International Journal of Transcontinental Discoveries (IJTD), ISSN: 3006-628X
Volume 5, Issue 1, January-December, 2018
Available online at: https://internationaljournals.org/index.php/ijtd

Millimeter-Wave Mobile Communication for 5G

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Article history: Received: 2 June 2018, Accepted: 16 June 2018, Published online: 6 July 2018

ABSTRACT

Due to shortage of global bandwidth to influence the development of fifth generation mobile communications it is necessary to resort to a different approach for bandwidth selection. One approach is to use millimeter-wave frequency spectrum for communication which was initially not used for cellular communications because of their short range and nonline-of-sight coverage issues. The mm-wave frequency spectrum is in use for short range wireless applications but its deployment to wide range of 5G communications is not yet standardized. This paper includes a study about the use of underutilized millimeterwave frequency spectrum for 5G mobile communications. It initially discusses the evolution of 5G.

Keywords—Millimeter-Wave, 5G, cellular, MIMO, 28 Ghz, 38Ghz

INTRODUCTION

With today's available technology, we have to wait for a couple of minutes to download a very large file, but with the recent advancements, that future is not far when we will download these large files in some seconds only.All the visual communications will also get so improved that we will feel like the person you are talking with is right in front of you. This is what current in-development companies are assuring as future scenario.

5G Technology is the full form of 5th Generation cellular technology.5G technology has come with many solutions for speed and coverage area problems, which makes it one of the most efficient and practical technology till now. 5G offers speed upto 1 Gbps even for many connections connected at the same time. 5G technology will also require a high frequency i.e. 5 GHz.

Access Technologies For Communication

Access technologies are technologies used for communication purpose as proposed in [2]. It becomes very tedious to provide each user a particular band-width. So, these technologies use only one band-width to provide services to many users.It is also known as multiplexing techniques. The communication medium provided here are of both types: wired and wireless. Different types of access technologies:

1) FDMA : Frequency division multiple access
2) TDMA : Time division multiple access
3) CDMA : Code division multiple access
4) OFDMA : Orthogonal frequency division multiple access
5) SDMA : Spatial division multiple access

FDMA

Frequency division multiple access is the technique which was very commonly used in first generation. This technique follows analog system. In FDMA , the whole spectrum was divided into its sub parts on the basis of frequency and those parts were assigned to users. The major drawback is that at a time, only one user is allowed to use the channel. So until one user finishes his call, all other users can not use the spectrum. For this method to convert into a full duplex method, we can use two channels,one for transmitter and the other, for receiver's side.

TDMA

Time division multiple access technique divides on the basis of time as it's name suggests.The technique was most used in the time of second generation. In this technique, the frequency if divided into different time slots, which improves spectrum capacity. In this technique, instead of just a given bandwidth, a user is allowed to use the whole frequency channel for the

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given period of time. All the users share this same frequency, but not at the same time. All of them are allowed at a particular time slot given to them. The base station keeps on switching it's user on the channel.

CDMA
In Code division multiple access technique, all users can have access to the single channel at the same time. It follows spread spectrum technology. Each user is assignes a specific and unique code so as to differentiate the data from other subscribers. In this technique, the transmission uses the whole band. The radio interface that was used for the third generation mobile phones was also one of the version of CDMA.

OFDMA
Orthogonal frequency division multiplexing technique divides a channel into many narrow orthogonal bands. These bands are spaced in a way not interfering each othe. This technique is used in long term evolution cell system. Here, Each narrow bands are further sub-divided into 15 KHz wide parts. This tiny parts carry the data in low-speed bit streams. The gap between each sub parts are used to package the data. As the design of this technique makes it more efficient than other techniques, it provides higher data rates.

SDMA
Spatial division multiple access is bases on the physical distance between users.For the sharing of channel, it uses physical separation methods. If two users, who want to use the common channel at the same time are physically separated enough to avoid any interface, in this case, this technique is useful. This method has a second name frequency reuse. This technique is popularly used in cellular radio systems.

Evolution
There are certain things that are to be taken into consideration while defining any generation:
-Technology used
-Services provided
-Capacity of device
-Power consumption
-Accessibility

1st Generation
The first generation technology was first introduced in 1980s and completed in early 1990.The first generation (1G) mobile communications technologies used analog radio signals and had limited capacity. They were bigger in size and gave speeds of up to 2.4 kbps. They allowed users to make a call only in one country.In 1G, for transmission of a signal, frequency modulation was used and all other decisions were taken at the base stations.

Drawbacks of 1G:
The basic principle of 1G is to use analog signal rather than some digital one. This technology is very slow.The signals here can not reach to some secluded or dense areas where 2G and 3G technologies can reach. These signals are widespread. The very first generation mobile phones, by using analog signals, were very large in size. Though it was a very big revolution in past time, even it that time they offered very low spectrum efficiency. Aslo there is no methos for encryption of analog data, because of which, security remains still a major problem.

2nd Generation
This technology was developed in the late 1980s.This technology gollows digital system.It uses TDMA technique. The maximum data rate speed that we can get from this technology is 64 kbps. This technology can be used for transmission of mms, picture message or text message. Global system for mobile communications standard describes protocols for 2G network that are used by mobile phones.

Drawbacks of 2G:
Though better coverage providence than 1G, 2G still can not reach in less populous areas with strong digital signals. So it can create a problem for higher frequencies data. 2G uses digital signals to transfer data,while 1G used analog signals. on one side, while analog signals have smooth decay curve, 2G digital signals have a jagged steppy curve, making it a disadvantage. 2G is not able to transfer video data.

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3rd Generation
3G Technology came in the 2000s. It is designed for multimedia communication. It promised faster communications services, including voice, fax and Internet, anytime and anywhere with seamless global roaming. These services are possible because the 3G spectrum provides the necessary bandwidth with transmission speeds from 125 kbps to 2 Mbps. 3G technology works on CDMA and its various technologies. Drawbacks of 3G:

It requires a very high infrastructure cost for base stations. It consumes a lot of power and hence the battery life of your handset tends to decrease. As it supported a variety of multimedia, it required stronger signals and thus network towers had to be placed nearer to each other. A lot of companies had faced problems in acquiring license for 3G. Also, these magnetic signals emit radiations which are very harmful to life.

4th Generation
This technology was introduced in 2010.It is sometimes called by the acronym MAGIC which stands for multimedia, Accessibility, Globally supported, Integrated wireless and Customer-friendly services. A 4G system must provide capabilities as defined by ITU standards in IMT Advanced. Advancement of technology means improved features. Hence, 4G had to increase its speed to reach up to 100 Mbps as well as this network was based on some standards which used packet switching.

Drawbacks of 4G:
4G might have become popular but its connectivity is restricted to only a certain number of areas. Also, all the current devices are not able to function on 4G so customers have to buy a brand new device just to access 4G available at very expensive rates. There has to be a lot more improved design to support all its applications and still it does not give full protection and security to our personal data. There is greater batter consumption and no connections in secluded areas. The following figure demonstrates why there was no need of frequency spectrum for other generations:

Generation	Requirements	Comments
1G	No official requirements. Analog technology.	Deployed in the 1980s.
2G	No official requirements. Digital Technology.	First digital systems. Deployed in the 1990s. New services such as SMS and low-rate data. Primary technologies include IS-95 CDMA and GSM.
3G	ITU's IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	Primary technologies include CDMA2000 1X/EV-DO and UMTS-HSPA. WiMAX now an official 3G technology.
4G	ITU's IMT-Advanced requirements include ability to operate in up to 40 MHz radio channels and with very high spectral efficiency.	No technology meets requirements today. IEEE 802.16m and LTE-Advanced being designed to meet requirements.

Figure 1.Requirements and challenges of 1G through 4G [5]

5th Generation
5G is the coming fifth-generation wireless broadband technology based on the IEEE 802.11ac standard. As the hype created about 4G technology has slowly and gradually started settling down, 5G is emerging bringing along the new era of globalization.

5G is brought with the core intention of providing higher than ever data rate speeds with wider coverage areas than current existing technologies as said by [7].

5G is going to affect Voice over Internet Protocol (VoIP) also. If we have a good enough Internet services, we can get phone services over the Internet rather than from a telecom company and pay much higher prices for that. In previous generations, voice over Internet faced some transmission rate problems, which would be overcome by 5G.

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5G will require change in product engineering also. While designing and assembling a device, some changes will be made according to 5G requirements.
The major vision of this technology is to provide Superefficient mobile network.

5G requirements
As 5G technology itself is unique, to establish it globally, it will require some changes to be done in our regular communication methods. Some of them are discussed below:

-Speed up to 10 Gbps
-Latency rate lowered to 1 ms
-Broader spectrum i.e. greater bandwidth
-Thousands of connected devices on a single platform
-Maximum availability
-Full coverage around the world
-Increased battery life
-Energy Efficient

Timeline
Initially in 2008, IT RD program for 5G mobile communication systems interested to working on this technology was developed.

The first innovation was started at one of UK's University. It was considered as the world's first research centre set up specifically for 5G mobile research.
In September 5th 2013,the European union launched the METIS project. It was the first international and large-scale research on 5G. It triggered extraordinary global interest on 5G.

Another project was initiated in 2013 called 5Green which focused more on designing green 5G networks.
In 2015, Huawei and Ericsson started testing 5G or it's related technologies in rural areas in northern Netherlands.
On January 29, 2016, Google also revealed that their 5G network development called SkyBender. Their plan was to distribute it through sun-powered drones.

Some key goals
Significantly faster data speeds- Achieving peak download speeds of 10 gigabit per second
Reduced latency rates - Latency defines the time a packet of data takes to reach a device from the sender. 4G hasn't been able to reduce the rate below 50 ms but for 5G, it's envisioned to go even lesser than 1 ms. This is the greatest challenge that companies have been facing for the development of robot cars and in other industrial areas.

A more connected world It will provide a capacity for a network that would be able to accommodate billions of connected devices from cars to household appliances to electricity meters and many more that will be supported on the platform provided by future mobile networks.

Mobility - Same experience at home, in the office or on the move. Provides robust communication in remote areas, disaster areas and unforeseen local traffic demands.

It provides more correct traffic statistics.
Coverage would be improved.
The technological solutions provided by 5G would bring more data security and privacy of personal data.
The user is simultaneously able to switch between several wireless access technologies.
The enabling technologies converging into this concept are communication, navigation, sensing and services. A determining factor for these technologies is the availability of radio spectrum. 5G aims to provide global connectivity to lay grounds for fast access to the internet users. In other words, 5G will set its network grounds even in dense urban environments.

5G networks are not going to be a massive network design. Instead, 5G networks will be designed in such a way that it will result as a combination of various technologies. So, unlike the previous generations, 5G will be able to support various applications such as Internet of things, connected wearables, immersive gaming and many more advanced upcoming technologies.

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5G network will offer the ability to handle the myriad of traffic types and the plethora of connected devices.For example, sensor networks need low data rate but HD video streaming demands very high data rate, so 5G will provide data rate speeds accordingly.Thus, 5G will be able to adapt to conditions at a given time.

What Makes 5G Future-proof

1) This technology would offer high resolution for in all the devices and would also offer large bandwidth.
2) The advanced and user-friendly interfaces of 5G technology is the reason why 5G seems more attractive and effective.
3) Subscriber supervision tools are also provided by 5G for fast access.
4) All the services provided by this technology would be given based on certain protocols to prevent any errors or system failure.
5) 5G is also willing to provide a large platform where it can support thousands of connections and huge broadcasting of data.
6) 5G technology offers unparalleled consistency.
7) It provides more correct traffic statistics than any other prevalent technology.
8) The customers would be able to access faster Internet with the help of the technology designed.
9) This technology aims to provide up to 10 Gbps speed, which is comparatively much higher than current speed we get.
10) 5G would also be capable of supporting VPN's. The new 5G technology will take all delivery services out of business prospect.
11) The downloading as well as uploading speed of 5G technology will be at its maximum rate.
12) Enhanced and available connectivity around the whole world will also be offered by 5G.

Challenges faced by 5G

1) Standardization :
   There are many groups already working to come up with the solutions of problems faced by older technologies like 4g,3g. They all want their technology to be future-proof. It does seem a challenge to bring them all to the same global standard.
2) Infrastructure :
   As the current parallel advancements are focusing more on using a large number of hardware components for the transmission of such high frequency signals, it would pose a problem in terms of space and also the distance that could be travelled by these waves as they have a tendency of getting absorbed easily which would lead to weaker connections.
3) Cost :
   Though companies like nokia think that 5G wont cost much more than what people are paying for 4G right now, it is still early to say that it wont cost much, given the transmission method and concepts are still not glass clear.
4) Time :
   5G technology is very new so the practical implementation is not possible before 2020 as mentioned in [1]that also only for commercial standards. It will take years for the network to become widespread.

Millimeter-Wave Frequency Spectrum

The millimetre waves are those high frequency radio waves whose wavelength ranges from 1 mm to 10 mm. The use of such high frequency waves means more bandwidth and greater the range of spectrum as in [4]. Though these waves can travel up to a short distance only as they get easily absorbed, they are very useful for transmission of a large amount of data such as in television broadcasting or in radar system. However, developing this technology for future use is facing some difficulties in the design and assembly of mobile device.

Figure 2 demonstrates how and which frequency bands are allocated to 2G, 3G, 4G.

Understanding the radio channel is an essential requirement should create future mm-wave portable frameworks and additionally. The channel, analysts and business professionals might afterward investigate new routines to the air interface, different access, structural methodologies that incorporate participation.

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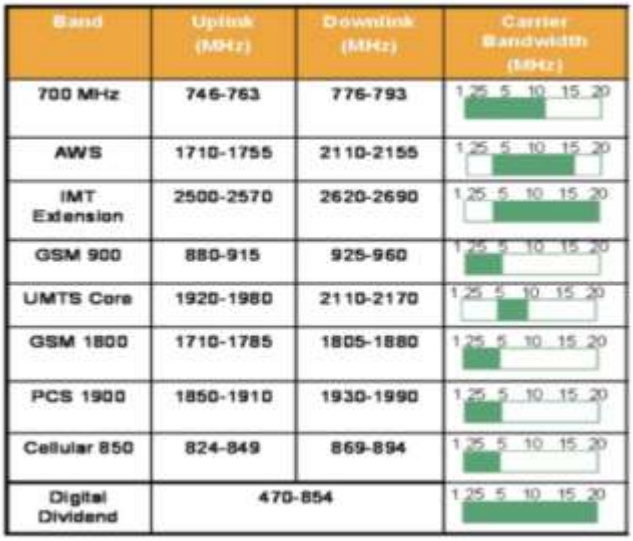
Mmwave Beam forming Proto type

As mentioned in [3] the mm-wave beamforming prototype was proposed by DMC R&D Center, Samsung Electronics, Korea. The prototype includes various array antennas, RF units and baseband modems. The receive and transmit antennas contain two different channels each containing 32 different elements arranged in an array pattern. The following parameters have been included in the prototype and its working was examined. The prototype was designed to check whether the antennas can be detected within 45ms of range.



Band	Uplink (MHz)	Downlink (MHz)	Carrier Bandwidth (MHz)
700 MHz	746-763	776-793	1.25 5 10 15 20
AWS	1710-1755	2110-2155	1.25 5 10 15 20
IMT Extension	2500-2570	2620-2690	1.25 5 10 15 20
GSM 900	880-915	925-960	1.25 5 10 15 20
UMTS Core	1920-1980	2110-2170	1.25 5 10 15 20
GSM 1800	1710-1785	1805-1880	1.25 5 10 15 20
PCS 1900	1850-1910	1930-1990	1.25 5 10 15 20
Cellular 850	824-849	869-894	1.25 5 10 15 20
Digital Dividend	470-854		1.25 5 10 15 20

Figure 2.Frequency bands allocated to 2G, 3G, 4G and LTE [3]

Key system parameters	Values
Carrier frequency	27.925 GHz
Bandwidth/FFT size	520 MHz/4096-FFT
Subcarrier spacing	244.14 kHz
Cyclic prefix size	0.18 × OFDM symbol
Modulation, coding (data rate)	QPSK, LDPC 1/2 (264 Mb/s) 16QAM, LDPC 1/2 (528 Mb/s)
Maximum transmit power	31 dBm (with 9 dB back-off), 1.26 Watts
Array antenna configuration per channel	8-element by 4-element (32 antennas) Uniform Planar Array
Array gain	18 dBi
FWHM	10° (Horizontal)/20° (Vertical)
Beam scanning range	±30° (Horizontal)
Effective isotropic radiated power (EIRP)	Max 49 dBm (Nominal 41 dBm)
Adaptive beam searching and switching time	45 ms

Figure 3.Parameters for the prototype [6]

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Prototype Test Results

The prototype was designed to check the parameters and the result showed that there was negligible packet delay involved when using the mm-wave prototype. Peak rate of 1.06 Gb/s was observed when tested this prototype was analysed in [6]

CONCLUSION

5G technology is definitely going to be a new revolution with it's higher than ever network speed and best coverage specialities. It will be able to handle the best and newest technologies. But there are some major changes to be brought for 5G to be at it's most efficient level. It still has challenges like standardisation and infrastructure, without solving which, 5G is not a perfect reality. It will have to be such a futureproof technology that no other developing technology will be able to replace it for long time.

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