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MASSIVE MIMO: A WELL KNOWN DIVERSITY TECHNIQUE AND KEY TO SIMPLIFIED 5G NETWORK.

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Abstract

Wireless communication network of the fifth generation (5G) is promising technology to meet the demand for higher throughput and huge user bit rate (data rate) growth .To increase the data rate system needs more spectrum, but available spectrum is limited. Therefore, increasing of spectrum is not possible. However, we need to improve the spectral efficiency and throughput. With this, new transmission techniques are required, with the most promising being millimeter waves (mm-W) and massive multi-input multi- output (m-MIMO). Related to wireless data traffic, the key parameter to consider is wireless throughput (bits/s) which is defined as:

Throughput = Bandwidth (Hz) × Spectral efficiency (bits/s/Hz).

Clearly, a high network throughput can be obtained by allocating more available bandwidth or improving spectral efficiency. To improve the throughput, some new technologies which can increase the bandwidth or the spectral efficiency or both should be exploited. In this paper, we focus on techniques which improves the spectral efficiency and this paper also aims to examine Massive MIMO as one of the key technology in the fifth generation (5 G) wireless communication standard. A well-known way to increase the spectral efficiency is using multiple antennas at the transceiver (Massive MIMO).

Key words: Massive MIMO, Spectral efficiency, Throughput, Band width.

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1. 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 (SISO) system and 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 receiver that can substantially improve the network throughput, capacity, and coverage without requiring additional bandwidth or transmit power level [1]. Due to multi-path propagation and shadowing due to large obstacles between the transmitter and the receiver, the transmitted signals are being attenuated in wireless communication, resulting in a fundamental challenge for effective communication. Multiple-input multi-output (MIMO) transmission is a well-known convergence strategy to boost communications efficiency. Furthermore, with multiple antennas, multiple streams can be sent out and hence, we can obtain a multiplexing gain which significantly improves the communication capacity, also deploying large number of antennas enables improvement in user quality of service (QOS) and cell coverage over conventional MIMO systems [2]. Massive MIMO can be categorized into distributed and centralized MIMO based on antennas position. In centralized MIMO all antennas are located at same position while as in distributed MIMO various antennas are located at different position but can be controlled by same control unit. To get better energy and spectral efficiency, researchers are focusing on centralized MIMO system. MIMO systems have gained significant attention for the past decades, and are now being incorporated into several new generation wireless standards (e.g., LTE-Advanced, 802.16m). Massive MIMO has demonstrated a 10 times increase in spectral efficiency over a point-to-point MIMO under practical propagation conditions with simpler algorithms for signal processing [3][4]. In this paper, we focus on techniques which improve the spectral efficiency and this paper also intends to review Massive MIMO as one of the key technology in fifth generation (5G) wireless communication standard.

2 Massive MIMO

Massive MIMO is a promising applicant platform for wireless systems of next generation. Massive MIMO which is an extension of MIMO, extends beyond the existing systems by adding even more antennas to the base station. Massive MIMO consists of more number of antennas compared to MIMO system and can be operated in time division duplex (TDD) and frequency division duplex (FDD) mode [5]. TDD mode requires less number of overheads compared to FDD. TDD mode uses channel reciprocity which eliminates downlink pilots. TDD suffers from problem of pilot contamination which affects channel estimation [6]. At node level, massive MIMO is scalable technology which in contrast with 4G technology. The “massive” number of antennas helps focus energy, which brings drastic improvements in throughput and efficiency [7][8]. In addition to the growing number of antennas, both the network and mobile devices adopt more complex designs for managing MIMO operations. That is all to say, these advancements are all aimed at achieving performance improvements needed to underpin the 5G experiences consumers expect in this new era .5G with 3.5 GHz, Massive MIMO offers improved coverage and greater efficiency than LTE, Massive MIMO technique is considered one of the most important driving elements of 5 G radio access technologies. This is a scalable technology with respect to the number of services antenna, which exploits the characteristics of multipath channels to provide spatial processing that can increase the signal strength .This spatial processing can be used to increase data rates, improve signal reliability and reduce transmitted power with more efficient use of the radio spectrum .The field test in Beijing organized by the IMT-2020 (5 G) Promotion

Group has just witnessed a new record of 5 G cell capacity: With 3.5 GHz 64T64R Massive MIMO. At 100 MHz bandwidth, 5 G cell speed hits 14.58 Gbps, which is 97 times that of 150Mbps potential LTE.

3 KEY CONCEPT OF MASSIVE MIMO TECHNOLOGY

MIMO techniques are widely employed in wireless communication systems because they provide us with significant performance improvement including diversity gain, array gain, and multiplexing gain. Each different gain is related to different types of system performance [9]. Massive MIMO is based on three key concepts, which are spatial diversity or diversity gain, spatial multiplexing or multiplexing gain, and beamforming or array gain

a) Spatial diversity or Diversity gain: Spatial diversity is one of the fundamental benefits of MIMO technology. It improves the reliability of the system by sending the same data across different propagation or by mitigating multipath fading.

b) Spatial Multiplexing or Multiplexing gain: In essence, massive MIMO base stations exploit a very high degree of spatial multiplexing to improve the system capacity. Spatial multiplexing increases spectral and energy efficiency by transmitting independent signals via different antennas that is multiple messages can be transmitted simultaneously without interfering with one another since they are separated in space. As the base stations are deployed with a large number of antenna arrays, simple linear beamforming/precoding is possible to increase the spectral and energy efficiency[10]. Energy efficiency is defined as the ratio of the spectral efficiency and the transmit power. With perfect CSI, the energy efficiency decreases as the spectral efficiency increases. However, a different result is obtained if imperfect CSI is available [7]. In the low transmit power region, energy efficiency increases with the spectral efficiency, while with high transmit power, energy efficiency decreases as the spectral efficiency increases[13]. To better visualize the concept of spatial multiplexing, think of a pipeline through which data is flowing between the base station and the phone on a mobile network. Consider a situation with one antenna on the base station and one on the phone that allows for only so much data to flow. Now, by installing more antennas on either side with proper spatial separation , multiple virtual pipelines can be created in the space between phone and the base station. This creates multiple paths for more data to travel between the base station and mobile[11]. So we can obtain a huge spectral efficiency and very high communication reliability.

c) Beamforming or Array Gain : Beamforming is another key wireless technique that utilizes advanced antenna technologies on both mobile devices and networks' base stations to focus a wireless signal in a specific direction, rather than broadcasting to a wide area[12]. Beamforming improves transmission coverage and QOS. The beam forming technique was first investigated in radar technology in the 1960s .However ,this technique was given more attention in the1990s when cellular systems gave rise to a new wireless communication[1]. Beamforming has become a key technique in recent years and provides us with significant advantages for 5G systems. The application of beamforming in massive MIMO systems has the following advantages: enhanced energy efficiency, improved spectral efficiency, increased system security, and applicability for mm-wave bands.

4 Benefits of massive MIMO

Massive MIMO is a key enabler of 5G's extremely fast data rates and promises to raise 5G's potential to a new level. The primary benefits of massive MIMO to the network and end users can be summed up as:

- Increased Network Capacity: Network Capacity is defined as the total data volume that can be served to a user and the maximum number of users that can be served with certain level of expected service. Massive MIMO contributes to increased capacity by enabling 5G NR deployment in the higher frequency range in Sub-6 GHz (e.g., 3.5 GHz); and second by employing MU-MIMO where multiple users are served with the same time and frequency resources[14]
- Improved Coverage: With massive MIMO, users enjoy a more uniform experience across the network, even at the cell edges, so users can expect high data rate service almost everywhere. Moreover, 3D beamforming enables dynamic coverage required for moving users (e.g., users traveling in cars or connected cars) and adjusts the coverage to suit user location, even in locations that have relatively weak network coverage.
- User experience: – Ultimately, the above two benefits results in a better overall user experience users can transfer large data files or download movies, or use data hungry apps on the go, wherever life takes them.

5 CHALLENGES OF MASSIVE MIMO

Despite Massive MIMO's huge advantages many issues still need to be addressed. Massive MIMO 's principal challenges are listed as:

1. Antenna mutual coupling and spatial correlation:

Theoretically, massive MIMO systems are considered to achieve high system capacity, spectral and energy efficiency with the increase in number of BS antennas. This assumption might be misleading when antenna coupling along with circuit power consumptions is considered. A usual practice when deploying antenna elements in the antenna arrays is to space them by a distance equal to wavelength of the transmitted frequency or more[15]. The mutual coupling effect can only be ignored if the antennas are well separated from each other. One of the challenges towards this end is the constraint physical area for deployment of large number of antennas at the base station. The proximity of the antenna elements as signal sources and electrical components causes spatial correlation and antenna mutual coupling respectively [16].

2. Pilot Contamination:

In a massive MIMO system, each terminal specifies an independent pilot sequence to be uplinked. However, the number of these independent pilot sequences is limited; therefore, they must be reused. The effect of reusing the same pilots between different cells will produce a conflict in the antenna array of a BS once they have correlated the desired received Pilot signal connected to a specific terminal with the pilot series. These associated sequences are referred to as pilot contamination[17]. The array antenna at the BS obtains a channel estimate that is corrupted by a combination of signals from other terminals using the same pilot sequence. These contaminated pilots affect downlink beamforming and result in interference directed toward those terminals, which are using similar pilot sequences. This undesired interference increases with an increasing number of antennas used.

Practical cellular networks consist of many cells. Due to the limited availability of frequency spectrum, many cells have to share the same time-frequency resources. Thus, multicell setups should be considered. In multicell 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 transmitted by users in other cells. This effect is called pilot contamination[18],which reduces the system performance . The effect of pilot contamination is major inherent limitation of Massive MIMO.

The question of pilot contamination was identified many years ago; however, its impact on massive MIMO systems appears to be considerably greater due to the enormous number of antennas in its construction compared with previous systems19][20].

Considerable efforts have been made to reduce this effect. One scheme is based on the development of the pilot itself, such as by reducing pilot overhead, or using different frequency reuse factors in multicell systems instead of using a frequency reuse factor of one[21].

By contrast, the other scheme concentrates on the development of precoding at the BS by adjusting the precoding matrix at one BS, which can mitigate the pilot contamination effect[19]. Pilot contamination could be efficiently mitigated by using both the open-loop power control (OLPC) and pilot reuse schemes.

6 CONCLUSION

Massive MIMO is seen as one of the key technology in fifth-generation (5 G) technologies to replace the traditional MIMO system.. Massive MIMO relies on the law of large number of antennas that can tremendously improve the signal strength, increases data rate and improves signal reliability. The number of antennas with orders of magnitude, e.g., 100 or more are able to increase the system capacity, spectral and energy efficiency by just performing simple linear beamforming/precoding techniques. Nonetheless, in future research works it is important to tackle the possible advantages of major MIMO problems such as spatial correlation and mutual antenna coupling, as well as hardware impairments.

REFRENCES

1 Design and Optimization for 5G Wireless Communications Haesik Kim VTT Oulu, Finland.

2 Massive MIMO: Fundamental and system design, Hien Quoc Ngo, Linkoping University, Sweden Thesis, Spring 2015

3 F. Rusek, D. Persson, B. K. Lau, E. G. Larsson, T. L. Marzetta, O. Edfors, and F. Tufvesson, “Scaling up MIMO: Opportunities and challenges with very large arrays,” IEEE Signal Process.

4 E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, “Massive MIMO for next generation wireless systems,” IEEE Commun. Mag., vol. 52, no. 2, pp. 186–195, Feb. 2014.

5 Massive MIMO: Ten Myths and One Critical Question, Emil Björnson, Erik G. Larsson, and Thomas L. Marzetta, IEEE Commun. Magazine, vol. 54, no. 2, pp. 114 - 123, 2016.

6 5G Americas White Paper: Advanced Antenna Systems for 5G – 2019

7 H. Q. Ngo, E. G. Larsson, and T. L. Marzetta, “Energy and spectral efficiency of very large multiuser MIMO systems,” IEEE Trans. Commun., vol. 61, no. 4, pp. 1436–1449, Apr. 2013.

8 Massive MIMO for Maximal Spectral Efficiency: How Many Users and Pilots Should Be Allocated? Emil Bj¨ornson, Member, IEEE, Erik G. Larsson, Senior Member, IEEE, and M´erouane Debbah, Fellow, IEEE

9 E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, “Massive MIMO for next generation wireless systems,” IEEE Commun. Mag., vol. 52, no. 2, pp. 186–195, Feb. 2014

10 F. Rusek, D. Persson, B. K. Lau, E. G. Larsson, T. L. Marzetta, O. Edfors, and F. Tufvesson, “Scaling up MIMO: Opportunities and challenges with very large arrays,” IEEE Signal Process. Mag., vol. 30, no.1, pp. 40–46, Jan. 2013.

11 Qualcomm.com/news/onq/2019/06/20/how-5g-massive-mimo-transforms-your-mobile-experiences.

12 Yang, H., Marzetta, T.L., 2015. Energy efficient design of massive MIMO: how many antennas? IEEE 81st Vehicular Technology Conf., p.1-5.

13 H. Yang and T. L. Marzetta, "Performance of conjugate and zero-forcing beamforming in large-scale antenna systems," IEEE J. Sel. Areas Commun., vol. 31, no. 2, pp. 172–179, Feb. 2013.

14 E. Björnson, M. Kountouris, and M. Debbah, "Massive MIMO and small cells: Improving energy efficiency by optimal soft-cell coordination," in Proc. Int. Conf. Telecommun. (ICT), Casablanca, Morocco, May 2013.

15 P. S. Taluja and B. L. Hughes, "Diversity limits of compact broadband multi-antenna systems," IEEE J. Sel. Areas Commun., vol. 31, no. 2, pp. 326–337, Feb. 2013.

16 J. Hoydis, C. Hoek, T. Wild, and S. ten Brink, "Channel measurements for large antenna arrays," in Proc. Int. Symp. Wireless Commun. Syst. (ISWCS), Paris, France, Aug. 2012, pp. 811–815

17 de Carvalho, E., Björnson, E., Larsson, E.G., et al., 2016. Random access for massive MIMO systems with intra- cell pilot contamination. IEEE Int. Conf. on Acoustics, Speech and Signal Processing, p.3361-3365.

18 J. Jose, A. Ashikhmin, T. L. Marzetta, and S. Vishwanath, Pilot contamination and precoding in multi-cell TDD systems, IEEE Trans. Wireless Commun., vol. 10, no. 8, pp. 26402651, Aug. 2011.

19 Ahmadi, H., Farhang, A., Marchetti, N., et al., 2016. A game theoretic approach for pilot contamination avoidance in massive MIMO. IEEE Wireless Commun. Lett., 5(1):12-15.

20 Ashikhmin, A., Marzetta, T., 2012. Pilot contamination precoding in multi-cell large scale antenna systems. IEEE Int. Symp. on Information Theory Proc., p.1137-1141

21 Wang, H.L., Pan, Z.G., Ni, J.Q., et al., 2013. A spatial domain based method against pilot contamination for multi-cell massive MIMO systems. Int. ICST Conf. on Communications and Networking in China, p.218-222