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5G - Current Developments and What to Expect

Rajat Yadav[1]
School of Information Technology and Engineering
Vellore Institute of Technology
Vellore, India

Garvit Kataria[2]
School of Information Technology and Engineering
Vellore Institute of Technology
Vellore, India

Abstract:- There have been plenty of developments in the field of mobile technologies in the past few years that has ultimately led to the current technology of 5G. It is being deployed by numerous telecommunication companies around the world. There are a few places where it is currently in use and under testing phase in others. The evolution of wireless cellular technology brought us faster data speeds and services. Many challenges will be faced before 5G becomes a household for every smartphone. With leading companies launching 5G compatible phones and worldwide recognition of this novel technology, it is important to understand the challenges and future opportunities in this domain. This paper has thrown light on the evolution of wireless mobile technologies, the concept of 5G, its challenges, further development opportunities and a proposed solution which can help overcome drawbacks of 5G and make it available to the mass.

Keywords:- *MIMO, mmWaves, Precoding, Spatial Multiplexing.*

I. INTRODUCTION

The need for 5G arises from the growing need for higher communication speed between various data sources like space technology, applied gaming applications, military services. Until the era of 3G, ping was not given major attention, but now there is a growing need for minimum ping and latency. 5G focuses on these major issues, which were not considerable attention in previous generations. It also focuses on maximum users covered under the minimum surface area of land covered.

The major change in technology from 4G to 5G is the use of massive MIMO[1], where MIMO stands for multiple input multiple output. In massive MIMO, there are a large number of transmitters and receivers, which enables the carrier signal of mmWaves to transmit in a minimum amount of time and minimise latency. mmWaves are extremely high-frequency waves, generally greater than or equal to 24GHz. These high frequency waves lead to a higher power.

mmWaves lead to a major limitation of 5G technology, which is less effective range of carrier signals. With an increase in frequency, the range of the signal tends to decrease, which is leading to plantation of a large number of 5G[2] transmitters across a 5G established city, giving rise to massively increased cost.

In the late twentieth century, the novel idea of mobile telecommunication was brought to the world, vigorous research and development have been going on since to provide us with mobile technology as we know it today. 1G was the advent of wireless technology which used analog signals. 1G focused on making phone calls (point to point communication) using satellite transmission, and the device used were basic satellite phone, which had only calling and voicemail features. We then progressed to 2G which leapt into digital signals from analog ones in the previous generation. The main addition in 2G from 1G was the introduction of internet services using digital signals, using the EDGE (Enhanced Data rates for GSM Evolution) technology. 3G mainly focused on increasing internet speed compared to EDGE using HSDPA (High Speed Downlink Packet Access) with the highest speed being 7.2 Mbps. 3G also focused on making video calls. 4G further focused on increasing speed using LTE (Long Term Evolution) and improving voice quality using VoLTE (Voice over LTE). Maximum real world speed of 4G observed is 60 Mbps. Now, 5G uses massive MIMO (Multiple Input Multiple Output), which focused on further increasing the speed, which is observed 1.5 Gbps in real world scenarios.

Mobile and wireless systems have made exceptional growth in the last decade. Now, more than 60% of the mobile phones available in the market have a WLAN adapter too. It is not surprising that upcoming mobile phones might have WiMAX adapter too, along with WLAN, Bluetooth,3G and 2G adapters. The idea of using 2.5G/3G Public Land Mobile Networks (PLMN) on one end and WLAN (Wireless Local Area Network) on the other, fostered analysis on their integration and using it together. In the case of 4G, it focuses on flawless integration of previously used cellular technologies such as GSM and 3G. Though QoS (Quality of service) support is a challenge in all wireless technologies, 4G requires multimode user terminals but safety mechanisms are different. Even though the integration of different wireless networks such as PLMN(Public Land Mobile Network) and WLAN(Wide Local Area Network) is still in practice nowadays, still several wireless systems from a single terminal are used exclusively. Blending of various wireless access technologies for the same session does not exist (e.g. download over FTP). Open Wireless Architecture (OWA) focusses to give open baseband processing modules along with open interface parameters to provide present and future wireless communication standards.

Fifth-generation wireless[3] (5G) is state of the art advancement in cellular technology, directed to greatly increase the bandwidth and responsiveness of wireless networks. Data transferred over wireless broadband connections can travel at rates as high as 20 Gbps, transcending wireline network speeds and it offers latency

of 1 ms or lower for applications that need real-time feedback. 5G also supports a definite increase in the volume of data transmitted over wireless systems due to higher available bandwidth and exceptional antenna technology.

In addition to advancements in speed, capacity and latency it allows network administration novelties, amongst them network slicing, which enables mobile operators to build multiple virtual networks within a single physical 5G network. This ability will aid wireless network connections to maintain specific uses or business cases and could be sold on an as-a-service basis. For eg., A self-driving car would need a network slice that is extremely fast, low-latency links so a vehicle could operate in real-time.

II. BREAKTHROUGH OF MOBILE TECHNOLOGIES

There has been a great breakthrough by mobile technologies over the past decade. Mobile technologies have evolved to be of very significant use in our day-to-day life. The continuous innovations have led to a number of generations of mobile technologies and is still going on till date. The evolution of wireless mobile technology started from 1G[4] followed by 2G, 3G, 4G, and 5G is currently in the testing phase by various companies in different areas of the world.[5]

A. 1G - First Generation

1G was the first generation of wireless mobile technology which was also known as AMPS(Advanced Mobile Phone System). The main characteristic of 1G was that the radio signals used by 1G were analog. It was introduced in 1979 till the mid-1980s. The voice during a call is modulated to a higher frequency (150 MHz and above). 1G supported only voice calls. It was eventually replaced by 2G. The maximum speed of 1G is 2.4 Kbps.

B. 2G - Second Generation

The second generation of wireless cellular technology was launched in 1991 on the GSM standard in Finland. Radio signals on 2G are digital, unlike 1G, which were analog. There are many advantages of 2G over its predecessor, which include digital encryption of call and text, and data services like SMS, picture messages and MMS. 2G also used the radio frequency spectrum more efficiently and enabled more users in one frequency band. The maximum speed of 2G with GPRS is 50Kbps. GSM (Global System for Mobile Communications) was the technology developed for 2G cellular standard. GSM used a digital TDMA (time division multiple access approach) to provide a system that would enable greater capacity to be achieved than the previous first generation analog systems. It used circuit switching. Circuit switching is connection oriented which means that a path is established between source and destination before the transmission starts. GSM is a PLMN (Public Land Mobile Network).

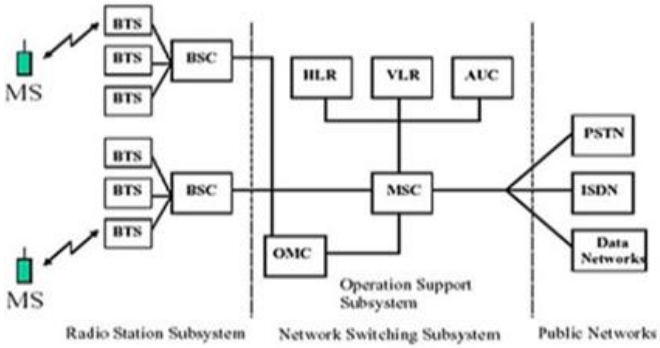

Fig 1:- Schematic diagram of a typical 2G network

C. 3G - Third Generation

3G was introduced in 1998 and brought with it faster data transmission speeds up to 7.2Mbps and minimum consistent speed of 144Kbps. It was launched for commercial use in 2001. Mobile phones with 3G[7] can be used for video calling and mobile internet access with the advent of 3G. It uses Wide Band Wireless Network. GSM Technology was improved to transition from 2G to 3G. 3G(UMTS (Universal Mobile Telecommunication Services), CDMA2000) is a more advanced form of 2G with a higher data rate. CDMA (Code-division Multiple Access) is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, which will optimize the use of available bandwidth. 3G is based on two parallel infrastructures which consist of packet switching along with circuit switching, which is the main technological difference from the previous generation, which used only circuit switching. In packet switching, the path is a dynamic route which is decided during transmission.

D. 4G - Fourth Generation

The fourth generation[8] of broadband cellular technology was released in 2008 is the current technology being used in most parts of the world. It offers a downloading speed of 100Mbps. This is a huge leap in networking speed from the previous standard. 4G offers a range of data services like HD video streaming, high quality gaming services, 3D TV, video conferencing. Long Term Evolution (LTE) is a 4G standard. 4G is capable of providing speed of 50Mbps theoretically. 4G system does not support the circuit-switched telephony system, rather it is based on IP packet-switched telephony.

III. EVOLUTION OF 5G

The idea for the need of a newer generation of mobile network comes from the growing requirement of internet in the world in various fields like space exploration, software development, advancement in cameras and videography tools, Internet of things (IoT), Big data transfer from different points of the world to another, et cetera. Hence, the need for 5G arises. Initial developments started way back in April 2008 when NASA along with Geoff Brown and Machine-to-Machine Intelligence (M2Mi) corp partnered to develop 5G technologies. 5G started to use a newer technology from 4G: Massive MIMO[9]: multiple

input multiple output targeting to improve coverage, bandwidth and speed. It groups the antennas together for levelled up throughput and spectrum organization. Massive MIMO basically increases the input sources, so as to get large inputs in a shorter period of time. Ericsson AIR 6468 reportedly used 64 transmit antennas and 64 receive antennas, while ZTE tested with 128. MIMO[10] was invented in 1993, which was a huge boost in networking technology then, but it wasn't ready for roll out in massive amount, now, it is refined highly. MIMO has three divisions.

A. Spatial Multiplexing

A high rated signal is divided into many low rated, and every single one of them is transmitted from a different antenna in the same frequency. Once the signals reach the receiver, provided that the receiver has accurate channel state information (CSI). Another use of Spatial multiplexing is that it can be used for transmission to many receivers at a given point of time, which is called as space-division access or multi-user MIMO.

B. Precoding

When the concurrent signals[11] emit from the transmitter, provided that gain and phase are in given limits, so as to maximize signal receivers side. It helps in stepping up the received signal. However, transmitted cannot maximize the signals at one given point of time. Precoding using many streams at a single point of time is helpful.

C. Diversity Coding

Diversity coding is used when there is no CSI at the transmitter. A single network stream is transmitted and it is coded using an approach called space-time coding. Diversity coding uses the fading of multiple antennas to increase signal diversity. Due to no CSI, no beamforming or array gain is noticed in diversity coding.

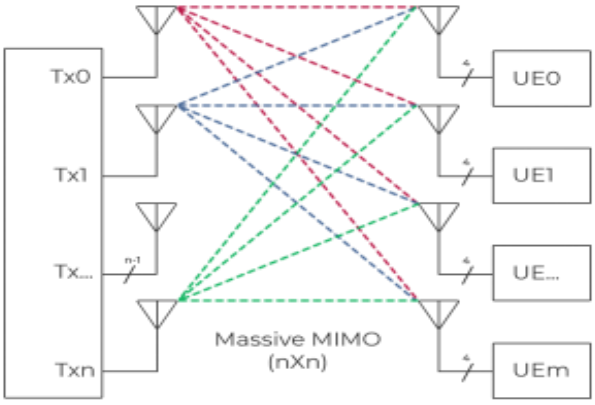

Fig 2:- Massive MIMO Architecture

IV. CURRENT DEVELOPMENTS

While the 5G network has already launched in cities like Chicago, Minneapolis, Providence, Washington DC, New York City, it is expected to launch soon in Los Angeles, Las Vegas. Cities which currently have 5G[12] are getting a high speed of download as 1.83 Gbps and upload speed of 152 Mbps. Though these speeds show remarkable downfall when the antennas are not in direct line of sight of the receiving device, which remains as the biggest challenges of 5G. Most of the companies are using frequency bandwidth[13] of 28GHz - 39GHz mmWave[14] for their 5G network and due to these high frequencies, the range becomes really less. Since frequency and wavelength show inverse relation with each other, the higher the frequency, the shorter the wavelength because of energy lost due to excessive collision between particles of air and photos of the wave.

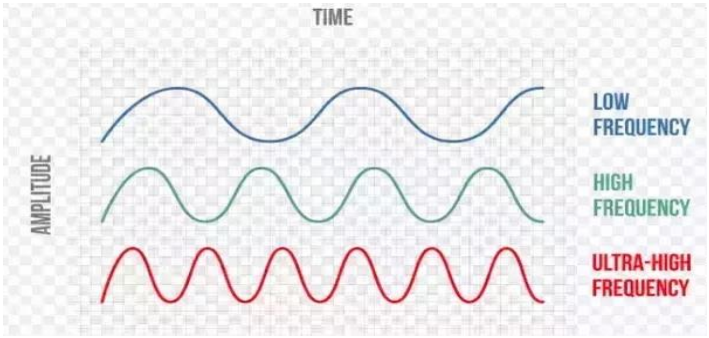

Fig 3

Companies and researchers around the world have been trying to tackle this constraint because testers are seeing a drastic drop in speed (as much as 7.5 times) when even the slightest of obstacle comes in the path of receiver and transmitter. To overcome this problem, companies plan to put 5G sites on every corner of the city so that every point in the city is in direct line of sight of one or the other 5G antenna. This would mean deploying 100s of 5G antennas with massive MIMO technology which would be ridiculously expensive for the company and to the customer.

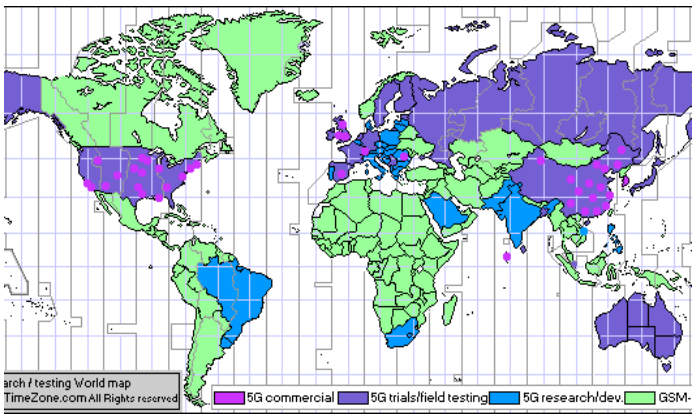

Fig 4:- Current 5G coverage (December 2019)

V. PROPOSED LOW COST SOLUTION

Mobile companies usually think of routers as strictly home or office appliance, but if we think about it, they can be a massive help for cost reduction in outdoor units of 5G transmission as well. 5G providing companies are planning to deploy an enormous amount of antennas all across the cities to tackle the problem of the low effective range given by one antenna. Instead of deploying antennas as repeaters all across the city, what we can do is to deploy high-speed wireless routers as repeaters[15], which would cost less than half of what it would cost for antennas[16]. Router manufacturing companies are providing routers for as low as $200 and speed as high as 3.2 Gbps, which comes under the cap of the maximum speed of 5G networks all across the world. The router will basically act as hotspots, but with a very high speed of 5G[17] compared to current standard hotspots deployed. There are currently few similar architectural models deployed in our daily life, for example, a college X uses high speed internet throughout the campus using modems as hotspots and only one or two transmitters. These modems receive the signals by a parent modem and transmits it to another modems, of which it acts as a parent. Although, there might be drawbacks like the upper limit of users connected to a hotspot at a time and time taken for users to disconnect from one hotspot and connect to the other while they are travelling. Companies will have to look into these drawbacks and work on how to improve them.

Fig 5:- A typical high speed Wi-Fi router

Many big cities and smart cities have shown interest in making the city connected through Wi-Fi hotspots instead of carrier data package using the current 4G network due to high data rates, but this can be seen as a solution to the high cost factor of 5G[17]. Some companies are even deciding on switching to Wi-Fi calling from standard carrier calling.

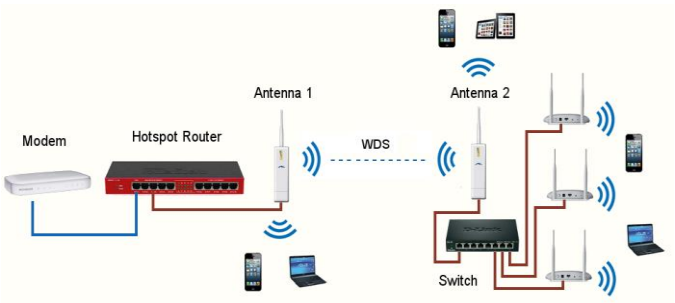

Fig 6:- Model architecture of a hotspot network

VI. SUMMARY

The world is currently taking a leap from 4G to 5G. With the ever-growing number of internet users and devices, 4G has reached its maximum serving capacity. The demand for higher speeds is also growing which introduces the need for a faster data communication standard. 5G operates in the Extremely High Frequency (range of 30Ghz to 300 GHz) which doesn't have any devices operating on currently. This will ensure the maximum use of bandwidth. The maximum speed provided by 4G under standard conditions is 50Mbps whereas this number takes a jump with 5G, where it is 1.5Gbps. 5G is taking over the world by providing massive data transmission rates. However, a lot of challenges are still coming to hinder the new technology. Continuous research and development is being undertaken by telecommunication giants to provide optimal solutions to the problems faced by 5G.

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