantly more energy efficient. The main disadvantage of 4G systems is the use of cell-specific reference signals, which reduces network energy efficiency while increasing system overhead.

E. 5G (Fifth Generation)

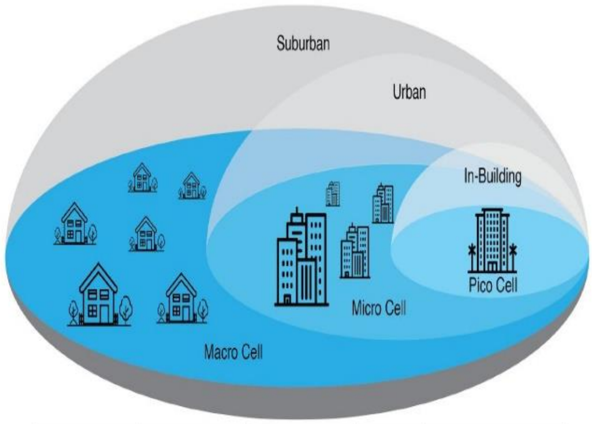
5G stands for the fifth generation. To fulfill the needs of faster data transfer speeds, the current 4G network will soon be taken over by the next generation of mobile networks (5G). Enhance energy efficiency is required for next-generation networks in order to meet the rising demand of network users. For data transmission, Device to device communications(D2D) & machine to machine communications(M2M) are two mechanisms that will be implemented in the 5G network. The next generation of networks will enable even faster data transmission speeds & will need more energy-efficient methods.

3. ENERGY EFFICIENCY IMPROVEMENT TECHNIQUES

1G through 4G cellular generations are intended to improve capacity. These generations are focused on maximizing the spectral efficiency of the information carried by electromagnetic waves. The types of equipment that are used in these technologies consume a lot of energy. This highlights the need of optimizing energy consumption while using wireless devices. To achieve green mobile communication, energy usage must be kept to a minimum. The main goal is to increase energy efficiency without impacting the needs of end-users. The future technology will place a premium on both spectrum and energy efficiency. The success of the 5G system is highly dependent on both energy & spectral efficiency. Energy Efficiency is often defined as the number of bits transferred per joule of energy used. The bit-per-joule energy efficiency is a critical design parameter in this regard, defined as the ratio of throughput in bits per second to power consumption in joules per second. Implementing virtualized network topologies, cloud radio & collaborative radio networks are the most straightforward methods of increasing energy efficiency. Some of the energy-efficient approaches have been described in the following sections.

A. Small Cell

A small cell is a scaled-down form of a base station that divides the cell site into several smaller parts, which in indoor/outdoor systems are composed of picocells, microcells, and femtocells. Small cells are designed to increase the edge data capacity, speed & overall network performance of macro cells.



Type	Output Power(W)	Coverage(Km)	Users	Location
Macrocell	>50	10 to 30	>2000	Outdoor
Microcell	1 to 10	0.2 to 2	100 to 1000	Outdoor/Indoor
Picocell	0.25 to 1	0.1 to 0.2	20 to 100	Outdoor/Indoor
Femtocell	<0.25	<0.1	<20	Indoor

Fig -1: Base Station Classification & Comparison

Base station types, ranging from Pico cells to Macro cells, are displayed in Figure 1. The use of intercarrier frequency techniques in small cells can significantly improve energy efficiency.

B. Simultaneous Wireless Information & Power Transfer (SWIPT)

Due to the increased demand for energy efficiency in wireless & cellular communication, integrating energy harvesting approach with wireless & cellular communication systems has recently gained popularity. Wireless Power Transfer (WPT) is an innovative & promising technology in wireless & cellular communication systems. All the nodes can charge their batteries through the use of electromagnetic energy in this system. Wireless Power Transfer technology utilizes both radiative & non-radiative techniques. It is non-radiative when power is transferred by magnetic fields or electric fields via capacitive coupling between metal electrodes, whereas it is radiative when a beam of electromagnetic radiation transfers power.

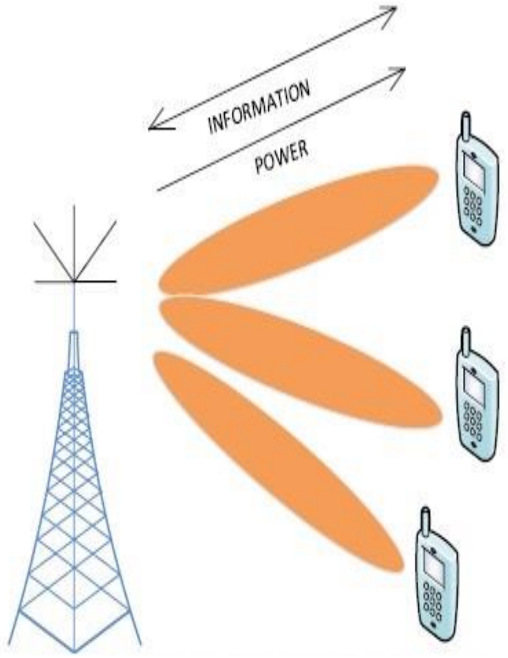


Fig- 2: Simultaneous Wireless Information and Power Transfer

Simultaneously how the power and information will be transferred to multiple users from the base station has shown in Figure 2. As the strong signals enhance the power transmission, and as a result, the level of interference increases as well. This technique is beneficial for sensor nodes or IoT devices that use control signals to charge the access point. Rectenna is one of the features that is used for this purpose, as it converts electromagnetic energy into uniform current. This is performed by separating the received signal into two orthogonal signals, which improves the system's energy efficiency. It is necessary to modify the existing communication system in order to accommodate SWIPT.

C. Massive MIMO

Massive MIMO is an emerging technology for 5G systems that aims to enhance capacity while also lowering power consumption. MIMO is the most popular technique in 4G technology, and it is utilized to increase the network's spectrum efficiency. MIMO(Multiple-Input Multiple-Output) mechanism offers combined multiplexing gains & diversity gains. When transmitting the same signals through different paths from the transmitter to receiver, diversity gain can be achieved, whereas multiplexing gain can be achieved by sending independent signals in parallel through the spatial channels. The couple of these factors contribute to energy efficiency degradation.

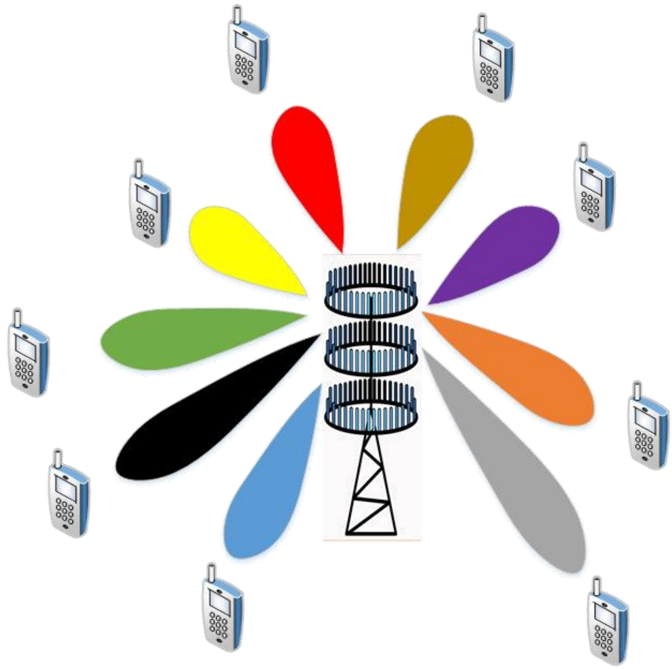


Fig- 3: Massive MIMO

Figure 3 illustrates the fundamental architecture of massive MIMO. Massive MIMO is an updated form of MIMO that is proposed for use in the next generation of networks, in which a more significant number of antennas are installed at the BS (Base Station) and is assigned to as Massive MIMO. Utilizing these huge antennas, the Base Station can now communicate with multiple subscribers simultaneously in the same frequency spectrum, increasing multiplexing gain & array gain. Massive MIMO technology is both efficient in terms of spectrum utilization and efficient in terms of energy utilization. By expanding the number of antennas and utilizing beamforming, the energy can be promoted to the efficient user equipment with minimal power loss. Massive MIMO is a technique that combines MIMO & beamforming. MIMO is a technique for spatially exploiting the complexity of a channel by directing energy in different directions; beamforming is a technique for concentrating energy in a specific direction.

D. Millimeter Wave

Millimeter waves are expected to be a key technology for 5G networks. It is allowed to fix the problem of efficient bandwidth allocation for HD video and massive multimedia content delivery. Between 30 and 300 GHz, a higher frequency band is used for wireless signals, resulting in a millimeter wavelength. Transmission speeds are expected to increase to multi gigabits per second in the coming years. However, implementing millimeter waves causes significant path losses and lower signal strength, limiting communication range. Millimeter waves employ spatial multiplexing techniques for data & signal transmission due to their limited wavelength range. Massive MIMO & adaptive beamforming mechanism are very essential in mm range and contribute significantly to the 300GHz frequency band. Utilizing beamforming mechanism for focusing the radiation pattern can help increase communication range and reduce power consumption. By setting up a direct directional link between the base station & subscribers , high transmission speeds can be achieved. As a result, signal interference as well as energy consumption will be decreased.

4. CONCLUSION

Energy Efficiency (EE) is a significant impediment to the development and expansion of telecommunications. This article aims to describe the increasing demand and need of energy efficiency in NGN(Next Generation Networks). A discussion has also been held on the significance of selecting the most appropriate Energy Efficiency Approach & green cellular communication. This article summarizes the Energy Efficiency methods, Massive MIMO & SWIPT in the context of green cellular networks.

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BIOGRAPHIES

MD SABBIR HOSEN received the bachelor's degree in Electronics & Telecommunication Engineering from Daffodil International University, Bangladesh, in 2018. He is currently pursuing the master's degree with the School of Computer & Communication Engineering, University of Science & Technology Beijing, China. His research interests focus on Cognitive Radio Networks and Smart Grid Networks.

SIDRATUL MONTAHA SILMEE currently pursuing the bachelor's degree with Department of Electrical & Electronics Engineering, Daffodil International University, Bangladesh. Her research interests focus on Green Communication and Smart Grid Networks.