I J C T A, 9(11) 2016, pp. 4957-4968

AN OVERVIEW OF MASSIVE MIMO SYSTEM IN 5G

Sk. Saddam Hussain*, Shaik Mohammed Yaseen[2] and Koushik Barman[3]

Abstract: 4G is proving good speeds up to 1Gbps. Then why do we need anything more. 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. The main technology that maybe used in 5G are massive MIMO, millimetre 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, 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 standardised.

Keywords: Massive MIMO, Beam Division Multiple Access (BDMA), channel estimate, energy efficiency, antenna selection.

1. INTRODUCTION

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 [1]. 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, millimetre wave communication, Beam division multiple access in massive MIMO etc. 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. [1]

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.

* Department of Electronics and Communications Lovely Professional University, Punjab, India
Email: shaik.hussain.saddam@gmail.com, smdyaseen.619@gmail.com[2], koushik.15737@lpu.co.in[3]

2. WHAT IS 5G AND WHY DO WE NEED IT?

5G is the name given to the next generation of wireless connectivity. It will provide great speeds and a good capacity. We are in the 4G now, having speeds of up to 150Mbps in areas of double LTE connections, 300Mbps for LTE-A connections and Pocket-lint (the largest independent gadget news and reviews site in the UK) has predicted that the speeds will improve up to 1Gbps in 4G. This speed is more than enough, then why on earth we need something more, why we need 5G? it is sure that 5G will provide unbelievable speeds between 10Gbps and 100Gbps. But latency is the thing that is very important, in 4G it is between 40ms and 60ms. This is a very low latency but not able to provide real-time applications like in a multi-player game we want our server to respond very quickly when a button is pressed. When it comes to 5G, they have promised a ultra-low latency between 1ms to 10ms. Then in future we can actually watch a cricket or football or any conference actually live without any delay. 5G is a technology that will appear to be invisible; it will be just there like electricity. Management of the available bandwidth is very important for improving the capacity, one idea is that as not all devices need the same bandwidth, we may provide bandwidth according to the needs and hence improve the capacity.

Some of the key technologies to be used in 5G are massive MIMO, device-to-device communication, millimetre wave communication and some multiple access techniques like beam division multiple access (BDMA). Everything around us will be connected to network, the sensors network, the ad-hoc networks, our accounts, laptops, pc etc. Analysis tells that by the year 2020, every person in UK will have 27 internet connected devices and 50 billion connected devices worldwide. This is definitely going to happen in future and it is given the name internet of things and beyond this it is internet of everything [1]. The devices connected may be mobile phones, tablets, watches, smart cloths etc. some may require significant amount of data to be transferred back and forth, the others may just need small packets of data, hence depending on these bandwidth can be allotted for the improvement of overall capacity of the system.

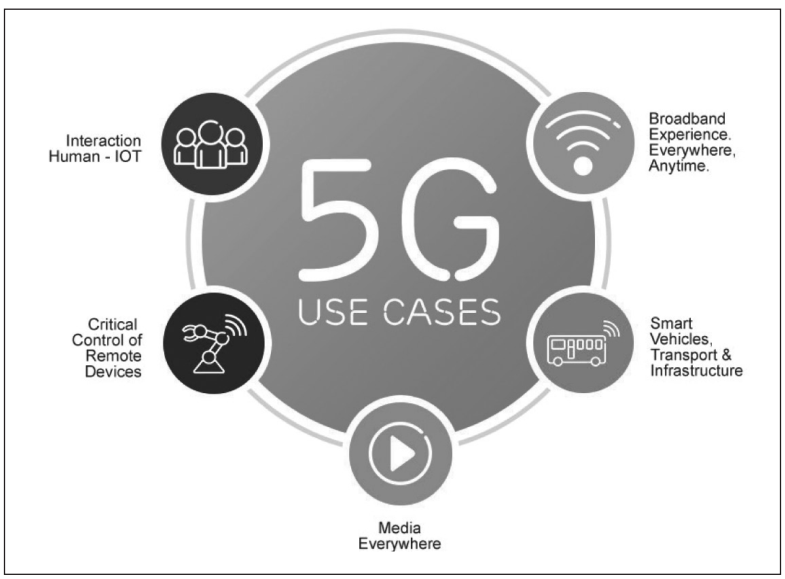

Figure 1. Things that will happen in future [1]

3. EVOLUTION OF 5G

First Generation (1G)-1981: The 1G was based on analog communication. They had poor traffic density i.e. only one call per channel, poor voice quality and they were insecure without any encryption.

Second Generation (2G)-1991: The 2G was based on digital communication with different standards. Among these standards the most famous were GSM (Global System for Mobile), CDMAOne (Code

Division Multiple Access One), IS-136, and PDC (Pacific Digital Cellular). GSM was the most famous of all; it's being used even now. GSM used a frequency band between 900MHz and 1800 MHz, they developed a technology called SIM for authenticate a subscriber for identification and billing purposes, and for encryption of data.

Second to Third Generation Bridge (2.5G)-2000: In 2.5G the data was added along with voice. In between 2G and 3G a famous service called GPRS (general Packet Radio Service) was introduced, which provided services like send and receive e-mail and picture messages. They provide operation speeds up to 115kbps, which was increased up to 384Kbps by using EDGE (Enhanced Data rates for Global Evolution).

Third Generation (3G)-2003: 3G used a higher frequency bands and CDMA for data transmission with speeds up to 2Mbps and supported multimedia services like MMS. The famous standard in 3G was WCDMA (Wideband Code Division Multiple Access) which achieved speeds between 384Kbps and 2048Kbps. They continued using SIM authentication for billing systems and for encryption of data.

Fourth Generation (4G)-2007: 4G can provide speeds up to 150Mbps in areas of double LTE connections, 300Mbps for LTE-A connections and Pocket-lint (the largest independent gadget news and reviews site in the UK) has predicted that the speeds will improve up to 1Gbps in 4G., ad hoc networking model is used as a base as there is no need for a fixed infrastructure. The famous standards used are LTE-A (Long Term Evolution- Advance) by 3GPP and Wimax by IEEE. They provide latency between 40ms and 60ms.

Table 1
Difference between 1G, 2G, 3G, 4G, 5G [11]

Technologies / Features	***1G***	***2G/2.5G***	***3G***	***4G***	***5G***
Evolution	1970	1980	1990	2000	2010
Deployment	1984	1999	2002	2010	2015
Data Rate	2 kbps	14.4-64 kbps	2 Mbps	200 Mbps to 1 Gbps for low mobility	10 Gbps to 100 Gbps
Famous Standards	AMPS	2G: GSM,C]DMA 2.5G: GPRS, EDGE, 1xRTT	WCDMA, CDMA-2000	LTA, WiMAX	Not yet defined
Technology behind	Analog cellular technology	Digital cellular technology	Broad bandwidth CDMA, IP technology	Undefined IP and seamless combination of broadband. LAN/WAN/PAN/WLAN	Undefined IP and seamless combination of broadband. LAN/WAN/PAN/WLAN
Service	Voice	2G: Digital Voice, SMS 2.5G: Voice+Data	Integrated high quality audio, video and data	Dynamic information access, wearable devices	Dynamic information access, wearable devices with AI capabilities
Multiplexing	FDMA	TDMA,CDMA	CDMA	CDMA	CDMA
Type of Switching	Circuit	2G: Circuit 2.5G: Circuit and packet	Packet	Packet	Packet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal and Vertical	Horizontal and Vertical
Core Network	PSTN	PSTN	Packet network	Internet	Internet

4. CAPABILITIES OF 5G

To enhance such a wide range of technologies, 5G obviously have to concentrate on some parameters which lead to the requirements and capabilities for the network to differ from other generations. Some of them are listed below Energy consumption and low cost: It has been always the great challenge for mobile communication to provide the services and features for low energy and low cost. However, to avail all the services for wireless sensor network wherein we have millions of sensors, subsystems and actuators connected, work has been done in many energy efficient protocols and algorithms and thus in 5G they are yet to be implemented.

Performance of Network: As the device energy consumption was up to manageable with high energy efficient algorithms there exists a problem of 'High Network Energy Performance' which is again a major emerging task for operator. Recent technologies are relaying on large solar panels for power supply, thus the energy problems in remote areas are widely handled by these solar panels.so energy efficient of large network is always a challenge for an operator to fulfill all its services [12].

Lower Latency: Latency is mainly defined as the delay response of the device.as the name suggest, it is the important parameter to achieve the promising services as higher data rates and high response time. However, to achieve the low latency it's always been a challenge for developers. As the 5G deals with higher data rates there exists a main issue of how to lower the latency. To support such lower latency applications should be given end-end latency of less than 1ms.

It is somehow achieved for fast growing applications as

- Traffic safety
- Control of infrastructure
- Industrial processes

High availability & Reliability: Another important aspect after lower latency is high availability and high reliability. High reliability includes the system services as well as hardware architecture where in high availability includes the channel bandwidth, providing a higher bandwidth is again a difficult task. Connectivity with the required characteristics is essentially available with less deviation [11].

Very large System Capacity: Traffic services for cellular communication systems are dramatically increasing. To enhance with such traffic in simple way, 5th Generation networks must be capable of transferring data at much lower cost on bit rate compared to present networking system. However, in order to operate with the same or even lower the energy consumption, 5G has to work on lower energy consumption per bit delivered. As compared with present scenario 5G system must be capable of supporting huge number of devices. Thus it's again a challenge for 5G operation in millions of wireless sensor networks which include sensors, actuators, sink, and sources etc. This challenge is mainly in terms of efficient use of protocols [13].

5. 5G ARCHITECTURE

In general a research have shown that a mobile subscriber stays inside for approximately 80 percentage of time and outside for approximately 20 percentage of time. From this scenario for a subscriber inside will receive a call when signal penetration through the walls, then that signal will undergo many losses and hence efficiency will be less, bit rate will be low and low energy efficiency. This is happening because there is only one base station at the middle of the cell site that handles all these. When it comes to 5G architecture it has different models for outside and inside. By doing so some of the penetration losses can be reduced. This will be implemented using massive MIMO technology by deploying hundreds of antennas.

Normally in MIMO system we utilized two or four antennas, by using massive MIMO we are increasing number of transmitter and receiver antennas approximately between ten to hundred, by doing so we are increasing the capacity gain [1]. In massive MIMO network two things are setup for establishing a reliable network. First, a base station will be installed in a cell site with multiple antennas on it or in the area of cell; these are connected with the base station using optical fibre cables. When a subscriber is outside he is connected to the base station directly or connected via multiple hops from the antennas creating virtual massive MIMO network. Secondly an antenna array will be installed in every building; these antennas will be in line of sight with the base station. The communication inside is done using technologies like Wi-Fi, visible light communication, millimetre wave communication etc [1].

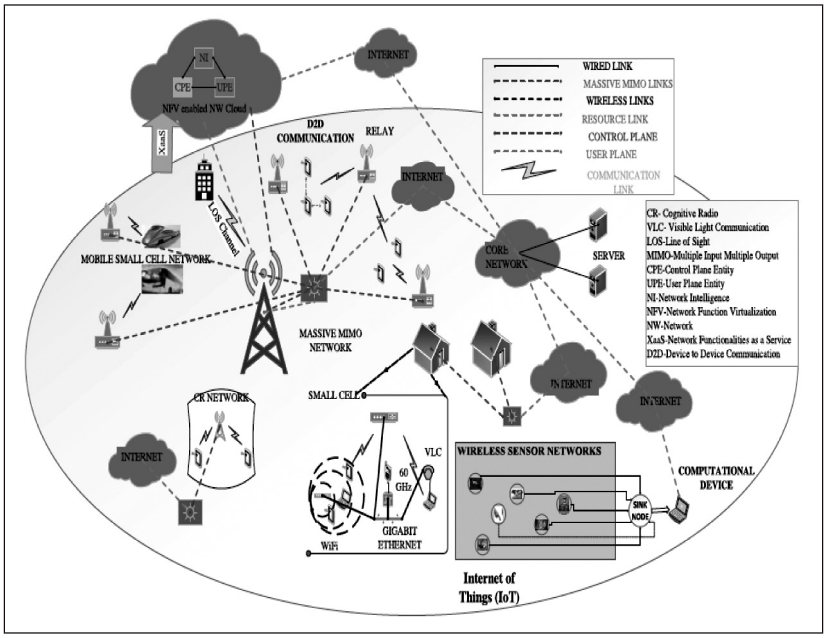

Figure 2. General 5G cellular network architecture [7]

6. MASSIVE MIMO

MIMO stands for Multiple Input and Multiple Output that means we use multiple antennas at the transmitter and receiver, this is called spatial diversity. Up until the 1990s, spatial diversity was often limited to systems that switched between two antennas. If we use multiple antennas at the transmitter we call it as transmitter diversity and at receiver we call it as receiver diversity.   By doing so we are increasing the channel capacity and reliability of the wireless network. During the start of this technology point-to-point MIMO were used were both transmitter and receiver have multiple antennas, soon it was over taken by multi-user MIMO where there were multiple antennas at the base station which communicated with the single antenna receiver. Due to this cost of the whole system was reduced because now costly antennas were only needed at the base stations, cheap antennas can be used at the single antenna end [3].

One advantage of this technology is that we can increase the capacity and reliability, the other is that we can reduce the error rate. If we can transmit multiple versions of our message through different channels the probability all the signals will be affected same will be less. At the receiver these multiple copies are received and processed to get our original message. Hence Diversity also helps to stabilise a communication link, improves its performance, and reduces error rate. Due to all these advantages MIMO technology is deployed as a part of communication standards such as 802.11 (WiFi), 802.16 (WiMAX), and LTE [3].

The communication in MIMO take place in two formats called spatial diversity and spatial multiplexing. In spatial diversity, the same data is transmitted through different paths; the data is received at the multiple antennas and processed. By spatial multiplexing we can improve the reliability of the link. The other technique is spatial multiplexing, where the data is divided into small parts and different part is transmitted through different path, by doing so we are increasing the speed, but reliability is less.

A MIMO system consists of a number of transmitter and receiver antennas and a fading channel through which the data will be sent. Let us consider we have *M,* number of transmitter antennas and *N,* number of receiver antenna i.e. we form a matrix for transmitter and receiver antennas having t number of rows in transition matrix similarly r number of rows in receiver matrix.

The basic equation for MIMO system is given by Y= H.X + W

Where, Y = N x 1 Receiver matrix

H = N x M Channel matrix

X = M x 1 Transition matrix

W = Noise

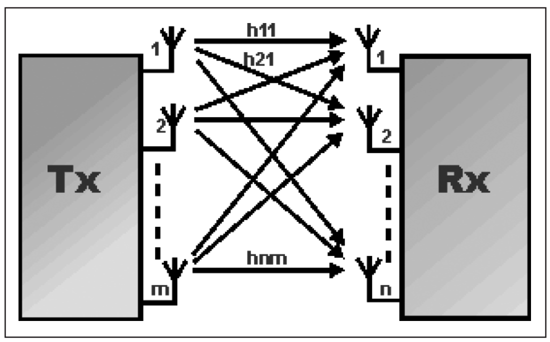

Figure 3: MIMO System

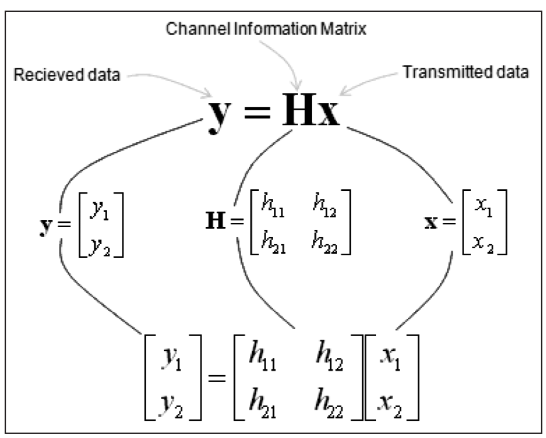

Figure 4: Matrix Representation of MIMO

In future to achieve more gain and to reduce the signal processing, massive MIMO or large-scale antenna system (LSAS) have been proposed. The general MIMO system consists of not more than 10 antennas, whereas in massive MIMO there could be 100 or more antennas [4], [5]. But not all the antennas will work at the same time; a limited number of antennas will be operating at a time because of the limitations to acquire channel state information. Massive MIMO technology can be made possible by combining the conventional TDMA, FDMA and OFDM multiplexing technology. Future prediction is that the Massive MIMO technology will use very low power in the order of milliwatts. The major challenges are multiuser multiplexing gains, error in channel state information and interference. The power consumption at the base stations is a growing concern [6]. We assume that the number of antennas at the base station is more than the number of users; hence we have more degree of freedom, so that we can perform effective transmition and avoid interference [7]. Another advantage of massive MIMO system is energy efficiency, prediction is that a single-antenna user in a massive MIMO system can reduce down its transmit power proportional to the number of antennas at the base station with perfect channel state information (CSI) or to the square root of the number of base station antennas with imperfect CSI, to get the same performance as a corresponding single-input single-output (SISO) system. So there will be higher energy efficiency and this is very important for wireless networks where excessive energy consumption is a growing concern [8], [9], [10]. If adequate power is available at the base station then massive MIMO system can increase the range of operation compared to SISO system.

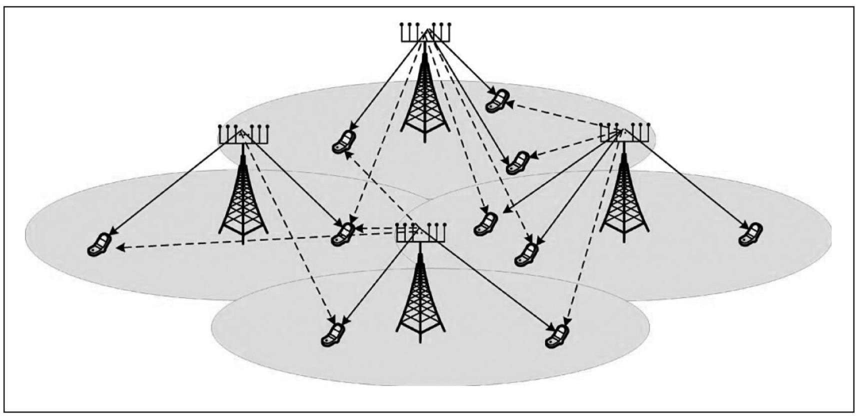

Figure 5: Illustration of Massive MU-MIMO systems

Massive MIMO system can be built with inexpensive and low power gadgets. The high power amplifiers may be replaced by low cost amplifier with output power in the range of milli-watt. Several expensive and bulky equipment like coaxial cable used for connecting the BS with other BS and mobile switching centre, can be eliminated. The massive MIMO system works on the principal that the noise, fading, any imperfections are averaged out when signals from several antennas are combined. Massive MIMO system has high degree of freedom, because they have more than 100 antennas but not all are working at the same time. Massive MIMO system will have very low latency. Latency in a system is due to fading, when the signal travel through multi path and reach at the receiver and add destructively. As in massive MIMO system there are going to be many antennas and high degrees of freedom this latency can be reduced. There are some limitations of massive MIMO that might be channel reciprocity and pilot contamination. These might happen due to adjacent cell interference, which need to be taken care.

7. BEAM DIVISION MULTIPLE ACCESS

The aim of mobile communication is to provide flexible and improved connection to everyone at low cost. As in future more and more subscribers are going to join to the network increasing the capacity, so future requirement is to provide a good capacity and quality of service. It's like there should not be any drop in speed wherever the subscriber goes and any number of them are connected at the same time to the network. The frequency band for 5G is yet to be decided, an prediction is millimetre band is going to be used 30 to 300 GHz may be used. The main obstacle in mobile communication is limited frequency and time, so to overcome this we have used many multiple access techniques like Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA) techniques, etc. [2]

The time and frequency are divided among many users but it is limited as frequency and time are limited. In future there will be more mobile station and will be increasing, the previous technique are not enough to manage. We need a new technique for 5G, so the Korean research and development came up with the idea of new multiple access technique called as Beam Division Multiple Access (BDMA). An orthogonal beam is provided by the base station to each mobile station. To allow multiple accesses in BDMA the beam is divided according to the location and improving the capacity. The base station and mobile station are in line of sight communication when they know each other's position, and hence avoiding the interference. BDMA is a new space division multiple access technique which uses phased antenna array, use beam forming technique to produce directive beam and uses multiple beam forming patterns for multiple access [2].

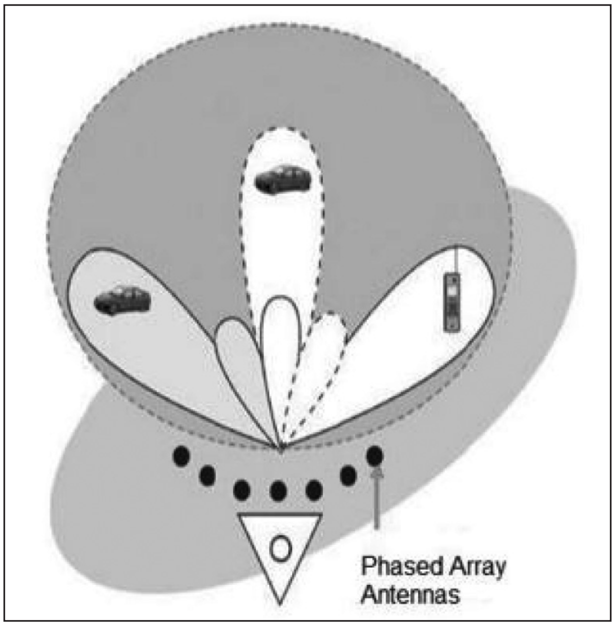

Figure 6: Beam Division Multiple Access [2]

When mobile stations are present at different positions or angles, each one of them are provided with a beam separately. If the mobile stations are in same location then they use a single beam, by using the available frequency/time for multiple accesses. The base station can change the direction, number of beams and width of the beam according to the position and speed of the mobile station. The available beam can be divided into three-dimensions and hence improving the capacity. The steps followed for set of connection are as follows:

- Initially the base station and mobile station are unknown to each, the mobile station determine its location and speed and transmit this information omni-directionally to the base station.
- The base station determines the direction and width of the beam depending on the information received from the mobile station. This beam is called downlink beam as it is from base station to the mobile station.
- Now the base station transmits this downlink beam to the mobile station.
- The mobile station on receiving this downlink beam track the direction of this beam for sending an uplink beam in the set direction.
- Base station on receiving this uplink beam establishes a communication. The periodic updating of beam must be done for communication to carry out smoothly.

8. CHANNEL ESTIMATE IN MASSIVE MIMO

In massive MIMO the communication is happening through spatial multiplexing, which require channel estimate in both uplink and downlink direction. In regular MIMO channel state information (CSI) is required at the base station (BS) for precoding in downlink and for detection in uplink. Channel estimate in MIMO is proportional to number of transmit antenna and is nothing to do with number of receiver antennas. In frequency division duplex (FDD), as uplink and downlink use different frequency there is a need to find the CSI in uplink and downlink separately. For uplink channel estimate a pilot sequence is send by all users to the BS, and this is independent of the number of antennas at the BS. However for downlink channel estimate there are two stages, first the BS send a pilot symbol to all users, next the users send the feedback with estimate CSI to the BS. The time required to transmit the downlink pilot symbol proportional to number of antennas at the BS. More the number of antennas at the BS the channel estimate become impractical. This problem can be overcome by using time division duplex (TDD), where channel reciprocity is used as the same channel is used for uplink and downlink. So just the channel estimate is one direction is enough. A TDD protocol is proposed in [14], shown below. This protocol says that, first all user synchronously send user uplink data, next user send a uplink pilot sequence which is used by BS to estimate the CSI for that user in that cell. BS uses this CSI to know the uplink data and form a beamforming signal for downlink transmission. But the pilot sequence from the neighbouring cell and the pilot sequence within the cell are not orthogonal, so there is problem of pilot contamination [4]. Linear min-mean square error (MMSE) method is used which can provide optimal results with less complexity. In addition to linear MMSE, a compressive sensing-based channel estimation approach is proposed in [15], a time-frequency training sequence design is developed in [16] for improving the spectral efficiency.

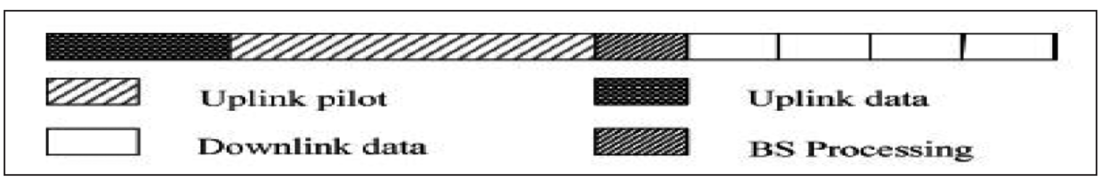

Figure 7: MIMO TDD protocol [14]

9. ANTENNA SELECTION

Due to the increasing demands of the subscribers there is a need for new technology which can handle this situation, such that it should improve the channel efficiency, data rate and provide required quality of service. MIMO is one of the solutions for this situation, it is able to provide the required performance using multiple transmitter and receiver antennas. By increasing the number of antennas we are improving our performance but it is costly in terms of size and hardware at the base station and the computation power at the base station. So we require a efficient method to reduce this cost, one way of doing this by using a fast antenna selection algorithm. Antenna selection algorithm can be applied at transmitter, receiver or both. For channel maximization we require a proper selection of transmitter antennas, there are some algorithms where selection is done based on power, channel correlation matrix and channel state information [19]. Some of the antenna selection algorithms have been discussed in [21] [22] and [23].

10. CAPACITY AND ENERGY EFFICENCY IN MASSIVE MIMO

Massive MIMO system will improve the capacity 10 times and the energy efficiency is improved 100 times that of a conventional MIMO system. The improvement in capacity is due to the use of spatial multiplexing. The beam division multiple access (BDMA) technique to be used in massive MIMO will allot a beam for each used which are orthogonal to each other. The mobile users in a same location will use the same beam using multiple access techniques like TDMA/FDMA, hence improving the capacity. The increase in the energy efficiency is also due to focusing of the beam in particular target location [17].

Figure 9 shows the concept of coherent superposition of wavefronts. The BS makes sure that the waveforms generated by all the antennas add constructively at the target and destructively anywhere else. Figure 8 from [8], shows the trade-off between the energy efficiency in terms of the total number of bits (sum-rate) transmitted per Joule per terminal receiving service of energy spent, and spectral efficiency in terms of total number of bits (sum-rate) transmitted per unit of radio spectrum consumed. This figure11 shows the spectral efficiency for uplink transmission from mobile users to the BS. The graph shows that uplink spectral efficiency is improved 10 times and the radiated power efficiency is improved by 100 times for massive MIMO [8].

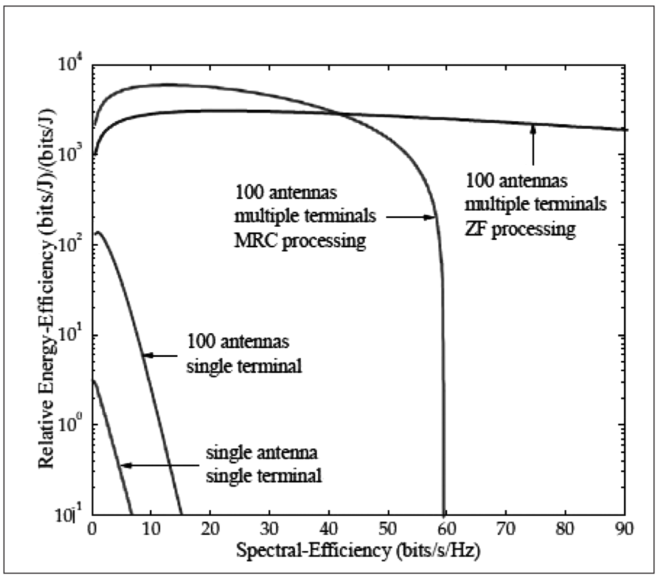

Figure 8: Spectral-Efficiency (bits/s/Hz) Vs Relative Energy-Efficiency (bits/J)/(bits/J)

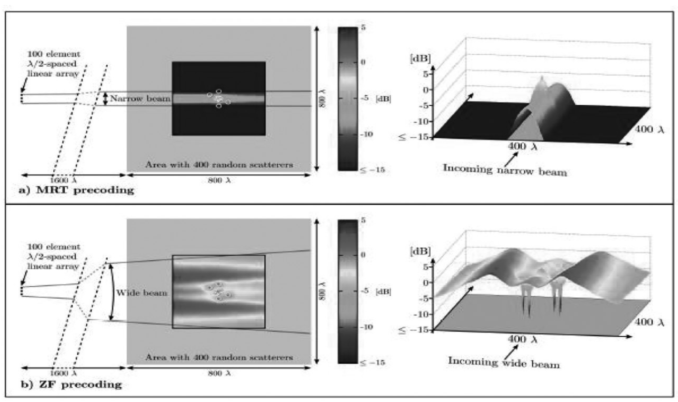

Figure 9: Relative field strength around a target terminal in a scattering environment of size 800λ×800λ, when the base station is placed 1600λ to the left. Average field strengths are calculated over 10000 random placements of 400 scatterers, when two different linear precoders are used: a) MRT precoders and b) ZF precoders.

11. CONCLUSION

5G will provide great speed and enough capacity; it's like wherever the mobile station moves there will be no drop in speed even though any numbers of mobile users are connected to the network at the same time. Massive MIMO is the future technology which will help to attain the requirements of 5G. TDMA, FDMA and other multiple access techniques may not be applicable to provide good capacity efficiency as the frequency and time are limited. So we need a new technique called Beam Division Multiple Access to be used in Massive MIMO to improve the capacity. The channel estimation in massive MIMO is a great challenge so as to provide low bit error rate. By using massive MIMO the system capacity is increased 10times and energy efficiency is improved by 100times. As the cost of infrastructure for 5G will be expensive, so one way to reduce the cost is by reducing the processing at the transmitter and receiver which can be achieved using a appropriate antenna selection algorithm. If all things fall in place 5G may be applicable by 2022/23. So there is going to be a Bright future ahead.

Refrence

1. Akhil gupta and Rakesh kumar jha, "A survey of 5g network: architecture and emerging technologies" *IEEE Access,* July 2015.
2. Chen Sun, Xiqi Gao, Shi Jin, Michail Matthaiou, Zhi Ding, Chengshan Xiao," Beam Division Multiple Access Transmission for Massive MIMO Communications", *IEEE,* 2015.
3. Lu Lu, Geoffrey Ye Li, A. Lee Swindlehurst, Alexei Ashikhmin, and Rui Zhang, "An Overview of Massive MIMO: Benefits and Challenges", *IEEE journal of selected topics in signal processing*, Vol.8, No.5, October 2014.
4. T. L. Marzetta, "Multi-cellular wireless with base stations employing unlimited numbers of antennas," in Proc. UCSD Inf. Theory Applicat. Workshop, Feb. 2010.
5. T. L.Marzetta, "Noncooperative cellular wireless with unlimited numbers of base station antennas," IEEE Trans. Wireless Commun., vol. 9, no. 11, pp. 3590–3600, Nov. 2010.
6. Vahid Tarokh, Hamid Jafarkhani, A. Robert Calderbank, "Space–Time Block Coding for Wireless Communications: Performance Results", IEEE Journal, vol.17, 1999.
7. E. G. Larsson, "Very large MIMO systems: Opportunities and challenges," 2012 [Online]. Available: http://www.kth.se/polopoly_fs/1.303070!/Menu/general/column-content/attachment/Large_MIMO.pdf
8. H. Q.Ngo,E.G.Larsson, and T. L.Marzetta, "Energy and spectral efficiency of very largemultiuserMIMOsystems," IEEE Trans. Commun., vol. 61, no. 4, pp. 1436–1449, Apr. 2013.
9. G. Y. Li, Z.-K. Xu, C. Xiong, C.-Y. Yang, S.-Q. Zhang, Y. Chen, and S.-G.Xu, "Energy-efficient wireless communications: Tutorial, survey, and open issues," IEEE Wireless Commun. Mag., vol. 18, no. 6, pp. 28–35, Dec. 2011.
10. C. Xiong, G. Y. Li, S. Zhang, Y. Chen, and S. Xu, "Energy- and spectral- efficiency tradeoff in downlink OFDMA networks," IEEE Trans. Wireless Commun., vol. 10, no. 11, pp. 3874–3886, Nov. 2011.
11. Sanskar Jain, NehaAgrawal, and Mayank Awasthi, "5G - The Future of Mobile Wireless Communication Networks," in *Advance in Electronic and Electric Engineering*, vol.3, 2013
12. R. Baldemair *et al.*, "Evolving wireless communications: Addressing the challenges and expectations of the future," *IEEE Veh. Technol. Mag.*,vol. 8, no. 1, pp. 24_30, Mar. 2013.
13. Ericsson White paper, "5G Radio Access," 2015.
14. T. L.Marzetta, "How much training is required for multiuser MIMO?," in Proc. 40th Asilomar Conf. Signals, Syst., Comput. (ACSSC), Pacific Grove, CA, USA, Oct. 2006, pp. 359–363.
15. S. Nguyen and A. Ghrayeb, "Compressive sensing-based channel estimation or massive multiuser MIMO systems," in Proc. IEEE Wireless Commun. Netw. Conf. (WCNC), Shanghai, China, Apr. 2013, pp. 2890–2895.
16. L. Dai, Z. Wang, and Z. Yang, "Spectrally efficient time-frequency training OFDM for mobile large-scale MIMO systems," IEEE J. Sel. Areas Commun., vol. 31, no. 2, pp. 251–263, Feb. 2013.
17. Erik G. Larsson, Ove Edfors, Fredrik Tufvesson, Thomas L. Marzetta. "Massive MIMO for next generation wireless systems," IEEE Trans. Wireless commun., Jan 23 2014.
18. Fredrik Rusek, Daniel Persson, Buon Kiong Lau, Erik G. Larsson, Thomas L. Marzetta, Ove Edfors, and Fredrik Tufvesson, "Scaling up MIMO" *IEEE signal processing magazine*, pp 40-60, Dec 2012.
19. S. P. Premnath, J. R. Jenifer, C. Arunachalaperumal," Performance enhancement of MIMO systems using antenna selec-

tion algorithm", *International Journal of Emerging Technology and Advanced Engineering,* Jan 2013.

20. Vahid Tarokh, Hamid Jafarkhani, A. Robert Calderbank, "Space–Time Block Coding for Wireless Communications: Performance Results", *IEEE Journal, vol.17,* 1999.
21. Yang-Seok Choi, Andreas F. Molisch, Moe Z. Win, Jack H. Winters, "Fast algorithms for antenna selection in MIMO systems", *IEEE 58th conference paper,* 2003.
22. Hongyuan Zhang, Huaiyu Dai, "Fast Transmit Antenna Selection Algorithms for MIMO Systems with Fading Correlation" *IEEE conference paper*, 2004.
23. Bing Fang, Zuping Qian, Wei Shao, Wei Zhong," RAISE: A New Fast Transmit Antenna Selection Algorithm for Massive MIMO Systems", *Springer Science+Business*, Media New York, 2014.
24. Basics of MIMO: http://www.radio-electronics.com/info/antennas/mimo/formats-siso-simo-miso-mimo.php
25. R. Müller, M. Vehkaperä, and L. Cottatellucci, "Blind pilot decontamination," in Proc. Of ITG Workshop on Smart Antennas, Stuttgart, Mar. 2013.
26. F. Kaltenberger, J. Haiyong, M. Guillaud, and R. Knopp, "Relative channel reciprocity calibration in MIMO/TDD systems," in Proc. of Future Network and Mobile Summit, 2010.
27. K. V. Vardhan, S. K. Mohammed, A. Chockalingam, and B. S. Rajan, "A low-complexity detector for large MIMO systems and multicarrier CDMA systems," IEEE J. Sel. Areas Commun., vol. 26, no. 4, pp. 473–485, Apr. 2008.