A Survey On Massive MIMO Antennas For 5G Applications

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Abstract—The 5G wireless communications lies in providing high data, extremely low latency, manifold increase in base station capacity, and significant improvement in users' perceived quality of service (QoS) as compared to current 4G LTE networks. Massive MIMO is expected to be one of the pillars of 5G. In this paper, we present a comprehensive overview of evolution of 5G, needs of 5G, and several application areas where massive MIMO antenna arise could lead to significant performance enhancement.

Keywords—*5G, massive MIMO, mm-wave backhaul, pilot contamination, ultra-dense network (UDN), software design network (SDN)*

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I. INTRODUCTION

Rapid changes in technology development around the world provide high demands in telecommunication systems. Modern lifestyle increases number of consumer to access information frequently at any place and any time with a higher speed rate. Over the last couple of decades, the world has witnessed gradual, yet steady evolution of mobile wireless communications towards second, third, and fourth generation wireless networks. Rapid penetration of wireless connectivity, almost exponential increase in wireless data (multimedia) usage and proliferation of feature-rich smart devices are gradually setting the stage for next major cellular evolution towards 5G [1].Massive MIMO is expected to be one of the pillars of 5G and beyond cellular systems. With millimeter wave communications, a large number of antenna elements can be used to form large arrays of reasonable sizes.

Massive MIMO is an exciting concept in wireless communications research that promises to address the massive capacity requirement demanded by 5G systems. These antennas can indeed have a primordial role in several aspects of 5G communications. They can reduce transmitted power, the complexity of the hardware and energy consumption of the signal processing with more efficient use of the radio spectrum. Overall, massive MIMO is an enabler for the development of future broadband networks which will be energy-efficient, secure, and robust, and will use the spectrum efficiently [2]. 5G wireless systems, with improved data rates, capacity, latency, and QoS will change the current cellular networks problems. A set of new, user-oriented mobile multimedia applications, like mobile video conferencing, streaming video, e-healthcare and online gaming are coming up with this technique.

II. LITERATURE REVIEW

A. Evolution of 5G

To date, four generations of cellular systems have been adopted with each new mobile generations emerging every 10 years. From early 1980's known as first generation 1G mobile wireless communication system. This generation was based on analog technology known as Advance Mobile Phone Service (AMPS). 1G has channel capacity of 30 KHz and frequency band was 824- 894 MHz. This generation uses circuit switching and totally designed for voice calls without data services. After 1G, in 1990's the 2G second generation mobile communication system was the first digital cellular system launched. This generation uses two digital modulation schemes: TDMA (time division multiple access) and CDMA (code division multiple access). Three types of advancements in wireless communication system are 2G, 2.5G and 2.75G. These are family members of second generation. 2G has speed of 64 kbps with a bandwidth of 30 to 200 KHz. Next to 2G, 2.5G system uses packet switched and circuit switched domain and provide data rate up to 144 kbps [3],[4].

The third generation 3G technology introduced in the year 2000 is seen more than pre 4G. Packet Switching is the technique for data sending in 3G networks. For video chatting and for high speed internet service, this network allows 15-20MHz bandwidth at a range of 2100MHz.The evolution of GSM is also a part of this generation. 3G, 3.5G and 3.75G are also family member of this generation. High speed internet service, video chatting are main advantages of 3G. A very new service in this generation is GLOBAL ROAMING is launched.

In early 2011, fourth generation 4G technology is presented. 4G offers a downloading speed of 100Mbps to 1Gbps.This generation focuses on additional gaming services, HD mobile TV, video conferencing and 3D Television. This generation includes wireless broad band access, Multimedia Messaging Service (MMS) and Digital Video Broadcasting (DVB). The technologies under the 4G umbrella are; LTE (Long term evolution) and Wi-MAX (Worldwide Interoperability for Microwave Access). 4G provides global mobility to support different services and devices [5].

5G is the fifth Generation Mobile Technology; it would be on ground by year 2020. 5G technology has a very high bandwidth nobody experiences this high speed ever before. The 5G technologies include all type of advanced features which makes 5G technology most powerful and in huge demand in near future, as it provides high speed streaming. 5G technology includes, MP3 recording, video player, large phone memory, dialing speed, audio player and much more user never imagine. With the launch of 5G a new revolution is about to begin. Pico net and Bluetooth technology has made data sharing very easy and accessible by everyone who connected with 5G [6].

III. REQUIREMENTS OF 5G

A. mm-Wave System

The mm-Wave bands provide 10 times more bandwidth than the 4G cellular bands. The mm-Wave band can therefore support the higher data rates required in future mobile broadband access networks. As shown in Figure 1, unlike the below 6GHz bands, in the mm-Wave bands we have to carefully consider the wireless conditions such as rainfalls, snowfalls and fogs. The combination of cost-effective CMOS technology that can now operate well into the mm-Wave frequency bands, and high gain, steerable antennas at the mobile and base stations, strengthens the viability of mm-Wave wireless communications. Due to the much smaller wavelength of mm-wave, it may exploit the polarization and new spatial processing techniques, such as massive MIMO and adaptive beam forming [6].

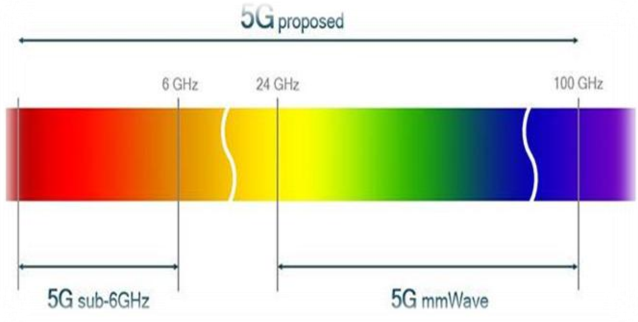

Fig. 1: mm-Wave band spectrum

B. Need for 5G

- It provides a very high speed, high capacity, and low cost per bit.
- It supports interactive multimedia, voice, video, Internet and other broadband services, greater effective and more attractive, and has Bi-directional, accurate traffic statistics.
- It is supporting large broadcasting capacity up to Gigabit which supporting almost 65,000 connections at a time.
- 5G technology offers remote management that user can get better and fast solution [7].
- 5G technology offers Global access and service portability.
- It provides the high quality services due to high error tolerance.
- 5G technologies provide high resolution for crazy cell phone user and bi-directional large bandwidth shaping.
- The uploading and downloading speed of 5G technology is very high.
- 5G technologies provide transporter class gateway with unparalleled consistency.

IV. ANTENNA CONFIGURATION FOR 5G MASSIVE MIMO

Multiple Input Multiple Output technology has been widely studied during the last two decades and applied to many wireless standards since it can significantly improve the capacity and reliability of wireless systems. Massive MIMO refers to the idea equipping cellular base stations with a very large number of antennas and gas been shown to potentially allow for orders of magnitude improvement in spectral and energy efficiency using relatively simple processing.

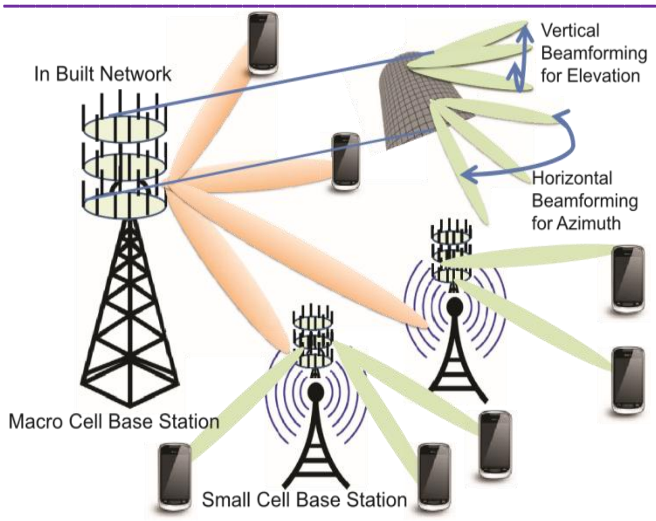

Fig. 2: Massive MIMO and beam forming

Due to large number, proximity and operations strict requirements are imposed on the design of antennas in massive MIMO systems. The array configuration in which antennas are placed, the individual patterns and mutual coupling all play roles in the performance of system. Thus, antenna configurations for use in massive MIMO schemes for 5G should be investigated and analyzed. For example, rectangular, circular, and cylindrical array configuration could be studied in terms of their element numbers, resulting pattern beam width, gain, mutual coupling, and their effects on coverage, the received signal strength and channel capacity. Several antenna element types could also be used such as dipole, horn antenna, and printed antennas [8], [9].

As shown in Figure 2, in UDN, the macro-cell base stations with large coverage control the user scheduling, resource allocation, and support high mobility users, while many ultra dense small cell base stations with much smaller coverage provide the high data rate for low mobility users. Due to ultra dense small cell base station, better frequency reuse can be achieved, and energy efficiency can also be improved due to the reduced path loss in small cells.

To enable UDN, a reliable, cost effective and Gigahertz bandwidth backhaul connecting macrocell base station and the associated small cell base station is prerequisite. Conventional optical fiber enjoys large bandwidth and reliability, but its application to UDN as backhaul may not be economical choice due to the restriction of deployment and installation. Hence mm-Wave backhaul is more attractive to overcome the geographical constraints [10].

V. Mm wave backhaul for 5G networks

Millimetre-wave (mm-wave) techniques ranging from 30 to 300GHz have become feasible and promising means to overcome the above-mentioned issues. Currently, the three most potential mm-wave bands include 28 GHz, 60GHz and the E-band, which are mostly unlicensed. With a huge available bandwidth, the gigabit data rate is practically achievable, which solves the capacity problem that exists in lower frequency backhaul systems. In mm-wave networks, directional links are commonly established to compensate for the high path loss. The use of highly steerable antennas greatly reduces interference, and high penetration losses due to walls and other obstacles also mitigate several interfering signals. Recently, the feasibility of mm-wave transmission within a range of a few hundred meters is proven by systematic outdoor measurements, which offer sufficient coverage for small cell backhaul [11],[12].

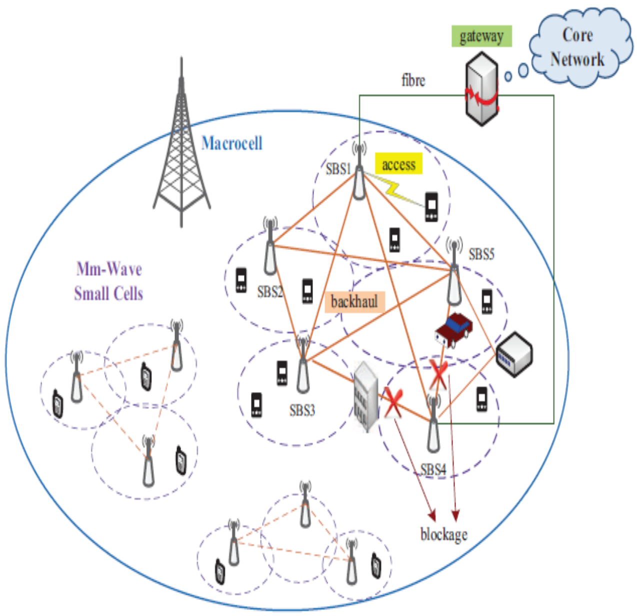

Fig. 3: System overview for 5G mm-wave backhauling

Traditional mm-wave techniques are mostly focused on direct single user link, but supporting multi streams for multi-user scenarios is likely to be a trend for future 5G backhaul with growing traffic demands. Directional communication paves the way for spatial reuse, which should be fully exploited to improve overall backhaul performance as shown in Figure 3. Moreover, high distance loss and blockage severely affect mm-wave network capacity, which requires suitable routing schemes to establish relaying links dynamically.

It is widely acknowledged that one of the biggest challenges of mm-wave communication is high path loss.

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The link attenuations at the 28GHz and 60GHz bands are approximately 21 dB and 28 dB larger than experienced in the conventional 2.4-GHz system with the same transmission distance, respectively. In order to compensate for such large loss, beamforming techniques are necessary in mm-wave backhauling [13].The ultimate goal of backhaul transmission is improving throughput. Highly directional transmissions in mm-wave communication lead to much less severe interference compared to conventional wireless cellular networks, which paves the way for spatial reuse to effectively save frequency and time resources, as well as to enhance throughput gain. Spatial reuse is particularly suitable for the dense small-cell scenarios, because the densely distributed devices bring much greater opportunity for concurrent transmissions [14].

VI. Pilot Contamination In Massive MIMO

Pilot contamination is the major factor to limit the performance of massive MIMO systems due to degraded channel estimation. A common technique for channel estimation is to transmit a known sequence of symbols (pilots) and evaluate the effect of the channel on these symbols at the receiver. In LTE, these symbols are known as reference symbols.The average received power of a pilot signal at the BS depends on the pathloss and transmits power of the mobile terminal. Furthermore, a terminal located closer to the BS usually has a lower pathloss, and hence a higher signal power at the BS. The terminals at cell edge usually have a higher pathloss and therefore a lowsignal power even while transmitting at their maximum power. This makes them susceptible to interference from non-orthogonal pilot transmissions in neighboring cells. On the other hand, terminals close to the BS enjoy a reduced pathloss, resulting in a better SINR [15],[16].

The uplink pilot sequence that is ideally assigned to any terminal in massiveMIMO systems is orthogonal. Therefore, number of pilots required ina system is upper bounded and are defined as the division of channel coherencetime by channel delay spread. In a general scenario the number ofmaximum orthogonal pilots for 1 millisecond coherence time is estimated to be 200. In a multi cellular system these pilots are used very quickly thatdemands the need of reuse of pilots. Pilot contamination is the term associated with the negative effects of reusing pilots in more than one cells.Correlation of pilot sequence assigned to a particular terminal with thereceived pilot signal gives the estimation of channel that is contaminated bychannels that use the same pilot sequence. Therefore considering downlink beamforming interference occurs in those terminals that have the same pilotsequence similar is the case for uplink transmissions. This interferenceincreases directly with the increase in service antennas.

Pilot contaminationis not only restricted to massive MIMO it is a general phenomenonbut it is appears at a high rate in massive MIMOs than ordinary MIMOs.There are several ways thatcan be used in order to avoid this contamination as the channel estimationis dependent upon it in many cases [17].

- One way is to use less number of reuse factor for pilots which sets thecells with same pilot sequence far apart. Or the allocation of pilotscanbe done adaptively but so far optimal scheme is not known.
- Blind techniques and channel estimation algorithms are also used to eliminate the effect of interference.
- Using precoding techniques that involve the network topology like pilotcontamination techniques. This utilizes the cooperative communicationover multiple cells that are outside the beamforming region in order to at least remove the effect of partially overlapping interferencecaused by pilot contamination [18].

VII. CONCLUSION

Rapid penetration of wireless connectivity, almost exponential increase in wireless data usage is gradually setting the stage for next major cellular evolution towards 5G. It also comprehensively described massive MIMO systems and its benefits and its applications for 5G ultra dense network. We have explored the mm-Wave mobile communications for future 5G network. Additionally, we have highlighted MIMO based wireless backhaul, which may become active research topics in the near future.

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