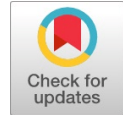


Massive MIMO and Beamforming Techniques of 5G Networks

Ravi Sekhar Yarrabothu, Pitchaiah Telagathoti



Abstract— *The need of wireless communication is increasing day to day life and it is mostly depends on spectral efficiency and bandwidth. The current operating wireless technologies are ranging between 300MHz to 3GHz band; consequently the 5G wireless network depends up on high frequency millimeter wave band ranging between 3GHz to 300GHz. The spectral efficiency can be improved by using Massive Multiple Input Multiple Output (MIMO) Technology. In this paper we are discussing MIMO along with some emerging technologies are present in 5G, they are Millimeter Wave, Beam Forming, and Beam Steering. By using these technologies the capacity is increased, higher data rates will be obtained, latency can be reduced and enhanced quality of service will occur.*

Keywords — *Massive MIMO, Beam Forming, Beam-steering, Millimeter wave, Device to Device, Radio Frequency.*

I. INTRODUCTION

The huge increment of mobile users in the nearer future, the available spectrum is not sufficient. Then we need to find the solution for future use, i.e. The wireless network efficiency need to be increased and it can be done in three ways those are Large number of access points are need to install, It requires additional spectrum and Enlarge the spectral efficiency. The installation of access points and additional spectrum are not the solution for future purpose, other way is to enlarge the spectral efficiency. It can be developed in two ways by using MIMO technology.

- a) In MIMO, the base station consists of hundred of antennas and these are continuously converse with user terminal on the same frequency time slot.
- b) Among the base station and user terminal several data streams are need to transmit.

This survey paper is discussing the wireless technology evolution and 5G technologies, those are *Massive MIMO*, in massive MIMO technology multiple antennas are used at the base station due to this the spectral efficiency is increased, in the presence of multiple antennas the transmission power is reduced and energy efficiency is obtained. *Beam forming* is another technique in which an energy efficient beam is transmits from base station to user terminal in desired direction. The inter cell interference and fast fading effects are reduced by using beam forming. *Beam steering* is another technology in 5G, this technique is widely used in radar systems, here the signals are continuously transmits from base station to the user terminal, when ever user requires to transmit the data, the base station allocates a channel to the user terminal.

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Millimeter wave is also known as millimeter band which is ranging from 30GHz to 300GHz, MIMO technology is used in millimeter waves are obtain more bandwidth. The radar systems, satellite communications, and backhaul are applications of millimeter wave. *Device to Device communication* [2] is one type of technology in 5G, which allows communication among mobiles in cellular networks. D2D communication is used in cellular networks and auto mobile industries. In auto mobile industries several wireless sensor nodes are deployed in to the vehicles and they can communicate with each other like vehicle to vehicle (V2V), vehicle to pedestrians (V2P) and vehicle to network (V2N), all these communications are done with the help of MIMO technology, because the vehicles need to communicate with in time without latency and it is possible by high data rates, these are obtain by using the massive MIMO technology.

II. EVALUTION OF WIRELESS TECHNOLOGIES

Wireless technology was invented in the year of 1985 by Marconi, the first wireless transmission was done by using Morse code signals. The radio frequency waves are widely used in wireless communications. The wireless technology is evaluated as 1G, 2G, 3G, 4G and 5G [3].

A. First Generation(1G)

During the time period of 1970-1980 [4], the first generation wireless phones are used for voice communication purpose, by using these technologies are Advanced Mobile Phone Services (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communication System (TACS), with data rate of 14.4Kbps.

B. B.Second Generation(2G)

Multiple users are allowed to a single channel is known as multiplexing. By using these techniques the second generation abilities are obtained, they are Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). In this generation the data transmission is done with the speed of 9.6/14.4kbps. The data transmission includes both the data and voice.

In order to support higher data rates, General Packet Radio Services (GPRS) was introduced in 2.5G. It has the capability to provide data rate up to 171.2kbps/20-40kbps. In this generation limited mobiles starts to support web browsing, with the help of web applications like multimedia services and streaming are initiate to grown up.

C. Third Generation (3G)

The third generation mobile communication starts support the video calling for the first time on mobile devices by introducing of Universal Mobile Telecommunication System (UMTS). The data transmission provides speed up to 3.1mbps/500-700kbps.

In 3G, other technologies are also implemented, they are CDMA200, Enhanced data rate for GSM evolution (EDGE), these are also supports the multimedia services and streaming.

To enhance the data rates in existing 3G network, another technology is introduced in 3.5G, i.e. High Speed Downlink Packet Access (HSDPA). The 3.5G contributes the high throughput and data rates (14.4Mbps) to the consumers.

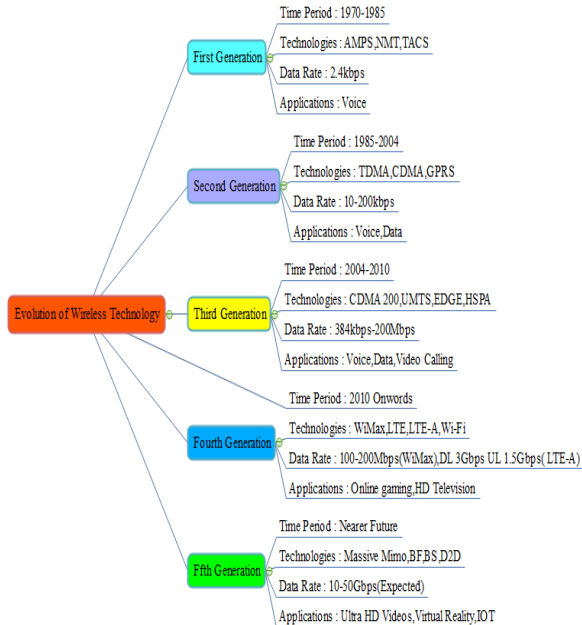


Fig 1: Wireless technology evolution from 1G to 5G

D. Fourth Generation (4G)

Now, the current technologies are WiMax, Long Term Evolution (LTE) and Wi-Fi are introduced in 4G. 3-5Mbps of data rates are provided by 4G. Data rates are having the capability to handle more advanced multimedia services and high definition streaming. In 4G portability, scalability, and mobility are also increased and latency will be reduced for mission critical applications.

F. Fifth Generation (5G)

Now, the 5G technology is not yet introduced to the industry, when it ready to use it will support high data rates and efficient bandwidth, it will available to the customers in nearer future.

III. MASSIVE MIMO

Massive MIMO [1] is an emerging technology, it has been updated with the present MIMO technology. This system contains hundreds of antennas is known as large array of antennas. The main motto behind this technology is to bring out the benefits of MIMO but on a large scale. Thomas Marzetta was demonstrated that very large number of antennas at the base station is greater than the number of user terminals and it will evanesces inter cell interference, fast fading and uncorrelated noise. The massive MIMO system serves tens or hundreds of user terminals by using the hundreds of antennas at the base station in the same time-frequency slot. It is also called as hyper MIMO, large MU-MIMO or Full dimension MIMO system. The antennas uses in this system are anticipates with low cost and efficient use of power. The antenna selection relays on the channel requirements and size of antenna, by reducing the size due to more power is transmitted from transmitter to space.

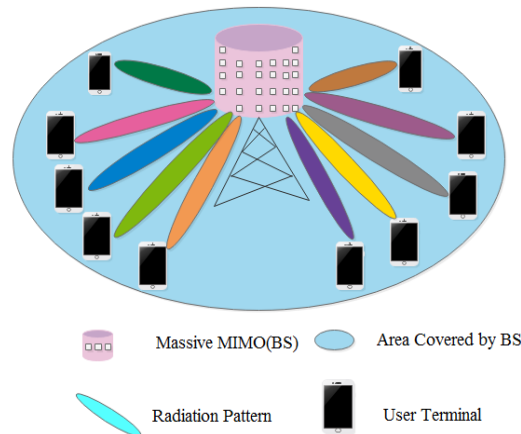


Fig 2: The antennas of base station are directing to each user terminal using Massive MIMO Technique.

Due to the increment of antennas at the base station the spectral efficiency is increased and the reliable communication is obtained by using these systems. The data transmission between the base station and user terminals are done by using the uplink and downlink. In this system, the uplink process is a combination of received signals which provide the large array gains. As shown in Fig 2 in the downlink process the base station contains large number of antennas, those are direct the energy beam into the specific direction to the individual user terminal, due to this magnitude and the signal power can be reduced, hence high energy efficiency is achieved.

The massive MIMO systems are using the simple linear signal processing technique, in this the linear pre coders are used for the downlink process and the linear decoders are used for the uplink process, here the massive antenna arrays are used at the base station are greater when compared to the user terminals, the base station and the user terminal are mutually orthogonal to each other, then the effect of inter cell interference and the noise are vanished.

IV. BEAMFORMING

In the process of beamforming, the antennas arrays are producing signals, main stream of the signals are anticipated to an angular direction from transmit antennas. To increase Signal to Noise Ration (SNR) in the receiver, all the received signals are logically mixed by using different scale factors, all these are mixed up at the receiver. In an antenna array system, the increased gain in SNR is known as beamforming gain [8]. From beamforming gain the variation in the slope of probability of bit error rate is known as diversity gain. A digital signal processor provides more degree of freedom with larger flexibility to execute efficient beamforming algorithms. The digital beamforming requires Analog to Digital (ADC)/ Digital to Analog (DAC) or mixers are use to implement the beam forming methods. In this method each antenna element needs an individual Radio Frequency (RF) chain, it will produce high complex architecture and requires more power hence the cost is also high because of each antenna element needs a separate RF chain.



Multiple data streams are used to transmit the data between Base station and User terminal. The advantage of digital beamforming [6] is, it produces more degree of freedom and less inter user interference as compared to the analog beamforming.

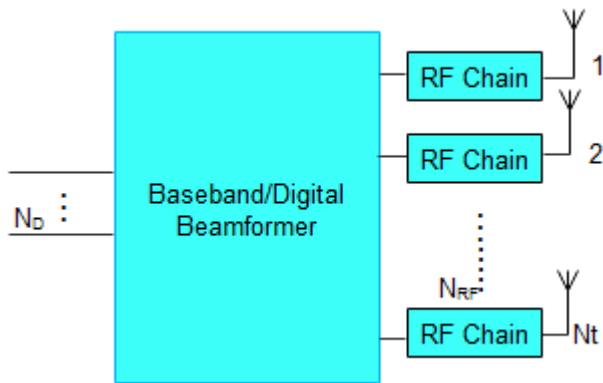


Fig 3: Digital Beamforming

In analog beamforming [7] less degree of freedom is obtain because the limited antennas and phase shifters are used, hence the complexity of analog beamforming is low and less power is required. The single data streams are used to transmit the data between base station and user terminal but the inter user interference is more due to the less degree of freedom.

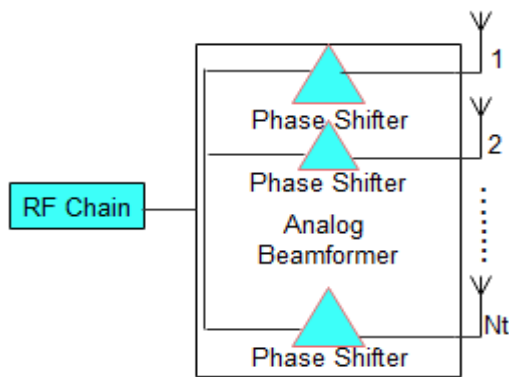


Fig 4: Analog Beamforming

The analog beamforming and digital beamforming methods having their own advantages and disadvantages because of this, another method is required to overcome the disadvantages, i.e. Hybrid beamforming [8] method. The architecture of this method is reduced due to large millimeter wave antenna arrays. There are two types of hybrid beamforming architectures, the first one is, antennas are attached to each RF chain present system, the second one contains group of antennas present in the system that are connected to single RF chain. The advantage of using Hybrid beamforming method is furnishes near optimal performance along with decrease of hardware and signal processing complexity.

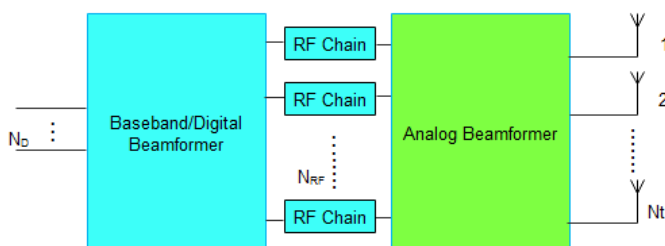


Fig 5: Hybrid Beamforming

V. RESULTS OF BEAM STEERING TECHNIQUES

In telecommunication and radar systems, several applications needed beam steerable antennas. Beam steering is about to shifting antenna elements like phase of RF signal [9]. This technique is needed for millimeter wave applications; they are point to point and point to multi point. The extremely directive beams are required in point to multipoint applications.

The subsequent features are required to obtain most advantageous beam steering method. They are *Insertion Loss*, a new device includes transmission line due to this reason loss will occur, and it will be measuring in DB. This is an important feature of beam steering technique. *Steering speed*, shows the performance of high speed beam steerable antenna and with what speed it will change the direction between nodes in a network. While steering how much range is covered is known as *Steering Resolution*, and range of steering is default or predefined. The Highest possible of angle of beam steering is called as *steering range*, the steering range of systems are fully range or particular angle.

Table 1: Comparison of beam steering techniques

| Beam steering Techniques | Bandwidth Phase Deviation | Insertion Loss | Steering speed | Steering Resolution |
|--------------------------|---------------------------|----------------|----------------|---------------------|
| Mechanical steering | None | None | Minimum | Steady |
| Beam forming | Maximum | Maximum | Maximum | Default |
| Reflect array | Maximum | Medium | Minimum | Default |
| Parasitic steering | None | Minimum | Maximum | Default |
| Integrated lens antennas | None | Minimum | Maximum | Default |
| Switched beam antennas | None | Medium | Medium | Default |
| Travelling wave antennas | Maximum | None | Medium | Steady |
| Retrodirective antenna | None | Minimum | Minimum | Default |
| Metamaterial antennas | None | Maximum | Maximum | Default |

The table 1 represents the comparison of beam steering techniques by using it features. In this different techniques are included, by using these techniques beam steering is implemented. Based on antenna performance the steering speed will be decided.

VI. RESULTS OF USING MILLIMETER WAVE AND OPTICAL WAVE

The higher data rates and additional band width are obtain by using millimeter wave frequency band, due to limitations of present micro wave frequency band higher data rates are not possible. The millimeter wave frequencies are ranging between 30GHz to 300 GHz [10]. This plays a vital role in upcoming technology.

Based on propagation several challenges are appear in millimeter wave band they are *free space loss*, it's equation is given by

$$L_{fs1} = 92.4 + 20\log F + 20\log d \quad (1)$$

Where 'F' is frequency in GHz and 'd' is distance among antennas in Km. This loss is highly effecting the link budget over long distance communication. To defeat these problems extremely directive millimeter wave antennas are needed. Rain drops are affecting millimeter wave frequency, the size of radio wavelengths are similar to raindrops size is known as *scattering*. *Non line of sight* is one of major challenge in millimeter wave, here the travelling signals are requires other ways to reach the receiver because there is no line of sight path present among transmitter and receiver. *Aerospace absorption* is another challenge; it occurs due to presences of gases in air, they are absorbing the channel hence the signal strength get reduces .

To defeat these challenges, an antenna is required for continuous communication with remaining nodes in the network along with it needs capability to redesign radiation pattern to avoid obstacle. To use this solution in 5G system, several challenges are need to determine.

- Approximating the direction of arrival of the signal, because in which direction the antenna need to redesign its beam and it plays a major role in system performance.
- The antenna containing the capability to know the difference among requires signals and noise signals.
- In point to multipoint applications several high density beams are required. To maintain high gain, it needs to reduce the power consumption in undesired direction and supply more power to the desired direction.

The Direction of arrival is classified into three methods, they are conventional beam forming method, subspace-based method and maximum likelihood method.

As shown in Figure 5, the benefit of optical wave over millimetre wave is its ability to offer a much narrower beam, which can be resourcefully steered via diffraction gratings, liquid crystal spatial light modulators.

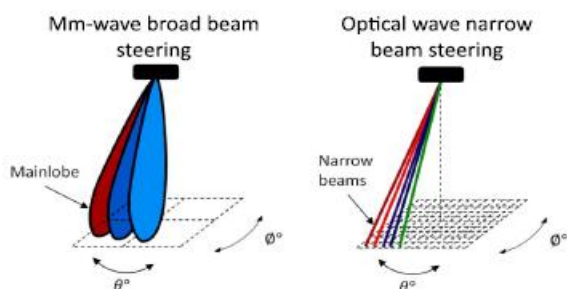


Figure 5. Integration of mm-wave beam steering and optical wave beam steering.

The integration of millimetre wave and optical technologies will enhance the capabilities of 5G in terms of lesser power, higher bandwidth availability and channel efficiency

VII. CONCLUSION

This paper discuss the evolution of wireless technologies, for upcoming 5G network higher data rates are needed, this requirement is fulfilled by using massive MIMO technology. In hybrid beam forming technique highly directive beams are used to obtain more degree of freedom and high energy efficient system. Different beam steering techniques are compared and discussed with the help of properties of beam steering technique. The current microwave spectrum is not enough for future, hence millimeter wave band is used to provide spectral efficiency. In conclusion, the massive MIMO, beamforming, beam steering and millimeter wave technologies are the promising technologies to satisfy the future use of wireless communication systems, radar systems, automobile industry etc.,

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