Massive MIMO and Beamforming Technique for 5G Mobile Network

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Abstract— MIMO is a technique that utilizes multiple antennas at transmitter end or in receiver finish to maximize the output, power and range of wireless system .In massive MIMO Base Station is outfitted with orders of magnitude a lot of antennas have shown over ten times spectral efficiency increase over MIMO with easier signal process algorithms. large MIMO helps to boost capability, spectral and energy efficiency and it will be designed by exploitation less price and low power elements. Even though its potential edges, this paper additionally précis some confronts faced by massive MIMO like antenna spatial correlation and mutual coupling and additionally non-linear hardware mutilations .These challenges encountered in massive MIMO reveal new issues that require advance investigation.

Keywords: MIMO; Massive MIMO; 5G; Opportunities; Challenges

I. INTRODUCTION

Multiple-input and multiple-output (MIMO) is a wireless technology that can provide significant performance improvement over the traditional single- input and single-output system, has attracted growing interest since being introduced in the past two decades. It is a key technology that takes the advantage of multiple antennas at transmitter and/or receiver that can substantially improve the network throughput, capacity, and coverage without requiring additional bandwidth or transmit power level [1]. The idea is to utilize multiple antennas at both the transmitting ends and receiving ends to separate independent wireless channels in a rich multipath environment, and uses them to transmit multiple data streams simultaneously to increase the channel capacity by applying diversity combining approach. To date, MIMO technology has been utilized in the fourth generation (4G) wireless communication standards, such as Long Term Evolution (LTE), wireless LAN (IEEE 802.11n), and Worldwide Interoperability for Microwave Access (WiMAX) [2]. The use of MIMO antennas, coupled with modulation formats, such as Orthogonal Frequency Division Multiple Access (OFDMA) can provide both increased channel capacity and protection against multi-path fading due to their rich scattering nature that provides improved spectral efficiencies.

Multiple-input and multiple-output (MIMO) has been well studied and understood in terms of point-to-point links to achieve enhance radio link reliabilities via diversity [3] and increase data rate via multiplex [4] as shown in Fig. 1. This has brought huge challenges for antenna designers to hosting multiple antennas in a single user MIMO to multiuser MIMO (MU-MIMO) to reduce the challenge to hosting multiple antennas in a size limited mobile terminal [3]. A MU-MIMO antenna system refers to a base station (BS) with multiple antennas simultaneously serves a set of single antenna users and the multiplexing gain can be shared by all users [4] as depicted in Fig. 2.

Extending the benefits of MU-MIMO, Massive MIMO also known as Very Large MIMO, Full Dimensional MIMO (FD-MIMO) and Large-Scale Antenna Systems are introduced, where BS is equipped with orders of magnitude more antennas, e.g., 100 or more [5]. Massive MIMO has shown over 10 times spectral efficiency increase over a point-to-point MIMO under realistic propagation environment with simpler signal processing algorithms [3], [6]. Therefore, this paper intends to review Massive MIMO as one of the key technologies in fifth generation (5G) wireless communication standard, its main progress to date, and summarizes its opportunities and challenges. The paper is organized as follows. In Section 2, the Beamforming for Massive MIMO is provided. A discussion of recent works related to Massive MIMO summarizing its opportunities and challenges are presented in Section 3 and Section 4 respectively. Finally, Section 5 concludes this paper.

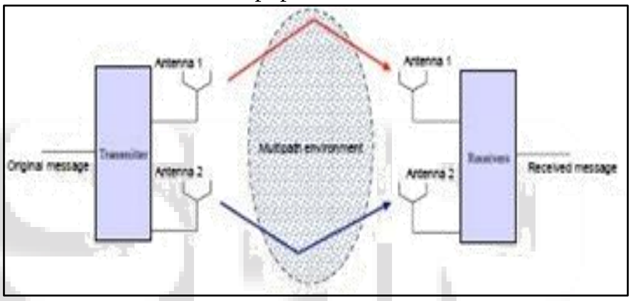

Fig. 1: Point-to-point MIMO links.

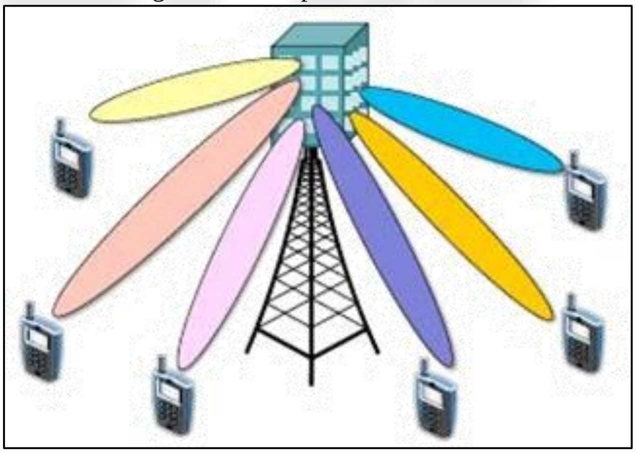

Fig. 2: Multiuser MIMO (MU-MIMO) antenna system.

II. MASSIVE MIMO FOR FIFTH GENERATION (5G)

The growth in wireless communication is categorized in Generations with the evolution from First Generation (1G) to Second Generation (2G) and from Third Generation (3G) to Fourth Generation (4G). The technology offered has also shift from telecommunication to multimedia communication parallel with the growth. Cellular communication systems have experienced rapid development ever since its inception, firstly with voice services, and recently, with the latest generation of mobile data services that allow high data transmission rates. The explosive growth of wireless systems coupled with the development of laptop and palmtop computers has evolved into an era of wireless networking. Modern wireless local area networks (WLANs) are implemented in a huge number of applications because WLANs introduce benefits such as improved flexibility, mobility and ease of installation. Mobile phones and WLANs are probably the most popular wireless system; however, the use of other wireless devices has also increased.

Current wireless communication technology is being pushed to its limit by the massive growth in traffic demands for mobile data services due to the continuously evolving requirements and expectations of both users and operators. Increasing data traffic has also driven the capacity demands for currently deployed 3G and 4G wireless technologies. The Long Term Evolution (LTE) in 3GPP is reaching maturity and (LTE) - Advanced embodying 4G has already been deployed with the data rates getting close to Gbps, where only incremental improvements and small amounts of new spectrum can be expected. According to Cisco [7], in 2014 alone, mobile data traffic grew to 69%, generating 2.5 Exabytes of data per month, compared to 1.5 Exabytes per month at the end of 2013. The rise in mobile data traffic in 2014 was reported to be 30 times more than all traffic across the global Internet in 2000. The GSMA Mobile Economy 2015 – Global [8] reported that, there are 3.6 billion unique mobile subscribers at the end of 2014. Further, addition of one billion subscribers is predicted by 2020, taking the global penetration rate to approximately 60%.

Concerning the state of the art on 4G network deployments, the number of smart phone users is increasing very rapidly worldwide and it is likely that 4G may come to saturation. Fifth Generation (5G) is considered as an incremental advance of 4G due to the emerging wide area wireless services and usage cases. As the next generation of wireless communication technology, 5G's vision and driving element must overcome the challenges meet by 4G in terms of high data rate coverage and a seamless user experience so that it continues to satisfy the ever increasing user expectations of Quality of Experience (QoE). The 5G wireless communication network should provide universal system architectures that support the technologies to meet the demands towards a multiplicity of future services which will be user-centric instead of operator-centric. Fig. 3 shows the landscape with some performance requirements envisioned for 5G [9].

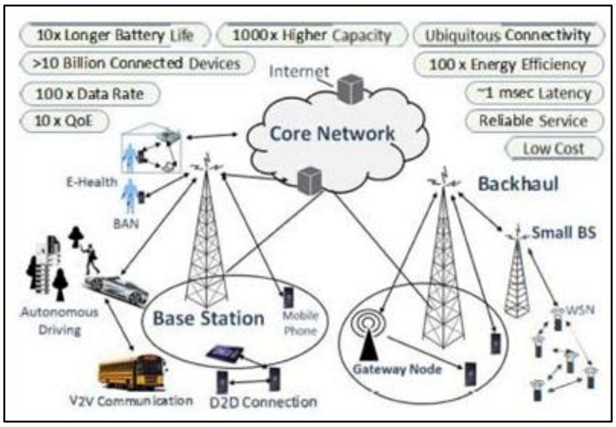

Fig. 3: 5G landscape and performance requirements.

The 5G system architectures have to be heterogeneous to meet with the above performance requirements to enhance the capacity and maintain user's connectivity. The use of massive multiple-input multiple-output (MIMO) communications – installation of multi antenna transmission/ reception - can provide increased channel capacity and improve the signal strength by mitigating multipath effect [10]. Therefore, massive MIMO technique is seen as one of the major driving element in 5G radio access technologies. It is a scalable technology with respect to number of services antenna that exploits the multipath channel characteristics to provide spatial processing that can improve the signal strength. This spatial processing can be used to increase data rates, improve signal reliability or reduce transmitted power with more efficient use of the radio spectrum.

III. BEAMFORMING FOR MASSIVE MIMO

Beamforming is a word that means different things to different people. Beamforming is the ability to adapt the radiation pattern of the antenna array to a particular scenario. In the cellular communications space, many people think of beamforming as steering a lobe of power in a particular direction toward a user, as shown in Figure 4. Relative amplitude and phase shifts are applied to each antenna element to allow for the output signals from the antenna array to coherently add together for a particular transmit/receive angle and destructively cancel each other out for other signals. The spatial environment that the array and user are in is not generally considered. This is indeed beamforming, but is just one specific implementation of it.

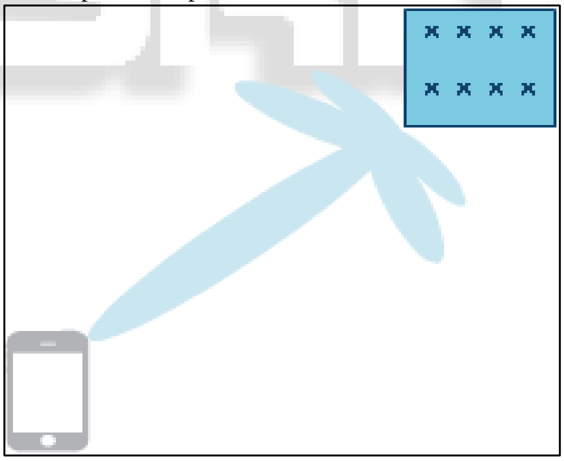

Fig. 4: Traditional beamforming.

Massive MIMO can be considered as a form of beamforming in the more general sense of the term, but is quite removed from the traditional form. Massive simply refers to the large number of antennas in the base station antenna array. MIMO refers to the fact that multiple spatially separated users are catered for by the antenna array in the same time and frequency resource. Massive MIMO also acknowledges that in real-world systems, data transmitted between an antenna and a user terminal—and vice versa—undergoes filtering from the surrounding environment. The signal may be reflected off buildings and other obstacles, and these reflections will have an associated delay, attenuation, and direction of arrival, as shown in Figure 5. There may not even be a direct line of sight between the antenna and the user terminal. It turns out that these nondirect transmission paths can be harnessed as a power for good.

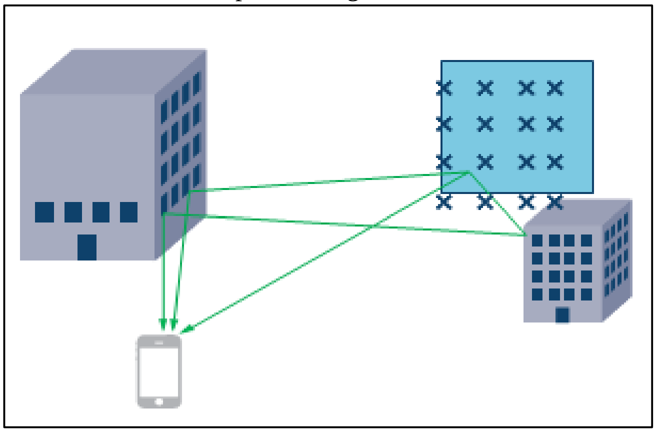

Fig. 5: Multipath environment between antenna array and user.

In order to take advantage of the multiple paths, the spatial channel between antenna elements and user terminals needs to be characterized. In literature, this response is generally referred to as channel state information (CSI). This CSI is effectively a collection of the spatial transfer functions between each antenna and each user terminal.

IV. THE SIGNAL PROCESSING THAT ENABLES MASSIVE MIMO

In the previous section we've represented however the CSI (denoted by the matrixH) is calculable. Detection and precoding matrices are calculated supported H. There are variety of strategies for calculating these matrices. This text focuses on linear schemes. Examples of linear precoding/detection strategies are maximum ratio (MR), zero forcing (ZF), and minimum mean- sq. error (MMSE). Full derivations of the precoding/detection filters from the CSI don't seem to be provided during this article, however the standards they optimize for, in addition because the benefits and drawbacks of every technique are measure mentioned. The signal process works within the transmission and downlink severally for the 3 linear strategies antecedently mentioned. For precoding there can also be some scaling matrix to normalize the facility across the array that has been omitted for simplicity.

Detection Type	
Maximum Ratio (MR)	$\tilde{s} = H^H y$
Zero Forcing (ZF)	$\tilde{s} = (H^H H)^{-1} H^H y$
NMSE or RZF	$\tilde{s} = (H^H H + \beta I)^{-1} H^H y$

Fig. 6: Uplink signal processing. H denotes the conjugate transpose.

Precoding Type	
Maximum Ratio (MR)	$x = H^* s$
Zero Forcing (ZF)	$x = H^*(H^T H^*)^{-1} s$
NMSE or RZF	$x = H^*(H^T H^* + \beta I)^{-1} s$

Fig. 7: Downlink signal processing. T denotes the transpose. * denotes the conjugate.

Maximum ratio filtering, as the name suggests, aims to maximize the signal-to-noise ratio (SNR). It is the simplest approach from a signal processing viewpoint, as the detection/precoding matrix is just the conjugate transpose or conjugate of the CSI matrix, H. The big downside of this method is that inter user interference is ignored. Zero forcing precoding attempts to address the inter user interference problem by designing the optimization criteria to minimize for it. The detection/precoding matrix is the pseudoinverse of the CSI matrix. Calculating the pseudoinverse is more computationally expensive than the complex conjugate as in the MR case. However, by focusing so intently on minimizing the interference, the received power at the user suffers. MMSE tries to strike a balance between getting the most signal amplification and reducing the interference. This holistic view comes with signal processing complexity as a price tag. The MMSE approach introduces a regularization term to the optimization—denoted as β in Figures 6 and 7—that allows for a balance to be found between the noise covariance and the transmit power. It is sometimes also referred to in literature as regularized zero forcing (RZF).

V. RELATED WORK

In the interrelated work of massive MIMO largely think about the spatial relation antennas for the base station. it's eminent to understand that base station directional antennas are used together with sectorization antennas [12] to extend SINR of the cellular network. In massive MIMO multiples antennas ar used, it poses the foremost challenges in it [13], variety of antennas are to extend the energy consumption and price furthermore. In mm wave (mm-Wave) bands have high path loss at their in operation frequencies that are essential for the high gain and enough to signal-to-noise ratio (SNR) at a really low distance [14]. Within the low vary wavelengths, of the mm-wave frequencies wherever the big antennas array is packed with little kind issue [8], the upper gain array are often a conflict to extend the path loss and crucial to supply the appropriate link budget [15]. Therefore, massive MIMO may be a most popular technology to beat these issues in line with their desirable achievements.

VI. CONCLUSION AND FUTURE SCOPE

The massive MIMO technique introduces a lot of efficiency within the present situation of wireless communication systems. The one antenna was converted into arrays of antennas for advanced beamforming techniques. The key benefits are that it will be up the SNR of the general system beside information transmission inside the cell throughout the time of interval. Within the huge MIMO, it's necessary for linear detection to perform the zero-forcing to permit the reliable detection to accumulate high-quality performance through enabling an increase within the dimension of arrays that mitigate the process problem and regarded as a tolerable area. Massive MIMO sustainably exaggerated the spectral efficiency and enhance capability and coverage. A base station uses a large number of antennas during a massive MIMO system, so it achieves high output and a lot of capability. the tiny cell system uses the low power mini bs to avoid interference simply and enhance efficiency .The idea of increasing EE by utilizing the spatial resource whereas suppressing the interference is worth investigation .Quality reduction plays a significant role in any system development.

Hence effective however easy algorithms are needed to get a decent pact between quality and performance.

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