International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 5 Issue: 3
ISSN: 2321-8169
36 – 40

A Survey: Massive MIMO for next Generation Cellular Wireless Technologies

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Abstract—The rapid development of MIMO technology in the area of wireless communications is to setting up of base stations with large number of antennas to improvements in energy and spectral efficiency. In this paper a detailed survey on massive technology, its advantages and comparison with existing method are proposed. The Long Term Evolution (LTE) has been designed to support only packet-switched services and is aimed to provide IP connectivity between UE and eNodeB. As we move forward ~~to~~5G becoming more promising next generation technology with increase in capacity, reduced latencies, support of very high frequencies (mmWave) with a smaller size single antenna, smaller the aperture for receiving energy. To overcome this small aperture on receiver side at high frequency, we need to use a large number of transmission antenna. This would be the main reason to use the Massive Multiple Input Multiple Outputs (MIMO).This paper focused on the massive MIMO performance, the gain, and return losses of different antennas operating at different frequencies.

Keywords--*5G, Massive MIMO.*

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I. INTRODUCTION

During last few decades, mobile communications have significantly contributed to the economic and social developments of both developed and developing countries. Today, mobile communication forms an indispensable part of the daily lives of millions of people in the world. The demand for wireless throughput and communication reliability as well as the user density is increase almost vertically. Therefore the future wireless communication requires new technologies in which many users can be simultaneously served with very high throughput.

Currently many operators in worldwide are deploying LTE/LTE-A to offer faster access with lower latency and higher efficiency than 3G and 4G. The challenging requirements of LTE-A are higher system capacity, higher data rate, support of massive connectivity, reduced cost, lower latency and higher efficiency [1].

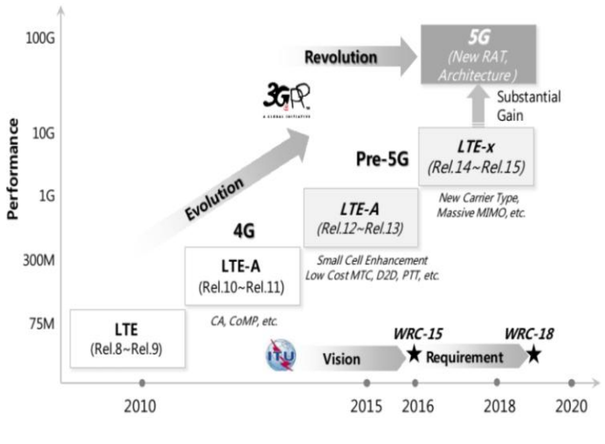

Fig.1 4G to 5G evolution

The 5G would be realized in the similar fashion even though many of 5G document say '5G should take drastically different evolution path from the one we saw before. We are already observed that some of the features are very advanced in 4G, but will become a kind of basic features in 5G. Fig.1 shows the evolution path of 4G to 5G [2] and [3].

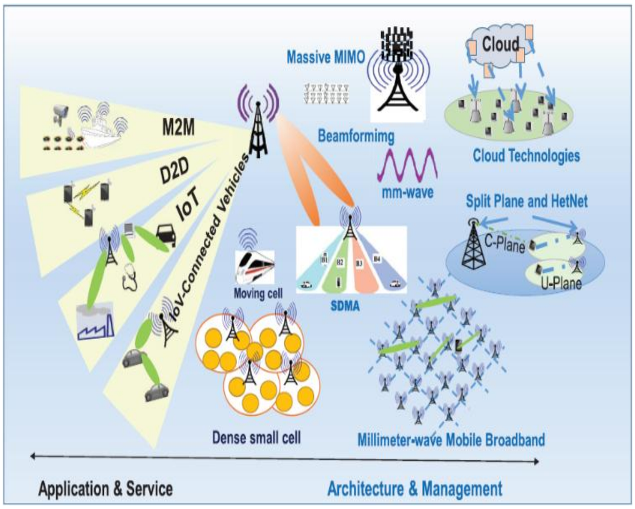

Fig.2 5G Schematic Wireless Networks

The Schematic Wireless networks using Massive MIMO that communicate between M2M, D2D, IoT etc., can achieve simultaneously is as shown in fig.2. One of the question is arises for the use of conventional low dimensional point-to-point MIMO with complicated processing schemes instead of Massive MIMO with simple linear processing schemes.

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II. Massive MIMO

In Massive MIMO, when the number of BS antennas is large, the channels become favorable and linear processing is nearly optimal. The multiplexing gain and array gain can be obtained with simple linear processing. It increases the number of BS antennas and the number of users with increasing the throughput [4].If the transmission antenna transmit signal with the power of $P_{transmit}$ then they received signal power with ideal condition is given in equation (1)

$$P_{receive} = \frac{P_{transmit}}{4\pi R^2} \text{ ------------------------ } (1)$$

Where R is the distance between the transmitter and receiver. The received power is decreased in proportion to the square of the distance from the transmission antenna.

This ideal equation does not contain any parameter about frequency or the gain of the receiver antenna. It means the received signal power is not influenced by signal frequency or receiver antenna gain. In reality, the received signal power is affected by the frequency (wave length) and receiver antenna gain as given in equation (2).

$$P_{receive} = \left[\frac{P_{transmit}}{4\pi R^2} * \frac{\lambda^2}{4\pi} * G_{receiver} \right] \ldots\ldots\ldots\ldots\ldots (2)$$

The received power is proportional to the square of the wavelength (λ). As we will use much higher frequency (meaning much shorter wavelength) signal in 5G then the received power will be much lower than in current communication system. Like, if we use 1GHz frequency in current communication and we will use 10 GHz frequency in 5G, the wavelength of 10 GHz is 10 times shorter than the wavelength of 1GHz. It means the received power at 10 GHz will be 100 times lower than the received power at 1GHz.

In real time situation it gets even more complicated as received power depends on because of the receiver antenna gain and transmission antenna gain as shown in equation (3).

$$P_{receive} = \left[\frac{P_{transmit}}{4\pi R^2} * \frac{\lambda^2}{4\pi} * G_{receiver} * G_{transmitter} \right] \ldots.. (3)$$

Hence we need to put in a mechanism to overcome the drastic received power reduction at high frequency and to increase the $P_{receive}$ by setting the parameters as follows.

i. Increase $P_{transmit}$ (Transmitter Power)
ii. Decrease the distance between the transmitter and receiver antenna.
iii. Increase wavelength (use low frequency).
iv. Increase receiver antenna gain.
v. Increase transmitter antenna gain.

It is difficult in reality to achieve larger $P_{receive}$ in principle, however to certain extent it can be increased by increasing receiver and transmitter antenna gain.

Another parameter may be consider to increase the antenna gain by means of design with smart materials but to compensate the huge amount of the power reduction cause by the increased frequency. The only way to increase the antenna gain is to increase the number of antennas and it is the major motivation of using Massive MIMO. The different MIMO formats are Single Input Single Output (SISO), Single Input Multiple Output (SIMO)and MISO. The MIMO require different numbers of antennas as well as having different levels of complexity.

The simplest form of radio link in MIMO is terms as SISO. The SISO effectively a standard radio channel and operates with one antenna. There is no diversity and additional processing required. However the SISO channel has limited in its performance.

The SIMO version of MIMO occurs where the transmitter has a single antenna and the receiver has multiple antennas and known for receiving diversity. The use of SIMO may be quite acceptable in many applications, but where the receiver is located in a mobile device such as a cell phone handset, the levels of processing may be limited by size, cost and battery drain.

MISO is also termed transmit diversity and the part of the data is transmitted redundantly from the two transmitter antennas. The receiver is then able to receive the optimum signal and used to extract the required data. This has a positive impact on size, cost and battery life as the lower level of processing.

The MIMO can be used to provide improvements in both channel robustness as well as channel throughput. The Multi User MIMO (MU-MIMO)is used toper form more than 2 user equipment (UE) simultaneously as illustrated in fig.3.Consisting of M transmitting antennas used to communicate with K user equipment’s using separate stream for each. The MU-MIMO used in current LTE (TM5) and WLAN (802.11ad). The scale of MU-MIMO will be much larger and also deployment will be more common. The real implementation of MU-MIMO for 5G will be much more challenging.

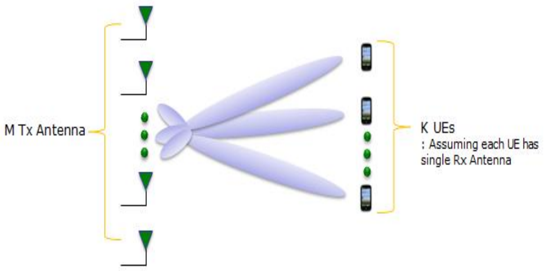

Fig.3. Antenna allocation

The implementation of MU-MIMO is depending on many factors with same number of users and same number of Transmitter/Receiver antenna and there can be different mode of antenna allocation as illustrated in Fig 4. The several factors to be considered for implementation of MU-MIMO are as follows.

- Number of users should be covered using this Antenna
- Number of Transmitters and Receivers antenna are used
- Type of Receiver design
- Type of Pre coding Algorithm

In MIMO system there are two modes which are popular as shown in fig.4. That is utilized in our LTE analyses which are Transmit Diversity mode and Spatial Multiplexing modes. Diversity modes can be used in the receive Diversity or Transmit Diversity side. Wherein received diversity side is simply combining operation of different replicas of the same transmitted signal; Transmit Diversity requires Space Time Coding operation of different transmitted signals. In contrast to the diversity modes, the Spatial Multiplexing mode which refers to splitting the incoming high data rate stream into N transmit independent data rate streams. The Spatial multiplexing modes is most important in the data throughput point of view in LTE system.

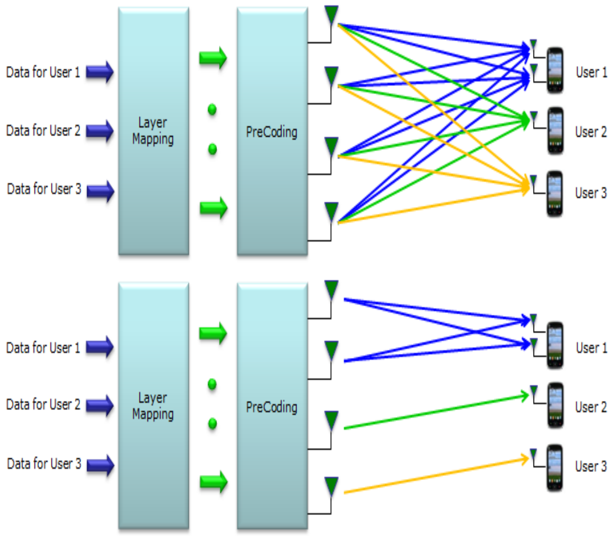

Fig 4. Different Antenna allocation Modes

The advancement technologies in Massive MIMO antenna will be a key feature for the 5G systems. By using more antennas efficiently and effectively, Coverage and the network capacity can be improved significantly. This can be done using the Multiuser massive MIMO with the increase in spectral efficiency which allows more bits to be transmitted per Hz, beam forming and beam-tracking techniques by focusing the energy in particular direction.

The designs of MU-MIMO is promising to significantly to help in both capacity and cell-edge user throughput. The5G not only enable the use of higher frequencies in the 3 to 6 GHz band for macro/small cell deployments, but it will also open up new mmWave opportunities at spectrum bands above 24 GHz for mobile broadband.

The abundant spectrum available at these high frequencies is capable of delivering extreme data speed and capacity that will reshape the mobile experience. However, mobilizing the mmWave comes with its own set of challenges. Transmissions in these higher bands suffer from significantly higher path loss as well as susceptibility to blockage.

The idea of mobilizing mmWave bands is no longer out of reach by utilizing a large number of antenna elements in both the base station and the device, along with intelligent beamforming and beam-tracking algorithms, to showcase sustained broadband communications even for non-line-of-sight communications and device mobility [5]

III. ANTENNA DESIGN

Micro strip antenna consists of very small conducting patch built on a ground plane separated by dielectric substrate. This patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. The conducting patch are designed of any shape like square, triangular, circular, rectangular, however rectangular and circular configurations are the most commonly used [6]. The Micro strip patch antennae can be fed by a variety of different methods. The four most popular feed techniques used for the Micro strip patch are Inset feed, Pin feed, Aperture coupling, Proximity coupling [7]. In this paper a Rectangular inset-fed patch antenna with two slots is designed using a substrate Rogers Ultralam1217 (tm) with dielectric constant of 2.2 which operates at 1.5 GHz, having (2x33) elements for Massive MIMO, which gives a return loss of -39dB with a gain of 8.348 dB suitable for Massive MIMO. To do the design simulations, the HFSS software is used because of its high performance analysis of the full electromagnetic (EM) wave field simulation. HFSS allows us optimizing of antenna structures in a faster way that significantly increases the speed of the design and reduces the intermediate experiments implementation cost.

The Multibeam system is a hardware solution based on a phased-array antenna with increased wireless communications capacity, enhanced spectral efficiency and higher quality of service[8]. This paper focuses on the design and implementation of the active multibeam antenna system for massive MIMO based on digital beam forming technology. A highly integrated multibeam system with 64 RF channels were designed operating at 5.8 GHz in TDD mode with noise figure less than 7dB having a receiver gain more than 60dB. The beamformer provides the required signal phase to all antenna elements in order to generate beams in various directions, which provides a verification platform for massive MIMO channel in the baseband for next generation wireless communication.

The Millimeter wave wireless technology presents the potential to offer bandwidth delivery comparable to that of fiber optics in the spectrum between 30 GHz to 300 GHz, with wavelength between one and ten millimeters. However, in the context of wireless communication, the term generally corresponds to a few bands of spectrum such as 38, 60 and 94 GHz, and more. For the recent development a band between 70 GHz and 90 GHz (also referred to as E-Band), have been allocated for the purpose of wireless communication[9].In this paper a compact millimeter wave massive MIMO dual- band (28/38 GHz) antenna array for future 5G communication systems is proposed. The array has been designed, optimized and simulated using CST program. The antenna consists of 12 arrays arranged in cylindrical shape with 25mm radius and each array is made up of 2*4 dual band antennas. The array was designed using Wilkinson power divider which operates at 28 and 38 GHz and achieves good impedance matching with gain of 12dB and 12.8dB. The simulated results show that S-parameters S11 for 28 GHz and 38 GHz less than -10dB.

A design of 4 port rectangular MIMO [10] antenna using FR4-epoxy which operates at 5-6GHz with optimization Genetic Algorithm to get good impedance matching across ports.

A concept and design of novel compact MIMO slot antenna [11] is implemented with acceptable reflection below –10 dB, but also exhibits over 21 dB isolation between radiators with MIMO. The table 1 gives comparative details of different antennas with thickness, operating frequency, gain and return loss.

Table 1. A comparative study of different antennas.

Type of antenna	Substrate thickness	Operating frequency	Gain	Return loss
patch antenna 2*33	0.16 Cm	1.5GHz	8.34 8 dB	-39dB
cylindrical shape 2*4 dual band, 12array antennas	0.254mm	28GHz and 38GHz	12dB and 12.8 dB	Less than -10dB
Thin planar lens antenna	0.203mm	28GHz	24.2 dBi	Less than -10dB
4 port rectangular antenna	1.6mm	5-6 GHz	10.2 dB	Less than -10dB

The table 1 gives comparative details of different antennas with thickness, operating frequency, gain and return loss. The patch antenna has 2*33 elements, operating at 1.5GHz has a gain of 8.34dB, when the size of array is increased to 12*2*4 elements, the gain is also increased to 12dB at 28GHz. The increased gain using higher order elements at high frequencies is considered to be a key success factor future cellular communication.

CONCLUSIONS

The idea behind increasing the elements number for the array antenna is to enhance the overall performance and signal to noise ratio. This is done by decreasing the return loss to the minimum, enhance the spectrum efficiency, directive gain, increase the antenna diversity which minimizes the fading effect, and extending the coverage range. With massive MIMO it is possible to implement high gain adaptive beam forming to produce the effect of increasing the coverage and create less interference in the system. The Massive MIMO increases the robustness both to unintended man-made interference and to intentional jamming. The adaption of massive-MIMO for 5G is an evolutionary challenge which would affect major change in component design for cellular systems and component design.

ISSN: 2321-8169
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