Massive MIMO: Fundamentals and Challenges for 5G

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Abstract: In this paper we have discussed about 5G and its advantages, a probable architecture for 5G and some challenges in 5G. The main technology that maybe used in 5G are massive MIMO, millimeter wave communication, device to device communication, beam division multiple access etc. In this paper we have discussed about massive MIMO, channel estimate in massive MIMO, beam division multiple access technique to be used in massive MIMO, antenna selection in massive MIMO, capacity and energy efficiency in massive MIMO.

***Index Terms*: MIMO- Multiple-Input Multiple-Output, TDD-Time Division Duplexing.**

I. INTRODUCTION

4G is proving good speeds up to 1Gbps. Then why do we need anything more [1]. The problem is that it is not able to provide real time applications. 5G is the name given to the next generation of mobile data connectivity. It will definitely provide great speeds between 10Gbps to 100Gbps and it will have enough capacity. But the thing that separated 5G from 4G is latency; the latency provided by 4G is between 40ms to 60ms, whereas in 5G it will provide ultra-latency between 1ms to 10ms. The standards for 5G will be set till 2020 and it will be applicable by 2022/23. In this paper we have discussed about 5G and its advantages, a probable architecture for 5G and some challenges in 5G [7]. The main technology that maybe used in 5G are massive MIMO, millimeter wave communication, device to device communication, beam division multiple access etc. In this paper we have discussed about massive MIMO, channel estimate in massive MIMO, beam division multiple access technique to be used in massive MIMO, antenna selection in massive MIMO, capacity and energy efficiency in massive MIMO. In future 5G is going to be a technology which will be invisible [3], I will be just there everywhere just like electricity. It is a very good area for research as standards and frequency band for 5G are yet to be standardized [2].

II. ORIGIN OF RESEARCH PROBLEM

Mobile networking is a wireless technology than can provide voice and/or data networking, through a radio transmission. Mobile phone is one of the most famous applications of mobile networking. In past circuit switching was used to transmit voice over a network, then we moved on to use both circuit-switching and packet-switching for voice and data, now presently we are using packet switching only, this is how spectrum has expanded from 1G to 4G. Today and in upcoming future wireless networks need to be improved for meeting the demand for increased data rate, improved capacity, reduced latency and good quality of service. We are in the 4th generation of wireless communication, so now research is going on for developing new standards for the next generation beyond 4G i.e. 5G. With increasing demands of subscribers definitely 4G will be replaced by 5G with the help of some advanced technologies like massive MIMO, device-to-device communication, millimeter wave communication, Beam division multiple access in massive MIMO etc. [3]. The technologies used in 4G like High-Speed Packet Access (HSPA) and Long Term Evolution (LTE) will be used as a part of future advancement. For this advancement we may use different methods, It may happen that we may use different spectrum access technique, increased frequency range, deploying large number of antennas etc. This whole thing started in 1970s, till now the mobile wireless communication has come a long way from analog communication to today's modern digital mobile communication providing the subscribers with improved data rate of megabits per second over wide area and few hundreds of megabits per second in a local area. We are going on well toward next stepping stone in future i.e. 5G.It is predicted that 5G will be in operation by 2020, hence immense research in going on in this field. The world is imagining a future where there is no restriction to the access and sharing of information from anywhere by anyone [1].

III. HOW MASSIVE MIMO WORKS

In Massive MIMO, TDD operation is preferable. During a coherence interval, there are three operations: channel estimation (including the uplink training and the downlink training), uplink data transmission, and downlink data transmission. A TDD Massive MIMO protocol is shown in Figure 3.1.

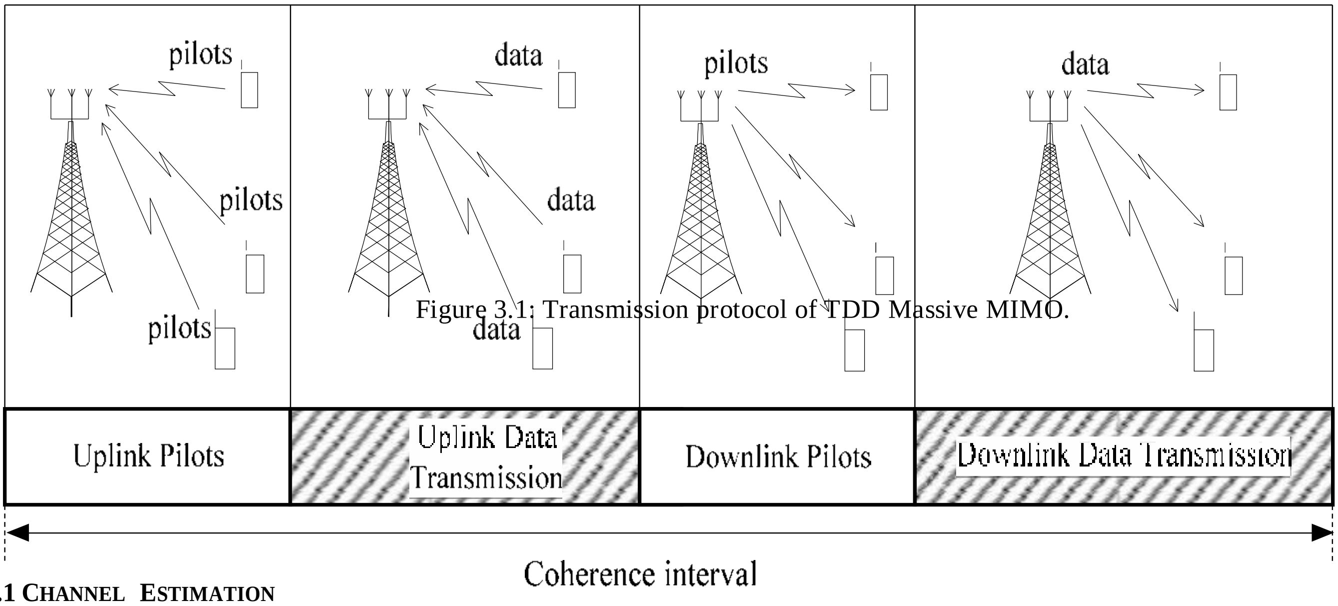

Figure 3.1: Transmission protocol of TDD Massive MIMO.

3.1 Channel Estimation

The BS needs CSI to detect the signals transmitted from the users in the uplink, and to precode the signals in the downlink. This CSI is obtained through the uplink training. Each user is assigned an orthogonal pilot sequence, and sends this pilot sequence to the BS. The BS knows the pilots sequences transmitted from all users, and then estimates the channels based the received pilot signals [4].

Furthermore, each user may need partial knowledge of CSI to coherently detect the signals transmitted from the BS. This information can be acquired through downlink training or some blind channel estimation algorithm [5]. Since the BS uses linear preceding techniques to beam form the signals to the users, the user needs only the e active channel gain (which is a scalar constant) to detect its desired signals. Therefore, the BS can spend a short time to beam form pilots in the downlink for CSI acquisition at the users.

3.2 Uplink Data Transmission

A part of the coherence interval is used for the uplink data transmission. In the uplink, all K users transmit their data to the BS in the same time-frequency re- source. The BS then uses the channel estimates together with the linear combining techniques to detect signals transmitted from all users[6][1].

3.3 Downlink Data Transmission

In the downlink, the BS transmits signals to all K users in the same time-frequency resource. More specifically, the BS uses its channel estimates in combination with the symbols intended for the K users to create M precoded signals which are then fed to M antennas.

3.4 Why Massive MIMO

The demand for wireless throughput and communication reliability as well as the user density will always increase. Future wireless communication requires new technologies in which many users can be simultaneously served with very high through- put. Massive MIMO can meet these demands. Consider the uplink transmission. (The same argument can be used for the downlink transmission.) From (2.3), under the conditions of favorable propagation (the channel vectors between the users and the BS are pair wisely orthogonal), the sum-capacity of the uplink transmission is

$$C_{\text{sum}} = \log_2 \det (I_K + p_u M I_K) = K \log_2 (1 + M p_u). \tag{3.1}$$

In (3.1), K is the multiplexing gain, and M represents the array gain. We can see that, we can obtain a huge spectral e ciency and energy e ciency when M *and* K *are* large. Without any increase in transmitted power per terminal, by increasing K and M, we can simultaneously serve more users in the same frequency band. At the same time the throughput per user also increases. Furthermore, by doubling the number of BS antennas, we can reduce the transmit power by 3 dB, while maintaining the original quality-of-service [1].

The above gains (multiplexing gain and array gain) are obtained under the conditions of favorable propagation and the use of optimal processing at the BS. One main question is: Will these gains still be obtained by using linear processing? Another question is: Why not use the conventional low dimensional point-to-point MIMO with complicated processing schemes instead of Massive MIMO with simple linear processing schemes? In Massive MIMO, when the number of BS antennas is large, due to the law of large numbers, the channels become favorable. As a result, linear processing is nearly optimal. The multiplexing gain and array gain can be obtained with simple linear processing. Also, by increasing the number of BS antennas and the number of users, we can always increase the throughput [5].

3.5 Challenges in Massive MIMO

Despite the huge advantages of Massive MIMO, many issues still need to be tackled. The main challenges of Massive MIMO are listed as follows:

3.5.1 PILOT CONTAMINATION

In previous sections, we considered single-cell setups. However, practical cellular networks consist of many cells. Owing to the limited availability of frequency spectrum, many cells have to share the same time-frequency resources. Thus, multi cell setups should be considered. In multi cell systems, we cannot assign orthogonal pilot sequences for all users in all cells, due to the limitation of the channel coherence interval. Orthogonal pilot sequences have to be reused from cell to cell. Therefore, the channel estimate obtained in a given cell will be contaminated by pilots trans- mitted by users in other cells. This effect, called pilot contamination, reduces the system performance [32]. The effect of pilot contamination is major inherent limitation of Massive MIMO [1]. It does not vanish even when the number of BS antennas grows without bound. Considerable e orts have been made to reduce this effect. The Eigen value-decomposition-based channel estimation, pilot decontamination, as well as pilot contamination precoding schemes are proposed in [33 35]. In [36], the authors shown that, under certain conditions of the channel covariance, by using a covariance aware pilot assignment scheme among the cells, pilot contamination can be efficiently mitigated. There is much ongoing research on this topic [1].

3.5.2 UNFAVORABLE PROPAGATION

Massive MIMO works under favorable propagation environments. However, in practice, there may be propagation environments where the channels are not favorable. For example, in propagation environments where the numbers of the scatterers is small compared to the numbers of users, or the channels from different users to the BS share some common scatterers, the channel is not favorable [31]. One possibility to tackle this problem is to distribute the BS antennas over a large area [1].

3.5.3 NEW STANDARDS AND DESIGNS ARE REQUIRED

It will be very efficient if Massive MIMO can be deployed in current systems such as LTE. However, the LTE standard only allows for up to 8 antenna ports at the BS [4]. Furthermore, LTE uses the channel information that is assumed. For example, one option of the downlink in LTE is that the BS transmits the reference signals through several fixed beams. Then the users report back to the BS the strongest beam. The BS will use this beam for the downlink transmission. By contrast, Massive MIMO uses the channel information that is estimated (measured). Therefore, to reduce Massive MIMO to practice, new standards are required. On a different note, with Massive MIMO, a costly 40 Watt transceiver should be replaced by a large number of low-power and inexpensive antennas. Related hardware designs should also be considered. This requires a huge e ort from both academia and industry [1].

IV. RESULTS AND CONCLUSION

In view of this article, we have comprehensively described massive MIMO systems from several different perspectives. By equipping a BS with a large number of antennas, spectral and energy efficiency can be dramatically improved. However, to make the benefits of massive MIMO a reality, significant additional re-search is needed on a number of issues, including channel correlation, hardware implementations and impairments, interference management and modulation [7].

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