Energy Efficient MIMO Based 5G Communication Network: A Survey

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***Abstract*: As we move closer to the fifth generation (5G) of communication networks, energy efficiency (EE) becomes a critical design requirement, as it ensures sustainable progression. Massive multiple-input multiple-output (MIMO)a technology, in which base stations (BSs) are equipped with a vast number of antennas to achieve many orders of spectrum and energy efficiency advantages, will be a critical 5G enabler. We present a complete review of state-of- the-art strategies for enhancing the EE gains offered by massive MIMO in this article (MM). We begin by providing an overview of MM systems and discussing how realistic power consumption models for these systems may be built. Thus, we review and point out some of the most prominent EE- maximization approaches currently available in the literature. Then, we examine "hybrid MM systems" that function in a 5G architecture and combine MM with other potential technology enablers such as milli metre wave, heterogeneous networks, and energy harvesting networks. Numerous potential and challenges arise in such a 5G architecture, as these technologies complement one another and their coexistence imposes several additional limits on the design of energy-efficient systems.**

***Keywords*: 5G Networks, Massive MIMO, Energy Efficiency, Millimeter Wave, Heterogeneous Networks, Energy Harvesting**

I. INTRODUCTION

The information and communication technology (ICT) sector is rapidly progressing toward fifth generation (5G) networks, which are expected to connect virtually everything on the planet to the Internet. Within 5G, a variety of interconnected networks will coexist, including smart cities, vehicle networks, and augmented reality centres. In terms of technology requirements, 5G networks should be capable of peak data speeds of up to 20 Gbps, average data rates of more than 100 Mbps, and seamless connectivity for a massive number of Internet-of- Things (IoT) devices per square kilometer. Energy consumption becomes a major consideration when developing 5G networks, as mobile communication networks contribute significantly to the global carbon footprint. According to trends [1,2], the ICT sector is expected to release more than 250 million tonnes of greenhouse gases per year by 2020. Thus, to ensure sustainability, 5G networks must consume less energy while achieving significant capacity growth.

II. GENERATION OF COMMUNICATION NETWORK

In the previous few decades, the global market has witnessed dramatic technological advancements in mobile communication. In 1979, Bell Labs introduced the conceptual paradigm for mobile communication systems [1]. Since then, mobile communication systems have evolved through four generations and are now entering their fifth generation, which is extremely dense, complex, but extremely efficient and data-rich. This increased from 2.4 Kbps in 1G to 100 Mbps in 4G, and over 1000 times faster data rates, or 10 Gbps, are projected in 5G networks.

The first-generation (1G) mobile networks launched in the 1980s used analogue transmission and had a maximum data rate of 2.4kbps. As a result, it may offer low-quality and limited-capacity voice-only services. The Advanced Mobile Phone System in a North America (AMPS) and the Total Access Communication System in the United Kingdom (TACS) aware both 1G mobile phone systems [3].

The Interim Standard 95 (IS-95) for North America and the European Global System for Mobile Communications (GSM) for Europe were both second generation (2G) a mobile networks established in the early 1990s ([4, 5]). 2Gsystems were digital circuit-switched networks capable of transmitting data at up to384 kbps and supporting both low-bandwidth and voice services.Due to the inherent characteristics of digital transmission, the system's capacity and quality were greatly increased over 1G,resulting in a market boom. In 2001, third generation (3G) system based on UMTS and code division multiple access (CDMA) technologies were created.3G systems are both packet-switched and circuit-switched digital networks capable of transmitting data at speed of up to 2 megabits per second [6]. 3G technology's essential features include increased capacity, faster data transmission and support for multimedia services. Fourth- generation (4G) mobile standards were established in 2009ato address 3G's shortcomings [7]. Long Term Evolution(LTE) 4G mobile systems enabled phone services over the Internet Protocol (IP), lowered resource costs, expanded network capacity, and increased data transmission rates [8].With the introduction of orthogonal frequency division multiple access (OFDMA) and multiple-input- multiple-output (MIMO), 4G networks areacapableaof significantly higher data rates, up to 100 Mbps. While wireless mobile Internet is a huge advancement in mobile technology, 4G is a significant advancement in mobile networks.Theagenerations of wireless mobile networks are depicted inaFigure1.The proliferation of multimedia-rich applications, machine-to-machine communication, and the Internet of Things (IoT)ahave increased the demand for data communication significantly in recent years [9].

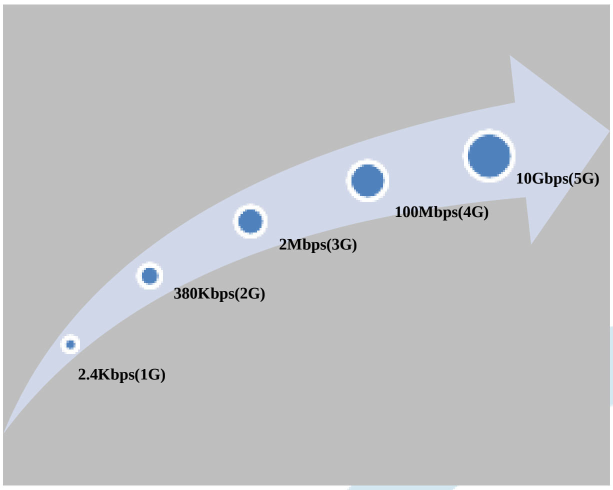

Figure1: Generations of Mobile Wireless Networks

According to Cisco's 2018 Forecast [10], data traffic from mobile devices will more than double globally between 2017 and 2022, growing at a compound annual growth rate(CAGR) of 46 percent, as illustrated in Figure 2. Mobile network traffic is a rising element. Additionally, it is predicted that by 2022, global data traffic from mobile communication networks would account for 20% of total IP traffic, and that 79 percent of Internet traffic will be transported via Wi-Fi and mobile networks. Additionally, it is anticipated that by 2022, the world will have 14.6 billion connections, 28.5 billion network devices, and around 4.6 billion Internet users [10]. In certain countries (for example China, India, and the United States), smartphone users have surpassed 100 million [11], owing to customers' need for constant wireless connectivity. The global market for mobile data and internet traffic is growing. The increasing demand for mobile data traffic exceeds the capacity of currently installed 4G LTE wireless networks.Thus, novel wireless mobile communication technologies with increased spectrum and data transmission rates are required quickly. Mobile communication has advanced to fifth-generation (5G) networks [12].

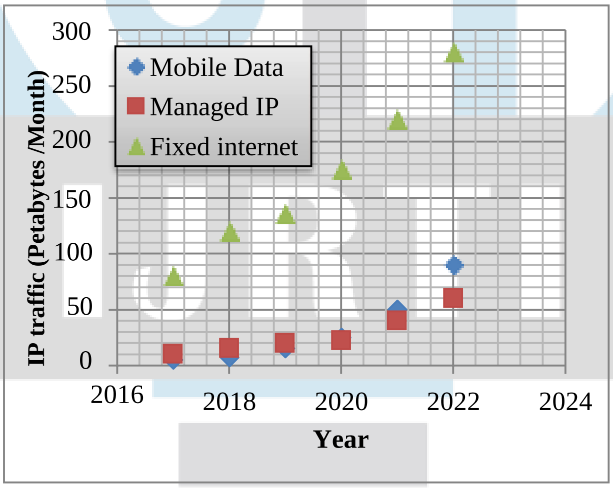

Figure 2: IP data traffic statistics

5G networks are intended to provide 1000 times the network capacity and link trillions of devices. It is capable of providing seamless access to a variety of services, including phone and data services, video chat, mobile television, multimedia messaging (MMS), digital video broadcasting (DVB), high definition television (HDTV) content, and amusement gadgets. 5G is intended to be quicker and more responsive, with the ability to link anything and everything. It guarantees high bit rates, a minimal probability of outages, maximum throughput, and a high spectral efficiency ([2, 13]).

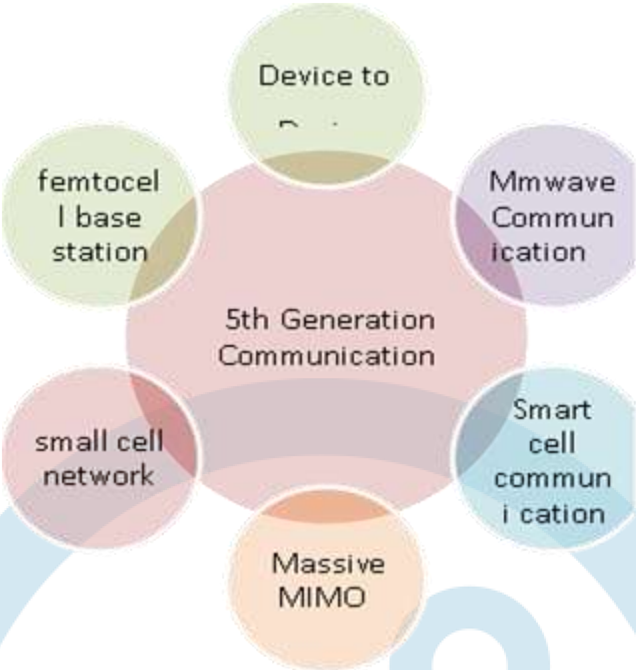

Figure 3: Application component of 5G communication network

Fig.3 depicts an imagined 5G-connected community. Network density, a crucial technology in 5G, may considerably increase capacity by adding cell base stations (SCBS) that form small cell networks (SCNs) to satisfy growing demand.Is implementing a policy of spectrum reuse for [14]. The distance between SCBS and end users will be shortened in ultradense networks (DNS), and SCBS will serve a high number of end users. SCBS will be distributed thickly and randomly in5G to optimize user experience and field spectral efficiency.

The planned UDN-based small cell network in 5G systems is viewed as a possible polution to 4G system difficulties ([15, 16]). It's worth noting that, while UDNs can provide numerous benefits (for example, increased capacity, higher data rates, higher density, smoother hand-off, and improved coverage), they still consume enormous amounts of energy, which is considered to be one of the major deployment—constraints of the 5G system [17]. The mobile access network consumes a significant percentage of the network's energy (60 percent) ([18, 16]), and the base stationa is the most energy-intensive component (BS).According to DoCoMo [19], 75–80% of energy usage happens in BS-level 3G and 4G LTE networks. Around 100 million SCN are expected to require 4.4 terawatt-hours (TWh) of electrical energy in 2020, accounting for 5% of the energy consumed by traditional macroa cell networks ([20]) and 5GUDN networks in 2026. Will result in a 150–170 percent increase in total network energy usage [13]. The widespread deployment of 5G would significantly increase a demand for energy and so contribute to the global energy crisis that is driving global climate change [14]. According to the Mobile Telephone Network (MTN), a multinational mobile telecommunications firm, the dense layer of smaller cells and increased antenna requirements would increase energy expenses as electricity usage doubles or triples throughout the day [15]. With the power of a 4G base station, a 5G base station is possible. Certain Chinese network operators that are pioneering 5G deployment globally have issued alerts concerning higher power usage. Additionally, the normal 5G site requires more than 11.5 kW of power, which is approximately 70% more than the base station, due to the requirement for RRU/BBU per site for 2G, 3G, and 4G radios. It is a combination of. New power-hungry components, such as millimetre-wave or microwave transceivers, faster data converters, field-programmable gate arrays (FPGAs), integrated MIMO antennas, and high-power/low-noise amplifiers, may be required for 5G macro base stations. Are comprised The high power requirements of 5G networks can create a number of issues, including insufficient alternating current power and battery capacity, excess backup battery capacity, and an inability to sustain high-power long-distance transmission. According to the data, overall energy consumption by cellular devices was 180 TWh in 2011 and is expected to reach 1400 TWh in 2025, a roughly 7.7-fold rise over the next decade and a half [3-6]. The carbon footprint of mobile networks is expected to expand dramatically over the next few years, in tandem with the global deployment of advanced mobile wireless infrastructure. Smartphone GHGE emissions climbed from 4% in 2010 to 11% in 2020 and will continue to grow at the same rate as data centre GHGE emissions increased from 33% in 2010 to 45% in 2020.

III. RELATED WORK

3.1 Energy-Efficient Mobile Network Technologies

Mobile network operators (MNOs) are increasingly facing the challenge of power supply to their large- scale networks.With the arrival of the 5G system, these issues will intensify because energy is a crucial operating expenditure(OPEX) aspect,and its smart control is considered necessary for network expansion and function. Energy Efficiency if the primary building element of any sustainable design [17]. Mobile network operators are currently interested in implementing short and long-term strategies to lower their energy bills by adopting energy-saving measures. Fig. 4 displays the different energy-saving approaches explored and recommended in the literature to boost the energy efficiency of the wireless mobile networks ([12]).

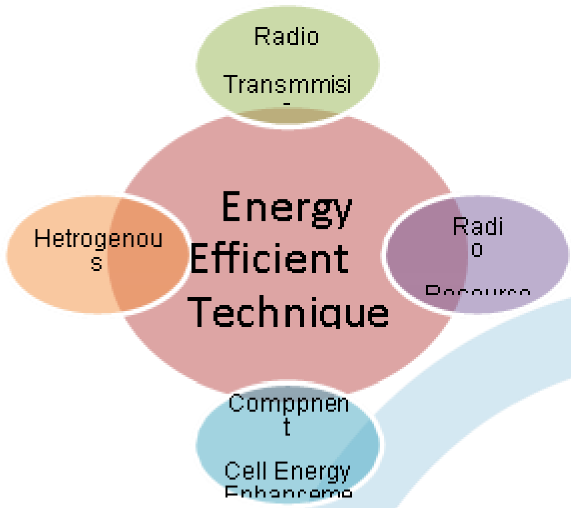

Figure 4: Energy-Efficient Technologies in Mobile Wireless Networks

3.2 Component Level Energy Enhancement

The majority of elements in today's mobile network architecture consume excessive amounts of energy [19]. The components of a base station (for example, the power amplifier, the colling equipment, and the baseband units) consume a significant amount of energy; for example, the power amplifier in a mobile base station consumes the most energy and the majority of the input energy is dissipated as heat.As a result, significant energy savings can be realized by incorporating more energy-efficient hardware components into the network. However, the cost of upgrading the system's hardware components will be higher. [12]. Energy-efficient power amplifiers, baseband processing units, and cooling equipment can all help to some extent with energy savings. [1] Presented a low-cost, energy-efficient power amplifier architecture for an LTE picocell base station. The design took advantage of break through manufacturing technologies in a balanced two stage architecture with low-power components, avoiding the use of high-power transistors. [5] Describes a high-linearity, high-efficiency power amplifier for wireless base station and fem to cell output stage applications. The suggested power amplifier is made of monolithic microwave integrated circuits and has a gain of 28dB.In comparison, [3] proposes the use of a gravity heat pipe exchanger to cool mobile base stations during the winter season, in lieu of the typical air conditioning system. The experiment was conducted to determine the heat pipe exchanger's cooling efficiency and to determine the effect of airflow rate and temperature on cooling performance and the number of heat transfer units. To limit the amount of energy consumed by communication overhead, The work in [4] presents a graph partitioning and rejoining strategy for baseband unit and remote radio head association.

3.3 Radio Transmission Process

Numerous technologies exist to improve the energy efficiency of radio transmission in mobile networks, including multiple-input multiple-output(MIMO), massive MIMO, millimeter-wave communication, device-to-device (D-to-D) communication, cognitive radio, and cooperative relaying [5, 8]. Massive MIMO makes use of a large number of antennas to improve spectral and energy efficiency [9]. Simultaneously, mm-wave communication leverages substantial portions of the mm-wave frequency spectrum to boost data rates to gigabits per second [6]. Dto-D communication allows devices to communicate directly with one another without passing via the BSs, hence improving the EE. '34, 35' The authors of [1] investigated EE optimization in a single-cell downlink massive MIMO system with only statistical channel state information (CSI) available at the base station (BS), and the authors of [2] investigated EE maximisation for the uplink of mmwave massive MIMO using the non-orthogonal multiple access (NOMA) technique. The authors of [3] examined the EE of various precoding techniques (e.g.,zero-forcing (ZF) and maximum ratio transmission (MRT)) in downlink massive MIMO with faulty CSI. While in [4], the EE performance of a wirelessly powered huge MIMO system is quantified in terms of the number of users and the number of BS antennas.[5] presents an overview of existing approaches to resource allocation and insight into green communication from the perspective of D-to-D communication.[6] presents a mechanism for maximizing both spectrum and energy efficiency in a device to device wireless communication network by deploying power control based on Mmatrix theory. Despite the EE benefits, such systems have a number of practical restrictions, for example, the power supply relays on power networks, and various complex trade-offs between performance and energy efficiency must be made [4].

3.4 Heterogeneous Network Deployment

The deployment of heterogeneous networks (HetNets) comprised of macrocells and SCBSs attempts to increase the entire system's energy efficiency. This heterogeneous combination of base stations has the potential to considerably minimize the distance between the serving BS and end customers. As a result, the SCBSs' required energy consumption can be decreased. These small cell base stations with minimal power consumption have been constructed and are deemed appropriate for use in areas with dense traffic demand [7]. In [8], dynamic on/off operation of small cell base stations is studied to lower the heterogeneous network's power consumption while maintaining coverage and preventing service failure. The work in [6] proposed a dynamic stochastic game between small cell base stations that combined user scheduling and power control for the purpose of increasing energy efficiency. In [9], a smart sleep approach is proposed as a user activity management algorithm for improving the energy efficiency of HetNets. Three distinct cellular network architectures (uniformly distributed cells, cell on edge, and macrocell-only network) are considered, as well as two distinct user distributions (uniform and hotspot.) [70] Presents energy-efficient power allocation and user scheduling algorithms in NOMA HetNets for the purpose of analysing the trade-off between energy usage and data rate performance for perfect and imperfect CSI. However, it should be emphasised that, as the number of mobile service users and devices continues to grow, a large number of SCBSs may be required, reducing the effectiveness of the energy efficiency gain achieved by this strategy. Due to the widespread deployment of SCBSs in 5G networks, the energy savings will be reverse due to the additional energy consumed by newly deployed SCBSs .[8]

3.5 Radio Resources Management

During peak load conditions, the number of BSs in a given area must be sufficient to provide the required level of service to mobile customers (QoS). Nonetheless, the network may be underutilised during off-peak hours, resulting in high energy consumption as a result of imprope spectrum utilization [7]. To accomplish this, resource-on-demand (RoD) techniques have been suggested and implemented, which dynamically alter available radio resources in response to changing consumer traffic demand [12]. Indeed,idle radio resources can be turned off during off-peak hours to conserve energy without impairing service quality. One of the most promising options for reducing mobile network energy consumption is to enable BSs to sleep during periods of low traffic demand [13]. For these reasons, sleep modes are recommended for dynamically shutting down some of the BSs when the system traffic demand is low [14]. The BS sleep mode technique is used with energy cooperation in [74]. The primary objective is to manage the flow of RE energy between SCBSs. The optimal traffic and load control within the microgrid is examined using a graph-based technique for HetNet and mobile edge computing (MEC) enabled HetNet networks. This combination of load control and energy sharing enables the self-sustainability of mobile networks organised into micro-networks in a realistic and cost-effective manner. While [15] develops a revolutionary real-time strategy for dynamically switching on and off SCBSs to conserve energy using a Markov decision process. In [16], the 4G LTE network scenario is studied for real-time research of RE-powered macrocell BSs with the sleep mode mechanism in order to minimise grid energy consumption and lower electricity bills.[17] examines the challenge of optimising the energy efficiency of dense mobile networks and proposes a dynamic base station switching on/off strategy. The problem of optimising energy efficiency is described as a difficultCombinational optimization problem and then solved using a two-step suboptimal algorithm. The cost of switching BS is investigated for both fixed and changing user distributions. The authors of [18] conducted an analysis of the environmentally friendly operation of heterogeneous LTE cellular networks. In the HetNet scenario, macrocell BSs and small cell BSs coexist. SCBSs are powered by renewable energy and the conventional power grid. Renewable-energy-powered BSs not only assist in offloading macrocell traffic, but also in offloading surrounding SCBS traffic in order to activate its sleeping mode. [16] examines the energy consumption models for both access and backhaul networks. The goal of this effort is to reduce the power consumption of the 5G access and backhaul networks while maintaining a high level of service. For the 5G access network, an analytical model was built that takes into account the number of active SCNs and puts other small cells into sleep mode, as well as two energy-efficient backhaul alternatives. The mmWave and passive optical networks are discussed in order to lower the network's energy usage. [19] powered BSs not only assist in offloading macrocell traffic, but also in offloading surrounding SCBS traffic in order presents a macro cell small cell architecture optimised for energy savings from a system-level approach. An efficient transmission mechanism is suggested that dynamically switches the SCBSs between service mode, sniffer mode, and sleeping mode in response to the network's dynamic traffic. [20] investigated resource scheduling of three-tier IoT systems using an energy-efficient approach to reduce energy usage and makespan. To handle the scheduling problem and generate processing sequences, a multi-objective estimation of distributive algorithm is provided.

IV RESERACH GAP

Massive MIMO is a novel wireless technique that will be used in 5G. Before implementing this new technology, many factors must be examined. This research looked into two factors that can affect large MIMO performance. The first factor affecting huge MIMO performance is channel quality. High channel correlation has been found to reduce the capacity and energy efficiency of huge MIMO systems. To lessen the influence of such channel circumstances, increase the transmit power to boost SNR. Increasing the antenna array spacing and adding more antennas at the BS can improve the channel capacity and EE. Many studies also looked into the impact of user allocation on massive MIMO capacity. The number of BS antennas increases the number of terminals that can be hosted in the cell. Too many users can reduce large MIMO's capacity. Massive MIMO is a new technology with many unknowns. So many research avenues exist. Listed below are some prospective research directions in massive MIMO:

a. Increase the number of BS antennas and analyse the effects of different estimate methods.
b. Comparing massive MIMO performance in multi-cell scenarios to current small cells.
c. Pilot contamination is one of the factors that can affect massive MIMO performance. The issue of other cells interfering with the training period is a highly important study direction. Larger frequency reuses factors help reduce pilot contamination. This reduces the pre-log factor and thus the spectral efficiency. The intensity of the signal inside the cell is substantially stronger than interference from other cells; hence increasing cell size helps reduce pilot contamination. The

issue is that consumers at the cell's edge may not be able to obtain adequate service. The size of the cell and the pilot reuse factor should be explored to decrease the influence of pilot contamination.

CONCLUSION

Due to the exponential expansion in data traffic demand, mobile wireless network operators have been pressed to expand network capacity while maintaining constant and low electricity consumption and operational costs. Due to the widespread deployment of SCBSs in the dense 5G architecture, an exceptional strain is placed on the power grid. Renewable energy is the ideal option for powering small cell networks in 5G infrastructure, as it reduces reliance on the grid and has a positive impact on the environment. This article does a detailed review of the literature on renewable energy approaches for powering mobile networks. We discuss renewable energy-enabled base stations, approaches for scaling RE sources, how energy can be exchanged between BSs, and how the mobile network can be integrated with a smart grid. Additionally, this report shows the numerous energy-efficiency measures employed by mobile network operators. Finally, a detailed assessment of the remaining technological issues in 5G networks is offered, along with new approaches.

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