A study on 5G Technologies

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Abstract: 5th generation wireless technology is given us dynamic speed and much more efficiency. It would create massive improvements in wireless technology's world. Now a days 4G is going on but as a user's and devices are going to increase day by day then in future there is a lot of traffic in 4G spectrum. Moreover, at that time we need a new technology, which is 5G.
in the near future, i.e., beyond 4G, some of the prime objectives or demands that need to be addressed are increased capacity, improved data rate, decreased latency, and better quality of service. To meet these demands, drastic improvements need to be made in cellular network architecture. This paper presents the results of a detailed study on the fifth generation (5G) cellular network architecture and some of the key emerging technologies that are helpful in improving the architecture and meeting the demands of users. This study has been undertaken to make a comprehensive study on 5G technology, existing research work in mobile communication is related to 5G technology and also detailed overview of important technologies that make 5G possible such as beamforming, small cell, Massive MIMO, Fullduplex and millimeter wave.

Index Terms – 5th Generation, Massive MIMO, Small Cell, fullduplex, millimeter wave, beamforming.

1.Introduction:

Mobile wireless industry has started its technology creation, revolution and evolution since early 1970s. In the past few decades, mobile wireless technologies have experience 4 or 5 generations of technology revolution and evolution. The telecommunication service in World had a great leap within last few years. 6 billion people own mobile phones so we are going to analyze the various generations of cellular systems as studied in the evolution of mobile communications from 1st generation to 5th generation. We can analyze that this could be due to increase in the telecom customers day by day. In the present time, there are four generations in the mobile industry. These are respectively 1G-the first generation, 2G- the second generation, 3G- the third generation, and then the 4G- the fourth generation,5G-the fifth second generation. 5G will also provide wireless connectivity for a wide range of new applications and use cases, including wearables, smart homes, traffic safety/control, and critical infrastructure and industry applications, as well as for very-high-speed media delivery. In contrast to earlier generations, 5G wireless access should not be seen as a specific radio-access technology. Rather, it is an overall wireless-access solution addressing the demands and requirements of mobile communication beyond2020. LTE will continue to develop in a backwards-compatible way and will be an important part of the 5Gwireless-access solution for frequency bands below 6GHz.Around 2020, there will be massive deployments of LTE providing services to an enormous number of devices in these bands. For operators with limited spectrum resources, the possibility to introduce 5G capabilities in a backwards-compatible way, thereby allowing legacy devices to continue to be served on the same carrier, is highly beneficial and, in some cases, even vital. In parallel, new radio-access technology (RAT) without backwards-compatibility requirements will emerge, at least initially targeting new spectrum for which backwards compatibility is not relevant. In the longer-term perspective, the new non-backwards-compatible technology may also migrate into existing spectrum.

1.1.MILLIMETER WAVES

All wireless electronic communication devices use specific frequency band, which is called spectrum. Typically it's up to 6GHz but nowadays this frequency spectrum get more crowded because day by day number of user and devices are increase so high. Carrier going to send a large amount of data on same range of frequency spectrum.[1] System going to provide slow service and more drooped connection. The solution is open some new range of frequency and here millimetre waves comes into picture. Range of millimetre waves is up to 300 GHz. This section on spectrum is never been used before. If this new range of spectrum will be, open that mean more number of bandwidth foe more number of users.[2] However, there is one main drawback of millimetre waves. These waves cannot travel through walls or any other obstacles. These waves easily observe by weather. Therefore, for solution need of small cells occurs.

1.2.SMALL CELL

Today wireless network travel large high power cell tower to broadcast signal, over long distance. Where, millimetre waves not able to traveling through obstacles, which means if devices are behind the any obstacles they lose signal. Small cell networks solve that problem. Using thousands of small tower mini base station. These small cell mini base stations are much closer together then traditional tower. So small cell able to transmit signal around the obstacles. This is specially use in cities.[3] As user moves around the obstacles this device, get automatically switched from one nearest small cell to another nearest small cell.

1.3.MASSIVE MIMO

MIMO stand for multiple inputs multiple outputs. Today's cellular base stations have dozen port of antenna for handling cellular traffic. Where MIMO base station can support 100 ports of antennas.[4]This can improve today's network capacity by factor of 22 or more. MIMO comes with its own drawback. MIMO antennas able to transmit information in all direction at ones and this entire signal get a serious interface which brings a new technology Beamforming.

1.4.BEAMFORMING

The Beamforming is like a traffic signal in system. Its broadcasting signal in every direction it would allow to base station to send focused stream data to specific user. This precision prevention system is more efficient. That mean station can handle more incoming and outgoing data at once. Process of this system is as follows. Supposed two or more devices are in city around the obstacles and make call.[5] So first massive MIMO collect that data and send to specific user with specific data sending algorithm that means Beamforming through which direction of data is where user want to send it which brings new technology full duplex communication.

1.5.FULL DUPLEX

In one scenario data can either transmit or either receives. This is call half duplex communication like walky-talky. Today's cellular base stations have same that problem. This is because of reciprocity principle. If you transmit data on radio frequency then it travel forward or backward on same frequency. So two devices are send data at a same time so error occurs because of reciprocity principle.[6] For solution researchers use silicon transistor to create high speed switches. This silicon transistor allows two user to transmit data at ones.

2.Literature review

Every new wireless technology gives faster speed and more functionality. 1st generation wireless technology for first cell phone. 2nd generation wireless technology gives text first time. 3rd generation wireless technology gives online platform and 4thgeneration technology which is nowadays every one using is deliver speed 1st generation wireless network introduced around 1980's up to 1990. This network give voice only cellular calls with speed up to 2.4 Kbps. AMPS,NMT,TACS this is all those technologies which used in this network. in 1st generation analog band width used. First time any network able to make calls . 1st generation network is first wireless network. There is also some drawback of this network. There is no room for spectrum enhancement. Also privacy is less in 1st generation network. capacity of calling is also less in 1st generation network.[7] and this of generation wireless technology is GSM based. Difference between 1G and 2G is analog signal used in 1G where digital signal used in 2G.This technology introduced around 1991. TDMA,CDMA technology which is used in 2G. 2G gives speed around 64 Kbps. Quality of sound is increased in 2nd generation network and also noise is reduced. Fist time SMS (short message service) and Email is established by 2nd generation network. There is also drawback of 2nd generation network. In this network signal easily dropped. 2G is based on digital signals and this digital signals are so weak so there for some time signal not reach up to tower. This generation network has low data handling capability.[7] 3rd generation technology introduces around 2000.WCDAMA/CDMA is technology which is used in 3G. Maximum speed of 3G is around 21.6 Mbps. In this network quality of digital voice signal is increased. 3rd generation is use large band width. In this network first tine able to do video conferencing also this network support TV to internet. There is also some drawback of 3rd generation network. Main drawback is cost because establishing of 3rd generation is so high. its require more band width. For proper connection more number of tower is required so initial cost of 3rd generation wireless network is so high. [8] 4th generation wireless network is packed switched wireless system with wide area coverage and high efficiency . 4G is more cost effective and high speed network. its provide speed around 20Mbps. Frequency band is used 2 to 8 GHz, this is the main advantage of 4th generation wireless network high speed. This network has low cost per bit and good spectral efficiency. 4th generation of wireless network provide high quality of service and high security. There is also some drawback of this network. Battery consumption while using 4G is so high. this network is hard to implement. Signal dropped so many times because it has high frequency. It need complicated hardware and very expensive to implement. it also required more number of towers.[8] But as more user come online 4G reach up to its limit in future and that's why need of 5G occurs. It will be able to handle thousand time more traffic compare to today's network and able to give speed ten times more. It will able to give more functionality and revaluation in some fields like virtual reality, automation driving, internet of things, online robotic surgery many more. Right now five brand new technologies immerging as a foundation of 5G and these technologies are as fol**low:**

1. **Beamforming**:

is a method used to generate the radiation pattern of an array antenna by adding constructively the weights of the signals in the direction of SOI and nulling the pattern in the direction of SNOI (interference).But this array can be antennas in the smart antennas context, or any other types of sensors (radars, medical sensors...etc) can be an array of microphones in the speech signal processing context. Beamforming can be employed at both the transmitting and receiving ends in order to achieve spatial selectivity i.e., an appropriate feeding allows antenna arrays to steer their beam and nulls towards certain directions, this is often referred to as spatial filtering.

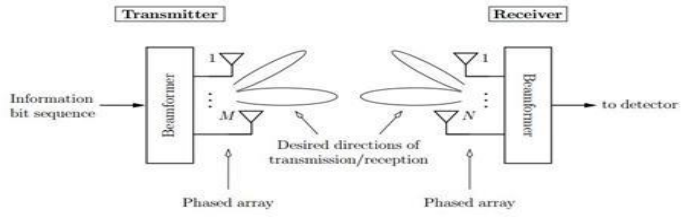


Figure 1: Beamforming Technique.

Smart antennas that can be controlled automatically are normally used according the required performance and the prevailing conditions.

Smart antennas can be divided into two groups:

Phased array systems:

Phased array systems: are witched and have a number of pre-defined patterns - the required one being switched according to the direction required. **Adaptive array systems (AAS):** This type of antenna uses what is termed adaptive beamforming and it has an infinite number of patterns and can be adjusted to the requirements in real time. MIMO beamforming using phased array systems needs the overall system to determine the direction of arrival of the incoming signal and then switch in the most appropriate beam. This is something of a compromise because the fixed beam is unlikely to precisely match the required direction. Adaptive array systems are able to direct the beam in the exact direction needed, and also move the beam in real time - this is a particular advantage for moving systems - a factor that often happens with mobile telecommunications. However, to eliminate the multiuser interference (MUI) in the multiuser multi-input multi-output (MIMO) system, different criteria have been proposed to design transmitter and receiver beamforming algorithms . An iterative beamforming algorithm has been proposed in [6] based on duality relation between downlink and uplink and in [26], by defining the difference between desired signal power and interference plus noise power as an utility function have been proposed for multiuser MIMO downlink systems. In contrast to analog beamforming, the digital beamforming technique can produce a large number of high-gain beams without degradation in signal-to-interference-plus-noise ratio (SINR). A digital beamforming technique can substitute the complex hardware functions of a beamforming network by using software algorithms implementable on digital signal processors. This is especially attractive to satellite communications since only a new suite of software has to be uploaded to the operating satellite if the beams require some modifications. For wireless communications different digital beamforming strategies have been proposed. They can be categorized into two classes: fixed digital beamforming and adaptive digital beamforming. For the fixed digital beamforming technique the weights of the antenna array are designed in advance and kept unchanged during operations. But for the adaptive digital beamforming strategies the weights are adjusted adaptively with the operating conditions. Nevertheless, it is expected that adaptive beamforming algorithms can provide a further enhancement of system capacity because of their adaptive interference nulling capability. In addition, these two major classes can be further divided into four digital beamforming strategies, namely, 1) single fixed beam/single user, 2) single fixed beam/multiple users, 3) single adaptive beam/single user [28], and 4) single Chebyshev dynamic beam/multiple users [28, 29]. While these four schemes are based on either fixed or adaptive beams, their deviation lies in the use of a single beam for multiple users or a single user. On the other hand, many adaptive beamforming algorithms have been developed in the literature. Among them, a popular one is minimizing the system output power subject to multiple linear constraints [30], and a penalty function method can be used to overcome the weight jitter and high sidelobe problems [24].But for large arrays as in satellite communications, techniques such as the contiguous [32] and overlapping [29] subarrays have to be considered. One modern category of adaptive beamforming is neural beamforming where adaptive processes are carried out using neural networks (NN) for real-time parallel processing. Different neural networks (NN) models have been proposed in the literature. For instance, the Hopfield NN (HNN) can realize the minimum mean-square error beamforming based on a neural optimization [31]. Another technique uses a feedforward NN to approximate the input-output relationship for beamforming [32].However; the implementation of digital beamforming in large-scale antenna systems is a great challenge because of its complexity, energy consumption, and cost. So, in a practical large-scale antenna deployment, hybrid analog and digital beamforming structures can be important alternative choices. That's why, it is expected that large-scale antenna systems with hybrid beamforming structures in the mm Wave band can play an important role in 5G.

2. Millimetre Wave (Mm Wave) :

The progression of the mm-wave bands is one of the most pressing solutions for 5G mobile radio networks. Nowadays the ever growing use of smart devices and also with the new innovative applications, the demand of data traffic is anticipated to increase over current targets by 1000x in 2020 and 10000x by 2025 [17]. The mm-wave band in the 30- 300GHz frequency range is being taken into account for proceeding 5G to achieve 1000 times more data traffic [18]. Due to the advancement of semiconductor technology helps to open scopes for low cost manufacturing and low power consumption of mm-wave components [19]. As a result, mm- wave systems offer a much higher frequency bands and more bandwidth than available in 4G networks. However, the use of mm-wave technology is limited because of harsh propagation conditions. So high path loss happens that reduces receive volume signal because receive antenna size is small to support short wavelength and high thermal noise decreases SNR that brings about from wider bandwidth. Also loss comes about more than that of below 3GHz band by water vapor (H2O), oxygen, rainfall and foliage of signal attenuation [20]. Hence, to minimize these propagation limitations, the system architecture and antenna structure should be effectively planned and also to increase capacity by the utilization of radio resources in the mm-Wave band in 5G mobile communication system. Beam forming technology on patch antenna array can be followed to be a solution for propagation limitations of mm-Wave communication system. 4G small cells will be deployed at street-level using micro/Pico base stations deployed on lamp posts and sides of buildings.

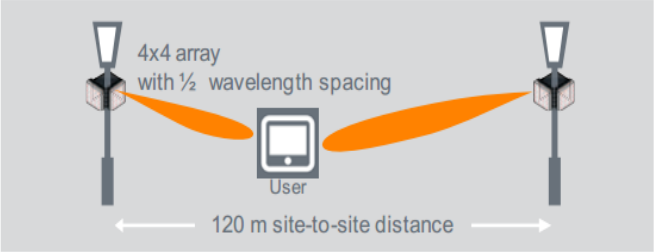
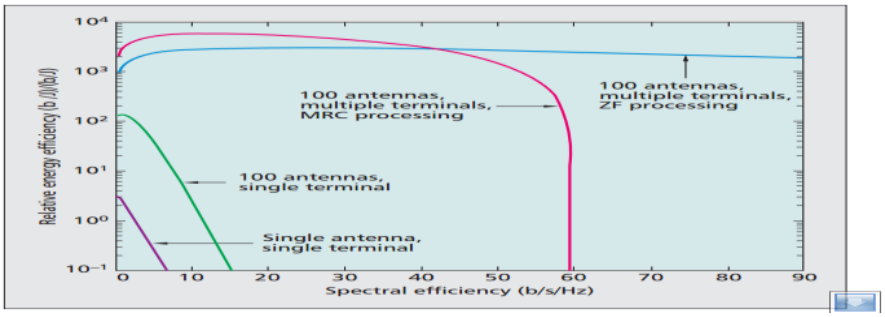


Figure 2: typical mm-wave street level deployment [6]

A Pico base station will be deployed every city block or roughly 120 meter site-to-site. The mm-Wave system idea is aimed to work out this small cell deployment by using higher frequency cellular transceivers co-located with the 4G base stations. These mm-Wave transceivers can simultaneously provide backhaul for 4G and also access for 5G [21]. Observation should also be focused on dynamic channel effects which will competent of power for 5G mobile networks due to rise of Doppler influence at mm-waves. Besides, for moved mobile devices as well as shadowing caused by moving person's impact will require to be measured. These effects introduce a significant time variance to the mm wave channel [22].

3. Multiple Input Multiple Output (MIMO) :

The ultimate actualization and work out of the 5^{th} generation (5G) radio access network with a super high bit rate and high capacity depend on the need of small cells utilizing both higher frequency bands and Massive MIMO technology. The current advancement of smart phones and the diversity of mobile applications and ministrations have resulted a broad explosion in the amount of mobile data traffic, and higher capacity transmission has turned out an obvious requirement. By 2020, outstanding contribution enhancements in radio access technologies and networks are essential for the 5^{th} generation (5G) mobile communication networks in order to make ready for the 1000 fold rise in the data traffic volume expected over the following 10 years [8], [9]. The proposal of Phantom Cell idea was to materialize the super high bit rates that overcome tens of gigabits per second and high capacity in the 5G networks [10] and furthermore which is distinguished by sum up small cells using higher frequency bands to a macro cell in a present cellular system. Most importantly, macro cell accommodates lower rate communications with high stability and to supply higher frequency bands easily, the small cells provide super high bit rates utilizing a much spacious bandwidth of over hundreds of megahertz. That's why, massive MIMO transmission techniques are needed to place such growing bit rates in small cells. Massive MIMO is an expectant technology that accommodates a very huge number of antennas, e.g., over 100 for 5G super high bit rate radio access [11], [12]. It is given in [13] that, MF-based non- cooperative Massive MIMO systems acquire an average throughput of 730 Mb/s per cell and total spectral efficiency of 26.5bps/Hzwithadatarateof17Mb/sforeachof40 subscribers in a 20 MHz channel in both uplink and downlink locations under realistic propagation considerations. AS a result, the Massive MIMO provides the higher beam forming (BF) gain that actually makes up the larger propagation loss in the higher frequency bands. Besides, to attain the super high bit rates, Massive MIMO can spatially multiplex a larger number of data streams. In recent past, Massive MIMO has obtained effective momentum to rise capacity in multi-user networks as potential candidate. Within limitations, the system processing gain goes to infinity as the number of base stations (BS) antennas reach to infinity. Because of that, both noise and multi-user effects can be eliminated [14]. Massive MIMO also performs consisting latency reduction on the air surface and in addition to an important feature for delay-constrained applications [15]. Another merit of Massive MIMO is that, the same frequency band can be reused for many users. This plus the channel hardening render frequency domain scheduling no longer needed .



Half the power-twice the force (from [9]): Improving uplink spectral efficiency 10 times and simultaneously increasing the radiated power efficiency 100 times with massive MIMO technology, using extremely simple signal processing, taking into account the energy and bandwidth costs of obtaining channel state information.

4. Small cell:

A small cell is basically a miniature base station that breaks up a cell site into much smaller pieces, and is a term that encompasses Pico cells, micro cells, femtocells and can comprise of indoor/outdoor systems. With a macro base station, there's one pipe going into the network; with small cells, it breaks the pipe into many pipes. The main goal of small cells is to increase the macro cell's edge data capacity, speed and overall network efficiency.
Small cells were added in Release 9 of the 3GPP LTE spec in 2008, and are one element of network densification, or adding more base station connections to the existing wireless infrastructure.
Small cells are typically used in very densely populated urban areas, such as shopping centres, sports venues, airports and train stations – basically anyplace you have a lot of people using data at a given point in time. Most small cell infrastructure deployments are targeted for outdoor use today. In contrast, indoor small cell systems may or may not incorporate Wi-Fi or unlicensed LTE bands (LTE-U)/Licensed Assisted Access (LAA), depending on the capabilities that service providers want to support. Small cells help in this pre-5G/LTE-Advanced Pro (LTE-A Pro) transition because they:

- Provide increased data capacity
- Help service providers eliminate expensive rooftop systems and installation or rental costs, which reduces the overall cost
- Help improve the performance of mobile handsets. If your phone is closer to a small cell base station, it transmits at lower power levels, which effectively lowers the power out of the cell phone and substantially increases its battery life.

There's currently a lot of discussion that true 5G will operate at higher frequency bandwidths, such as 28 GHz or 39 GHz. Small cells will also be critical at these millimetre wave (mm Wave) frequencies because the signals cannot penetrate walls or buildings and the cell sizes will have a coverage radius of less than 500 meters. Years down the road, there may be an overlay for those 5G networks, on top of the systems used for small cells today.

5. Full duplex:

Today's base stations and cell phones rely on transceivers that must take turns if transmitting and receiving information over the same frequency, or operate on different frequencies if a user wishes to transmit and receive information at the same time. With 5G, a transceiver will be able to transmit and receive data at the same time, on the same frequency. This technology is known as full duplex, and it could double the capacity of wireless networks at their most fundamental physical layer: Picture two people talking at the same time but still able to understand one another—which means their conversation could take half as long and their next discussion could start sooner. Some militaries already use full duplex technology that relies on bulky equipment. To achieve full duplex in personal devices, researchers must design a circuit that can route incoming and outgoing signals so they don't collide while an antenna is transmitting and receiving data at the same time. This is especially hard because of the tendency of radio waves to travel both forward and backward on the same frequency—a principle known as reciprocity. But recently, experts have assembled silicon transistors that act like high-speed switches to halt the backward roll of these waves, enabling them to transmit and receive signals on the same frequency at once. One drawback to full duplex is that it also creates more signal interference, through a pesky echo. When a transmitter emits a signal, that signal is much closer to the device's antenna and therefore more powerful than any signal it receives. Expecting an antenna to both speak and listen at the same time is possible only with special echo-cancelling technology. With full duplex and other 5G technologies, engineers hope to build the wireless network that future smartphone users, VR gamers, and autonomous cars will rely on every day. Already, researchers and companies have set high expectations for 5G by promising ultralow latency and record-breaking data speeds for consumers. If they can solve the remaining challenges, and figure out how to make all these systems work together, ultrafast 5G service could reach consumers in the next five years.

2.1. Theoretical Framework:

5G Technology is a name used in various research papers and projects to indicate the next most important stage of mobile communication standards beyond the 4G standards Presently, 5G is not a term officially used for any particular specifications. 3GPP standard release beyond 4G and LTE [1]. The implementation of standards under a 5G umbrella would likely be around the year of 2020.

Key terms of 5G Technology:

1. 5G is a completed wireless communication with almost no limitation; somehow people called it real wireless world
2. Additional features such as Multimedia Newspapers, also to watch T.V programs with the clarity as to that of an HD T.V.
3. We can send Data much faster than that of the previous generations.
4. 5G will bring almost perfect real-world wireless or called "WWWW: World Wide Wireless Web
5. Real wireless world with no more limitation to access and zone issues.
6. Wearable devices with AI capabilities.

7. Internet protocol version 6 (IPv6), where a visiting care-of mobile IP address is assigned according to location and the connected network. [23]
8. One unified global standard.
9. Pervasive networks providing ubiquitous computing: The user can simultaneously be connected to several wireless access technologies and seamlessly move between them (See Media independent handover or vertical handover, IEEE 802.21, also expected to be provided by future 4G releases). These access technologies can be a 2.5G, 3G, 4G or 5G mobile networks, Wi-Fi, PAN or any other future access technology. [9] In 5G, the concept may be further developed into multiple concurrent data transfer paths. [10]
10. Cognitive radio technology, also known as smart radio: allowing different radio technologies to share the same spectrum efficiently by adaptively finding unused spectrum and adapting the transmission scheme to the requirements of the technologies currently sharing the spectrum. This dynamic radio resource management is achieved in a distributed fashion, and relies on software defined radio. See also the IEEE 802.22 standard for Wireless Regional Area Networks. [24] 11. High altitude stratospheric platform station (HAPS).

3. CONCLUSION

5th generation technology going to revaluation in wireless technology. So there are technologies which enables 5G and pave the way for a better and more reliable internet, experts are still working on this five technology. So here in this paper I had present the important detailed over view regarding each technologies separately which are named as Millimetre waves, small cell, massive MIMO, Beamforming, full duplex, this all technologies are still in progress. It would also include some new technologies. All of this system work together it would be a challenge. Mobile has become the essential part of our everyday life. Their current development is the outcome of various generations. In this paper we also review the various technologies, which they are being used in various network generations, This field is still full of research opportunities and research on upcoming technology 5G is carry on which is coming in.

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