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Various Insights of Wireless Communication

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Abstract: *Communication is a globally growing industry, In the past five years, we have seen more than 3 generation of communication technology. This paper is an effort to understand the insights of communication technology. The communication is simply the transformation of information from source to the destination. There are different generations of communication technologies this paper gives an insight on the different generation and the key aspects of communication. The major changes of the technology that affected the communication system is clearly mentioned and explained. The modulation methods used in the communication are QAM and OFDM, which have taken the communication technology to a different perspective. In reality, the theoretical standards are not yet achieved in the modern communication system. this is due to the interferences in the physical environment. This has created a research gap to analyse. The effort is to understand and summarise the key aspects of communication system.*

Keywords: 4G, 5G NR,5G,BPSK, GPRS, GSM, LTE, Modulation, OFDM, QAM, QPSK

I. INTRODUCTION

A simple definition of wireless communication goes as A system of transformation and reception of signal, without the help of cables or wires or Any form of electrical conductors connecting between them. In most of the wireless communication technologies, the commonly used signals are radio waves. Some of the examples of wireless communication systems are two-way radios, Cellular telephones personal, digital assistants, wireless networking, and others.

This paper gives an insight of different technologies, methodologies, modulation techniques and a brief history of evolution of Communication system. The discussion starts with the introduction of various communication, a general block diagram that represents the communication system, followed by different generations of communication, And various parameters for classification of wireless communication [1].

A brief description of different modulation schemes are discussed And finally, technologies and techniques that are used in wireless communication for the advancement of the speed and communication are also mentioned.

II. STRUCTURE OF COMMUNICATION SYSTEM

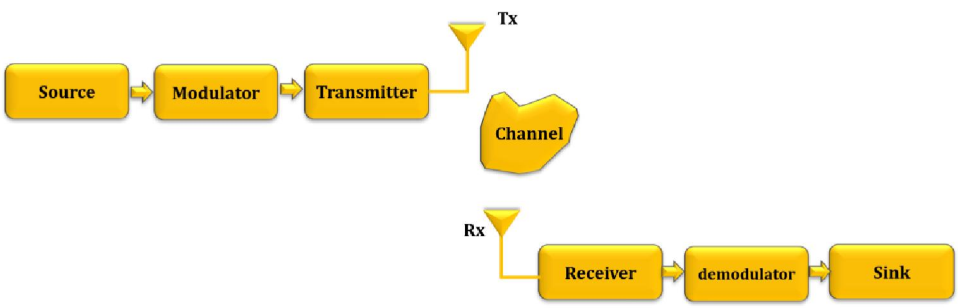

Figure 1. The fundamental model of communication system

Figure 1 shows the fundamental model for a communication system. This block diagram represents the basic system of communication channel. It has source, modulator, transmitter, receiver, demodulator, and sink. The source is the origin of the signal that has to be transmitted through the channel. The message signal is modulated and is transmitted through the channel. Channel carries a signal from the transmitter to receiver during the process. It adds noise and degrades the quality of the signal. The receiver received a signal demodulated set and sends the signal to the sink [2].

III. EVOLUTION OF WIRELESS COMMUNICATION – THE GENERATIONS

In the history of wireless communication, Marconi made a benchmark by inventing Morse Code. He was able to transmit his Moore's code using radio waves for about 3.2 kilometres in the year 1895. History this was recorded in the history of science, stating as the first wireless transmission.

Which were capable of communicating wirelessly, were developed by Martin Cooper, who was working as an engineer in Motorola Company during 1970s. This was the very first invention of a first generation mobile phone.

A. 1G Mobile communication system

In the year 1979 Nippon Telephone and Telegraph company of Japan developed the first generation mobile network. Soon, it gained its popularity in European countries like England, Finland and also in the United States. As this was the very first attempted towards the wireless communication, it has many flaws and technological limitations. The key features of first generation system were: The frequency of operation was 800 to 900 megahertz, With the bandwidth of 10 megahertz the technology used frequency modulation and had only voice service. Disadvantages of the system was having poor quality, poor battery life, the mobile phones were not handy. And the security was not up to the mark [3] [4].

B. 2G Mobile Communication System

Soon after first generation, the second generation started, It introduced a new digital technology in wireless transmission, which was known as global system for mobile communication (GSM). The wireless standards for the base communication were capable to support up to 64 kilobits per second. This was sufficient to transmit SMS email services and also CDMA was developed in the same time. The CDMA had different and efficient features for the users with better data rates. The key features of 2G communication were SMS services roaming the enhanced security. But still, it had a few disadvantages of limited mobility and lower data rates.

To improve the data rates in the second generation. Another two services were also launched, which were known as 2.5G and 2.75G systems. The system used a General Packet Radio Services (GPRS). And it was successfully implemented in this technology. It has a capacity to speed up the data rate up to 171 kilobits per second First, in the same time, EDGE (Enhanced data gsm evolution)technology was also developed and was adopted. The edge technology was capable to support 473 kilobits per second [5].

C. 3G Mobile Communication System

In 3^{rd} generation of mobile communication system Universal mobile terrestrial system was introduced It had a data speed of 384 kilobits per second. It also supported video calls for the first time in the mobile devices. Smartphones became very popular across the globe who wants the 3^{rd} generation communication system was introduced. The Android system developed several applications which were capable of using multimedia chat, email video and games for the users. The key features of 3^{rd} generations are video calling high data rate, multimedia message support, mobile app support and many others.

To improve the data rate in the 3^{rd} generation network. High speed data link packet access and high speed uplink packet taxes was developed. Theoretically, these techniques where capable to provide 2 megabits per second of data rate. There is an improved version of 3G network with 3.9 G system, which is known as LTE (Long term evaluation) services. The the disadvantages of this communication system was costly mobile devices, higher bandwidth required support of higher data rate And the spectrum licence was also expensive [6].

D. 4G Communication System

The enhanced version of 3rd generation network is 4th generation communication system This was adopted by IEEE. This system offered higher data rate and had capability to handle more advanced multimedia services. The LTE and LTE advanced wireless technology was also used in 4th communication system.

LTE systems can transmit voice and data simultaneously, which provides more data. All services, including voice services, can be transmitted via IP packets. Sophisticated modulation schemes and carrier aggregation are used to provide uplink/downlink capabilities [7].

E. 5G – Fifth generation communication system

5G networks leverage advanced technology to provide customers with a super fast internet and multimedia experience. The existing advanced LTE network will be transformed into a powerful 5G network in the future.

In initial deployments, 5G networks will operate in non-standalone and standalone modes. In non-private mode, LTE spectrum and 5G-NR spectrum will be used together. The control signal will be connected to the LTE core network in non-standalone mode.

The standalone mode will have the 5G-NR spectrum with higher bandwidth to the dedicated 5G core network. The sub-6 GHz spectrum in the FR1 range is used for the initial setup of 5G networks. 5G technology will use mmWave and licensed spectrum for data transmission to capture more data. Advanced modulation techniques have been developed to support the massive data of IoT [8] [9].

IV. THE PERFORMANCE PARAMETERS TO MEASURE THE 5G COMMUNICATION

There are several parameters that defines a perfect communication channel. The communication channel has several parameters that can define the performance. Few of the highlighting parameters that can be treated as the most important that can be ultimate parameter measure are mentioned below:

Peak data rate peak spectral efficiency area traffic capacity latency data rate experienced by the user energy efficiency reliability, bandwidth, mobility, Interference, SNR, PSNR, BER, PAPR and many others to Pen [10] [11] [12].

V. MODULATION SCHEMES IN 5G COMMUNICATION

Modern wireless communication systems, including 5G, use the effective modulation scheme known as orthogonal frequency division multiplexing (OFDM). To create a high-data-rate communication system, OFDM combines the advantages of Frequency Division Multiplexing (FDM) and Quadrature Amplitude Modulation (QAM). BPSK (Binary Phase Shift Keying), QPSK (Quadrature Phase Shift Keying), 16QAM (16-state QAM), 64QAM (64-state QAM), and other specific modulation patterns are all referred to as QAM. For further details on QAM, see References 1 and 2.

Simply said, FDM is the notion that several communication channels can coexist if a portion of the frequency spectrum is set aside for each channel. The general (US) frequency allocation for FM broadcast radio is 87.8 MHz to 108 MHz, which is split into channels that are 0.2 MHz wide [13][14].

A. OFDM

R. W. Chang [see Ref 3] was the one who initially put forth the fundamental idea of OFDM, understanding that bandlimited orthogonal signals may be paired with a sizable amount of overlap while avoiding interchannel interference. We can build a collection of subcarriers using OFDM that cooperate to transport data across a number of frequencies.

These subcarriers need to perform orthogonal tasks. The integral of their product over the specified time interval must be zero for two functions to be considered orthogonal in mathematics. Orthogonal functions can be thought of being statistically unrelated in a more general sense [15].

Figure 2 demonstrates how N subcarriers with identical spacing can be merged to create a parallel signal array. QAM is used to modify each subcarrier. The usage of these modulated subcarriers can assist independent

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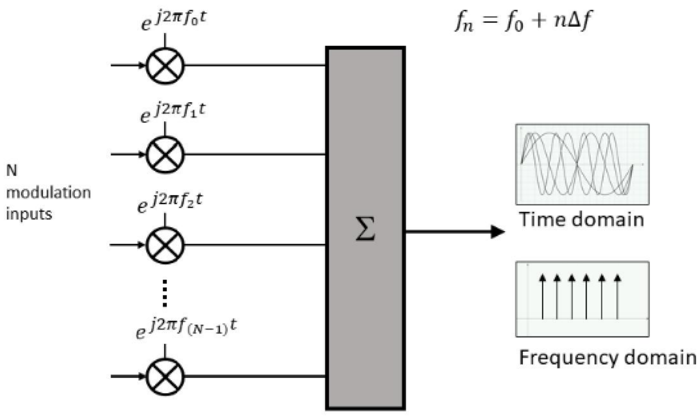

Figure 2: subcarrier Spacing

We can represent these subcarriers mathematically, using the complex form consistent with the use of QAM.

$$x(t) = \sum_{n=0}^{N-1} c_n e^{j2\pi f_n t}$$ Where, $$f_n = f_0 + (n \cdot \Delta f)$$

Since OFDM systems have been implemented in analog fashion, the aforementioned equations represent continuous functions. Modern systems, on the other hand, are virtually entirely digital and make use of digital signal processing and the newest semiconductor process nodes.

Modern OFDM systems use subcarriers that exist in discrete (sampled) form with a sample rate of:

$$f_s = \frac{1}{\Delta t}$$ With N subcarriers spaced by

$$\Delta f = \frac{1}{N\,\Delta t}$$

For simplicity, **Figure 3** shows just four unmodulated subcarriers in the time domain. The black trace is f_0 and the other traces are higher frequency subcarriers, spaced at multiples of Δf.

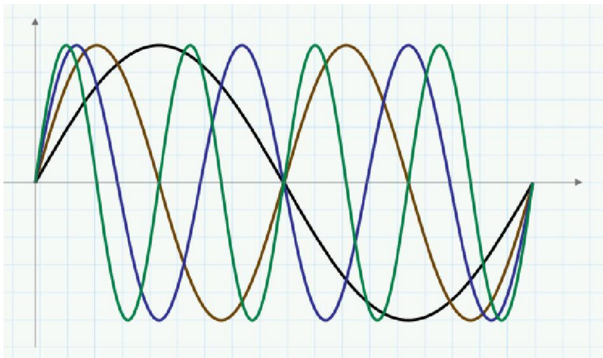

Figure 3. This OFDM signal contains four carriers spaced apart by Δf corresponding to f0, f1, f2, f3.

Figure 4 plots these same subcarriers in the frequency domain, shown with some modulation bandwidth to indicate the overlap between subcarriers. The subcarriers are orthogonal to each other and will exhibit minimal interference to the other subcarriers, resulting in efficient use of bandwidth. Note that the amplitude of each subcarrier crosses zero at the center of other subcarriers, minimizing adjacent subcarrier impact [16] [17].

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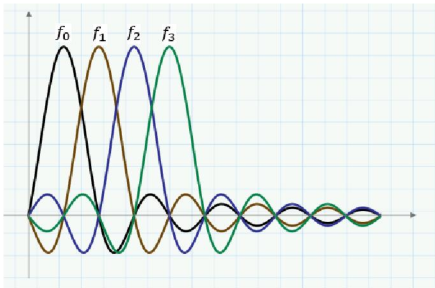


Figure 4. Frequency domain representation of a four-carrier OFDM signal.

A basic block diagram of an entire end-to-end OFDM system, which consists of a transmitter and receiver, is shown in Figure 5. On the left side of the diagram, the bit stream enters the system. As is standard practice, this single bit stream is demultiplexed (DEMUX) into smaller bit streams that are fed to each of the N QAM modulators individually**.**

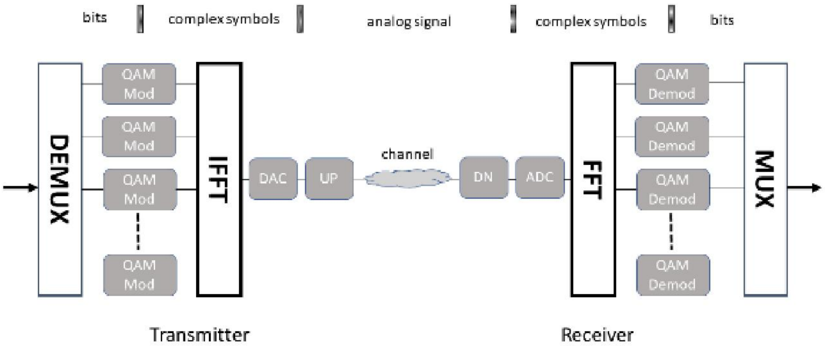


Figure 5. A complete OFDM system includes a transmitter (left) and receiver (right). Power amplifier in transmitter not shown.

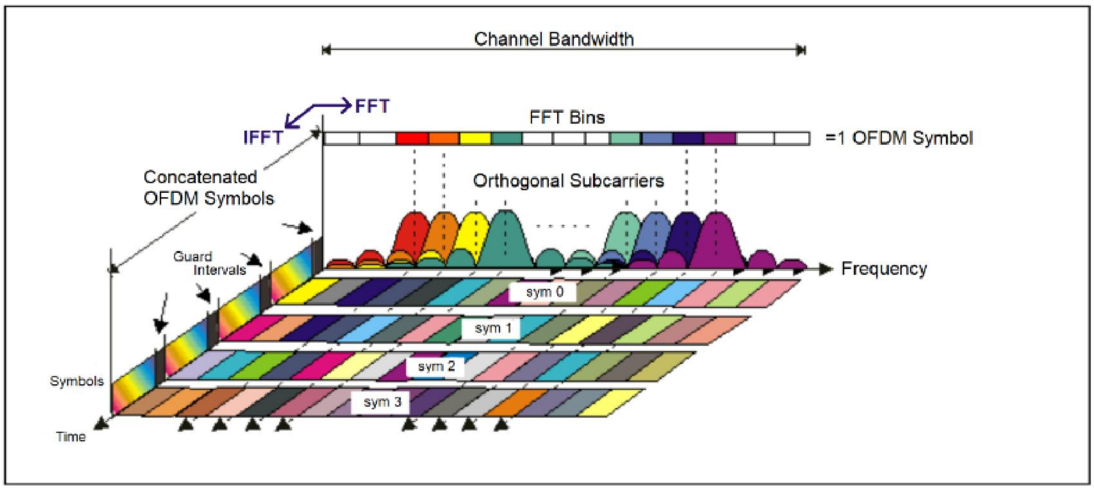
Using the Inverse Fast Fourier Transform (IFFT) to quickly produce the time domain waveform from the array of modulated subcarriers is a crucial OFDM enabler. Because the resulting OFDM signal is digital, the Digital-to-Analog Converter (DAC) is used to transform it into an analog signal. Prior to being sent over the air, this baseband signal is often up-converted (UP) to a higher frequency (and maybe amplified).

The procedure is reversed at the receiver. The OFDM signal is downconverted to baseband using an analog downconverter (DN). The signal is converted from analog to digital by the Analog-to-Digital Converter (ADC), which then sends it to the FFT block. The FFT block converts the time domain signal back to an array of frequency domain subcarriers carrying QAM modulation. Each subcarrier's bit stream is replicated by the QAM demodulators, and after being multiplexed (MUX), the original single data stream is recreated.

The key concepts are 1) creating a wide-bandwidth system by merging many QAM subcarriers and 2) effectively converting those subcarriers as a single wireless signal using the FFT and IFFT. It is possible to utilize QAM modulation ranging from BPSK (one bit per symbol) to 256QAM (8 bits per symbol). A lot many subcarriers (perhaps 4096) are used in combination with this to achieve very high data rates.

B. Time Plus Frequency

A perspective of an OFDM signal in the time and frequency domain is shown in Figure 6. The vertical axis indicates amplitude, and the horizontal axis is frequency. The third axis, which protrudes from the page and represents time, enables us to follow the progression of the OFDM signal from the rear of the graph to the front. One set of OFDM subcarriers is transmitted down the channel for each symbol in the figure.



Frequency-Time Representative of an OFDM signal

Figure 6. Combined time/frequency domain view of OFDM signal. (Image: Keysight Technologies)

Keep in mind that a guard interval was added to provide the symbols some space in time. This is an easy way to stop interference between symbols in the channel caused by multipath propagation. A more sophisticated technique produces CP-OFDM, a variant of OFDM, by inserting a Cyclic Prefix (CP) within the guard interval. The guard interval for the CP is constructed by copying the final portion of the IFFT record and attaching it to the beginning of the record [18] [19] [20].

C. Uses of OFDM

One of the first standards to use OFDM was the wireless LAN standard IEEE 802.11a. With 64 subcarriers spread by 312 kHz, this standard uses a variety of QAM modulation schemes, including Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16QAM, and 64QAM.

OFDM is used in mobile wireless networks to create large bandwidth channels. With a fixed subcarrier spacing of 15 kHz, current 4G (LTE) mobile wireless uses OFDM for the downlink (base station to mobile device). The subcarriers may be modulated using QPSK, 16QAM, or 64QAM.

Both uplink and downlink OFDM are used in the 5G New Radio (NR) standard. With its great degree of flexibility, the NR specification can be used for a wide range of applications. With up to 3300 subcarriers, the carrier spacing is adjustable (15 kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz, and 480 kHz). QPSK, 16QAM, 64QAM, or 256QAM are among the subcarrier modulation options [21].

VI. 5G COMMUNICATION STANDARDS

Table 1: 5G Communication Standard table

Minimum requirement	**5G performance requirement type**
Downlink: 20 Gbps Uplink: 10 Gbps	Peak Data Rate
Downlink: 30 bits/sec/Hz Uplink: 15 bits/sec/Hz	Peak Spectral Efficiency
Downlink: 100 Mbps Uplink: 50 Mbps	Data rate experienced by User
Downlink: 10 Mbits/sec/m2 in indoor hotspot (eMBB test	Area Traffic Capacity

environment)	
• 4 ms for eMBB • 1 ms for URLLC	Latency (User Plane)
• 20 ms (10 ms encouraged)	Latency (User Plane)
1 x 106 devices/Km2	Connection Density
(All the below figures are in units of bits/sec/Hz/TRxP) Indoor hotspot: DL:9/ UL:6.75 Dense Urban: DL: 7.8/ UL: 5.4 Rural: DL: 3.3/UL: 1.6	Average Spectral Efficiency
• Efficient data transmission (Loaded case) : To be demonstrated by "average spectral efficiency". • Low energy consumption (no data case): This test case should support high sleep ratio/long sleep duration.	Energy Efficiency
1 x 10-5 probability of transmitting layer-2 PDU of 32 bytes in size within 1 ms (in channel quality of coverage edge for Urban Macro-URLLC test environment.)	Reliability
• Dense Urban: up to 30 Km/h • Rural: up to 500 Km/h	Mobility
0 ms	Mobility Interruption Time
• At least 100 MHz • Up to 1 GHz for operation in high frequency bands i.e. above 6 GHz	Bandwidth (Maximum Aggregated System)

The table 1, provides the standard ratings and specification of the 5G technology that is available globally

7. Summary Table

Table 2: Comparison table of the different generations of communication

Features	1G	2G	3G	4G	5G
Start/Devlopment	1970/1984	1980/1999	1990/2002	2000/2010	2010/2015
Technology	AMPS, NMT, TACS	GSM	WCDMA	LTE, WiMax	MIMO, mm Waves
Frequency	30 KHz	1.8 Ghz	1.6 - 2 GHz	2 - 8 GHz	3 - 30 Ghz
Bandwidth	2 kbps	14.4 - 64 kbps	2 Mbps	2000 Mbps to 1 Gbps	1 Gbps and higher
AccessSystem	FDMA	TDMA/CDMA	CDMA	CDMA	OFDM/BDMA
Core Network	PSTN	PSTN	Packet Network	Internet	Internet

The table: shows the different technology eras in communication. The five different generations of communication system is mentioned in the table with different technologies, frequencies, bandwidth and access system names with the core network used [22] [23].

VIII. CONCLUSION

The maximum achievable speed for a 5G communication in the heavy traffic is not as per the prescribed theoretical value. The 5G communication system supports 100 times increased traffic capacity and network efficiency than 4G communication. The maximum speed that 5G communication can deliver is 20 gigabits per second, which is not able to achieve practically. This paper describes different technologies in and different generations of communication system, Which is started developing from 1980s to till date. The rapid growth is seen after 2015 all over the globe, Showing a drastic improvement in the communication technology. This is an effort made to understand the insights and the challenges faced by the 5G communication. The performance parameters are listed that can be improved to enhance the existing technology. The improvement in the speed of communication by avoiding the interferences and improving the parameters can be listed as a future scope of this paper.

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