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From 5G to beyond 5G: A Comprehensive Survey of Wireless Network Evolution, Challenges, and Promising Technologies

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Abstract: The histrionic growth of mobile subscribers, disruptive ecosystems such as IoT-based applications, and astounding channel capacity requirements to connect trillions of devices are massive challenges of the earlier mobile generations, 5G turned up the key solution. The prime objective of the 5G network is not only to maintain a 1000-fold capacity gain and 10 Giga Bits per second delivered to a single user, but it also assured quality-of-service, higher spectral efficiency, the ultra-reliable and improved battery lifetime of devices and massive machine-type communication (mMTC). The huge traffic load and high amount of resource consumption in 5G applications, augmented reality and virtual reality for magnificent virtual experience, and wireless body area networks will seriously affect the channel capacity of cellular cells and interrupt the admission and service of other users which makes compulsory new means of channel capacity and spectral efficiency enhancement techniques. In this research, we review several key emerging wireless technologies to increase channel capacity and spectral efficiency that will not only lead to improve network performance but also meets the ever-increasing user demands. We investigate various benefits and current research challenges of using these technologies. We analyze massive multi-input multi-output technology (mMIMO) an efficient technique and promising solution for the 5G and Beyond 5G (B5G) networks with several benefits and features. Moreover, this paper will be of vast help to the researchers who will involve advance investigation and also to the wireless network operator industry that is in the search for smooth development of state-of-the-art 5G and B5G networks.

Keywords: mMIMO; 5G; augmented reality; virtual reality; wireless body area networks; IoT applications; beyond 5G

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1. Introduction

The deployment of fourth-generation long-term evolution network (4G-LTE), and its extension long-term evolution- Advanced (LTE-A) in various countries have not only accomplished the International Mobile Telecommunications Advanced (IMT-A) constraint by utilizing IP envisioned for all services but also maintained up and around 1 Gb/s less mobility and 100 Mb/s data rate for large mobility. The histrionic growth of more mobile data subscribers in recent years is the result of people's craving for faster internet while on the go. The Wireless World Research Forum (WWRF) forecaste around 7 trillion mobile products will provide 7 billion individuals in 2017; which is about 1000 times the world's population [1]. While as per Ericsson's technical mobility report published in 2017, almost 29 billion devices are forecast by 2020 including 18 billion IoT related [2]. Furthermore, Rangan et al. [3] predicted 50 billion devices by 2020 and will keep up growing exponentially by around 5 zetta-bytes per month in 2030 [4]. IoT applications demand such as smart homes/cities/grids etc., sensors networks, explosive big data, and wearable artificial intelligent devices are increasing exponentially [5,6]. That has raised substantial attention to form new mobile standards in the telecommunication market.

Against these requirements, the massive data; peta-bytes (10,005 bytes), internet speed in Giga-bits per second (GB/s), and connection to trillions of devices definitely need next-generation wireless communication systems. To encounter these huge challenges, design and establish new standards for the next 5G communication, the academia, the standardization agencies, and the telecom industry are working in accordance [7,8]. Also, drastic enhancements and new innovations are essential to be made during network design both in physical and upper layers [9]. Emerging technologies such as disruptive ecosystems like IoT named as connected community and machine-to-machine (M2K) communications are also in consideration to be an important part and known as tactile Internet, a newly invented term [10]. METIS [11] and 5GNOW [12] are two main European ventures to address 5G networks. To reduce the firm orthogonality and synchronization criteria in present systems, particularly, 5GNOW explored new physical layer patterns by using non-orthogonal waveforms.

The key objective of the 5G network is not only to maintain a 1000-fold capacity gain and 10 Giga Bits per second delivered to a single user but also to assure quality-of-service, higher spectral efficiency (SE), the ultra-reliable and improved battery life of devices, less expensive and massive machine-type communication as dissipated in Figure 1. Only 5G networks can tackle these challenges and it will contribute a true universal boundless mobile experience through upgraded terminals, low latency, and ultra-reliable connectivity. The major challenge of the 5G network is tremendous mobile traffic demand.

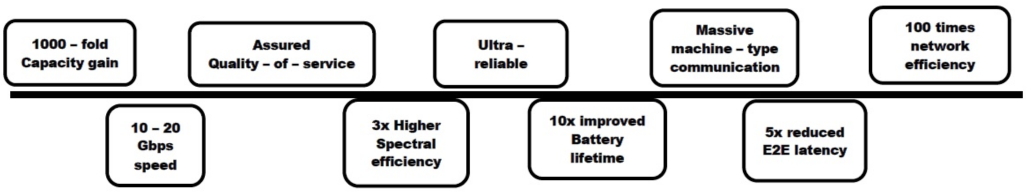

Figure 1. The prime objective of 5G.

This would certainly place a huge amount of traffic load at the edge and a huge amount of data will be processed in the cloud and consume a large number of resources which will not only affect the inadequate capacity of traditional cellular cells but also interrupt the admission and service of other subscribers. Another challenge for organizations is to process multiple repositories from multiple users using multiple applications in multiple environments simultaneously, producing a large amount of digital garbage and useless information. For example, data received from smart homes and health care are processed at the edge [13], processed at the fog to produce helpful information [14], and visualized in subscriber devices. Therefore, the edge, the fog, the cloud, and even the subscriber devices play an important role in the life process of the management of this data (i.e., smart cars, virtual reality, and health care). Therefore, it is a need to design, develop, and implement architectural models to produce on-demand and edge-fog-cloud processing systems to continuously handle big data.

The key problem with the ongoing development of mobile wireless systems is that it is thoroughly dependent upon network densifying to the cells or enhancing spectrum to attain the required throughput. The saturation point of these rare resources is almost reached. Moreover, cell densification and bandwidth increase also increases network latency and pay the cost of expensive hardware. Therefore, the throughput can effectively be increased by an untouched factor of SE without increasing cell densification and bandwidth to meet the current needs of wireless networks. Considering all these challenges, it also makes compulsory new means of channel capacity enhancements and SE techniques. Massive MIMO is an important part of the 5G key enabling technologies and is considered to be the solution to the above-discussed challenges.

The data rate that can be communicated by a certain bandwidth in a particular communication network is referred to as SE, measured in bits/Sec/HZ. Spectrum efficiency, spectral efficiency, or bandwidth efficiency is a technical quantity described as the data rate that can be communicated over a specified bandwidth and used to measure a frequency band. It can be enhanced through increasing modulation order.

We outline various capacity enhancements and SE improvement techniques in this research that will not only lead to enhanced network performance but also meets the ever-increasing user demands. We thoroughly discuss the benefits and current research challenges of using these technologies and presented subsequent contributions in this article.

- A brief summary of the 5G and beyond 5G, is represented.
- A significant review of key enabling technologies, in terms of enhancing channel capacity and spectral efficiency is described.
- Massive MIMO (mMIMO): a perfect candidate for achieving high data rate, channel capacity, and energy efficiency.
- Extensive description of the strengths and shortcomings of research efforts in implementing mMIMO.
- Comprehensive analyses of these challenges and open research problems as well as state-of-the-art solutions including various figures and tables are presented.

We also present previous 3GPP wireless technologies standardization and the current deployment of 5G in the world. Moreover, we identify various research challenges and open research issues that need to be addressed in future mMIMO systems for 5G and B5G. Considering these challenges, this study will surely be helpful for the researchers working on mMIMO for 5G. The remaining article is categorized into various sections. In Section 2, the evolution of the 5G network summarizes, in Section 3 related work and SE improvement techniques have been discussed while in Section 4, we discuss the features, challenges, and benefits of key enabling techniques. Section 5 briefly describes a framework for supporting mMIMO technology and system-level performance features as a solution for the present challenges particularly to the enhancement of channel capacity and SE, with state-of-the-art proposed solutions. Finally, the article is concluded in Section 6.

2. 5G Evolution

The 5G cellular system offers an extremely expandable and flexible network scheme to connect everything and everybody, everywhere. Several industries, e.g., DOCOMO, Huawei, ZTE, Ericsson, Qualcomm, Samsung, Vodafone, and Nokia Siemens Network have paid countless enthusiasm to develop 5G networks so far. Broadly, 5G is categorized into three domains:

- Ultra-Reliable Low Latency Communication (URLLC): fast and highly reliable with 100% coverage and uptime, applications to unmanned vehicles and smart factories
- enhanced Mobile Broadband (eMBB): whose goal to provide large data applications, massive device and user capacity for wireless broadband services
- Massive Machine Type Communication (mMTC): which permits a massive number of wireless devices connection density, energy efficiency, and reduced cost per device [15–17].

The early 5G spectrum in various countries is below 6 GHz but an additional wireless spectrum above 6 GHz and beyond is also proposed for enhanced capacity and SE [18]. The 3rd Generation Partnership Project was developed in 1998. It consists of seven regional/country telecommunications standards developing organizations whose aim is to regulate general policies and specifications, and produce reports that define 3GPP technologies. The 3rd Generation Partnership Project (3GPP) specifications are organized as releases that consist of several technical reports and specifications, each one of which may have concluded after various revisions [19]. A new release offers fresh radio access technology and/or improvements to an existing one and denoting to the achievement of certain milestones [20].

In Rel-13, mMTC and Narrow Band IoT (NB-IoT) were previously established by 3GPP to enable an extensive range of cellular devices, particularly designed for machine-to-machine, IoT applications and deployment scenarios [21]. In 2019, 3GPP has already initiated commercial deployment of Release 15 (Rel-15) focusing on eMBB and URLLC. The 5G networks are aimed to work with existing 4G networks by using a range of cells; macro cells for wide area coverage and small cells for in-building, homes, hospitals, schools, and smart forms as shown in [22]. During 5G connection formation, the user device will connect to both 4G for control signaling and 5G for fast data connection. The next phase of 5G is named Release 16 (Rel-16). Phase 2 of the 5G network will be presented in 2023 decided by the ITU World Radio-communication Conference in 2019 (WRC-19) to secure an additional mobile spectrum to meet consumers and business needs [21]. Rel-16 truly emphasizes industrial internet-of-thing (IIoT) related enhancements for Industry 4.0 as well as enhanced URLLC, the Time-Sensitive Communication (TSC), a platform for Non-Public Networks (NPN) wireless and wire-line convergence and complete system resiliency [19].

Rel-15 not only offers extraordinary performance for 5G standards but also provides extensive backward compatibility for new releases in coming years with additional features for ultra-high reliable communication, enhanced data rate, low latency, and improved security characteristics in Rel-16 and in discussion Rel-17 [23]. Release 17 (Rel-17) is an evolution to 5G-advanced systems and connects the community and provides an improved platform for multi-access edge computing, functioning in frequency bands beyond 52 GHz, aiding for reduced capability (RedCap) user equipment(UE), and proximity services, IIoT framework [24], virtual reality [25], smart homes automation [26], multi and broadcast architecture, Non-Terrestrial Networks (NTN), autonomous vehicles [27], and unmanned aerial systems (drones) [28–31] as shown in Figure 2. Furthermore, a physical uplink shared channel (PUSCH) and physical uplink control channel (PUCCH) will be used in Rel-17 for uplink. Release 18 (Rel-18) is officially the evolution of 5G-Advanced. It will bring improvements in the extended reality and field of artificial intelligence by employing machine-learning-based techniques at multiple network levels, that will permit highly intelligent network solutions. This artificial intelligence (AI) based on machine learning (ML) solutions will use solve multi-dimensional optimization issues and intelligent network management with regard to non-real-time and real-time operations. Moreover, cyclic-prefix orthogonal frequency-division multiplexing (CP-OFDM) and discrete Fourier transform (DFT) spread OFDM (DFT-S-OFDM) in the uplink will be investigated. Ookla is a famous speed test provider to test the performance and internet speed of an internet connection [32]. As per Ookla 5G interactive map tracks, 5G roll-outs commercially in more than 132,031 locations across the globe by 216 operators including 220 pre-Release [33]. The world's first commercialization of 5G sub-6 GHz spectrum C-band aggregation by Qualcomm Technologies, Inc. and NTT DOCOMO, INC enabled in Japan [34]. Table 1, briefly discusses new performance requirements and targets of 5G as compared to B5G [35].

Table 1. Comparison of 5G and Beyond.

Attribute	5G	Beyond 5G
Types of application	- URLLC - enhanced Mobile Broadband - massive Machine Type Communication	- Hybrid emBB and URLLC - mMTC - URLLC - Reliable eMBB
Types of Device	- Tablets and Smartphones. - Drones - Sensors	- Tablets and Smartphones. - Drones - Sensors - Wearable appliances

Table 1. *Cont.*

Attribute	5G	Beyond 5G
Energy and SE	10× (bps/Hz/m^2/Joule)	100× (bps/Hz/m^2/Joule)
Data Rate	1 Giga bits/sond	100 Giga bits/sond
End-to-end Delay	5 (ms)	1 (ms)
Processing Delay	100 (ns)	10 (ns)
Spectrum	- MmWave - Sub-6 GHz	- Mm Wave - Sub-6 GHz

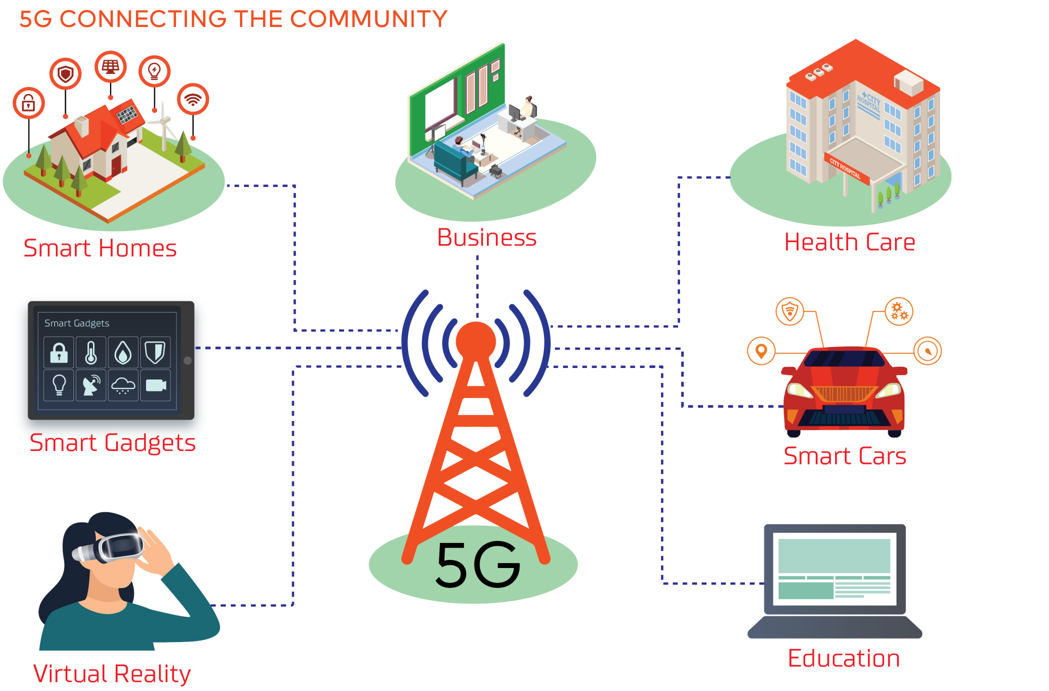

Figure 2. 5G, connecting the community.

3. Related Works

There is no comprehensive review of both channel capacity and SE enhancement techniques together in 5G networks and Beyond. However, some papers explore channel capacity enhancement techniques, while some SE improvement techniques are in subtopics. To deliver ultra-fast data speed by using increased spectral efficiency in 5G networks various authors have proposed different techniques including NOMA [36–38], OFDM [39,40], D2D communications [41,42], mmWave-SCN [23], MIMO [43], by enhancing modulation. As in [2], the authors mentioned that integration of NOMA with mmWave technology can also be a solution by the multiplexing of NOMA but they discussed it conceptually while the algorithmic designs to realize NOMA and the implementation methods are still a myth. Similarly, the authors in [44] declared mMIMO an efficient method for improving SE but were unable to explain how it will mitigate the challenges. Narcis et al. [45] also discussed key enabling techniques for 5G and considered mMIMO can significantly increase the SE but the results will not fully achieve the predicted requirements of 5G-PPP and IMT-2020, especially higher data rate of 10 Gb/s along with linked densities of 100 k–1 M devices/km^2. They also provide the solution to this problem by using super high and extremely high-frequency bands which will obvious drawback of giant propagation loss. A brief comparative overview of the existing surveys on 5G key enabling techniques has been investigated in Table 2.

Table 2. A comparative overview of existing surveys on 5G key enabling techniques.

Authors & Ref.	mMIMO	Beamforming	D2D	Small Cell	mmWave
Al-Falahy et al. [46]	✓	✓	✗	✓	✓
Shafique et al. [47]	✓	✗	✓	✗	✗
Sudhamani et al. [48]	✓	✗	✓	✓	✗
Sharma et al. [49]	✗	✗	✗	✗	✓
Hossain et al. [50]	✗	✗	✓	✗	✗
Akyildiz et al. [51]	✓	✗	✓	✗	✓
Adedoyin et al. [42]	✓	✗	✓	✗	✓
Nguyen et al. [36]	✗	✗	✗	✗	✓
Salah et al. [52]	✓	✓	✗	✓	✓
Saha et al. [53]	✗	✗	✗	✓	✓
Vaezi et al. [54]	✓	✗	✗	✗	✓
Ahmad et al. [55]	✓	✗	✗	✗	✓
Sufyan et al. [This Work]	✓	✓	✓	✓	✓

Spectral Efficiency Enhancement

Spectral efficiency refers to the amount of information that can be transmitted over a given amount of spectrum, while channel capacity refers to the maximum amount of information that can be transmitted over a communication channel. Increasing the SE of a system can lead to an increase in the channel capacity, as more information can be transmitted over the same amount of spectrum. Some common SE improvements techniques include:

- Multi-carrier modulation (MCM) techniques such as Orthogonal Frequency Division Multiplexing (OFDM), which divide the bandwidth into multiple sub-carriers and transmit data simultaneously on each sub-carrier.
- The mMIMO technology that uses multiple antennas to transmit and receive data simultaneously, increasing the data rate and improving the quality of the signal.
- Adaptive Modulation and Coding (AMC) that selects the best modulation scheme and coding rate based on the channel conditions to maximize the SE.
- Channel equalization which compensates for channel impairments, such as attenuation and distortion, to improve the signal quality and increase the data rate.
- Interference Management techniques such as power control, beamforming, and interference cancellation which reduce interference from other signals and improve the signal quality.
- Cognitive Radio which uses advanced signal processing techniques to dynamic allocation of spectrum resources to optimize SE while avoiding interference with other users.

Overall, these techniques are used in various communication systems, including wireless communication systems, to increase data rates, improve the quality of the signal, and make more efficient use of available bandwidth. Recently, an increasing number of research attention have been done on OFDM-IM (the combination of conventional OFDM with indexed modulation (IM) to provide a trade-off between SE and EE. In [56], a new concept of sparsely indexing modulation (SIM) is used to enhance SE. Another new combination of spacetime electromagnetic models of Tx/Rx antennas with OFDM, leading to the EM-OFDM, is proposed to enhance antenna SE by ratios up to 300% [57]. A promising and innovative digital modulation technology to provide tradeoff between SE and EE is Spatial modulation (SM), investigated in [58]. The primary goal behind SM is to transmit extra information using ON/OFF states of transmit antennas to reduce the implementation cost by minimizing radio-frequency chains. The authors in Refs. [46–48] have focused on massive-MIMO techniques—but not all in one. Similarly, the authors in Refs. [50,51] have focused on D2D communication as a suitable candidate for 5G networks. The authors in [51] have focused on mmWave, D2D communication, and mMIMO. In [36], the authors only discussed mmWave as a promising candidate for 5G key enabling techniques. The authors in Refs. [54,55] have focused on mMIMO and mmWav. Therefore, this comprehensive survey is motivated to yield broad and thorough information about all important 5G key enabling techniques for the improvement of channel capacity and SE.

Generally, new signal processing techniques for 5G communication networks can be characterized into the following four parts:

- New modulation, signal estimation, and coding techniques.
- Effective spectrum management and new schemes (licensed and unlicensed).
- Using new spatial processing schemes.
- New system-level enabling technologies.

4. Key Enabling Techniques

As Table 3 discusses various multiple access techniques for different mobile communication generation but there is no specific performance metric for 5G networks so far. Several new signal processing techniques are in the study by academia, industry, and telecom operators so the ultimate goal of the 5G system in terms of flexibility, enhanced channel capacity, SE, compatibility, power efficiency, reliability, peak service rates, etc. can be achieved successfully. Among these classes, various potential technologies have achieved the targeted setup for 5G networks, which are mentioned in Figure 3. Several of these technologies, when combined together can attain greater performance as compared to their individual performance. Each technology has exclusive potential advantages and challenges, described in detail.

Table 3. An overview of different generations, 3GPP Release's and multiple access techniques.

Technology	3GPP RELEASE	Access Techniques
2G system	Release 96 for 14.4 kbps user data Release 97 for GPRS Release 98 for EDGE	FDMA and TDMA
3G system	Release 99 for UMTS	CDMA
LTE (2 × 2 MIMO)	Release 9	OFDMA
4G LTE Advanced (4 × 4 MIMO)	Release 10	OFDMA and OFCDM
4G LTE-Advanced Pro	Release 13 and beyond	OFDMA and OFCDM
WiMAX	Release 9	OFDMA
5G systems	Release 15 for Phase 1	OMA for downlink, NOMA for uplink
	Release 16 for Phase 2	-
5G-Advanced	Release 17	CP-OFDM and DFT-S-OFDM
	Release 18	TDD and FDD

4.1. Millimeter-Wave Communications (mmWave)

The majority of overwhelming communication networks are already operating in the microwave band, which makes it too scary.

The millimeter-wave (mmWave), becomes an important facilitator of 5G networks as a result of the availability of abundant spectrum resources at the millimeter-wave band from 30 to 300 GHz promising high data rate [59]. It is a key research area for wireless power transfer [31], solution for high bandwidth vehicular communication [60] and unmanned aerial vehicles (UAVs) [61,62], as it let huge antenna arrays to be arranged in lesser form-factor. Therefore, mmWave is considered to be the main candidate to achieve improved network capacity and data rate. According to the US Federal Communications Commission, various frequency spectrum's within the mmWave appear promising and suitable players for 5G networks and Beyond, as well as the local multi-point distribution service (LMDS) band ranging from 28 to 30 GHz, the non-licensed 60 GHz band, and 12.9 GHz located from 71–76 GHz, 81–86 GHz, and 92–95 GHz in the E-band [46]. Moreover, the mmWave is revolutionary because it has distinct propagation requirements such as: hardware constraints and atmospheric absorption as compared to microwaves.

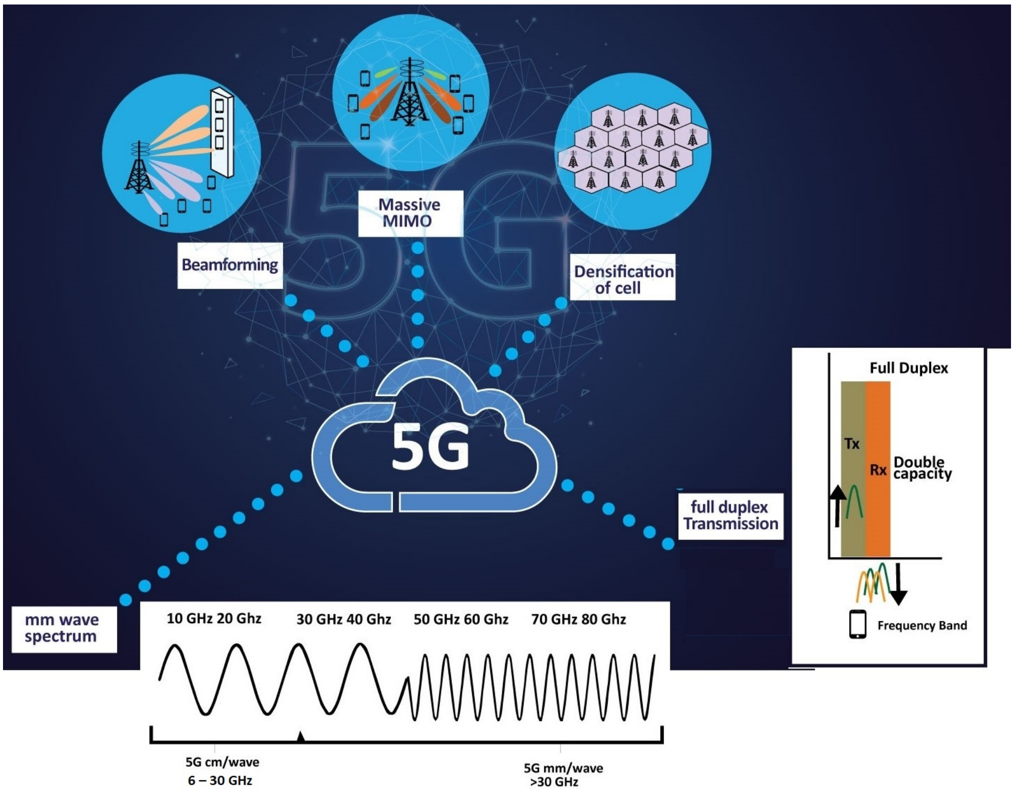

Figure 3. 5G key enabling technologies.

It is broadly acknowledged that the mmWave must be utilized together with a limited cell radius of less than 100 m to reduce high-rise path loss. High path loss in mmWave as compared to MW bands below 3 GHz is considered main challenge, give by:

$$L_{FreeSpace(\mathrm{dB})} = 32.4 + 20log_{10}f + 20log_{10}R \quad (1)$$

where L is free space path-loss measured in decibels (dB), f (GHz) the carrier frequency and the distance between transmitter and receiver is R, measured in meters. This can be understand clearly that an extra path loss of approx. 23 dB & 31 dB when moving the operational frequency from 2–28 GHz and 70 GHz, respectively. As the non-LOS (reflected) signal is very weak, the mmWave can use highly directional antennas for line-of-site (LOS) communication. Another serious challenge of mmWave is signal attenuation at high frequency spectrum. This is very problematic as it limits signal propagation because the energy of mmWave is absorbed by water vapor and oxygen. The third challenge of mmWave signal is its penetrates with high loss, makes it very sensitive for the buildings [46]. However, due to the limited number of simultaneous connections at these extremely high frequencies, the mmWave channels are sporadic nature (scattered) in the angle/spatial domains. Hence, by using either hybrid analog-to-digital beamforming with a large scale antennas of coupling mmWave with massive MIMO and NOMA can avoid this restriction and can yield very high SE gain [54].

To the bottleneck of existing wireless bandwidth, enhancement of channel capacity, and SE a solution is proposed in [63]. There are various challenges of mmWave communications do exist, such as beam training and tracking, device association, directivity, sensitivity to blockage, and high propagation loss which are under research and need to address [64]. Guang et al. [65] developed an adaptive low-latency approach that uses cooperative networking to overcome end-to-end latency and boost systems channel capacity. In [23], a new technique mmWave small cell network (mmWave-SCN) is proposed that is a combination of mmWave, mMIMO, and network densification to combine additional infrastructure nodes and spectrum. The resulting mmWave-SCN contains features from mmWave and SCN, such as flexible deployment and management, ultra-high data rate support, and ironic obtainable spectral resources. Peng. Yu et al. [66] proposed the mmWave Aerial Base Station (mAeBS) by the grouping of the aerial base station (AeBS) and mmWave. This technique provides efficient and strong maneuverability, adequate spectrum resources, and also overcomes the shortcoming of proneness to obstruction by flexible adjustment of mmWave position. In [67], smaller antennas are made by combining even smaller antenna arrays which demonstrate the effectiveness of beam steering and narrowing (BSN) techniques for enhanced channel capacity. Hamed et al. [68] presented a framework to incorporate the high data rate and growing user demand in mmWave cellular network in the 28 and 73 GHz band by dividing a dense mmWave hexagonal cellular network into various smaller cells with their own base stations. The analysis shows a better spectrum and energy efficiency.

4.2. Multiple Access Techniques

Various 5G multiple access techniques have been proposed so far by the telecom industry and academia including Interleave Division Multiple Access (IDMA) [69], Low Density Spreading Multiple Access (LDSMA) [70], Lattice Partition Multiple Access (LPMA) [71], Sparse Code Multiple Access (SCMA) [72,73], Pattern Division Multiple Access (PDMA) [74–77], Power-domain NOMA [78,79] and various others are briefly explained in Figure 4.

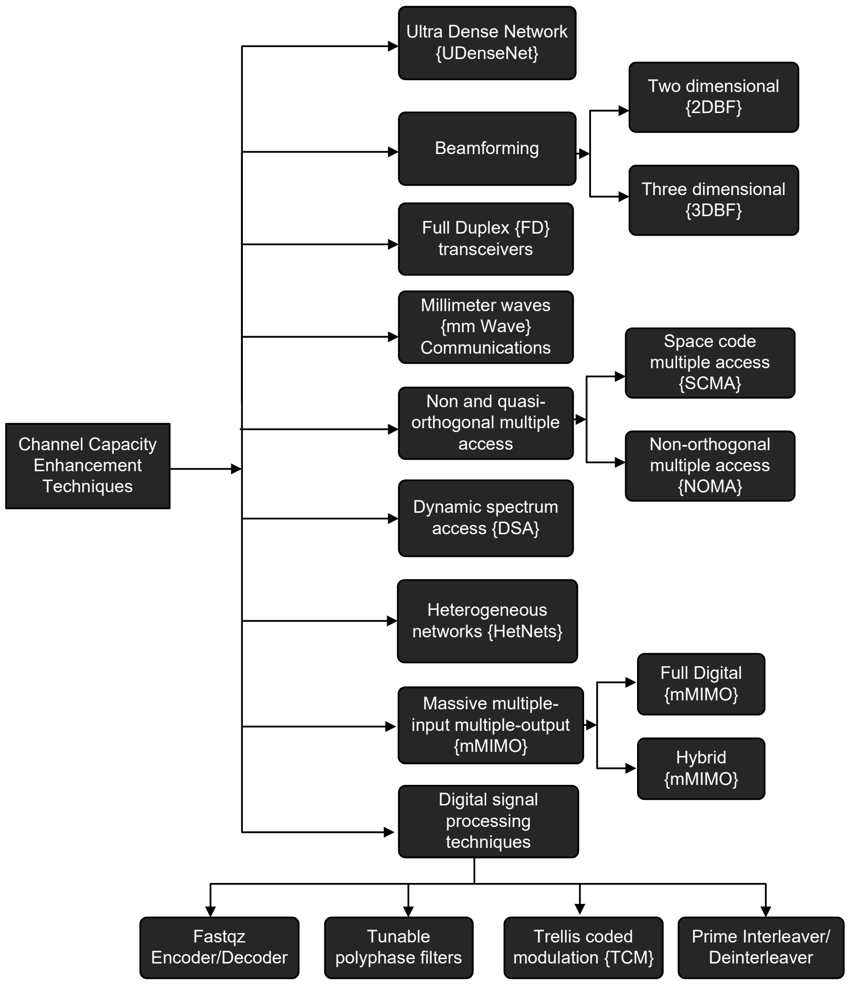

Figure 4. Summary of key enabling techniques for channel capacity and SE improvement.

4.2.1. Non-Orthogonal Multiple Access (NOMA)

NOMA is an effective and favorable technique to enhance user capacity, user fairness, and SE for 5G and beyond wireless networks [80]. In NOMA, several users are allocated similar and single resource sections (time and frequency) in a specified time. The subscriber separation is attained by various interference cancellation schemes [81,82]. Shin et al. [83] categorized into single-cell NOMA and multi-cell NOMA while Mahmoud et al. [84] classified NOMA into two general types: code-domain and power-domain multiplexing. The Performance analysis of cooperative NOMA, practical implementation aspects, and research challenges such as hardware complexity, error propagation, carrier frequency offset, and timing offset estimation are discussed in detail. Even though the implementation of NOMA in wireless communication is comparatively new but key ideas such as successive interference cancellation (SIC), superposition coding, and message passing algorithm (MPA) have previously been developed over and above two decades ago [85–88]. The key features of NOMA are a balanced trade-off between system throughput, user served fairly, and greater throughput yield than Orthogonal-Multiple access (OMA). The article [89] provides a systematic combination of dynamic spectrum access and MIMO, features, challenges, and futuristics in the standardization activities regarding the execution of NOMA in 5G communications. In [54], an extensive research has been done on NOMA-enabled massive MIMO, and the spatial domain in designing subscriber pairings, pilot allocations, and relevant signal processing methods have solely been exploited.

4.2.2. Sparse Code Multiple Access (SCMA)

SCMA allows non-orthogonal communication of various user signals amongst code and power domains, which may well improve SE and provide stronger connectivity with limited resources. The authors in [90] conducted SCMA to attain an improved link-level performance, delivering additional multiple access capability through reasonable complexity and energy consumption hence, considered SCMA as an enhanced energy-efficient approach while Nikopour et al. [91] developed a technique for SCMA to increase the downlink throughput of a deeply loaded network. He found that SCMA can increase link adaptation as a result of reduced colored interference and enhanced SE of wireless networks. In [92], the authors derived and implemented SCMA-MIMO by combining MIMO and SCMA technologies to accommodate the ever-increasing number of users, reliability, and SE improvement for the next-generation 5G networks. Jienan et al. [93] proposed an efficient and affordable decoding algorithm based on a Bayesian program learning scheme and Monte Carlo Markov Chain (MCMC) which can reduce 60% computation complexity and only 0.5-dB performance loss related to a similar decoding algorithm.

4.3. Ultra-Dense Network (UDense Net)

Cell densification has become the major contributor to enhance capacity in previous generations of wireless communications, about 4–5 macro-cell base stations (MBSs) /km^2 in 3G, around 8–10 micro-cell BSs/km^2 in the 4G and expected increase of 40–50 small-cell BSs (SBSs)/km^2 in 5G [94]. The principal goal of cell densification is to address the coverage problem by spatial frequency-reusing and offloading the data traffic to the SCs. High splitting gain by dense small cells was a major challenge. Hence, an ultra-dense network (UDN or UDense Net), with one macro-cell BS that serves a huge variety of small-cell BS's, is widely considered a key player in achieving capacity. UDense Net is known as a promising technology to enhance SE, capacity, and significant system performance by utilizing spectrum opportunities locally for every single hertz. It also possesses the advantages of low transmission power, effective expansion of coverage, the throughput of the network, and flexible deployment [95,96]. However, several challenges including security, interference, mobility support, flexible back-haul connectivity, and energy consumption also exist. Similarly, In [59], two architectures: self-back-hauled small cells for UDense Net and direct access were investigated and results showed a 30% rate improvement. In [69], increased handover rates by using a trace methodical approach to secure the network by continuous monitoring. Wang et al. [97] suggested a network architecture for UDense Net by two effective localized mobility management techniques which have performance evaluation results of the average handover signaling costs, average packet delivery cost, average latency, higher handover latency and average signaling load to the core network. Li et al. [98] addressed the problem of anti-jamming communication in an unknown environment for UDense Net by a deep reinforcement learning base anti-jamming algorithm. This algorithm is represented in an actor-critic framework. For the selection of anti-jamming action, a convolution neural network (CNN) is used as an actor, and a deep neural network (DNN) as the critic for the value estimation.

4.4. Dynamic Spectrum Access (DSA)

As per 5G vision, spectrum bands have two categories: Below 6 GHz Band and above 6 GHz. The scarce and costly below 6 GHz band is exceptionally crowded as it is already been allocated to several communication systems. The challenging demand for data by a factor of 1000× can be addressed by exploiting additional bands, licensed and unlicensed. The cellular operators find unlicensed spectrum effective, economical, and less crowded supplement to enhance the capacity of existing soon-to-be overloaded wireless networks as a radar might be operating in the same band. An advanced dynamic channel access strategy to enhance the quality of experience has been investigated in [88]. The DSA is an access technique of sharing licensed-plus-unlicensed heterogeneous spectrum, as a means to feed emerging wireless network technologies. It has the advantages of low cost, enhanced coverage, channel capacity and bandwidth, high quality of service, and less interference [99–101]. In [102], extended dynamic spectrum access, a solution proposed for the unbalanced spectrum loads and perceived capacity bottleneck. The DSA has two broad classifications: cognitive-inspired radio access and co-operative-inspired radio access. A survey of advanced schemes for spectrum sharing to a significant increase of the spectrum efficiency in 5G networks which is extensively endorsed by both the industry and the academia [103].

4.5. Full Duplex (FD)

The name "duplex" in communication system denotes the ability of two systems are able to transmit and receive data. However, simultaneous data flow capability of the system is termed as Full-Duplex (FD). FD wireless has gained substantial research interest recently, its numerous benefits at higher layers, and doubling the network capacity by simultaneous transmission and reception on a single carrier without acquiring a new spectrum. Thus, data loss can be minimize and uninterrupted users transmission for channel sensing is achieved by using FD. Hence, FD increase the utilization of spectrum and in the process, improves network capacity but by paying the cost of increased hardware complexity and energy consumption. However, another challenge related to FD receivers is the transmitter's self-interference (SI) which is so powerful (a billion to a trillion times) and ranges from 90 to 20 dB. This high power at the transmitter side suppresses the desired signal at the receiver. So, to have full utilization of the FD network, it needs to be redesigned not only at the physical layer but also at the medium access control layer [104–108]. To reduce the SI on an acceptable level to the thermal noise researchers have developed several efficient techniques in the past such as a combination of passive and active cancellation methods. Columbia University conducted recent research on integrated full duplex radios by using non-magnetic complementary metal oxide semi-conductor circulators [109]. The use of a single antenna and recent evolution's in SI cancellation/suppression methods turned FD communications a promising candidate to increase spectrum efficiency and channel capacity for 5G and B5G networks.

4.6. Beamforming

The smart antenna technique which consists of a closed-loop pre-coding where we can steer the wireless beam flexibly toward the desired subscriber is called beamforming. It is proven technology for improved array gain, signal quality, network coverage, higher channel capacity, SE, and reduced inter-cell interference. It employs digital signal processing techniques that identify the directional antenna beam patterns by using several antennas at the transmitter side. Smart antennas equipped with beamforming abilities can be organized such that the transmitted signal can be directed to the desired location with exact precision and avoid unwanted signals from an undesired path simultaneously. It can be rotated electronically by phase shifting in 5G networks. The impact of suitable antenna configurations for directional multi-antenna beamforming have shown to improve the Ricean factor gain, increased SNR and low root-mean-squared (RMS) delay spread because of multi-path dispersion at the receiver. Beamforming consists of two-dimensional beamforming (2DBF) and three-dimensional beamforming (3DBF). By using narrow pencil beams, spatial degrees of freedom can be exploited by avoiding inter-cell interference [18,110,111]. Therefore, beamforming is considered to be key player for improving SE.

5. Massive MIMO

The Multi-input multi-output technology (MIMO) has been almost a decade, but equipping base stations (BS) with multiple antennas is a new concept in 5G and beyond 5G (B5G), called massive MIMO (mMIMO) [95,112–114]. The mMIMO has proven an efficient player for industrial Internet of things (IIoT) networks [115], mobile edge computing [116], virtual reality [117], 5G wireless communication networks [118], autonomous driving [119], augmented reality [120] and wireless sensor networks [121–123].

The advantage of mMIMO includes a massive shoot-up in SE, a minimized latency, and an expandable air interface arrangement. It is a multi-subscriber technology, in which every BS is equipped with a large number of active antennas M, arranged in an array and simultaneously communicates a set of single-element K customers on a similar frequency and time resource such that $M >> K$ making the signal pre-coding process simple and increase SE [124,125]. The difference between the 4G sector antenna and 5G massive-MIMO geometry is shown in Figure 5 which consists of >100 elements. The huge nature of mMIMO itself is the cause of reduced latency as it removes the channel frequency dependency which stops the effect of frequency selective fading on the signal strength. Therefore, every transmitted signal safely arrives at the receiver without suffering channel distortion with decreased latency.

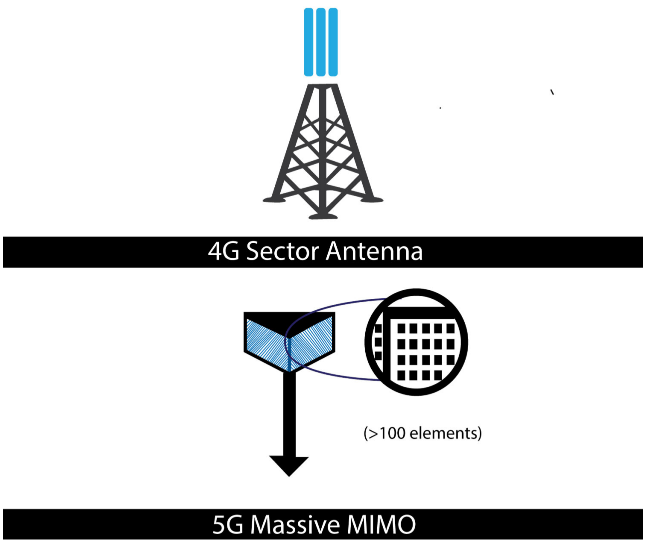

Figure 5. Difference between 4G and 5G massive-MIMO antenna.

The mMIMO can be implemented by two feasible approaches: full digital configuration and hybrid configuration. In fully digital mMIMO a wide-range digital signal processing unit is required along with a digital-to-analog converter for every antenna element [126,127]. The hybrid (analog-digital) mMIMO system that merges analog beamforming and digital MIMO signal which overcomes the amount of digital-to-analog converters [128–130]. The first implementation of mMIMO in real time and public implementation is, with M = 100 and K = 10 [131]. In mMIMO, an antenna array of the base station contains M dipole antennas with λ wavelength, each consisting of an effective size of $\lambda/2 \times \lambda/2$. This implies that an array of 1 m^2 can fit a hundred antennas at 1.5 GHz and 400 antennas at 3 GHz carrier frequency [132]. The array can be of any geometry; cylindrical, distributed arrays, linear or rectangular.

Table 4, describes the unique features of mMIMO which make it prominent from other key enabling technologies effectively. The SE of a specific group j is impacted by the model signaling completed in different cells. Assume, the pilot reuse factor f is an integer with the distribution of L sections into f split cell groups: $f = \tau_p\ /K$.

Table 4. Features of mMIMO on other key enabling techniques.

Sr. No.	Characteristics	Reference
1	Increased Throughput	[133]
2	Reduced Radiated Power	[134]
3	Unlimited Capacity	[135]
4	Hardware Efficiency	[136]
5	Energy Efficiency	[137]
6	Multi-user Gain	[138]
7	Enhanced Antenna Design	[139]
8	No Cost for Extra Site	[108]
9	Single-carrier Transmission	[140]
10	Enhanced Spectral Efficiency	[141]
11	Highly Secure	[142]
12	Low Latency	[16]
13	Anti-jamming	[143]
14	Robust	[144]
15	Enhanced QoS	[145]
16	Reliability	[146]
17	Omni-directional	[147]

The global pilot reuse f = 1 and non-global pilot reuse f > 1 are very well known. As the hexagonal cell topology contains six cells in each stage, the lowest pilot reuse factors which increase to symmetric pilot reuse patterns are f = 1, 3, 4. Consider an mMIMO scenario with base station antennas M = 200 and $\tau_c = 400$ symbols a coherence interval, where customers are homogeneously distributed in the cell except for the 10% cell center. These channels show uncorrelated Rayleigh fading by a distant dependent channel attenuation having a path loss exponent of 3.7. By taking f = 1, 3, 4 suppose an easy policy for power allocation.

$$\rho_{j,k} = \frac{\delta}{\beta^j_{j,k}} \tag{2}$$

where $j = 1, 2, \cdots, L$ and $k = 1, 2, \cdots, K$ Here $\delta > 0$ is a configuration framework that calculates the achieved SNR at every BS antenna and is known as statistical channel inversion power allocation:

$$\rho_{j,k} \times \frac{\beta^j_{j,k}}{\sigma^2_{BS}} = \frac{\delta}{\sigma^2_{BS}} \tag{3}$$

The average SE is an outcome of the different users with non-identical pilot reuse factors and processing schemes by considering two separate SNR levels δ/σ^2_{BS} = 0 and 20 dB. The two different SNR levels yield essentially similar performance as evident in [132]. Therefore, SE can be increased by increasing the number of antenna elements because of increased data rates to the subscribers, relatively low cost to the network operators, coverage improvement, and increased service reliability [52].

As the array gain is not noise-limited and constructs the SE interference-limited, it demonstrates that Massive MIMO works equally fine at low and high SNR's. The second observation is that dissimilar pilot reuse factors are required at dissimilar customer loads (i.e., No. of subscribers K). The pilot reuse of $f = 3$ is required at less load while $f = 1$ is desired to minimize the Prelog factor $(1 - fK/\tau_c)$ when the value of K is very large. By choosing the appropriate f, mMIMO can offer a high SE above an extensive range of various customers. The mMIMO delivers stable SE for any $K > 10$ and does not require complex scheduling as every active subscriber can essentially be served at the same time in each coherence interval or a minimum of τ_c /2 subscribers, resulting in half of the coherence interval for data, which is normally greater than a hundred; the high amount of SE is then shared among all the subscribers. The significant design parameter in mMIMO is a pilot reuse factor which depends on the user load, total number of BS antennas, and propagation environment. In 3GPP Release 18, the evolution of MIMO will continue. During the commercial deployment, significant performance loss due to outdated channel state information (CSI) by UE has been investigated with moderate or high mobility in multi-user MIMO (MU-MIMO) scenarios. To increase the performance of medium or high-mobility UE will be explored for potential CSI enhancements [32].

It is also observed that a suitable trade-off between SE and energy efficiency (EE) has an important impact on the 5G network and Beyond 5G. Hence, a balance between SE and EE is urgently needed. Also, effective algorithms need to be proposed to achieve a satisfactory trade-off. The SE in mMIMO can significantly be increased by the following methods:

- By enhancing transmit power.
- By utilizing the uplink and downlink space division multiple access (SDMA) techniques.
- By acquiring an array gain.
- By obtaining channel state information (CSI).

Therefore, mMIMO is considered the ultimate solution for high data rate, channel capacity, and spectrum efficiency in 5G and B5G.

5.1. Classification of Applications

Massive MIMO is considered a key technology for the 5G and beyond networks because it can significantly enhance spectrum efficiency, reduce frequency spectrum constraints, and completely utilize existing space resources. The mMIMO can be classified into two applications categories smartphones and base stations as shown in Figure 6.

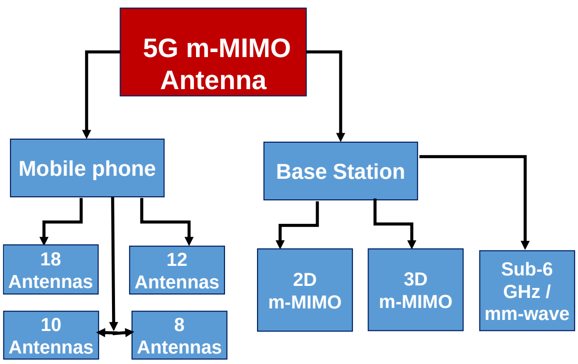

Figure 6. Classifications of applications for 5G massive-MIMO antennas.

5.1.1. Mobile Phone

Various mMIMO systems for mobile phone applications for 5G and beyond networks have been investigated that are categorized by a number of antenna elements such as 18, 12, 10, and 8. In [148], an 18-port 5G mMIMO antenna operating in the sub-6 GHz band is investigated. The 18-slot antennas were simply adjusted on the 6-inch board, performing as a radiator which is used for modern smartphones. The measured results of this mMIMO antenna have high isolation > 20 dB, and peak efficiency > 87% over the operating frequency. A 12-element MIMO antenna is presented in [149] for 45/5G mobile phones. As per the measured results, the ergodic channel capacity of 34 b/s/Hz and 26.5 b/s/Hz, were achieved in LTE bands 42/43 and 46 respectively. Although, this design achieved enhanced channel capacity, a trade-off between the isolation of <-12 dB, and total efficiency of $>40\%$ has been observed. Various 10-elements mMIMO antennas for the 5G smartphones have also been investigated [150–154]. All designs were proposed for 4G/5G smartphones operating in the sub-6 GHz band and prototypes were fabricated to evaluate isolation, efficiency, and MIMO diversity performances. It has been observed that a 10-element MIMO antenna array can achieve the maximum ergodic channel capacity of 51.4 bps/Hz.

Similarly, various 8-elements mMIMO antennas systems for the 5G smartphones have been presented operating in sub-6 GHz frequency band [155–158]. In order to consider the importance of backward compatibility, these designs are equally capable of working in two frequency bands including multi-and or wide-band structures. Although the antenna elements of mMIMO in the mobile phones must be in equal or greater number than eight antennas, various designs are not able to support the massive-MIMO system in the 5G mobile phones regardless of employing the same number of mMIMO antennas. Nevertheless, all such designs are observed to be suitable candidates for the mMIMO systems.

5.1.2. Base Station

For the design of 5G mMIMO base stations, the 2D model is the utmost simple planar mMIMO arrangement is an array of $N \times M$ configuration of the planar array. The various designs (cylindrical, planner, and circular) significantly affect the mMIMO system performance. As the beam can be adjusted only horizontally, usually the circular or planar array design shows a considerable reduction. Moreover, these designs also fail to increase channel capacity demands. Therefore, it is proposed that 3D massive arrays such as hexagons, cylinders, triangles, etc. arrangements should be adopted [159].

Many 5G base station antenna designs have been investigated in this study [160–163]. For an indoor MIMO base station, an ultra-wide-band portable multi-element antenna consisting of 121 physical antennas to construct a 484-port is investigated in [164]. This antenna is effectively working on a wide frequency range from 6 to 8.5 GHZ and uses 3D radiation patterns to measure total efficiency of around 70%. It has been observed that 64 QAM can simultaneously be transmitted for a single user with 8 antennas, and 5 Gbps is feasible at 200 MHz. Moreover, a 10 Gbps throughput for multiple users in an outdoor environment is also possible [165]. Another high isolation 32 elements mMIMO antenna with a measured bandwidth of 250 MHz For next generation 5G base stations is investigated in [166]. The decoupling of 32 dB among array elements with a reduced ECC of 0.0001 is observed by this proposed MTM-based method.

In [167], an mMIMO antenna system having 288-elements and 72 ports is presented for 5G base stations. A 3-layer configuration with 24-ports on every side of the antenna system. The single port gain of 9.41 dBi and 64% efficiency was measured. It has been observed that increasing the antenna elements significantly increases channel capacity in the mMIMO system. A significant variation in gain patterns also has been experimentally evident from various antenna elements in a finite array. The mutual coupling and edge effect are the main players in the beamforming which is directly dependent on the arrival angle. The key concept of mMIMO is to obtain all the functions of traditional MIMO but over a large scale. The mMIMO is analyzed as an efficient technique for B5G networks with several benefits and features, listed in Table 5 which briefly describes a comparison of various key enabling techniques with mMIMO [168]. The key problem with the deployment of mMIMO is a radio-frequency pattern that increases the difficulty of the symbol detectors can be addressed by combining analog and digital beamforming, called hybrid beamforming structure [169–172]. In [173], a detection algorithm for perfect mMIMO has been proposed to increase performance and decrease complexity. This paper briefly discusses various mMIMO detection algorithms in detail. Likewise, A practical test at Lund University was conducted utilizing around 100 BS antennas along with up and around 50 field programmable gate arrays. The obtained results show that mMIMO can simultaneously work for a number of users in a static inside/outside environment using a similar frequency and time band [174]. As conventional wireless communications systems are unable to provide the SE's that 5G applications require, the mMIMO is becoming a reality now because it can simultaneously provide in the downlink and uplink direction of B5G due to uplink-downlink duality. In [132], SE is expressed as an outcome of the number of base station antennas M. To achieve the highest SE, the functional subscribers are optimized for each M. As per IMT-Advanced, the performance baseline SE is in the range of 2–3 bit/s/Hz/cell, subject to simulation scenario. The results shown in [175], with $M = 100$ antennas an achievement of 52 bit/s/Hz/cell which is 17× to 26×, and with $M = 400$ antennas an unbelievable 38× to 57× enhancement over IMT-Advanced. Importantly, the number of active subscribers grows together with the SE. The SE for each user can obtain by dividing the top curve by the bottom curve and surprisingly the SE per user exist in the modest range of 1–2.5 bit/s/Hz [176]. Similarly, Yoshio et al. [177] also evaluated the transmission features of mMIMO by using asymptotic eigenvalue distribution of a Wishart matrix and determined about 20% enhancement in the channel capacity by using spatial correlation. Moreover, MmWave base station 256-element antenna arrays and mobile antenna of 32-element arrays are already commercially available [44]. Furthermore, results in [178], show that the Massive MIMO is important to not only enhance the SE but surely able to be the driving force to achieve increased area throughput in 5G networks. The mMIMO technology is proven to be true for providing 10-fold or even fifty-fold enhancement in SE over IMT-Advanced by serving several users at the same time.

Table 5. Comparison of mMIMO with other key enabling techniques.

Technology	Enhanced Data	Energy Efficiency	Increased Channel Capacity	Enhanced Spectral Efficiency	Substantial Device Support
mMIMO	✓	✓	✓	✓	✓
FD	✗	✗	✓	✓	✗
mmWave	✓	✓	✓	✓	✓
DSA	✓	✗	✓	✓	✗
UDense Net	✓	Partial	✓	✓	Partial
NOMA	✓	Partial	✓	✓	✓
SCMA	✓	✓	✓	✓	✓
Beamforming	✓	✓	✓	✓	✓

5.2. Open Challenges of mMIMO

The mMIMO is obviously high-caliber and remarkable to the conventional multiple antenna networks. Although, massive MIMO and 5G technology can be wonders for future wireless networks. However, several hardware issues such as the choice of the material, the limited size of the mobile phone chassis, overall cost, and characteristic parameters (bandwidth, mutual coupling, gain, efficiency, etc.) can be observed for both of the above-discussed applications. The unlimited variety of smartphones, operating in different frequency bands is another problem for antenna designers.

Although, the impact of mutual coupling and limited space in the 5G mMIMO system is challenging. However, the decoupling techniques and compact antenna size can be used to enhance isolation among the antenna elements. In this part, we report the most recent advancement of research on challenges in mMIMO frameworks with regard to the most serious problem of mutual coupling by targeting the recent literature published between 2018 to 2023.

To implement MIMO in 5G and beyond networks, there are various research challenges that need to be addressed such as mutual coupling, channel estimation, signal detection, energy efficiency, and pilot contamination. The narrow space in smartphones is a major challenge and the effect of coupling between adjacent antenna elements severely decreases the MIMO performance. Hence, the reduction of mutual coupling is highly desirable as it offers high isolation, efficiency, and MIMO diversity performance. Various decoupling techniques have been addressed in Table 6 to reduce mutual coupling.

Table 6. Futuristic suggested solutions for MIMO antenna to reduce mutual coupling.

Ref.	Year	Solution Suggested	Frequency GHz	Outcome Type
[179]	2018	Metal meandering strips	3.2–5	Simulated
[180]	2018	Pattern multiplicity	2.5–2.64	Simulated and tested
[181]	2019	Transmission- line decoupling	2.45	Simulated and tested
[182]	2019	Molecule-shaped structure	2.4–10.6	Simulated and tested
[183]	2019	Frequency-selective surface	3.5–4.9	Simulated and tested
[184]	2020	Decoupling network	3.3–4.5	Simulated and tested
[185]	2020	Decoupling super-strate	3.3–4.5	Simulated and tested
[186]	2021	Sub-Miniaturization	0.61–0.96 −1.7–5	Simulated and tested
[187]	2021	Split Ring Resonators	2.73–3.12 −4.33–4.68	Simulated and tested
[152]	2022	Defected Ground Structure	5.82–5.94	Simulated and tested
[188]	2022	SICL Feeding Structure	24.5–26.5	Simulated and tested
[189]	2023	Defective Ground Structure	2.2–2.64	Simulated and tested

Metal meandering consisting of metal-strip lines is an effective technique to overcome mutual coupling. This solution was proposed in [179] to achieve effective decoupling by meandering strip lines vertically and horizontally among 16 antenna elements. A six-element, three ports antenna is proposed in [180] that demonstrates pattern diversity by loading periodical inter-digital capacitors on the radiating elements. The proposed dual-polarized antenna was found to have an omni- directional radiation pattern and efficient mutual coupling of below −20 dB between any two ports. This design is considered an important milestone in the implementation of the mMIMO network for 5G and B5G due to the low coupling effect. The isolation can be improved by orthogonal geometry of the antenna elements using molecule fractal structure given in [182]. This technique shows improved isolation of higher than 20 dB. Another efficient solution reported in [183], is to reduce mutual coupling by inserting a frequency-selective surface scheme among the array elements. To improve isolation further, a frequency-selective surface decoupling structure in the substrate is used which blocks the propagation of the electromagnetic wave (EM) in the substrate. The effect of both the coupled magnetic and electric fields was removed by using the Frequency-selective surface (FSS) decoupling structure. An embedded decoupling scheme is introduced in [184] by combining parallel reversed C-shaped metal strips with two inverted U-shaped metal strips that produce additional coupling while placed near a pair of closely spaced dipole antennas. The reported result was a 10 dB mutual coupling reduction over 3.3–4.5 GHz and demonstrates the advantages of the wide-band frequency spectrum, embed-able, radiation pattern distortion alleviation, and dual-polarized capabilities for MIMO applications. Another, mutual coupling reduction for large antenna arrays is proposed in [185], using ϵ-negative meta-surface superstrate. This decoupling meta-surface structure is very useful to restore the radiation patterns, maximum mutual coupling reduction of 25 dB, broaden the bandwidth of the array, and minimize the active voltage standing wave ratio. The work published in [186] also represents low mutual coupling, good decoupling of the radiators, and impedance matching. In [187], a dual-band MIMO antenna is proposed over a frequency range of 2.7–3.1 GHz and 4.3–4.6 GHz showing improved isolation of higher than 21 dB and efficiency of 80% and good MIMO diversity performances. The mutual coupling was reduced by using a split ring resonator structure on the radiator. Another hybrid decoupling technique to reduce mutual coupling is presented in [152] using the defected ground structure (DGS) and circular ring parasites. The DGS reduced the effect of coupling between antenna elements whereas, the circular ring parasites reduced the mutual coupling between perpendicular antenna elements. A novel 64-element dual-polarized mMIMO antenna operating in 24.5–26.5 GHz frequency band is presented in [188] and mutual coupling is reduced to -23 dB for the entire bandwidth by using substrate-integrated coaxial line feeding structure. As the Substrate-integrated Coaxial Line Feeding (SICL) transmission contains a microstrip line, shielded by two rolls of metallic vias on both sides and two ground planes above and below, aiming for an extremely low coupling feature. In [189], L-shaped stubs and DGS are used to reduce mutual coupling effects. The L-shaped stubs are placed on one side of the two patches, which generate a new coupling current for antenna excitation and create an additional coupling path.

The huge amount of channel state information in beamforming will surely be questionable, particularly for the downlink. Therefore, mMIMO can only be operational in the time division duplexing because of feedback schemes, restrictive cost of channel estimation, and channel reciprocity. Thus, it will be unsuitable for frequency division duplexing but pilot contamination in time division duplexing is also a huge challenge in mMIMO. So, new means of channel estimation, feedback measures, and solutions need to be proposed for 5G and B5G. Moreover, if the transmission power is excessive in an amount that is typically 3–5×, the mMIMO will experience thermal noise and pilot contamination from other cells which require passive cooling. Thirdly, The researcher will be unable to justify techniques and algorithms due to insufficient channel models for mMIMO as to cope with the huge amount of data, tremendously fast algorithms will be needed. Furthermore, enhancing the antenna elements creates consequential challenges not only to equipment but also to operators and manufacturers.

6. Conclusions

As the need for high-speed internet increases substantially, the 5G system should have the ability to meet these requirements and provide aid for multi-fold improvement in channel capacity and network connectivity. This paper explains a comprehensive survey that carried on the basics of challenges involved in previous wireless networks, evolution, and implementation of 5G wireless network that has been described in terms of enhanced data, channel capacity, and spectral efficiency.

To deliver ultra-fast data speed, SE improvement is vital in 5G networks that can be improved through D2D communications, mMIMO, by enhancing modulation order, and acquiring new effective transmission waveforms. To encounter substantial traffic growth, 5G wireless systems are expected to achieve higher channel capacity by utilizing mm-wave band, dense small cell deployment, beamforming and mMIMO technology. The critical review illustrates mMIMO technology is the solution to not only the increase in SE but also a motivation in relation to accomplishing higher orders of area throughput in 5G and B5G. However, it faces various critical challenges which need to be solved prior to the implementation of the next-generation wireless networks. Although the mMIMO is investigated as truly a key player amongst others due to its various features, still there are various secondary key emerging technologies such as FD, mmWave, UDense Net, and beamforming, their challenges and features with the focus on the enhancement of data rate, channel capacity, and SE. Moreover, this paper inspires researchers for the enhanced outcome of various problems, trends research gaps, and future directions in 5G and B5G networks.

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