5G Scope of Applications and Development: A Comprehensive Review

1Kaza Mrudula 2Pragya Sinha 3Balaji S 1,2 U.G Student, 3 Associate Professor

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Abstract

5G network implementation is a very promising and developing field in wireless networks; MIMO is one of them that use RF technology. MIMO is multiple input and multiple output network, which is one of the potential gateway for normalizing 5G network. In this paper, we discuss how the introduction of MIMO can deduct the existing problems that would be eliminated entirely, like the fairing wireless network rates. It also discusses the possibility of new problems that could be created by this potential technology and also the various methods implemented to mainstream the idea of 5G. The purpose of why the research should be pursued in the direction of the 5G is discussed and also the parameters influencing 5G technologies.

Key Words: Massive MIMO, beam forming, spatial multiplexing, small cell heterogeneous network, full duplex, fifth Generation.

1 INTRODUCTION

5G is the next generation network, that promises to deliver what today’s mobile users requires. The emerging needs of the current generation include faster data speeds and more dependable services [1][2]. The objective of improving the scope of 5G technologies offers a higher capacity than the current 4G, a greater number of smart mobile users, and associating device-to-device, reliable and massive device communications lowering the battery consumption,
uniform GBPS data throughput [3] and more importantly better application of the Internet of things. This 5G technology could increase the accessibility of data on the Internet and utilize the spectrum more effectively. MIMO is one the many approaches to effective implementation of 5G networks.

MIMO is currently being used in numerous applications from LTE to Wi-Fi, but at the moment, the number of antennas is considerably limited [4]. The use of microwave frequencies opens up the prospect of using multiple antennas on single equipment develops a real opportunity because of the antenna size and spacing in terms of the wavelength. The spectrum now used is 4G is 3-6GHz which is already very crowded with already existing devices. Some of the ultimate challenges we face in 5G are the exponential increase in the traffic of the users, spectrum insufficiency and increase in density of the network [5]. To implement 5G networks, we need to make use of the unused 6 GHz to 300 GHz spectrum of frequencies as shown in figure 1. For this we need the wavelength to be in millimetres. Hence we use millimetre waves [6]. The main cause of the growth in capacity is probably anticipated to come from network architectural advancements, considering heterogeneous networks and conjunction of information and communication technology [7].

![5G Spectrum](image)

**Figure 1: 5G Spectrum**

2 DISCUSSION

2.1 MIMO

MIMO is multiple input and multiple output network of antennas for the communication systems. In this, multiple arrays of antennas are used as both input and output as shown by Figure 2.
Figure 2: Basic structure of MIMO

TABLE 1: SOME PROMINENT RECENT WORKS ON MIMO

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Reviewed works</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>1.</td>
<td>Owzian, A. et al.[8]</td>
<td>It discusses the possibility of various technology components like radio link, multi-RAT and multi-layer networks, multi-node/multi-antenna/mixed spectrum banding.</td>
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<td>2.</td>
<td>Larson, E. et al.[9]</td>
<td>This work discusses the potential advances which can be achieved through MIMO and also the various drawbacks the practical application of MIMO.</td>
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<tr>
<td>3.</td>
<td>Sun, S. Rappaport et al.[10]</td>
<td>This work contains a comparative study between two most common approaches of MIMO realization - beamforming (BF) and spatial multiplexing (SM).</td>
</tr>
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</table>
| 4.   | Boocadil, F. et al.[11] | This work focuses on potential disruptive technologies and their implications for 5G for example.  
- Shifting the spectrum to mm wave frequency  
- Architectural change and introduction of MIMO  
- Making devices smarter i.e. explicit intelligence at device side. |
| 5.   | Han, O. M. et al.[12] | This work discusses the shortcoming of MIMO like mutual coupling between antenna elements that restrict channel capacity in the system. It can be overcome by using a three-element single-band printed inverted-F antenna (PIFA) system functioning in the 28 GHz band millimeter-wave (mmWave) fifth generation wireless communications. |
| 6.   | Wang, C. X. et al.[13] | In the following work, a potential cellular architecture is proposed which separates indoor and outdoor possibilities, it also discusses various capable technologies for fifth generation wireless communication systems, for example massive MIMO, energy-efficient communications etc. |

2.1.1 Parameters effecting MIMO

Performance of MIMO is affected by following parameters:

a) Antenna Design:

Dielectric Resonator antenna array:

Dielectric resonator antennas (DRAS) have been a frequent topic of study in the past decades. In addition to low profile and light weight, they propose numerous other striking features like very low conductor loss and absence of surface-wave loss [14][15]. Their radiation characteristics make them brilliant contender in the field of wireless communication system [16][17], particularly where the
operation is in the millimeter-wave band. The advantages such as low loss, ease of excitation, wide impedance bandwidth and light weight makes them more feasible [18][19]. There are many array structures that influence 5G spectrum analysis like microstrip patch antenna and graphene array[20][21][22]. Figure 3 explains the block diagram of various antennas which can be used for 5G systems.

b) Transmission /Reception of Signals:
MIMO can be deployed by either spatial multiplexing or beamforming divided based on their techniques of transmission.

i) SPATIAL MULTIPLEXING
The message signal is divided into various subdivisions where respective divisions are transmitted simultaneously with the same channel but using different antennas [10]. This can be achieved through increasing the levels of power processing units. The MIMO system was thus used to reduce the interference caused by multi-path propagation and the first step to using multi-path propagation. The transmission is done using a solitary radio using ESPAR (Electronically Steerable Passive Array Radiator) antenna for the 22 MIMO transmission adopting a λ/16 spaced single RF (Radio Frequency) is considered ideal [23][24]. As 960 kHz bandwidth is concerned the period of the control signal should be shorter than 1/960,000 second to avoid severe distortions deduced by spectrum spreading that is a typical feature of beam switching receiver as described in [25][26]. The points to note are that, the number of data streams cannot be larger than the number of transmitter antenna components and that we need a sufficient number of receiver antenna components. The transmission is further accentuated with the implementation of beam forming which helps in concentrating the beam to the beam as explained in the next section.

ii) BEAMFORMING
This technique uses a method where a beam pattern is formed that is phased in such a way that it forms a concentrated beam. This method can be used to decrease Signal-Noise Ratio and decreases path loss [10]. Beamforming antennas have the capability to provide a major breakthrough in ad hoc networks. The major problematic function of beamforming with a single receiver antenna is interchanged with multiple receiver antennas, i.e. multiple directions are considered. That is multiple path of transmission have to be considered [27][28]. One of the many algorithms such as
random unitary beamforming (RUB) realizes multiple-user diversity gain over MIMO. We can enhance RUB in the terms of the energy efficiency [29] and thus obtaining the power requirements [30]. An accurate algorithm of radiation pattern beamforming for a massive MIMO active antenna system is faced with many new challenges [31][32]. It is inferred from Fig. 4 that as ASD increases, spectral efficiency is increased in SM and in BF spectral efficiency is decreased[33][34]. Beamforming accented with array is also a very popular research topic for transmission and reception of signals [35][36][37]. Table 2 gives a brief comparative study between SM and BF.

![Figure 3](image)

**Figure 3**: Steps for design and fabrication of 5G antenna. (a) Existing DRA array structure, (b)&(c) Proposed advancement for a DRA array, (d) Microstrip antenna design

### 2.2 SMALL CELLS

Massive MIMO and dense small cell (DSC) are clustered together to boost the system capacity. Keeping in mind both the performance
and practical deployment, we recognized that the square array is more suitable for small cell deployment [40]. By placing further transmitters with moderate numbers of antennas at typical open-air hotspot locations would be a good way to improve network capacity [41].

2.2.1 Heterogeneous networks using small cell and massive MIMO

A heterogeneous network, also known as HetNet, is a wireless network system consisting of nodes with diverse transmission coverage area and powers [42]. Table 3 efficiently describes the role of HetNet in 5G application and realization.

2.3 FULL DUPLEX

Full duplex (FD) is among the techniques used for improving the scope of 5G spectrum as we observe significant growth in the spectral efficiency of an entire link and thus increasing the throughput over the same bandwidth. With incorporation of FD in today’s half duplex transmission, we can observe a significant improvement of up to 116% in session throughput and 77% in packet delay [45]. Moreover, the most appropriate range for FD systems can be accomplished by the use of microwave antennas with very large broadside and very less orthogonal gains with analog self-interference dissolution methods [46]. The major drawback of FD is of self interference i.e., FD systems suffer majorly from a leakage of power between the transmission and reception antennas. The major technique to cancel self interference is:

- Passive techniques: The idea is the separation of antenna and also shielding of the reception signals from the transmission signals at the FD radio. The main objective is the seclusion and shielding of the reception from transmission [47].

- Active techniques: They operate in both analog/digital fields. The key objective in the analog field is to subdue the self-interference at the circuitry-chain of analog receiver prior analog-digital-conversion. With incorporation of sophisticated signal processing schemes, the main objective is to cancel the self-interference in the digital domain [48].
### 3 Challenges

The primary challenges of present day cellular networks such as: higher data rates, excellent end-to-end performance, user-coverage in hot-spots and crowded areas with lower latency, energy consumption, and cost per information transfer are expected to be solved by the evolving 5G cellular wireless networks. By the existing definition, small cell backhaul connections are to be used to forward/receive the end-user (small cell user) information to/from the core network [49][50] and to mitigate interferences [51]. Energy efficiency scaling of antennas, backhaul load management, growth of variable data traffics and the trade-offs arising from these constraints producing large scope of promising future research in 5G technologies.

These challenges have to be addressed. So, 5G systems will implement a multi-tier architecture comprising of macrocells, various types of licensed small cells, device-to-device(D2D) and relays networks to serve users with diverse quality-of service (QoS) requirements in a spectrum and in an energy-efficient manner [52][53]. Some of the prominent requirement for 5G is described in the Figure 4.

#### TABLE 2 COMPARATIVE STUDY BETWEEN BF AND SM

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<td>1.</td>
<td>Kim, J. H., Lee, K., &amp; Chun, J. (2007)[48]</td>
<td>A new closed-loop MIMO (Multiple-Input Multiple-Output) is proposed where the signal space steering done in a Rayleigh frequency-flat fading channel environment that incorporate transmit beamforming and spatial multiplexing. Diversity gain is accomplished by multiplexing gain by spatial multiplexing and beamforming.</td>
</tr>
<tr>
<td>2.</td>
<td>J.Piao, D.,Jia, X., Ma,Y., Guo, Q., &amp; Li, Z. (2017) [39]</td>
<td>This paper shows that in comparison to the BF array, the SM array has a more strong performance over skewed antenna, because of the broader beam width.</td>
</tr>
<tr>
<td>3.</td>
<td>Atkinson, L. A. (2017)[40]</td>
<td>Using OFDM, multiple antennas of the same vehicle will be able to reuse the same frequencies polarizations without interference. This will be increasing spectrum availability while still providing the same transmitter power spectral density and total RF power emission.</td>
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#### TABLE 3 : HetNet TABLE
4 Conclusion

This article is the result of reviewing many research works to improve understanding and gives complete analysis of how to improve the scope of 5G spectrum and its applications. Many technologies have been emerging and various methods to implement them effectively are also coming into existence. Many different network array structure and technology like massive MIMI, BM, SF, HetNet etc have been analyzed and compared and contrasted to find the
best possible solution for the emerging 5G technology. One of the many approaches would be to enhance the type of antenna arrays as discussed in the paper. Improving the line of transmission and reception is an indispensable factor. By improving the factors and coalescing various types of technologies together, the desired results can be achieved to expand applications of 5G spectrum.

References


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antenna using low-power CMOS switches. In Microwave Conference (EuMC), 2015 European (pp. 726-729). IEEE.


