Millimeter Wave for 5G Network: A Survey

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Abstract

The Shortage in a bandwidth has forced to use under-utilized millimeter-wave (mmwave) spectrum for wireless communication for upcoming 5G mobile communication networks. In future the goals that need to be analyzed are low response time, increased in speed, greater capacity and good service quality. To overcome these objectives massive changes in cellular network architecture is required. The paper discusses fifth generation mobile communication and upcoming technologies for satisfying the customers need and changes in the network architecture. The main concern will be on 5G network architecture, along with the exploitation of higher frequencies, mainly millimeter wave (mmwave), one of the promising technologies for future 5G cellular networks. In comparison to existing communication technology, millimeter wave communication is different in terms of directivity, high propagation loss, sensitivity to blockage. To fully employ the characteristics of mmwave it has several technical challenges. Further research is to be done for 28 GHz and 38 GHz band and above 60 GHz band.

Keywords: *5G, mmwave*

Introduction

Due to the raise in demand of the mobile traffic, the challenge between capacity requirements and shortage in spectrum becomes more important**.** The scarcity of wireless bandwidth in the existing communication network is one of the main difficulties in fifth generation wireless networks**.** To provide multi-gigabit communication services, huge bandwidth ranging from 30 GHz to 300 GHz. One of the promising technologies for 5G mobile network is the millimeter wave communications. Currently the research is going on for the higher end frequencies such as 28 GHz to 38 GHz band and other high end frequency bands ranging from 71 to 71 GHz and also E-band ranging from 81 to 86 GHz)

However the is progress in technology of electronics product such as CMOS, radio frequency integrated circuits to be used in the millimeter wave frequency band. However still there are many challenges in physical and MAC layer, and at lower frequency. Characteristics of mmwave communication such as the high propagation loss, sensitivity to blockage, directivity of millimeter wave communications requires new challenges to make changes in architectures and protocols [3]. A report by Wireless World Research reveals that mobile data traffic is (at least) doubled every year and will exceed traffic from wired devices by 2018 and it is also predicted that by 2020, there will be around 50 billion devices serving the community [6]. And there will be more than six devices per person, which include not only human communications but also machine communications [1].

Evolution of wireless Technology: Due to advancement in technology the coverage, the mobility, spectral efficiency and data rate are on rise. First generation and second generation are using circuit switching network whereas 2.5 generation and 3rd generation are using packet as well as circuit switching and 3.5G to 5G uses packet switching network. It additionally also separates between authorized range and unlicensed range. The upcoming generations are using the licensed spectrum while the most of the wireless technologies are utilizing the unlicensed spectrum. Following section discusses the wireless technologies evolved and new upcoming [14].

1G: First generation of mobile network was launched in 1980's. Provides the data transfer rate of 2.4kbps.Major subscribers are Advanced Mobile Phone System (AMPS), NMT. It has many

disadvantages such as low capacity, no security, fast handoff, it is also susceptible to eavesdropping [2], [14].

2G: The second generation was launched in 1990's.It support the data rate of almost 64kbps and 2G used the GSM (Global Systems for Mobile communications) firstly. It basically provided the voice communication. Since the low power of the radio signals 2G portable handset battery endures longer. Several services are given like mailing service and short textual Messages. Other achievements are Global System for mobile communication, Code Division Multiple Access [2] , [14].

2.5G: It uses second generation mobile network integrated with GPRS (General Packet Radio Services).It uses structure of 2G networks; however it uses circuit and packet switching and 144kbps date rate are provided by it. CDMA 2000**,** GPRS, Enhanced Data Rate for Global Systems for Mobile communications Evolution is some of the supported technologies.

3G: The 3rd generation was introduced in late 2000. It provides data transfer rate to 2Mbps. It uses IP (Internet Protocol) based services integrated with high speed mobile. Quality of voice is improved and global roaming facilities were provided good service quality along with rate of transmission. However it consumes more power as compare to previous generations and plans are bit expensive. [3], [4**].** Introduction of WCDMA (Wideband Code Division Multiple Access) and (CDMA) Code Division Multiple Access 2000 technologies**.** Also some of the emerging technologies such as (HSUPA/HSDPA) and EVDO (Evolution-Data Optimized) as improved the data rate up to 5-30 Mbps [2], [14].

3.75G: The future of mobile data services are Long-Term Evolution Technology and Fixed Worldwide Interoperability for Microwave Access. 3.75G can boost the network capacity and able to provide wide range of facility services with high speed [2], [14].

4G: One of the higher standards than 3G and 2G. This standard provides the facility of IP based service as compare to existing one, also gives higher data rate with multimedia and data support. Major applications support by it is Multimedia Messaging Service (MMS), HDTV and Mobile TV [2], [14].

5G: It can replace the 4G technology due to increase in demand of users by advancement in technology such as BDMA (Beam Division Multiple Access) or FBMC (Filter Bank multi carrier) multiple access. In BDMA mobile station will communicate with the base station. Each mobile station is allocated an orthogonal beam and based on locations, BDMA will divide antenna beam by providing the multiple access and system capability will get increase. A plan to transfer towards 5G is based on current trends; since 4G has not taken some of the concerns that of 5G i.e. low latency, large number of devices connectivity, quality of service, more capacity.

5G Wireless Requirements

As such now no worldwide standard is available for 5G wireless network. The technical terms of this network would be available in the coming years only. But some of the requirement is established by industries are [5], [8], [11], [12].

Coverage and Data rate: It is expected that 5G will be available at anywhere and anytime at a speed of or data transfer rate of 1 Gb/sec [8]. Mobility users will experience different data rates at low and high peak. It also provides the quality of service for the users moving with a high speed as compared to the existing one [5], [8], [11], [12].

Latency: Minimum amount of time required to reach at the destination in case of 5G network it will almost around 1-5ms[5], [8], [11], [12].

Connected devices: As compare to current wireless technology it is expected that in near future large number of devices will be connected almost reaching to 100 times more. Requirements of all these devices may vary such as reliability and delay [5], [8], [11], [12].

Multiple RATs: It is said that 5G will not change the current wireless technology. It will join together the recent network structure with the 5G**.**

Energy and cost efficiency: 5G network should be designed for greater cost efficiency. As compared with recent wireless technologies the energy efficiency of 5G network must be reduced to a factor of 1000 which is measured in bit/Joule [5], [8], [11], [12].

Table 1 Evolution of Wireless Technology [9] [13].

Name	1G-1st Generation Technology	2G-2nd Generation Technology	3G - 3rd Generation Technology	4G-4th Generation Technology	5G- 5th Generation Technology
Launched in Year	1980s	1993	2001	2009	probably 2020
Switching network	Circuit	Circuit switching, Packet switching	Packet switching	All Packet	All Packet
Technology used	Analog	Digital	CDMA 2000	Wi-Fi , WiMAX	wwww
Data Bandwidth	2kbps	64kbps	2Mbps	1Gbps	Higher than 1Gbps
Quality of Service (QoS)	Voice	SMS , Digital Voice, high Capacity	High Quality video ,audio, data	Wearable devices	Devices with AI capability
Multiplexing	FDMA	CDMA, TDMA,	CDMA	CDMA	OFDM, CDMA

5G Network Architecture

Figure 1 describes the 5G network architecture.

Radio-links describes the growth of new broadcast waveforms and new trends in radio resource organization and multiple access management [2].

Multi-antenna and Multi-node transmissions describes the highly developed inter-node management schemes and multi-hop technologies and scheming of multi-antenna transmission or reception technologies based on array of antenna configurations [2].

Network dimension describes the need, mobility organization and traffic management, and different schemes for efficient interference organization system in heterogeneous network [2].

Spectrum usage describes the currently working spectrum band as well as extended spectrum band of operation; along with this it also describes the usage of each band development.[2]. [5].

Device-to-Device (D2D) communications includes direct communication between two mobile users without going through the core network

Massive Machine Communications (MMC) includes the broad application range for the Internet of things such as security system, health management, electronics appliances vending machines and cars [2].

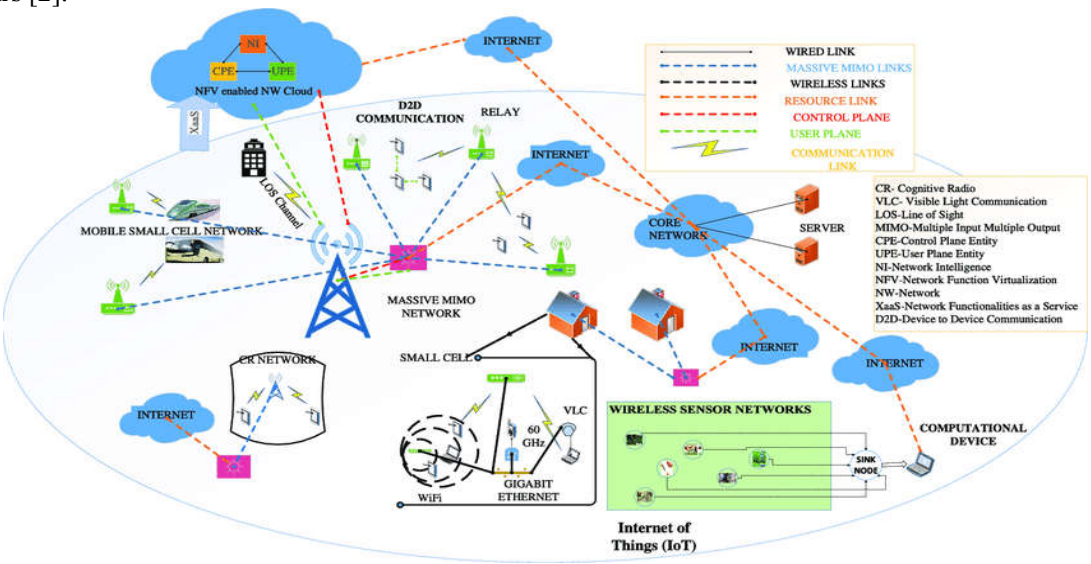

Figure 1: A General 5G Cellular Network Architecture [1]

Moving Networks (MN) will improve and enlarge connecting potentially vast populations of mutually moving communication gadgets [2].
Ultra-dense Networks (UDN) provides or aims to better exploit the under-utilized spectrum and to boost the capacity raise the energy efficiency of radio links [2].
Ultra-reliable Networks (URN) will allow high degrees of accessibility [2].

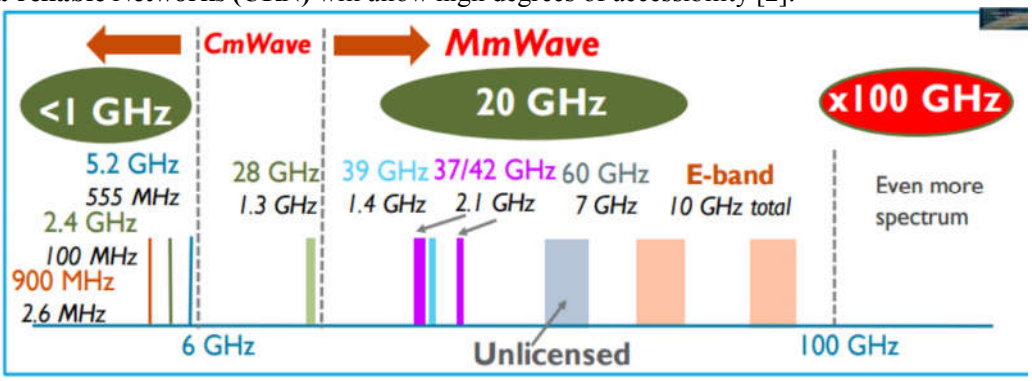

Figure 2 Millimeter Wave Technology

One of the promising technologies for future cellular systems is mmWave. A frequency band for the mmWave lies between 30 GHz to 300 GHz. As the number of mobile data subscribers is increasing rapidly, need for more bandwidth also arises**.** Presently available Mobile frequency spectrum has limited bandwidth and is below the mm band**.** Because of this mobile operators are exploring millimeter wave band as mobile frequency spectrum having support for the larger bandwidth**.** However penetration losses are higher in mmwave as it cannot penetrate objects and walls in the buildings and suffers attenuation due to rain. Researchers are focusing on increasing spectral efficiency due to restricted spectrum availability for commercial cellular systems, by using efficient channel coding, MIMO, OFDM and interference coordination**.** Following key characteristics differentiate mmwave communication from others (1) the requirement of large multi-antenna arrays at receiver and transmitter ends of the link (2) The specular nature of propagation (3) accessibility of ultra-wide bandwidth channels**.**

Table 2 Features of 5G Millimeter Wave Technology [7], [10]

Features	Description
Data rate	Greater than 10Gbps
Frequency Bands	The bands ranging from 30 GHz and 40GHz up to 100 GHz
Bandwidths	1) 10 subcarriers of 100 MHz each can provide 1GHz Bandwidth due to carrier aggregation at 40 GHz and 500 MHz to 2 GHz Bandwidth can be achieved without carrier aggregation at 40GHz.
Distance coverage	2 meters for indoor to 300 meters for outdoor
Modulation types	CP-OFDMA < 40GHz SC >40GHz
Frame topology	Time Division Duplex

5G millimeter wave Advantages:
5G millimeter wave is one of main challenger in the future of mobile wireless communication domain and some of the advantages given are 1) Can accommodated more subscribers due to the availability of more bandwidth 2) Short bandwidth in just millimeter range so suitable for small cell deployment 3) To prevent types of losses channel sounding features are used in 5G network to work suitably at in mmwave frequencies. 5**)** Large number of antennas can be packed due to small physical size. Which leads to enhance the capacity by massive MIMO in AP 6) 5G mmwave support multi-gigabit backhaul up to four hundred meters and cellular access up to 200-300 meters**.** Because of all these advantages, mobile communication over sub-6GHz wireless technologies is suitable 5G mm wave.
5G mm wave disadvantages:
The disadvantages of the 5G mmwave are 1) Penetration and Atmospheric attenuation losses are much higher in mmwave which limits the distance covered by 5G mmwave in cellular mobile deployment. It supports two meters in indoors and about 200-300 meters in outdoors based on channel conditions and AP height above the ground. 2) Supports only LOS (Line of Sight) propagation. Hence

coverage is limited to LOS. 3) Foliage loss is significant at mm wave frequencies. 5) Power consumption is higher at millimeter wave due to more number of RF modules due to more number of antennas. To avoid this drawback, hybrid (analog and Digital) Beamforming architecture which has fewer RF chains than number of antennas needs to be used at the receiver, mmwave hardware circuits are designed in low power analog processing circuits[10].

Security

The receiver should be setup in the path of radio connection or should be very near in order to sniff mmwave emission. The millimeter waves are blocked by buildings or many solid structures and have a narrow beam width which creates inbuilt level of security. Sniffing antenna provides a detection mechanism for network under attack causes loss of data integrity. To fully protect the network against attack some cryptographic algorithms can be used.

Conclusion

This paper summarizes the usage of mmwave mobile communication for 5G cellular network, and how the preceding generations of Communication systems problems can be overcome by the 5G Cellular system and its is evolved to be the one of the most capable System**.** As per the global requirement for cell spectrum research is going on for mmwave mobile communications, since the massive bandwidth is existing at mmwave wave frequencies which results in very high information transmission rate additionally it also helps the node to stay in transmission mode for the minimum amount of time and consequently, minimizes the chances of its transmission being detected**.** Considering all these features mmwave frequencies is going to serve the wireless communication for future generation's network and providing quality of service (QOS).98% of energy is absorbed by oxygen at 60 GHz and 28 GHz to 38 GHz are the frequencies which have low rainfall attenuation and atmospheric attenuations. Further research need to take place in 28 GHz and 38 GHz band and above 60 GHz band and the characteristics of different frequencies desires to be studied.

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