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# OFDM Technique for 4G and Different Proposed Techniques for 5G - A Review

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***Abstract*: With the increasing demand of high data rates and the arrival of new ideas like Internet of things (IOT), machine to machine communication (M2M), and fifth generation (5G), the current OFDM technique does not suffice the need so is unsuitable for future 5G wireless networks. Although the current serving technique for the fourth-generation (4G) mobile communication is OFDM which is also applied in various other systems like Wi-MAX. However, the OFDM has some limitations like PAPR, OOB, and use of cyclic prefix (CP). Hence the need for new waveforms candidates like UFMC, FBMC, and GFDM is overwhelmingly welcomed for the 5G air interface. In the year 2020, it is expected that 5G will be deployed in many countries. They aim to provide high spectral efficiency, high speed, greater density of users, high capacity, pseudo outdoor communication etc. This paper gives an overview of OFDM for 4G, best-suited waveform candidates for 5G and lastly shows a performance based comparison of various multicarrier modulation schemes.***
***Keywords*: 4G, 5G, IP, Communication, OFDM, Data rates.**

## I. INTRODUCTION

As the most served and effective available technique so far for communication purpose is Orthogonal frequency division multiplexing (OFDM), which employs a square window in time domain thereby allowing a very efficient implementation and thus has been adopted in several broadband wired and wireless communication systems. OFDM earned all of the attention from the market because of the various advantages like robustness against multipath fading, ease of implementation, immunity to frequency selective fading, resilience to ISI, spectrum efficiency, simple channel equalization. Despite these advantages, OFDM suffers from a number of drawbacks including high peak-to-average power ratio (PAPR), use of cyclic prefix (CP), out of band radiation (OOB), sensitive to carrier offset and drift. So all these drawbacks give a setback to OFDM and thus not preferred for future 5G air interface [1]. Till now 5G is not completely defined it is believed that 5G will be the integration of several techniques and the work is in progress. Some of the known requirements for 5G are 1000× higher mobile data volume per geographical area, 10–100× higher typical user data rate, 10–100× more connected devices, 10× lower energy consumption (more battery life), End-to-end latency of <1 ms, 5G access in low populated density areas

Once all the above characteristics are achieved, the 5G research community has accordingly envisioned of some fields where it can make an impact and are as follows [2], [3].

*A.* Broadcasting of 3D or 4k video in small-sized densely deployed cells demands several tens of Mbps to achieve a good quality of experience (QoE). The MIMO and massive MIMO techniques are proving to be the best candidate for system spectrum efficiency, diversity, and multiplexing and thus will contribute towards the achievements of 5G.

*B.* The name in the list is for the internet of things (IOT). A lot of research work is in progress as it is an emerging field and so for the IOT finds its application in real-time constraints such as internet of vehicles, machine to machine communication, smart grid, monitoring, transportation, health and environmental measurements, etc. The IOT applications don't require large bandwidth and as the power saving is mandatory so duty cycle is intentionally kept low.

*C.* The focuses on low coverage area are prime importance of 5G, as the low populated remote areas suffer network problems low data rates and unreliable solutions, the 5G has eliminated it all and thus contributes to better living and connectivity in remote areas. The 5G research group has given it a name wireless regional area network [2].

Now all these characteristics are not possible to achieve with the OFDM technique, hence the need for new waveform contenders is required. The choice of waveforms depends upon a number of factors and will be investigated for 5G networks. The various contenders that are investigate in order to implement for future 5G networks are as follows Orthogonal Frequency Division Multiplexing (OFDM), Filtered Orthogonal Frequency Division Multiplexing (FOFDM) [4], Windowed Orthogonal Frequency Division Multiplexing (WOFDM) [5], Filter Bank Multicarrier (FBMC), [6] Generalized Frequency Division Multiplexing (GFDM)

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[7] and Universal Filtered Multicarrier (UFMC) [2]. Although it is not finalized which one will be employed so it is believed that 5G research group will come up with an integrated waveform that will live up to the expectations.

## II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) AS IN 4G

OFDM is basically a multi-carrier modulation technique in which FDM (frequency division multiplexing) is implemented to map and transmit data over the channel. In this complete carrier is divided into a number of sub-carriers or high data rate stream is split into low data rate streams. This data is then mapped and transmitted simultaneously over the available bandwidth. The symbol duration increases because of low rate parallel sub-carriers and thus diminishes the effect of multipath delay spread. In OFDM different parameters are to be considered such as a number of subcarriers, subcarrier spacing, symbol duration, symbol size, modulation method, IFFT size, peak power clipping. In OFDM each subcarrier should be orthogonal to other subcarriers present in the data so that the effect of inter-symbol interference is reduced. The fig. 1 shows orthogonality among three sub-carriers and mathematical expression required to carry out orthogonality among subcarriers is carried out in the equation below.

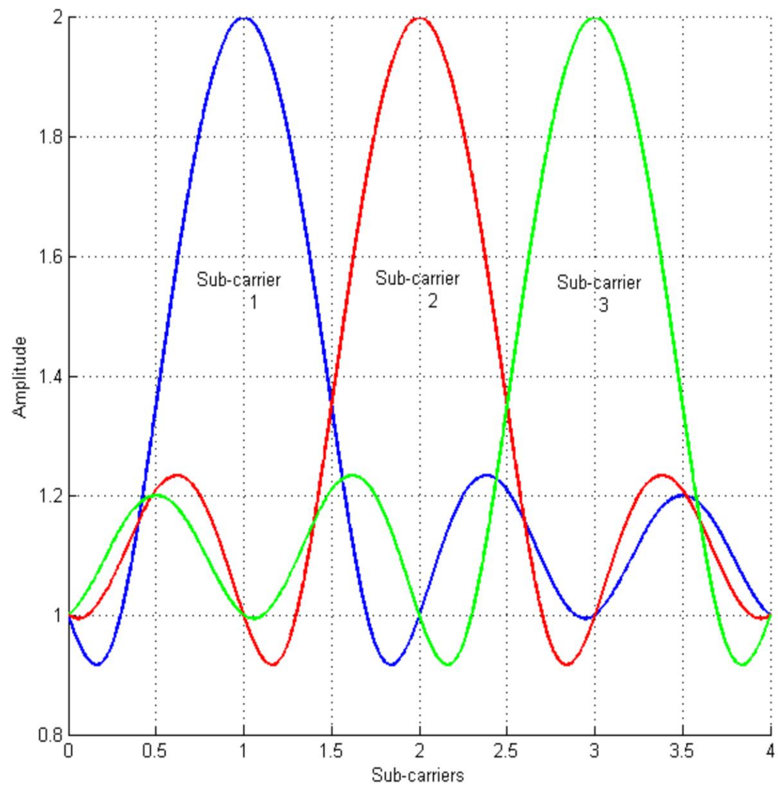


Fig. 1 Orthogonality among Three Sub-Carriers

To understand the concept of orthogonality among subcarriers, let's consider a complex exponential signal which is time limited and defined as $\{e^{j2\pi tf\,k}\}_{K=0}^{N-1}$. Such signals are said to exhibit orthogonal only if the integral product of two signals over an interval is zero, as shown in expression.

$$\frac{1}{T_{sym}}\int_0^{Tsym} e^{j2\pi tf_k} e^{-j2\pi tf_1}\,dt = \frac{1}{T_{sym}}\int_0^{Tsym} e^{j2\pi tf}\ \frac{k}{Tsym}\ e^{-j2\pi t\frac{i}{Tsym}}\,dt$$

$$= \frac{1}{T_{sym}}\int_0^{Tsym} e^{j2\pi\frac{k-i}{Tsym}}\,dt$$

$$= \begin{cases} 1, & \forall\ integer\ k = i \\ 0, & otherwise \end{cases}$$

The above derivation shows orthogonality among carriers and is the condition to be implemented in OFDM signals. Since OFDM signals are orthogonal to each other so overlapped subcarriers can be used which in turn makes OFDM a bandwidth efficient modulation scheme. Orthogonality is not only used to achieve bandwidth efficiency but it must also reduce the effects of ICI. Fig. 2 below shows the block diagram of the OFDM communication system.

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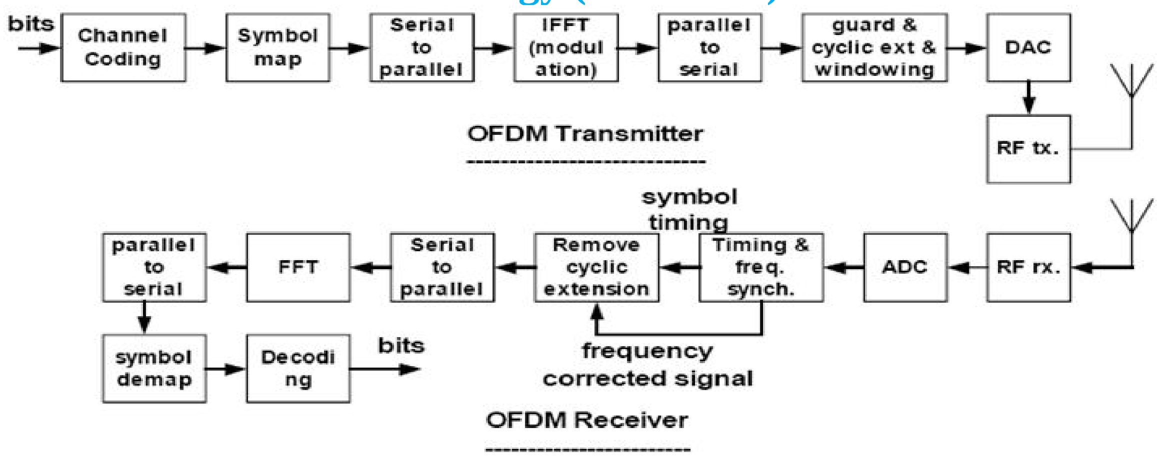


Fig. 2 OFDM System Block Diagram

Figure 2 illustrates the basic process involved in OFDM systems in the form of blocks. OFDM gained a lot of attraction due to its advantages like spectrum efficiency, resilience to interference, immunity to selective fading, immunity to delay spread, and simple equalization. OFDM thus finds its diverse application in the fields of communication and the most know such technology is a fourth generation (4G). Besides all these advantages OFDM has some limitations like high peak to average power ratio (PAPR), use of cyclic prefix (CP), out of band radiation (OOB), sensitive to carrier offset and drift. These shortcomings in OFDM has made it unsuitable for the use in future wireless networks like 5G, although OFDM will still serve as a root framework for new 5G waveform design. So the farewell to OFDM for the 5G network is not made completely possible rather evolve 4G OFDM in designing the new waveforms for 5G networks.

## III.5G TECHNOLOGY

Since 1980 when first generation system was introduced and till now there is seen a rapid growth in the field of communication and mobile technology. With every passing decade, the mobile generation is changing and as the current generation is 4G introduced in early 2010. The year 2020 is said to be the year for the fifth generation (5G) systems which is smarter and sophisticated technology. The 5G wireless broadband technology is actually based on IEEE 802.11ac standard. The 5G is said to offer speed of 1Gbps and provides an end to end fully connected society. The use of cognitive radio and other techniques in 5G systems make them intelligent in the way that they can differentiate between mobile and fixed objects and thus will be able to serve many network applications at the same time. Although 5G is evolving the key technologies leading towards 5G is still under process and needs a lot of attention. So many researchers and scientists are working on the project in the hunt for new techniques that will better suit 5G.

### *A. Key Technologies In 5G*

This section provides an overview of different techniques which will play an important role in the development of 5G mobile communication system.

1) *Filtered Orthogonal Frequency Division Multiplexing:* In OFDM the effect of large out of band emission due to the rectangular shaping of temporal signals is largely alleviated in FOFDM by using transmit filter which is cascaded after the modulator as shown in Fig. 3.

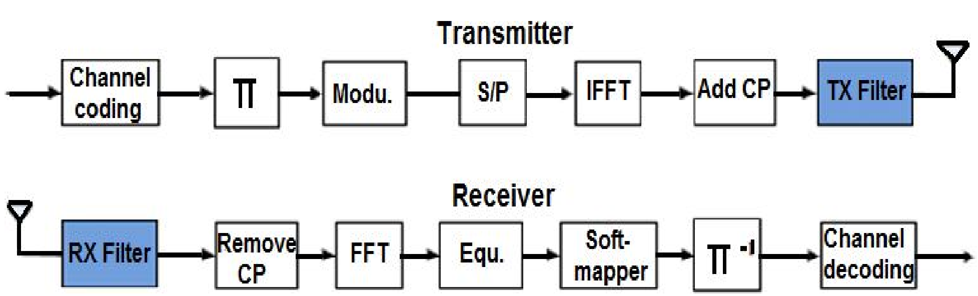


Fig. 3 Transmitter and Receiver Structure of FOFDM [4]

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Filtering process in FOFDM is done through specially filters which are suitably designed to suppress high side lobes thereby making FOFDM a bandwidth efficient technique. Besides this, filtering operation becomes challenging when the spectrum pulses are not continuous and the filter is redesigned for each available chunk of spectrum.

2) *Windowed Orthogonal Frequency Division Multiplexing :* This technique is also very much similar to conventional OFDM while the difference being in WOFDM we use the rectangular window to smoothen the edges of pulses which reduces adjacent carrier interference (ACI) and provide better spectral containment. Also to surmount the troubles of high PAPR and fading due to multipath property, WOFDM incorporates signal randomization and channel estimation and by employing forward error correction BER of approximately 1e-6can be received. Fig. 4 below shows the block diagram of WOFDM system.

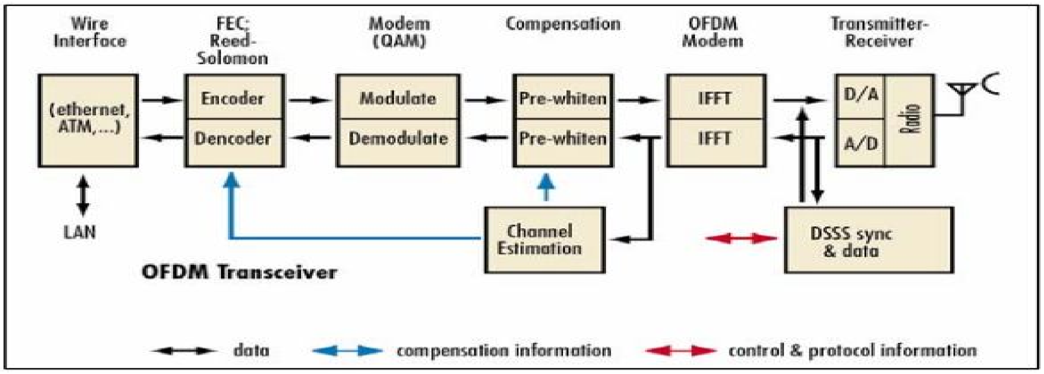


Fig. 4 Block Diagram of WOFDM Transceiver

3) *Filter Bank Multicarrier (FBMC):* It is a highly developed technique of OFDM which does not employ CP but uses arrays of filters at source and destination. Filter bank multicarrier applies filtering on a per-subcarrier foundation and is reckoned as an attractive substitute to OFDM to present an improved out-of-band spectrum characteristic. The plus point of this technique is that without using the CP, it can give an efficient and better performance than conventional OFDM. With such attributes, it is considered as one of the most capable modulation technique for 5G. This technique employs a bank of filters and the data in parallel pass through each filter. In FMBC offset-QAM is applied to comply with the factual orthogonality rule with the result FBMC exhibits non-orthogonality in the complex domain. OFDM with offset Quadrature amplitude modulation (OFDM/OQAM) is the most common FBMC technique [8].

The prototype filter in FBMC is to be carefully designed in order to minimize the ISI and ICI also to maintain the size of side lobes as small as possible. In FMBC we employ $N$ filters and the length of transmitted signal is given by $L = N \times p$, where $N$ is the size of FFT and $p$ is the length of each polyphase filter. The Fig. 5 shown below which is localized in time and frequency domain is obtained by employing isotropic orthogonal transform algorithm (IOTA) prototype function with $p = 6$, for use in FBMC system.

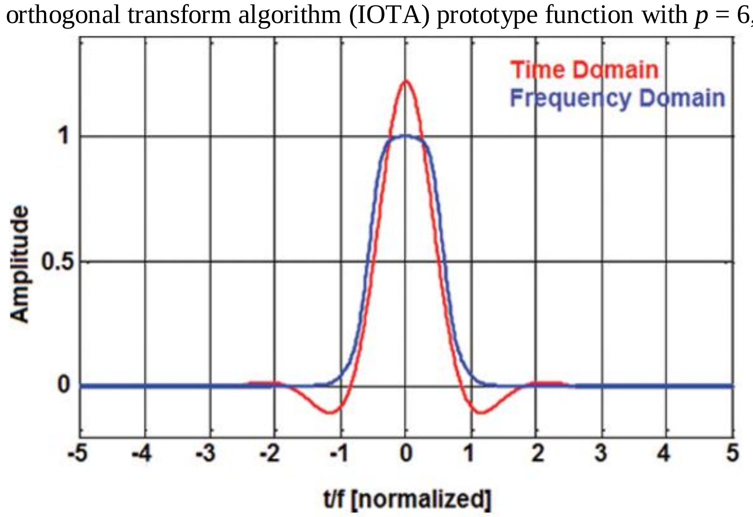


Fig.5. Time and Frequency Response of IOTA Prototype Function

The Fig. 5 shows that the time domain pulse is normalized to the average power of unity and frequency domain spectrum is

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normalized to the peak value of unity while both x-axis and y-axis shows the normalized value of symbol interval T and symbol rate $1/T_a$ respectively. Thus by the use of prototype filter subcarriers can be restricted in FBMC and also CP can be removed which results in better spectral efficiency when compared to OFDM.

4) *Universal Filter Multicarrier (UFMC):* UFMC is actually an integrated technique of FBMC and OFDM and is very much effective scheme known so far for 5G. This technique is different from FBMC in the way that filtering function is performed on a group of sub-carriers whereas in FBMC filtering is performed on each of the subcarriers. ). Fig. 6 shows the block diagram of a UFMC transmitter. The bandwidth is divided into numbers of subbands and is allocated to the number of sub-carriers. At the transmitter, N-point IFFT operation is performed which converts the time domain of the signal to a frequency domain. At receiver, FFT is performed which converts frequency domain to a time domain [9]. The technique efficiently reduces the sidelobe which increases the performance of the system.

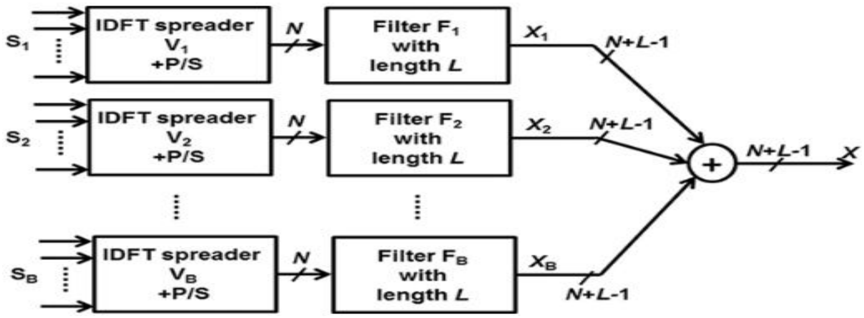

Fig. 6 UFMC Transmitter

The cyclic prefix can be dropped in UFMC and its additional symbol duration overhead is used to introduce sub-band filters. In addition to this orthogonality is still maintained between subcarriers. While FBMC is lagging in a feature of backward compatibility to demodulate legacy OFDM signals and suitability of UFMC for communicating in short bursts makes UFMC a better technique [2].

5) *Generalized Frequency Domain Multiplexing (GFDM):* It is a block based non-orthogonal multicarrier transmission in nature and is first contender waveform for a 5G mobile communication system. This scheme spreads data across two dimensions namely time and frequency. In this technique, transmission is achieved by using a time and frequency localized pulse and the modulation is based on a Balian low theorem [10]. GFDM can achieve higher spectral efficiency because of the fact that it doesn't require guard band and thus avoids adjacent channel interference (ACI). In this technique, a filtering is used for each subcarrier which reduces the sidelobe, PAPR, etc. At receiver, it implements the Poisson summation algorithm for each symbol [11]. The Fig. 7 below shows the block diagram of GFDM system.

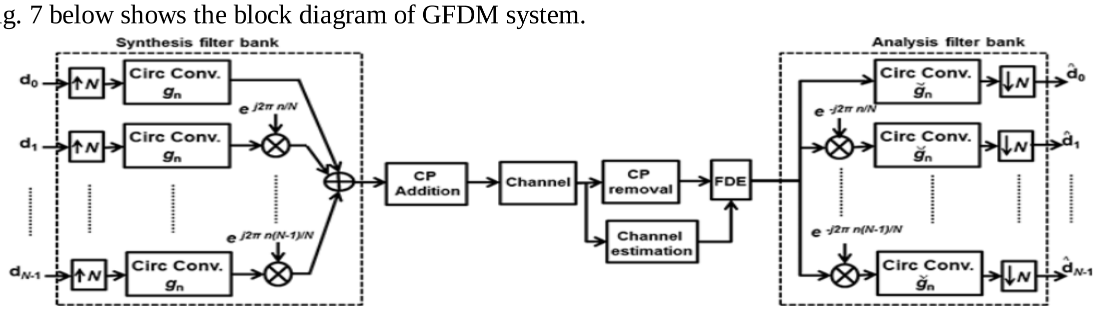

Fig. 7 Block Diagram of a GFDM Transceiver System [7]

*B. Spectrum Allocation For 5G*

Federal Communication Commission (FCC) has listed some band that can be licensed for 5G are as follows:

1) 24 GHz Bands: 24.25–24.45 GHz and 25.05–25.25 GHz.
2) LMDS Bands: 27.5–28.35 GHz, 29.1–29.25 GHz and 31– 31.3 GHz.
3) 39 GHz Band: 38.64–40 GHz.
4) 37/42 GHz: 37–38.6 GHz, 42–2.5 GHz.

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*5)* 60 GHz band: 57–64 GHz and 64–711 GHz.
*6)* 70/80 GHz: 71–76 GHz, 81–86 GHz and 92–95 GHz.

*C. Features Of 5G* [12]

*A. Fast Network:* The user in the year 2020 will experience a data-rate greater or equal to 1 Gbps [12].

*B. Reliable service in crowd areas*: 5G aimed to give a better service and connectivity in crowd place such as shopping malls, the metro station [12].

*C. Service in Remote Place*: Some of the application for remote place includes remote meter reading for billing purpose, e-health like telemedicine, smart city, and video surveillance. 5G aimed to improve this service in remote place [13].

*D. Integration of numbers of low power devices*: Hence 5G aimed to supports huge number devices consuming low power and such devices will be seamlessly integrated into commercial 5G mobile [13].

*E. Intelligent Handover:* 5G, an intelligent handover is expected with the least delay during the switching of the network.

*F. Pseudo Outdoor Communication:* Research has proved next generation mobile communication system is aimed at pseudo outdoor communication where network coverage, data rate, and other services in the indoor area are equivalent to the outdoor area.

*G. Utilization of White Spectrum*: White band utilization should be one of the important aims of 5G because at present white band spectrum is un-utilized and its utilization solves the issue of spectrum crisis in maximum possible extent.

*H. High Capacity:* In the year 2020, consumption in wireless traffic is expected to increase by 30% hence 5G network should accommodate the increasing numbers of users with the best quality of service.

## IV. COMPARISON

In order to have the clear vision of various techniques and technologies, its good have a comparison on the basis of performance and specifications. This section is all

*A. Comparison between 4G and 5G.*

TABLE I:
Comparison Between 4g And 5g Technology

| Specification | 4G | 5G |
|---|---|---|
| Full form | Fourth generation | Fifth generation |
| Data bandwidth | 2Mbps to 1Gbps | 1Gbps and higher as per need |
| Frequency Band | 2 to 8 GHz | 3 to 300 GHz |
| Standards | All access convergence including OFDMA, MC-CDMA, network-LMPS | CDMA and BDMA |
| Technologies | Unified IP, seamless integration of broadband LAN/WAN/PAN and WLAN | Unified IP, seamless integration of broadband LAN/WAN/PAN/WLAN and new advance technologies based on OFDM modulation used in 5G |
| Service | Dynamic information access wearable devices, HD streaming, global roaming. | Dynamic information access wearable devices, HD streaming, and any demand of the user. |
| Multiple Access | CDMA | CDMA, BDMA |
| Core network | All IP network | Flatter IP network, 5G network interfacing (5G-NI) |
| Handoff | Horizontal and vertical | Horizontal and vertical |
| Initiation from | Year 2010 | Year 2015 |

*B. Comparison of various MCM schemes*

TABLE II:
Comparison Of Different Multi-Carrier Modulation Schemes [15]

| Figure of merit | OFDM | FOFDM | WOFDM | FBMC | GFDM | UFMC |
|---|---|---|---|---|---|---|
| PAPR | High | High | High | High | Moderate (for SC-FDE) | High |
| OBE | High | Low | Low | Low | Low | Low |
| SE | Low | Low | Low | High | High | High |
| Computational complexity | Low | Moderate | Moderate | High | High | High |
| Short burst traffic | No | No | No | No | Yes | Yes |
| Fragmented spectrum | No | No | Yes | Yes | Yes | Yes |
| TO resiliency | Poor | Poor | Moderate | Good | Good | Good |
| CFO resiliency | Poor | Poor | Moderate | Good | Good | Good |

## V. CONCLUSION

This paper introduces with the existing technique used for current 4G systems and previews different techniques proposed for future 5G networks. As the development of the mobile and wireless networks is going towards higher data rate so in future networks there is a migration of existing network to IP-based networks. The all IP based communication takes place on the network layer. 5G is a promising generation of wireless communication that will change people's lives. One of the major concerns in 5G is the validation of new concept proposed by different researchers. Finally, we conclude that the main aim of 5G is to make the wireless network world free from obstacles and provide reliable service with more functionality to end nodes.

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I concede the way my guide Deepika Rana played an important role in carrying out this work and all those difficult times when it was looking like a blind alley. She gave me confidence and motivated me to take up this work. All my toiling efforts were based on her motivation. Finally, i would like to mention my parents which are the be-all and end-all inspirations and motivations to me.

## REFERENCES

[1] Ijaz, A., et al. Enabling massive IoT in 5G and beyond systems: PHY radio frame design considerations. IEEE Access. 2016;4:3322–3339.
[2] 5GNOW deliverable D3.2_v1.3. 5G waveform candidate selection.2014.
[3] NGMN. 5G white paper.
[4] Xiao, P., Toal, C., Burns, D., Fusco, V., Cowan, C. Transmit and receive filter design for OFDM-based WLAN systems. In: International Conference Wireless Communications and Signal Processing (WCSP); October 2010; IEEE; pp. 1–4.
[5] Bala, E., Li, J., Yang, R. Shaping spectral leakage: a novel low-complexity transceiver architecture for cognitive radio. IEEE Vehicular Technology Magazine. 2013;8(3):38–46.
[6] Siobhan, P., Siclet, C., Lacaille, N. Analysis and design of OFDM/OQAM systems based on filterbank theory. IEEE Transactions on Signal Processing. 2002;50(5):1170–1183.
[7] Farhang, A., Marchetti, N., Doyle, L.E. Low complexity transceiver design for GFDM (forthcoming). arXiv:1501.02940.
[8] Du, J., Xiao, P., Wu, J., Chen, Q. Design of isotropic orthogonal transform algorithm-based multicarrier systems with blind channel estimation. IET Communications. 2012;6(16):2695–2704.
[9] Vida Vakilian, Thorsten Wild, Frank Schaich, Stephan ten Brink, Jean-Francois Frigon, Universal filter multi-carrier technique for wireless system beyond LTE, Global Workshop Broadband Wireless Access, 2008, pp. 223–228.
[10] Ivan Gaspar, Maximilian Matthe', Nicola Michailow, Luciano Leonel Mendes, Dan Zhang, Gerhard Fettweis, GFDM Transceiver using Precoded Data and Low-complexity Multiplication in Time Domain, 2015, pp. 1–4.
[11] The impact of Timing and Frequency Offsets on Multicarrier Waveform Candidates for 5G. Amir Aminjavaheri, Arman Farhang, Ahmad RezazadehReyhani Behrouz Farhang- Borophene, CTVR/The Telecommunications Research Centre, Trinity College Dublin, Ireland.
[12] ICT-317669 METIS Project, Scenarios, Requirement, and KPIs for 5G Mobile and Wireless Communication System, www.mettis.2020document.com.

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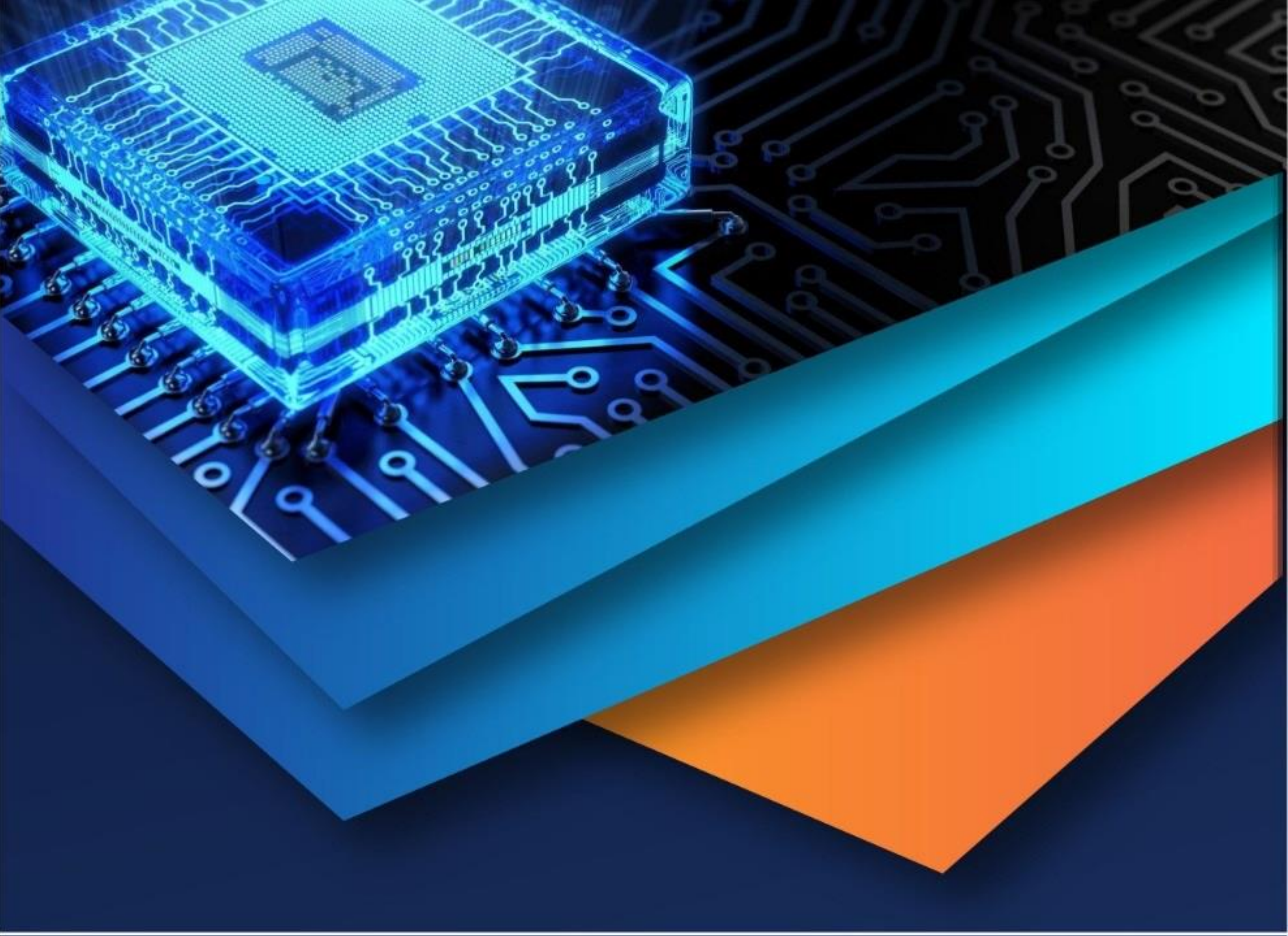
ISSN: 2321-9653


[13] 5g Radio Access Ericsson White Paper, 2013.
[14] Farhang, A., Marchetti, N., Figueiredo, F., Miranda, J.P. Massive MIMO and waveform design for 5th generation wireless communication systems. In: 1st International Conference on 5G for Ubiquitous Connectivity (5GU); November 2014; IEEE; pp. 70–75.

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