Massive mimo: a next requirement for next generation

[1]Supriya Vinayak Musale, [2]Dinesh V. Rojatkar
[1,2]Department of Electronics and Telecommunication Engneering
Government Engineering College, Chandrapur, India

***Abstract*- MIMO technology is a foundation for modern wireless networks. It stands for Multiple Input Multiple Output. It uses antennas that receives and transmits electromagnetic waves. Upcoming MIMO technology will add more bandwidth and add more capacity of clients. MIMO technology allows exploiting the directivity of signals. This is the reason why MIMO has become an enabling technology for current 4th generation of mobile communication. Future generation of mobile communication system is fifth generation. These increases demands for higher data rates. One of most promising solutions for these challenges is Massive MIMO. It is MIMO technology with massive number of antennas i.e. hundreds and thousands of antennas for transmission at base stations. It appears to change the shape of future antennas dramatically. We might imagine a façade of building becoming huge array of multiple integrated antennas. In this paper we will learn more about massive MIMO.**

***Keywords*- SISO, MISO, MU-MIMO, M-MIMO, OFDM, Spatial multiplexing**

I. INTRODUCTION

In wireless communication, electromagnetic waves transmitted from the transmitter suffer mainly from attenuation of signal strength and second is the interference between the users. In designing future wireless communication system, the major challenges faced are increased spectral efficiency and improved link reliability. Diversity provides the replicas of transmitted signals at receiver that helps in reducing fading and interference therefore improving link reliability. There are commonly two forms of diversity, first time diversity and second frequency diversity but in recent years, spatial diversity is used due to reason that it is provided without loss of spectral efficiency. In this diversity, the use of multiple antennas at both ends of wireless link has the potential to achieve higher data rates.

II. BACKGROUND

First Physical wireless communication link i.e. SISO which stands for Single Input and Single Output. In SISO, single antenna element at transmitter side which is radiating electromagnetic waves towards single antenna at receiver side. The main issue occurring is the attenuation of signal strength. One of the solutions for this issue is the deployment of multiple antennas at transmitter side which is MISO i.e. Multiple Input Single Output. Consider as shown in below diagram each antenna at transmitter is linked to the antenna at receiver and characterized by complex number h1, h2, h3, h4.

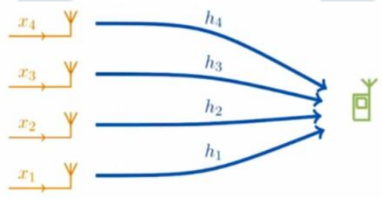

Figure1: baseband representation model

Here shows the transmission model where y is the output signal at the receiver.

$$y = \sum_{m=1}^{4} h_m x_m + n = \boldsymbol{h}^{\mathrm{T}} \boldsymbol{x} + n, \quad h_m \in \mathbb{C}$$

Y is described as linear combination of transmitted signals x1, x2, x3, x4 which arrives at the receiver with linear weights h1, h2, h3, h4 which equals the respective channel coefficient. N is noise added during transmission.

To design transmitted signals, when we have to transmit dedicated signal S to the receiver, matched filters are used due to which beam-forming is obtained as shown in below figure.

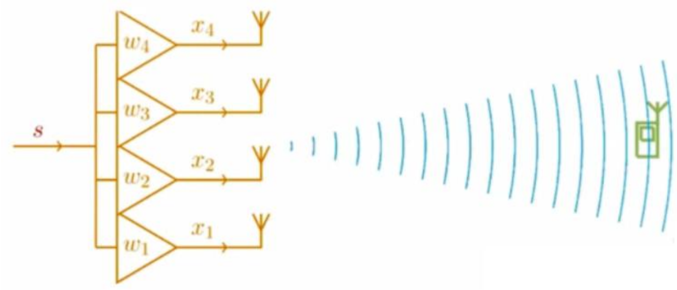

Figure2: Beam-forming obtained using matched filter

Next is the Multi User-MIMO, it has brought drastic improvements that are first is the increased and simultaneously many terminals are served. Second is increased energy efficiency because the base stations focus energy in spatial direction where the terminals are located. Third is increased reliability which is obtained by more number of antennas that provides distinct paths. Fourth is interference is reduced.

Now going large is the Massive MIMO where massive number of antenna elements is used for transmission. It is an emerging technology that uses antenna arrays with hundreds of antennas serves number of terminals simultaneously at same time-frequency resource.

III. WORKING PRINCIPLE OF MIMO

MIMO is effectively radio antenna technology that uses multiple antennas at the transmitter and receiver end that enables various paths for data streams that choose different paths for each antenna. On contrary MIMO works on multipath propagation (reflect signals). It transmits multiple parallel signals through multiple antennas as shown in below figure.

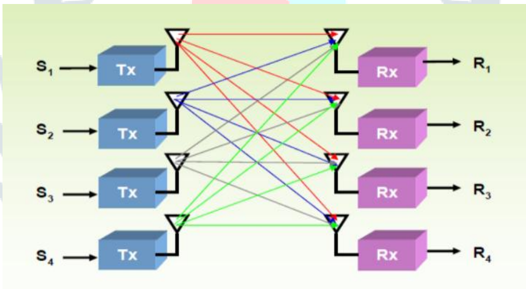

Figure3 : MIMO

In urban areas, signals will bounce off trees, buildings and finally reach the receiver through different paths. An algorithm is used to sort out multiple signals at the receiver to produce one signal having originally transmitted data. MIMO OFDM uses IFFT at transmitter and FFT at receiver. Simultaneously in single channel multiple data streams are transmitted and multipath signals are collected by multiple radios at receiver. Hence, MIMO increases speed, range and reliability.

A. KEY TECHNOLOGY THAT ENABLES MIMO: OFDM

OFDM stands for Orthogonal Frequency Division Multiplexing. In this method, digital signals are encoded by using multiple sub carriers as compared to the single carriers used in earlier systems. Due to this symbols get distributed over these carriers and hence symbol rate reduces, power consumption reduces, bandwidth increases, capacity increases and ultimately the speed increases. This is something new in MIMO technology as compared to that of other technologies. The orthogonal part of OFDM is the sub carriers are orthogonal to each other and hence crosstalk is avoided. Hence, design of transmitter and receiver using OFDM is easy as compared to that of traditional FDM technique.

IV. MASSIVE MIMO (M-MIMO)

Massive MIMO is the system that uses integrated antenna elements in large scale that one can imagine a façade of the huge building consisting antenna array. Massive MIMO is also known as ‘Hyper MIMO’, ‘Large Scale Antenna System’, ‘Full Dimensional MIMO’, and ‘Very Large MIMO’. The basic concept of massive MIMO is to achieve all the advantages of the conventional MIMO but on a larger scale. Massive MIMO enables the development of various future broadband systems that will be spectrum efficient, energy efficient, robust and further more. Massive MIMO will connect the whole world i.e. connect internet to people, internet to things, and various infrastructures.

Massive MIMO depends on spatial multiplexing. Spatial Multiplexing provides improvements in SNR ratio and also the reliability of the system with respect to various forms of fading. It increases data throughput capability by providing additional data capacity that utilizes different capacity. Spatial Multiplexing depends on both uplink and downlink.

V. ADVANTAGES OF MASSIVE MIMO

Massive MIMO has great potential and some benefits of this Massive multi-user MIMO system are listed below:

i. High spectrum efficiency: It is obtained by increased capacity. M-MIMO can increase the capacity 10 times and even more. This capacity is increased as MIMO uses spatial multiplexing. Large multiplexing gain and antenna array gain is obtained due to which high spectrum is achieved.
ii. High energy efficiency: M-MIMO uses extra antennas that focus energy in smaller region of space to bring huge improvement in throughput and radiated energy efficiency. As energy is focused with extreme sharpness, energy efficiency is achieved.
iii. Increased robustness: robustness is increased due to the use of large number of antenna elements. According to reference [1] massive MIMO increases robustness both to intentional jammers as well as unintentional interference which is manmade.
iv. M-MIMO can be built using simple, low power and inexpensive components. Instead of expensive, ultra large amplifiers used in conventional MIMO, massive MIMO uses hundreds of low cost amplifiers. Large co-axial cables and many expensive and heavy elements are completely eliminated.
v. High reliability: It is obtained due to large diversity gain.
vi. Reduction in latency on air interference: Fading limits the latency on air interference. Fading is the reason to limit the performance of wireless communication link. Hence in M-MIMO due to the use of large number of antennas and beamforming, fading is reduced.
vii. Simplified MA layer: use of OFDM technology assures same channel gain at each subcarrier. This makes each terminal to utilize the whole bandwidth. Hence renders the physical layer and simplifies the multiple access layer.
viii. Due to orthogonal MS channels extremely narrower beam, physical security is enhanced and inter user interference is weaken.
ix. Scheduling scheme is simplified.

VI. DISADVANTAGES OF M-MIMO

There are various limiting factors of Massive MIMO that are discussed below:

i. Pilot Contamination: In M-MIMO every terminal is assigned an orthogonal uplink pilot sequence. These pilot sequences are bounded with coherent interval. Therefore it becomes easy to exhaust the pilot sequences in multi cellular system. A consequence arises by re-use of pilots from one cell to another and is known as pilot contamination. Bounded coherent interval and bandwidth limits the orthogonal pilot subcarriers that leads to pilot contamination.
ii. High complexity in signal processing: M-MIMO utilizes large number of antennas and spatial multiplexing that increases complexity in signal processing.
iii. Channel reciprocity: TDD mode of M-MIMO depends on channel reciprocity.
iv. Sensitivity towards beam alignment: M-MIMO uses extremely narrower beam that is sensitive to the movement of MS or swaying of antenna array.

VII. APPLICATIONS OF MASSIVE MIMO

Some of the applications of M-MIMO are mentioned below:

i. It is used in 4G LTE (Long Term Evolution). It is 4G wireless broadband technology by the 3rd generation (3GPP).
ii. It is used in LTE advanced which is major step in the evolution of LTE networks.
iii. It is also used in advanced WLAN versions. For example 802.11ad, 802.11ac, etc.

VIII. CONCLUSION

In this paper, we have focused on unrealized abilities of Massive MIMO. Massive MIMO is technology that enables future generations such as 5G is the next generation to come. It has great potential to increase spectrum efficiency, energy efficiency, robustness and reliability. It also reduces the use of bulky hardware. It also reduces the expenses due to use of low power, low cost hardware. There are further more unrealized challenges to built Massive MIMO.

REFERENCES

[1] Erik G. Larsson, ISY, Linköping University, Sweden,Ove Edfors, Lund University, Sweden, Fredrik Tufvesson, Lund University, Sweden,Thomas L. Marzetta, Bell Labs, Alcatel-Lucent, USA-MASSIVE MIMO FOR NEXT GENERATION WIRELESS SYSTEMS.

[2] T.L. Marzetta and B.M. Hochwald, "Capacity of a Mobile Multiple-Antenna Communication Link in Rayleigh Flat Fading," *IEEE Trans. Inf. Theory* 45 (1),1999, pp. 139–157.

[3] T. L. Marzetta, Noncooperative cellular wireless with unlimited numbers of base station antennas, IEEE Trans. Wireless Commun., vol. 9, no. 11, pp. 35903600,Nov. 2010.

[4] 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, pp. 4060, Jan. 2013.

[5] A. Pitarokoilis, S. K. Mohammed, and E. G. Larsson, On the optimality of single-carrier transmission in large-scale antenna systems, IEEE Wireless Commun. Lett., vol. 1, no. 4, pp. 276279, Aug. 2012.

[6] J. Hoydis, C. Hoek, T. Wild, and S. ten Brink, "Channel measurements for large antenna arrays," in *IEEE International Symposium on Wireless Communication Systems (ISWCS)*, Paris, France, Aug. 2012.