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A Roadmap towards Connected Living: 5G Mobile Technology

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Abstract: ***Internet of things connecting everyone requires vast networking connection. Trillions of devices are supposed to be connected due to IoT. The growing need of connectivity resulted in development of mobile networks from 1G towards 5G. Digitally connected world demands enormous bandwidth & flexible network. They need superior throughput, increased data rate, improved network capacity and less delay in the system. The expectations from 5G are getting high. With capacity a thousand times greater and data rates up to 20 Gbps. 5G contribute novel radio frequency band like 6 GHz. 5G has advanced features which helps to resolve many problems. Audio video streaming, mobility, switching network, slow network connection, buffering & loading problems were sorted with 5G. It enables cloud based services with its accessibility and flexibility features. The aim of 5G is to provide very low latency, improvement in QoS & increased rate of data. All features of 5G such as speed, cell distribution, mm wave, latency, spectrum, MIMO, slicing are discussed. Literature Survey on 5G wireless communication technology provides an analysis of recent advances towards 5G, their limitations, challenges, countermeasures and future research areas. All stakeholders, such as industry, academics, researchers, mobile operators, vendors, standardization authorities, regulatory bodies are working together for deployment of 5G. The data and information related to 5G which is accumulated from all stakeholders provides an overview of 5G and anticipated 5G technologies. There is significant research & developments going on in 5G networks by different research groups. Their work is highlighted in this paper. This will give new directions in research and will pave the way to new applications. 5G will be supporting different kind of services required by the user. OFDM (Cyclic-Prefix) is not good enough for such kind of services. To fulfill these service requirements, an improved waveform is needed. This paper provides performance comparison of the candidate waveforms like GFDM, BFDM, FBMC, UFMC, NOMA and different variants of OFDM. Based on above result analysis and discussions a new waveform is proposed which overcomes the disadvantages of previous waveforms in use. An improved alternative waveform and multiple access technique proposed is a good initiative. Better results are possible by combining these two methods Windowed & Filtered OFDM. WFOFDM supports MQAM modulation. Hybrid WFOFDM is a good waveform contender resulting in improved performance, reduced OOB emission in shorter (6 or 8) window length, increased spectrum efficiency. This proposed new improved waveform is flexible and is also compatible with new multiple access technique and new modulation scheme.***

Keywords : 5th Generation, Beamforming, BDMA, BFDM, Cellular, Cloud, D2D, FBMC, GFDM, Latency, Multi carrier, MIMO, mmWave, NOMA, OFDM, Radio Access Network, Spectrum, UFMC, Variants of OFDM, Wireless networks

I. INTRODUCTION

Need for increased rate of data is growing continuously for fulfilling the users demand for smarter, faster network which is fully secure. Mobile networks have witnessed considerable improvement to boost the system's performance. Technology change up till 5G has experienced enhancement in rates of data, switching to digital from analog, shifting to packet from circuit switching. To provide increased data rates to all users more resources allocation is required in the spectrum. For flexible network ultra dense network and small cells will be deployed. While developing new mobile technology the performance improvement parameters such as connectivity, scalability, compatibility, interference, legacy networks, jitter & energy efficiency are also considered. Technology enhancement from 2G to 3G provided improved network speed and faster downloads. This allowed video calls in real time. LTE & LTEA provided higher capacity networks. Data, Voice, Video transmission was achieved through wireless connectivity. 3G was designed for voice data & multimedia. 2G offered data & voice services. In 2G the data rate was 64 Kbps, which increased up till 2 Mbps in 3G. In 4G it increased to 50–100 Mbps. 5G will improve connectivity, scalability & compatibility. It will increase rate of data transfer and will enhance network efficiency. Remote controlled operation of machines & appliances on 5G is possible in real time. 5G is energy efficient mobile communication technology offering high throughput, high reliability, increased scalability and low latency. The key technologies to fulfill the requirement for 5G system are cloud based RAN, MIMO, network densification, small cells addition, virtualization of resources, improved energy efficiency, D2D communication, transmission and reception simultaneously. 5G uses OFDM and packet switching offering high bandwidth and increased network coverage area. millimeter wave covers 30 GHz - 300 GHz frequency range. For 2 km distance it provides a data rate of 20 Mbps. mm wave band is effective for increased usage of Internet. It has highly flexible and dynamic ad-hoc wireless network. It provides 5 to 20 MHz bandwidth, 40 MHz optimally. It uses intelligent antennas and modulation method which is flexible. It enables high bandwidth which is bidirectional. It enables transfer of enormous giga bytes data. The digital revolution has resulted into new applications like Big Data, IoT, 3-Dimensional media, Machine Learning. This requires enormous data traffic handling capacity. The need of high speed connectivity has therefore become a necessity.

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The huge data needs multiple Gbps throughput and bps/km^{2}area efficiency. 11.6 billion devices will be connected on mobile in 2020 which exceeds the total population of world projected around 7.8 billion. By 2021 it is anticipated that the data traffic of mobile per month will increase to around 50 petabytes. Data traffic on mobile will continue to grow at a faster rate. Video traffic is expected to reach more than 77% of the total traffic by 2020. Video traffic is a major challenge to upcoming 5G networks. Therefore aim of 5G systems is achieving higher rates of data in multiples of tens of Gbps. The second objective is achieving ultra low latency of < 1 micro second round time. It provides 500 km/h maximum mobility with reduced latency. Transmission waveform used in 4G is OFDM. It is compatible with MIMO and is easier to implement. It uses simple schemes for modulation & demodulation. Peak value is high in comparison to average value of system. PAPR is high around 12 dB which is the main problem of CP-OFDM. Functionality of output power amplifier gets affected due to high PAPR. Its efficiency decreases as proposed by Zaidi A., Athley F., et.al. [1]. As a result battery of user equipment gets discharged very fast. CP-OFDM is having very low spectrum efficiency. Out of band side lobes are very high. Out of band (OOB) emission are unacceptable as they cause interference. To decrease this windowing or filtering method is proposed. A flexible cost effective waveform which is compatible and capable for meeting the desired demands is crucial.

1.2. Paper Structure

Section 2 contains literature survey on wireless communication technology, Section 2.1 details correlation of different generations of mobile, Section 2.2 gives mobile generations features, Section 2.3 contains work area & key vision of different authors, Section 2.4 introduce research groups and their work, Section 3 contains the proposed methodology. Sections 3.1 contains development towards 5G, Section 3.2 contains features of 5G, Section 3.3 gives merits & demerits of 5G, Section 4 contains the result analysis and discussions, Section 4.1 compare and analyze the candidate waveforms and propose new one, Section 4.2 compare and analyze the different multiple access techniques, discuss their merits and demerits and propose the best suitable for 5G, Section 5 presents the conclusions

II. LITERATURE SURVEY

Literature survey describes the evolution in mobile due to service needs of increased number of subscribers. Features, performance analysis, merits and demerits of different generations; work done by different authors in this area are illustrated. The different research bodies and groups from academics, industry who are working and promoting research in innovative wireless technologies are also described along with their key research area.

2.1. Correlation of different generations of mobile from 1G towards 5G is given below:

Roadmap of different mobile technologies is explained in this paper. Challenges such as spectrum crisis and energy consumption which cannot be accommodated by 4G need to be resolved in 5G.

Table 1. Different generations of mobile from 1G towards 5G

1st generation (1G)	First generation of mobile (1980-1990). It supported data rates from 1 kbps to 2.8 Kbps. It used circuit switching. It used analog technology known as Analog Mobile Phone Service. It used 40 MHz bandwidth and frequency range of 800-900 MHz. It used Frequency Division Multiplexing. It supported only audio. It provided low quality calls. Power consumption was very high. It suffered from various drawbacks such as poor audio links, low data capacity, no security & unreliable handoff.
2nd generation (2G)	Second generation of mobile (1991-2007). 9.6 kbps to 19.2 kbps data rate with 64 kbps maximum. It used packet switching to increase spectrum efficiency. It used digital technology. The bandwidth required is about 20-200 KHz. It used GSM, IS-95 and CDMA technology. To improve the quality of audio, it used digital modulation. It provided email and SMS services. It is more secure. It used digital encryption to improve security. It offered better connectivity. It cannot handle complex data like videos. Networks offer the limited data services. It improved the transmission quality and coverage. 2.5G was launched between 2G & 3G. 200 kbps data rate. It used Enhanced Data Rate and GPRS
3rd generation (3G)	Third generation of mobile (2008-2011). 144 Kbps to 2 Mbps data rate. The Bandwidth required is about 5-20 MHz. It used circuit and packet switching. It used Wireless Web. Quality of voice improved. Quality of Service improved. It supports CDMA, WCDMA and UMTS. It supports HSUPA & HSDPA. Data rates improved. It offered access to broadband multimedia services. It offered services broadband wireless data; It offered services of video calls. WLAN & Bluetooth allowed device to device communication. Quality of Service was poor. It was unable to fulfill the demands of network efficiently.
4th generation (4G)	Fourth generation of mobile (2012-2019). 100 Mbps data rate in full mobility. 1Gbps data rate in low mobility. It uses CDMA multiplexing & packet switching. It uses internet protocol. It offers support to Integrated wireless solutions. It supports services & applications like High Definition Television, Digital Video Broadcast, Video Chatting and Multimedia Message Services. It offers Global Mobility Support. LTE-A supports around 1Gb/s

5th generation (5G)	Fifth generation of mobile (2020 onwards). 10 Gbps data rate. 6 GHz frequency bands. Achieves 500+ Mbit/s speed. Target air latency is 1-4 millisec. Tested air latency is 8-12 millisec. 5G networks are digital cellular. Service area is divided in small areas named as cells. Sounds and images in analog form are converted to digital. It is transmitted in bits. 5G devices communicate using radio waves with low power transceiver and local antenna array over allocated frequency channels. Local antennas are connected to Internet via telephone network through optical fiber or wireless backhaul connection, thus offering high bandwidth. 5G uses millimeter waves. mm waves have smaller antennas and have trouble passing through walls. massive MIMO is another technique which can be used for increasing the data rate. Each cell has multiple antennas which communicate with wireless devices. Multiple bit streams of data will be transmitted simultaneously. In beamforming base station calculates the optimized network route to the wireless device. It organizes multiple antennas working as electronically scanned phased arrays which are controlled by computer to create radio waves beams to reach the wireless device. 5G supports million devices per square kilometer. It supports FCMA & BDMA. The earlier generation of mobile depend on base station so were known as network centric. 5G is having full network which is managed by the devices. 5G works on device centric approach. It resulted in better throughput, reduced latency, improved system capacity and increased spectral efficiency.

Mobile Generations depicted in Fig. 1

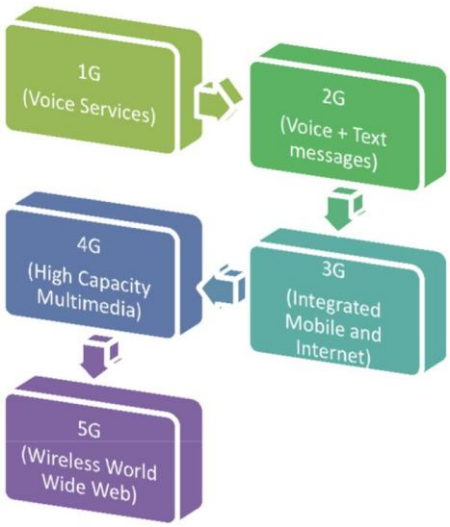

Fig. 1 Mobile Generations

2.2 Features of different generations of mobile from 1G towards 5G are given below:
This paper provides correlation of mobile networks from 1G towards 5G. Readers will have understanding of features such as location of first commercialization, deployment, core network, switching type, bandwidth, frequency, multiplexing, web standards, standards technology, handoff, antenna type, radiation pattern, diversity and MIMO, key differentiator services, weakness & shortfalls. The performance parameters such as energy efficiency, spectral efficiency, network capacity, throughput, data rate, types of switching technique used, multiplexing, hardware requirements are clearly defined and discussed. The shortcomings of different generations were analyzed for removing them in 5G. This data collection on different issues & challenges will help the researchers for understanding the current problem. It will motivate them to work on proposed solution and improved outcome for future generations

Table 2 Generations of mobile

Technology	1G	2G	3G	4G	5G
Place of Commercialization	USA	Finland	Japan	South Korea	San Marino
Deployment	1980-1990	1991-2007	2008-2011	2012- 2019	2020 onwards
Network	PSTN	PSTN	Packet	IP	IP
Switching type	Circuit	Circuit	Circuit and Packet	Packet	Packet
Bandwidth	2 Kbps to 2.4kbps	16 Kbps to 64 Kbps	2Mbps to 30Mbps	100Mbps to 1Gbps	Higher than1Gbps
Frequency	824 MHz to 894 MHz	850 MHz to1900 MHz	1.8 GHz to 2.5 GHz	2GHz to 8GHz	3GHz to 300GHz
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA, BDMA
Web		WWW	WWW IPv4	WWW IPv4	WWWW IPv6
Standards	MTS, IMTS, AMTS	EDGE, GSM	IMT2000, HSUPA, HSDPA	LTE, LTE Advanced Wi-Max, Wi-Fi	Single unified

Technology	Analog	Digital	UMTS, EDGE, WCDMA IP, HSUPA, HSDPA	Wi-Max, Wi-Fi , WLAN LTE, LTEA OFDM , OFDMA MC-CDMA, LMPS	4G+WWWW 4G , OFDM
Handoff	Horizontal	Horizontal	Horizontal	Horizontal, Vertical	Horizontal, Vertical
Antenna				Sub Wavelength	Array
Radiation Pattern				Omni Directional	Multi Directional Beam
MIMO				Compatible	Compatible
Key Differentiator	Mobility	Secure	Enhanced Connectivity	Faster, Reduced Latency	Excellent rate of data, Enhanced coverage area, Zero dropped calls , Improved Performance, Almost zero latency
Service	Voice only Analog phone calls, No Data service	Voice Data Messages	Voice Messages High Speed Data Video	Global Roaming, Dynamic Access to Information, Voice messages, Data, Multimedia, Video	International Roaming, Dynamic information access, Voice messages, Data in Gbps, Multimedia, Video, High Speed, High Capacity
Weakness & Shortfalls	No Security , Poor Spectral Efficiency, Poor quality voice, Low capacity	Difficult to support Internet & e-mail, Limited data rates, Digital signals depends on location & proximity, Require strong signals for mobiles	Following old mobile specific architecture & Protocols, Limited data rates, Needs higher capacity networks	High Battery Usage, High data rates and capacity for users, Poor Spectral Efficiency, Hardware Required is Costly	Yet to be Deployed

2.3 Work Area & Key Vision of different authors is given in Table 3

Literature Survey on 5G wireless communication technology provides an analysis of recent advances in mobile technology towards 5G. Some of the researchers, their area of research, work done by them along with their research initiative & vision is highlighted

Table 3 Work Area & Key Vision of different authors

Ref.	Author	Work Area & Key Vision
[2]	Ericsson	Proposed that due to IoT, the things which will be connected via internet will be around 50 billion
[3]	Mehta H., Patel D.,	1G network are not secure, have low quality voice links, less capacity and unreliable handoff. It fulfilled the basic needs of users such as voice. 2G provided wide coverage area & high capacity
[4]	Mir M. M., Kumar S.	First generation of mobile (1980-1990). It used analog technology known as Analog Mobile Phone Service. It supported data rates from 1 kbps to 2.8 Kbps. It used 40 MHz bandwidth and frequency range of 800-900 MHz.
[5]	Anju Uttam Gawas	Proposed that 1G used analog technology. It used circuit switching. It was slower and not effective for communication and data transmission. It was not capable enough to provide services to remote rural areas. It has no security, poor voice quality, low capacity and problematic handoff. To overcome these problems and address these issues 2G was launched. WCDMA is the air interface used by UMTS. The drawback was that it consumed more power. 3G networks need different devices which were not compatible. 3G licensing & agreement costs were very high. 3G handsets were not available in few regions. To overcome all these problems 4G was launched
[6]	Meenal G. Kachhavay	4G also popular as LTE was launched for providing improved quality of service. The main expectations from 4G were continuous and uninterrupted connectivity. It supports services & applications like Mobile Television, High Definition Television, Digital Video Broadcast, DVBMMS, Video Chatting, Multimedia Message Services and access to wireless broadband

[7]	J.G. Andrews	5G mobile technology will provide continuous connectivity, without any interruptions. It will meet the increasing demands of billions and trillions of things connected which generates real time traffic. Smooth real time connectivity will be provided to the users
[8]	Satinder, Babbar V.	Fourth generation of mobile (2012-2019). It used packet switching & CDMA multiplexing. LTE-A supports around 1Gb/s. It offers Global Mobility Support.
[9]	Akhil Gupta, Rakesh Kr. Jha	Proposed 5G technology with 5G cellular network architecture. They posed different issues & challenges in 5G technology. 5G will provide great platform for forthcoming networks. It enables a perceived fully connected world. It will be providing support to technologies like smart cities, smart homes, Internet of Thing, intelligent vehicles, automatic smart appliances, real time health care, smart transport, smart farming agriculture, smart learning and education
[10]	Kwadwo, P., Agyapong	Proposed that in 5G the front haul portion of telecommunications architecture consists of the links between centralized radio controllers and radio heads at the edge of mobile network. It is in fusion with the back haul portion of the network. Network functions virtualization is replacement of the functions of network on smart and dedicated appliance like firewalls, load balancers and routers. Its objective is to change the ways to deliver the services and development of networks. Using NFV the network functions can be simplified and efficiency can be increased rendering faster services. In 5G NFV will virtualize all things and applications. It will enable network slicing and distributed cloud, which will help in creating flexible programmable networks
[11]	DMC R&D Center	5G deployment will be by the end of 2020. It will provide great features to users. It will provide 1Gbps data rate, 100Mbps speed, It will support 4G and Wireless World Wide Web. It will operate on IPv6. It will utilize CDMA, BDMA and millimeter wireless.
[12]	Bego Blanco	Proposed the present standardization scenario of 5G. To meet these challenges proposed in current scenario the network software is playing major role. The data and information related to 5G was collected from various stakeholders. It was analyzed; use cases, scenarios and relevant to upcoming 5G enable technology. This helps in identifying future research directions. It will be able to meet the user demands, expectations and service requirements.
[13]	R. Henderson and M. Langridge	5G technology will support all the available applications. 5G will enable cognitive radio and multimode. It will emphasize on user stations advancements. Stations will be able to support different types of wireless technologies. For servicing among the multiple access networks which are available the base station will select the optimum one
[14]	Chaudhary R. R	Proposed massive MIMO, another innovative approach for 5G networks. It includes enormous devices which are mobile connected, ultra dense networks and machine type communication. MIMO increases network capacity by utilizing multipath propagation. Multipath happens when a signal takes multiple paths from the antenna at transmitting end to that of receiving end. It is practical method for receiving & sending multiple data signals simultaneously on the same channel using multipath propagation. It is different from the smart antennas developed to improve the performance of single data signal like diversity & beamforming
[15]	Kwadwo P.A	Proposed that MIMO antenna arrays have fewer antennas. Multiple antennas are deployed in MIMO arrays. It is utilized for beam shaping and directing the transmitted and received signals. MIMO antenna improved the efficiency of spectrum by 10 to 20 times in the same frequency bandwidth. MIMO, digital antenna arrays, adaptive array antennas, multiple antennas are the antenna arrays having smart algorithms for signal processing. They are used for identifying the spatial signal signatures like the direction of arrival of signal. It uses them to compute beamforming vectors which are used for locating and tracking the antenna beam on the target mobile.
[16]	Larsson E.G	Proposed that the objectives of 5G can be achieved by reducing the latency and boosting the data rate. This allows mm wave to be used, inspite of low diffraction and high attenuation. This methodology will enhance the capacity of the network in wireless communication. This can be achieved using multiple antennas for transmitting and receiving.
[17]	Eduardo Castaneda	Proposed the multiple techniques which help to achieve the collective optimization task for the downlink in MU-MIMO.
[18]	Carolina Fortuna	The heterogeneous devices bundle up densely to form the basis of machine to machine communications. They enable direct communications among digital devices. They provide services to multiple applications such as home automation, body area networks, industrial automation, urban service enablers, transport, agriculture, medical and entertainment. They use current and upcoming wireless technologies, serviced by 5G, eNodeBs and IoT. With help of applications and control programs it can be controlled by using software interfaces. This curtails onsite manual adjustments and control. The functions are split into two parts in both the downstream & upstream directions as proposed by them. The application programming interface which was developed using languages which are object oriented is similar to the state transfer principles. They proposed localization using control applications implemented by using restful functions
[19]	Zoraida Frias	Proposed that 5G will be providing continuous uninterrupted fiber like services to its users. 5G will provide much faster services by achieving high speed and zero latency. It will fulfill the different and multiple needs & service requirements of the users in terms of reliability and security. European Union has affirmed the single market regulation in telecommunications. This will ensure that all the traffic which gets routed through the internet is equally treated. They analyzed the likely differences which exist between 5G and the net neutrality regulation. They recommended network virtualization. The net neutrality was based on traffic conditions and its optimization. This proved to be very complicated in a network where the network slices are created based on users demand. This is as per the requirement of Quality of Service for a particular application.
[20]	Jing Wang & Chih Lin	5G is expected to provide continuous, homogeneous, uninterrupted and consistent connectivity across the world

[21]	Erik Dahlman	Investigated details of 5G radio access technology. To get improved flexibility, better air interface and enhanced performance they proposed some principles which need to be followed for networks. They highlighted the key 5G technology components such as duplex arrangement, flexible system plane, multiple connectivity, massive MIMO, improved waveforms and integration of front haul back haul.
[22]	Garg S.	Proposed that D2D communication is direct device to device communication among two devices without the involvement of base station. It can operate on the in band and out band spectrum. In traditional networks all the communications are routed via base station. It offers low data rate and is suitable for messaging services and voice calls. Users need higher rates of data services for gaming, video sharing and social networking sites. It therefore increases network spectral efficiency, improves throughput, delay and energy efficiency
[23]	Ian F. Akyildiz	Stated that the 5G has to fulfill the rising demand of users for increased rates of data. It is extending to new locations covering remote areas with wider networks. It will offer high data rate around 1Gbps, Battery consumption is less, Multiple data transfer rates are available, More Secure, Improved Energy efficiency, lower latency, reliable connectivity and Better spectral efficiency
[24]	Shahid Mumtaz	Proposed several enabling technologies for 5G. The aim is to evolve a flexible network. All stakeholders including researchers, academicians, industrialist, vendors, mobile operators, regulatory bodies & standardization authorities are working together to make 5G operational. They have collected all the 5G related data and information from different stakeholders. This is done for complete review, survey of the 5G upcoming technologies, noting the advances & development from the point of view of stakeholders, opening up new research areas on services and applications for upcoming wireless networks.
[25]	Pablo Salva, Garcia	Proposed that the motivation towards 5G is video applications like streaming. The users which require high quality videos need high data rate and continuous connectivity. To achieve adaptive video streaming 5G-UHD framework was proposed. The optimization procedure for video streams and the architecture was also proposed. Using a virtual 5G test bed the model system was developed. The framework design was validated by empirical experiments. Performance parameters were evaluated based on the results
[26]	Jiasong Mu	Analyzed that the ZigBee networks are economical and simple so they are widely used. They consume more power which needs to be improved. It supports machine to machine communication and connects smarter devices. The currently deployed ZigBee networks can be connected with 5G terminals. Data transmission can be improved and data rate can also be increased. For different types of communication a nearest access routing algorithm performance was analyzed which was based on physical depth. To reduce congestion on ZigBee networks the traffic gathered from the 5G terminals is transmitted through the IP networks. In ZigBee networks nearest access routing algorithm effectively route the traffic as confirmed by simulation results. This has resulted into enhanced performance with reduced latency, very few packets transmitted via ZigBee nodes, zero overheads on routing, increased packet delivery ratio from ZigBee devices and less hop counts
[27]	S. Zhang	The daily life of people will be changed with the integration of IoT and 5G. People will be getting continuous uninterrupted connectivity. This will help them to upload the daily activity data and control commands of IoT. This will be generating an enormous uplink data flow which will be easily handled with faster efficient 5G networks
[28]	Akhil Gupta, Rakesh Kr. Jha	Supports concepts in which smart objects are connected through the internet. It supports the following applications: Internet of Things: It connects different things such as devices, objects, machines, animals and people to internet. Unique identification is given to each thing. It is having an ability to transfer the data through network without involvement of user. Internet of vehicles: Heterogeneous sensors deployed in vehicles are connected using vehicle Ad hoc networks. To store and process the IoV data cloud computing is used. Traffic delays are caused due to distances between the cloud and IoV sensors. Data transmission is complex due to the mobility of vehicles Health care: Doctors can monitor the health of patients in real time through connected devices via internet. The smart device will gather medical and health data and will send collected information and data to the doctor through internet Smart home: Smart homes involve all home appliances and devices like thermostats, security cameras, lighting fixtures, refrigerator, door locking mechanism
[29]	Gaikwad Vaibhav Vitthal and Bhor Pooja Vijay	Proposed large data rates for small range communications. They explored that this is very useful for technologies like mm wave communications, ultra wideband, Wi-Fi, Small cell and visible light communications. High frequency waves are required in visible light communication and mm wave. They are not effective and competent for distant mobile communications. They explored that these waves will not be able to penetrate dense materials thoroughly. They can easily be scattered by smoke, fumes, gases, vapors, rain droplets, vegetation and plants
[30]	S. Jia	Proposed that Inter vehicle communication using road side units require spontaneous networks. Vehicular adhoc networks will lead to smart & safe transport system. It will provide obstacle reports, issue warnings, apply emergency brakes, follow a vehicle and reduce delays. It will send notification of nearby shops, restaurants, petrol pumps to the driver of vehicle
[31]	Mamun A.A., Anwar S. Ali H.	Proposed that heterogeneous networks are unified. They have the capability to connect with application servers and access single segment in and out of the network of operators. HetNet uses the best connected concept. It is aimed at client terminals associated with the best quality. HetNets in session cellular approach will provide full connectivity

[32]	Farris	Proposed that integration of IoT with 5G and integrated environments deployment is giving rise to new paradigm shift. To meet the varying user requirements the heterogeneous networks and devices have the capability to club their capacities. High end IoT devices applications are based on real time processing of data and control commands. Mobile IoT Federation was proposed for providing services to such devices which are delay sensitive. Reduced latency was the result of the cooperation between public and private clouds. In public cloud all cloud resources such as hardware, software and other infrastructure are possessed, handled and supported by the cloud provider.

2.4 Researchers working on development of mobile technology and the work done by them

Various groups of researchers from industry, academia is working on different technical issues for future generations and standards of wireless communication. Their area of research and work being carried out is discussed as it is very important to know in which direction R&D is moving for development in 5G.

Table 4 Research groups & their area of research

Group Name	Their work
METIS 2020	METIS2020 is leader engaged in development of 5G networks. It started in 2012 and covers new concepts and topics. It is laying the foundations of 5G from the inputs provided by industrialists, academicians, researchers, mobile operators, and telecom vendors. Osseiran A. et. al. [33] proposed that 5G integrates new applications. METIS started FP7, framework program 7 project for research. FP7 is the research & development program for innovation. Proposed by FP7 Internet Resource et. al. [34]. They made demonstration of the work done by them for advances in architecture. They proposed a prototype channel with over 140 components based on new technology. FP7 Integrating Project METIS et. al. [35] proposed their test bed evaluations also. For flexible air interface design the best solution is filter bank multi carrier. The 5G performance parameters like actual user data rate, user data rate during peak hours, overall traffic volume per user, total traffic volume per area were evaluated, verified and validated by the results of simulation. An improvement of 40% is achieved by 5G over 4G in average per user traffic capacity. Average traffic capacity offered by 4G was maximum 16 Mbps per user. The results have shown that the latency is reduced to 1millisecond. The flow of traffic in various types of architecture for outdoor dense urban environments as well as indoor offices was presented by D.S. Baum, J. Hansen, J. Salo et. al. [36]. They are conceptualizing a collaborative evaluation of the design of 5G RAN and overall 5G architecture layout by consulting all stakeholders and working towards global agreement.
METIS 2020 (Continued)	Y. J. Bultitude et. al. [37] after considerable research and measurements proposed a novel model of channel for D2D and V2V communications. J. Medbo, K. Borner, K. Haneda et. al. [38] proposed that in 5G channels modeling the spatial consistency needs to be accounted for D2D communications. This is inadequacy of the present channel models as proposed by the Institute of Electrical et. al. [39]. The METIS-II Project et. al.[40] proposed to foster the functionality design & architecture of 5G RAN. mm MAGIC project et. al.[41] of 5G millimeter wave RAN proposed an novel design of radio access technology covering 6 to 100 GHz frequency range
5G Public Private Partnership	5GPPP is part of Horizon2020program of European Commission. It aims at industry driven research based on performance in enhancement of technology. It delivers solutions, architectures, technologies and new standards for emerging networks. 5G and IoT will be integrated for achieving the desired results of providing zero latency and huge continuous connectivity. 5G Infrastructure Public et. al. [42] focused on automatic and connected mobility. They proposed that for fixed as well as mobile accesses it will have combined and focused capabilities. It provides a platform for 5G-PPP projects engaged in development of Vehicle-as-Infrastructure, V2X concepts and components. They considered broad range of topics related to automation. They discussed and analyzed use cases, business aspects, infrastructure capabilities, spectrum usage, safety, security and evaluated the performance of KPIs. They are working on development of new services and technologies. They are focusing on making the software network reliable, stable and carrier grade. They aim to bridge the gap between NFV and E2E. They are evaluating the performance of MEC, Fog, Cloud RAN, distributed clouds and novel 5G infrastructures. They are working on development of the methods of assessment, test, evaluation, measurement, validation, verification, test cases, tools & procedures. They focused on reproducibility properties of the experimentation, developed common methodology for integration and deployment. They are identifying specific areas contributed by standards bodies such as IETF, 3GPP, and ETSI
5G Infrastructure Association	5GIA represents the private side. Public side is represented by European Commission. The 5G IA is working on advancements of 5G. The association brings together all stakeholders, industrialist, academicians, researchers, telecom operators, manufacturers. The 5G IA carries out research and development in projects, technology skills, strategic areas, standardization, frequency spectrum in collaboration with academia and industry for 5G development
5G & Beyond Forum	5G and Beyond forum was formed in 2019 by the center for Wireless Communications at UC San Diego. It is working on innovations in communication, networking, circuit, sensing and analytics techniques. It is leading to next generations of networks. It enables new applications and user experiences like smart transportation, smart manufacturing, health and immersive multimedia. Experts from industry and academia are working together. It is proposing new research projects which will carve innovations in wireless communications
5G Brasil	5G Brasil promotes the development of 5G in Brasil. It has around twenty two associates including industrialists, researchers, telecom operators & manufacturers. They are working on research activities of 5G. They proposed novel front haul & back haul infrastructure. Also working on Future Frequencies Bands. Defining Market Actions & Verticals Regulatory Actions, Use Cases & Pre-Standards. They proposed that 5G must be deployed for remote rural areas also.

5G Americas	5G Americas is an association of industry, manufacturers, trade organization, telecom operators & service providers. They are focusing on the advancements of LTE wireless technologies towards 5G. They are working on designing an infrastructure which can handle the increasing number of wirelessly connected devices on internet. Their primary focus is on improvement in networks, throughout, services and applications.
5G Mobile Forum	5GMF was formed in 2014. It is promoting R&D activities in the field of 5G. It is liasioning & coordinating with organizations, manufacturers, industries, universities for collection of information related to 5G. They are engaged in dissemination of information & enlightenment activities for 5G.
5G Forum	5Gforum group of Korea is engaged in innovations and research for 5G. It was formed in 2013. It is liasioning with all stakeholders including academic professionals, industry experts, mobile telecommunication carriers and manufacturers. The objective is to promote 5G activities. They are focusing on improvement in technology & standardization. They are planning to deploy 5G by 2020
IMT 2020 Promotion Group	IMT2020 was formed in 2013. They proposed massive MIMO based on the earlier promotion group IMT-Advanced. It liaisons with all the stakeholders for research and development in 5G. It's group members are professionals from industries, universities, research institutes, telecom operators & other vendors working for 5G
5G Non Orthogonal Waveforms	5GNow intends to expand the coverage area and network capacity through air interface framework for scalable service and new waveform design proposed by G. Wunder, P. Jung et. al. [43]. 5GNow is focusing on research and development towards reasonable feasible waveforms**,** unified robust frameworks, zero latency and immense reliability. They portrayed gabor signaling. Amplified signal is aggregate of time & frequency domain description. The shift & switching method of a prototype window is introduced for design of filter. Gabor coefficients provide scaling factor. To acquire the information of the signal in time & frequency plane they proposed to use Fourier Transform. Internet Resource et. al. [44]. Integration of Internet of Things with 5G creates a need for system redesign. They proposed novel key PHY layer technology components. It provided very low latency**,** sparse signal processing and filtering functionality. This resulted into an improved air interface which is flexible, scalable and supports the requirements of 5G
5G novel radio multi service adaptive network	5GNorma objective is to develop a flexible, efficient & adaptive 5G network. The network is dynamic in nature and possesses the capability of sharing of resources among telecom operators as proposed by 5th Generation Public Private Partnership et. al. [45]. They started new projects 5G Xhaul and 5G Cross haul. The objective is to design the dynamic reconfigurable front haul & back haul network. For C-RANs & small cells a novel cognitive control plane is proposed. The objective of CogNet is smart management of network. 5th Generation Public Private Partnership et. al. [46] proposed that the objective of COHERENT is synchronized control of HetNets and spectrum management
Emphatic	Enhanced multi-carrier professional adhoc communications (Emphatic) proposed MIMO transmission. They focused on the advancement of relay based communication techniques. They aimed for highly flexible filter bank, equalization and multihop. They proposed different schemes for FBMC under selective frequency channels for MIMO transreceiver as proposed by Internet Resource et. al. [47].
5G Green	5G Green objectives are to provide a viable green result for eco friendly advancement in 5G as proposed by Olsson et. al. [48]. Energy efficiency is a global concern. Frequent signaling and computation have resulted into very high energy consumption.
Newcom	Network of Excellence in Wireless Communications (Newcom) research group explored the upper limits of wireless networks. It is working on multihop routing and networking. They are doing research on multihop coding, mobile broadcasting, localization, Cloud RAN, distributed antennae and spectrum overlay. To reach the destination the message needs to hop via multiple subsystems. They are focusing on channel and improvement of energy efficiency in 5G. The base band processing is dependent on the modulation scheme, resource block and system bandwidth. Internet Resource et. al. [49].
NYU Wireless	NYU Wireless research group have conducted the experiments on mm wave for 5G. They calculated the path loss by doing experiments on model of mm wave proposed by T.S. Rappaport et. al. [50]. Its Industrial affiliates program provides student internships, fellowship opportunities and infrastructure support. This program offers access to wireless propagation database, student resume book and its publication library
5G Innovation Centre	5GIC research group from UK brings together leading academicians and industry partners to foster the 5G infrastructure. In P2P point to point communication they accomplished 1 Tbps speed. It is a miraculous progress in wireless speed gain. Internet Resource et. al. [51]. 5GIC research group is having more than 170 researchers. It is having world's leading open and independent test bed covering 4km^2. It provides outdoor & indoor environments for the Internet of Things and broadband mobile. It provides testbed for new 5G and IoT applications. Prototypes have been implemented. Integration of 5G & IoT helps in all areas of daily life. The application in healthcare delivers benefits using early warning systems. The 5GIC's membership includes hardware manufacturers, SMEs and major network operators. It provides a path for UK SMEs to the mobile market, which otherwise has high entry barriers. Enterprise M3 LEP developed the local economic plan featuring 5G technology and 5GIC. High impact in 5G technology is achieved by contributing to common international standards. 5GIC has set up two standards groups - the 5GIC Strategy Advisory Board and the Standards Strategy Group. New Industry Specification Groups (ISGs) on Next Generation Protocol and Broadcasting/Mobile have also been created. The creation of these groups and the development of 5G standards would have been impossible without the ability to run trials on the testbed. As 5G matures, the research focus has shifted from technological development to applications and data analysis. The 5GIC is collaborating with the Digital Catapult to capture data generated by IoT applications. It is creating a "5G Hub", linking three 5G test beds.
4G Americas	4G-Americas proposed information centric networking. They are working on research and development of 5G
3GPPP	3GPPP is working for the growth and development of 5G. They are focused to provide exceptional system capacity. They are improving the current 5G standards.

Electronics and Tele-commu-nications Research Institute	ETRI, Korea, focused on improvement in D2D communication and the protocol stack. Internet Resource et. al. [52] & J.S. Bae et. al. [53] ETRI Achievements & Developments: ETRI developed 2011 : Automatic Korean to English interpretation technology 2010 : 4G LTE Advanced Smart Ship Technology 2009 : 4D System which was based on SMMD 2008 : Vending machine, World's first digital content based machine 2007 : 3.6 Gbps 4G (NoLA) 2006 : Wireless Home Network 2005 : DMB Service, Embedded Software Solution 2004 : WiBro Prototype
Southern California & New York University	Researchers at Southern California University and New York University explored the spectrum resources at the frequency of millimeter wave. This is an imperative option to meet out their responsibility on the crunch in spectrum as explored by T. Rappaport et. al. [54]. Capacity for current LTE system is improved due to stationing of antenna arrays
Texas University	Researchers in Texas University proposed massive MIMO. This is antenna arrays deployed at a very large scale. They have the ability to provide services to diversified users simultaneously at similar point of time. They give higher rates of data as proposed by A. Alkhateeb et. al. [55].
Georgia Institute of Technology	Georgia Institute of Technology proposed an innovative WSDN design**.** SoftAir improves spectrum efficiency and maximize capacity as it is self adaptable flexible network architecture. I.F. Akyildiz, P. Wang et. al. [56] explored that SoftAir enables changeover and shift from hardware based network to software based network which are programmable flexible and economical
Qualcomm	Qualcomm et. al. [57] explored that for immense throughput at mm wave 5G supports short range communication. 5G at less than 6 GHz frequency bands enhances the broadband services
Samsung	Samsung introduced mm wave technique for 5G. It was having 7.5 Gbps peak download rate at 28 GHz carrier frequency. It is faster by 100 times as compared to 4G as proposed by Samsung Electronics et. al. [58].
AT&T	AT&T focused to boost network performance and cost efficiency by working on novel technologies like SDN and NFV. They conducted trials along with Intel and Ericsson for implementing the novel network architecture and prepared for their deployment as proposed by AT&T et. al.[59].
Huawei's	Network slicing gives flexible and efficient 5G network. On consolidated network architecture, multiple applications are enabled as proposed by Huawei et. al. [60]
Korea Telecom	Proposed 5G network services based on millimeter wave
NTT DoCoMo	Explored 5G research on small cells. NTT DoCoMo et. al. [61] proposed that for smaller cell coverage area this offers higher spectral density
China Mobile	C. L. I. C. Rowell et. al. [62] proposed that China Mobile developed an array of 128 antenna, model for performance analysis
Telecom operators	Formed alliance for 5G trial specifications. Korea Telecom, NTT DoCoMo, Verizon and SK Telecom focused on colloquial platform development for 5G
Others	Pekka Pirinen et. al. [63] submitted that other research bodies also exist. It cited few researchers and mentioned contributions made by them

III. PROPOSED METHODOLOGY

This section primarily focuses on the technical development in modulation scheme and improvement in multiple access technique. A novel waveform contender which is an improvement over OFDM is proposed. It overcomes the shortcomings of OFDM and is best suited for upcoming 5G networks. Using this new technique will improve flexibility, scalability & compatibility. Distributed allocation of resources & computing, mm wave communication, RAN architecture, flexible, economical virtualized cloud based core network is proposed to be used in 5G. It is proposed that small cells of low power are deployed for achieving reduction in consumption of energy. The virtual cloud based network and data centric servers improved the energy efficiency and power of computing. Energy efficiency is improved by use of NFV and SDN. This reduced the requirements of energy & is helpful in green environment preservation. A generalized communication protocol compatible with upcoming networks is proposed which can be easily downloaded whenever required by user. D2D communication provides secure, reliable and energy efficient network for nearby devices in close proximity. 5G will also be covering remote rural areas. These methodologies are proposed in our research to achieve the desired objectives of increasing the bandwidth, spectral efficiency and enhancing the flexibility of RAN

3.1 Proposed methodology for development towards 5G is given in Table 5

Table 5 Proposed methodologies for developments towards 5G

Millimeter wave commu-nication	To enhance the speed by 1000 times mm wave is the best choice. Mm wave has wavelength ranging from 3–300 GHz. On an unlicensed spectrum along with traffic offloading the carrier frequency is 5 GHz Wi-Fi. Licensed spectrum ranges from 750 MHz to 2600 MHz. The physical layer of millimeter wave spectrum is lesser utilized so needs to be designed. Availability and faster data transfer rate can be achieved by traffic offloading, beam forming and Massive MIMO. Cloudification of radio resources will also help in achieving faster data transfer rate. T. Rappaport, S. Sun et al. [64] explored the propagation behavior, path loss and penetration characteristics of carriers of frequency 28 GHz & 38 GHz which results from urban structure. This data is very beneficial in 5G for designing the physical layer by deployment of millimeter wave. T. Levanen et al. [65] proposed the design of mm-wave communication for 5G which helps to achieve ultra-low latency. This is the primary requirements for 5G.
Architecture	RAN and the network well connected are achieved through mm-wave. In base stations high bandwidth is used as devices connected to the internet are rising continuously. A macro-cell is loaded with the overheads for connecting large devices around ten thousand per cell to the internet. To accommodate the payload overhead and increased signaling simple architecture is used. Bae J.S. et. al. [66] explored that 5G efficiency is improved by deployment of millimeter wave RAN. Antenna array structures graphics were proposed for beam forming. Handover among the multiple beams is faster which is facilitated by mechanism of beam control. In three dimensional spaces, radio transmission signals of highly directive beams are formed. Space division multiple accesses were made possible after giving off the 2D arrays. This is known as beam division multiple accesses. The patch antennas used in the arrays for user equipment are 2D NXM. Radio access method is reliable, secure and robust because of the capability of quick handoff among different beams. Millimeter wave RAN is having less coverage so usage of relay transmission overcomes this. The handoff process is controlled by eNB or base station and not by core node. eNB or base station is responsible for allocation of resources in 4G. To achieve improved QOS they have designed algorithms. For cognitive radio links, an algorithm for allocation of resources based on game-theoretic computations was proposed by L. Baochun, X. Hong et. al. [67]. For operations based on macro cells, 5G uses algorithm for allocation of resources. Beam-forming is not possible. Intelligent flexible networks which are easier to install and have low cost are required. Virtual networks are made possible due to networks which are based on cloud
Modulation techniques	In 4G the multiple access technique used is OFDMA. OFDM is the modulation technique which is used. Spectral efficiency is dependent on multiple access & modulation techniques. In 3G CDMA technology was used. OFDMA succeeds CDMA. PAPR is very high so required to be handled by improvements proposed in OFDMA. To prevent inter-block interference, its need of cyclic prefixes is to be sorted out. With the present hardware structure, the applicability of OFDM on wide band mm-wave is not certain. F. Schaich, T. Wild et. al. [68] did analysis and comparison of UFMC, FBMC & OFDM schemes used in 5G. In FBMC subcarriers are passed through filter banks to suppress the side-lobe. This helps to achieve better spectral efficiency in comparison to OFDM. The 5GNOW group et. al. [69] is considering four waveforms, GFDM proposed by G. Fettweis, M. Krondorf, S. Bittner et. al. [70], UFMC proposed by M. Mukherjee et. al. [71], FBMC proposed by N. Vander Neut et. al. [72] and BFDM proposed by G. Wunder et. al. [73] for 5G. This provides an air interface which is very efficient. It is also independent of synchronization requirements and orthogonality.
Cloud RAN	This novel RAN transport must support fronthaul, midhaul & backhaul. This work views at a segment of the C-RAN architecture as the fronthaul network. Air interface is not able to support the high definition video to low bandwidth control signals. Massive MIMO, modulation and coding techniques are part of RAN. D. Sabella et. al. [74] proposed that network sustainability and energy efficiency can be achieved by using RAN. RAN capacity is kept in a centralized server with help of cloud-based RANaaS. The customers get the services on demand. The base station is to be segregated into radio access unit in order to achieve this. To satisfy the network requirements of any cell that experiences very high traffic, baseband unit and its reserve pool needs to be created. The small cells of low power which are deployed must be able to make the reserved capacity available to those cells which need it whenever there is a burst in traffic. This will help in reducing the consumption of energy. Energy efficiency and computational power can be optimized by using data-center servers. By availability of resources which are cloud-based the core and backbone network can be virtualized as proposed by V. Jungnickel, J. Costa-Requena et. al. [75,76]
Energy efficiency	The number of connections in 5G is expected to reach 1.4 billion by year 2025. Consumption of energy and efficiency are the major concerns while deploying new networks. Major requirement of 5G is reduced consumption in energy for network maintenance and green environment. S. Tombaz, K.W. Sung, J. Zander et. al. [77] proposed that a network has unavoidable network energy requirements which are densified by cell size reduction. As the networks have greater number of smaller cells so the backhauling and idling power will lead to major portion of consumption in energy. S. Zhang et. al. [78] proposed that 5G frame-work is deployed with network functional virtualization and software defined MAC. M. Olsson et. al. [79] proposed energy efficient, low latency 5G network in their research project named 5G Green. With regard to logical partition of data & control plane M. Olsson et. al. [79] agreed with the proposals of S. Zhang et. al. [78]. For flexible and energy efficient 5G architecture this is a potential solution. The 5G Green project proposed optimized energy efficient HetNet architecture. This will improve network capacity by meeting traffic demands of users. Resources based on cloud are to be sensibly allocated. Anchor is management framework for optimized allocation of resources in the cloud is proposed, evaluated and implemented by B. Li, H. Xu et. al. [80].
Protocol Stack	The basis of a communication system is a Protocol Stack. A generalized protocol stack for the d2d communication was proposed by A. Gohil et al. [81]. It is compatible with the other open source available protocols. Whenever the user equipment requires the protocol is downloaded easily. The user equipment's belonging to different networks are connected via base station.

3GPP D2D	To boost cell capacity 3GPP D2D services are used. Searching of restaurants, retail outlets, cab availability, doctors and petrol pump is made easy. D2D connectivity is very important. LTE Direct et. al. [82] emphasized that LTE-D uses a licensed spectrum and enables discovery of ON devices within 500m range in a secured manner. P2P proximity communication protocols which are mostly used are Bluetooth and Wi-Fi direct. J. Qiao, et. al. [83] proposed Mm-wave D2D communication. Mobile devices are equipped with beam-forming technology and electronically steerable antenna. Use of beam-forming technology and highly directive antenna will result in less interference during transmission between base station and D2D users. There is congestion in network when a multimedia file is shared among neighbors. T. Abdelzaher et. al. [84] proposed that this congestion is managed by traffic sensing media retrieval framework. To timely retrieve the media files from cloud is made possible by Media Scope.
3GPP D2D (Continued)	This is a framework which is specifically developed for mobile devices. For sharing multimedia files among neighbors this type of framework is used by D2D multimedia sharing techniques. A primary requirement of 5G is that the coverage must be there in rural areas as well. These needs are served by a satellite. Bandwidth and power should be allocated efficiently among multiple beams using multibeam satellite systems. Non-GEO satellite constellation for onboard beam-forming has reduced the latency. J. Domme et al. [85] proposed that reusing an FBMC technique is feasible over downlink satellite communication. This is done to make the handoff between satellite coverage and terrestrial infrastructure seamless & easier.

3.2 5G Features are given in Table 6:
5G is promising to fulfill the requirements and need of higher data rate and improve the QoS with its improved features:

Table 6: 5G Features

Parameters	Features of 5G
Enhanced Capacity	5G gives 100x improvements over 4G, 1000x higher speeds
Latency	1 millisecond latency, real time connectivity
Connected devices	70% of IoT devices like TV, mobile, tablet, fridges, cars will use mobile internet technology by 2022, 29 billion connected devices to internet by 2022, 18 billion connected devices related to IoT, 75.44 billion connected devices to internet by 2025, 10 billion active connected devices by 2020, 22 billion active connected devices by 2025
Increase in Efficiency	Spectrum efficiency increases, Higher utilization of resources, Reliability increases
5G support to Internet of Thing	Smart Home Appliances, Automatic Vehicles, Health, Transport, Agriculture and Education
Connectivity	5G provides uninterrupted, consistent, uniform, connectivity , 10 Gbps connectivity, 99 % availability and coverage
Network Energy usage	Reduction in network energy usage
Resolution	High resolution
Accuracy	The traffic statistics makes it accurate
Speed	10 Gbps data rate, In 5G the uploading and downloading speed is 20 times faster than 4G

3.3 5G Merits & Demerits
The strengths and weaknesses of 5G are analyzed in detail. The demerits identified needs to be resolved. This research will act as a guideline for future work being carried out in 5G

Table 7: 5G Merits & Demerits

Merits	Demerits
It gives higher resolution & bi directional large bandwidth shaping	The old devices are not compatible with 5G. They are required to be replaced with new compatible one which is a costly affair
It helps to bring all the networks on a single platform	The growing infrastructure requires higher costs and reliability
For quick action it facilitates the subscriber supervision tools	Privacy and security issues are to be resolved.
It supports heterogeneous services	5G is late & still under review. Research on its feasibility is still going on
It provides uniform, uninterrupted and consistent connectivity	Speed claimed by 5G seems to be difficult to achieve

IV. RESULT ANALYSIS AND DISCUSSIONS

Section 4 contains the result analysis and discussions, Section 4.1 compare and analyze the candidate waveforms and propose new one, Section 4.2 compare and analyze the different multiple access techniques, discuss their merits and demerits and propose the best suitable for 5G
4.1 Performance comparison of the candidate waveforms and proposal of new one are given in table 8
Various types of waveform contenders are discussed to replace the existing OFDM by the best available and suitable alternative. This is necessary to meet the 5G requirements. The improved waveforms contender with windowing & filtering produces good results as compared to OFDM. These candidate waveforms are compatible with technologies such as multiple access schemes, modulation and coding. The performance comparisons of different waveforms are done to prototype & implement this technical aspect in 5G

Table 8: Performance comparison of the candidate waveforms and proposal of novel waveform

OFDM	In OFDM frequency band is split into different sub bands. Using the digital modulation technique each sub band is separately modulated. Overlapping closely spaced sub carriers which are in large numbers are parallely transmitted, which results in improved spectral efficiency. J. Bingham, et. al. [86] proposed that multi-path propagation helps to overcome the effect of frequency selective fading. M. Schwartz, et. al. [87] explored that every subband is required to have satisfactory bandwidth. Equalization is used to mitigate the multiple flat fading sub channels. Interference caused by the adjacent sub carrier is called Inter Carrier Interference. It degrades the performance of OFDM transmissions. It severely affects the communication as carrier frequency, mobile speed and OFDM symbol duration increases. (ISI) Inter symbol interference is signal distortion where one symbol causes interference with the consecutive symbols. The preceding symbols have same result on adjacent symbols as noise. It is usually due to multipath propagation. ISI introduces errors at the receiver. Therefore while designing the transmitter and receiver filter the objective is minimizing the ISI. ISI and ICI in an OFDM symbol can be removed by using cyclic prefix also known as guard band. CP conserves orthogonality of subcarriers and eliminates ICI & ISI. OFDM is an efficient modulation scheme for digital audio broadcast, modems and wireless applications
BFDM	In BFDM, we replace orthogonality with bi-orthogonality in transmit & receive signals. Representations of these signals in time frequency domain are pair wise orthogonal. Therefore this is flexible to design a model prototype. Instead of matched filter an optimally mismatched filter can be used. BFDM is suitable for sporadic traffic. These are robust to frequency dispersion in transmission. The limit of duration of symbol is set in OFDM transmission. Advantage of BFDM is good tradeoff between performance & complexity**.** BFDM has perfect reconstruction, better spectral power density and very low PAPR.
FBMC	In FBMC, a bank of filters is used. FBMC for the first time introduces filter banks in OFDM and eliminates the CP. Pulse shaped filters are applied for every subcarrier. Filtering is done to cut out the unwanted side portions, which causes interference. OOB results due to roll off of the side portions of one subcarrier into adjoining subcarriers. The filter array used is equal to subcarriers. This is to lessen the OOB power leakage. This reduces costs and increases the spectral efficiency. Spectral efficiency is better than all other waveforms. It overcomes the disadvantages of OFDM. It has reduced (OOB) interference. It enhances the system's performance, flexibility and efficiency. FBMC is more flexible because of individual filtering of sub carriers. It uses offset QAM. A burst approach is used to establish the flexible allocation of resources in time & frequency domain. Training sequences are used for channel estimation and synchronization. For cognitive radios, FBMC is better as proposed by Bellanger M. et. al. [88].
UFMC	UFMC group's the subcarriers to sub bands. A bank of filters is used. It uses subband filters. These filters are applied for every individual subcarrier. It separately applies filtering to each of the subgroup. The side lobes are reduced significantly in comparison with OFDM. Use a shorter filter length in comparison to FBMC & OFDM. It becomes useful in burst communication; high bandwidth data burst transmission over short period as proposed by Vakilian V. et. al. [89]. It requires low overhead and less complexity in comparison to FBMC. UFMC is having orthogonal subcarriers and is a multicarrier signal format. This is to cater to the complication of loss in subcarrier orthogonality at receiving end. It's useful in M2M communications and IoT applications. It is compatible with MIMO. Frequency synchronization between the base stations and user equipments is better as compared to CPOFDM
GFDM	GFDM Generalized Frequency Division Multiplexing uses block-based modulation technique. It is flexible. It is configured like SCFDM and OFDM. The available & accessible bandwidth is divided into various narrow band subcarriers or lesser number of wide band subcarriers. GFDM signal is created in such a way that the complexity of transmitter & receiver becomes less. This reduces synchronization and equalization issues. GFDM uses filter bank multi carrier concept. Multiple symbols are integrated to constitute the OFDM burst signal. These multiple symbols are transmitted per sub carrier. In GFDM firstly the data symbols are up sampled. Pulse shaped prototype model filters are used for performing circular convolution. The orthogonality is disturbed due to filtering. Subcarriers will no longer be orthogonal to each other. This results in crosstalk producing ISI & ICI as proposed by Fettweis G, et. al. [90]. For one symbol or packet there is only one CP. Tail biting convolution coding technique reduces the length of cyclic prefix. Thus GFDM spectral efficiency is improved and OOBE is significantly reduced.
NOMA	In Non Orthogonal Multiple Access, by superimposing the signals in power domain, non-orthogonality can be introduced at the transmitter end. It requires more complex receivers. It allows the optimum utilization of available radio resources. Network capacity improves. It uses SIC for decoding. It is likely to restore the weak signals by using SIC successive interference cancellation method.
NOMA (Contd.)	The power of individual signal must be different from power of superimposed signals. It has demerits such as error propagation and complexity
Filtered OFDM	In FOFDM radio spectrum is divided in frequency bands. Frequency band divided in sub bands. They are simultaneously filtered using different filters. In this individual sub band uses distinct spacing & varying CP length as per the application. Distinct services are allocated in various sub bands. Inter block interferences are generated by filtering. OOB interferences and emission can be reduced by proper filter design. Energy consumed by guard band is minimized as explored by Abdoli J. et. al. [91]. The length of filter is unlimited. It is MIMO compatible & flexible
Windowed OFDM	The W1 samples are copied from end & affixed at start of symbol. By adding initial W2 samples to the end cyclic prefix is formed. Symbol length is converted to N + CP + W1 + W2 in WOFDM time domain. The transformation amidst adjoining symbols is reduced by help of the soft edge rectangular pulses as explored by Zayani R., Medjahdi Y., et. al. [92]. OOB leakage is reduced. It is MIMO compatible. WOFDM design is a settlement among ISI & ICI. ICI localization also improves as window length increases. With long delay spread, the robustness towards channel decreases.

Windowed & Filtered OFDM	Better results are possible by combining these two methods Windowed & Filtered OFDM. Improvement in performance. Hybrid WFOFDM is a good waveform contender. The spectrum efficiency increases. Reduced OOB emission in shorter (6 or 8) window length as proposed by An C. et. al. [93].

Section 4.2 compare and analyze the different multiple access techniques, discuss their merits and demerits and propose the best suitable technique for 5G

4.2 Merits & demerits of multiple access techniques and proposal for the best suitable for 5G are given in Table 9

Table 9: Merits & demerits of multiple access techniques and proposal for the best technique suitable for 5G

Multiple access technique	Merits	Demerits
FBMC	Frequency localization. Supports loose synchronization. Implementation is easier & efficient. It is powerful for center frequency offset. OOB reduction is best	Computational complexity is very high. Implementation complexity is also very high due to requirement of additional filter. Long filter duration is an overhead for short bursts communication. Supports offset. QAM. Complicated. It does not support MQAM format. Not compatible with MIMO. High PAPR. Spectral efficiency can only be achieved when the data length is larger. It is sensitive towards the errors produced due to CSI. It is not useful in M2M communications and IoT applications
OFDM	Compatibility with the MIMO. Simple in computation. Simple modulation. Simple demodulation.	Perfect synchronization requirement. Cyclic prefix is required. Pilot contamination. High OOB emission. High PAPR
UFMC	Compatibility with MIMO. ISI protection. Shorter symbols. Robust to CSI errors. Frequency localization	Implementation complexity is less as compared to that of FBMC. Implementation complexity is more as compared to that of CP-OFDM. Sensitive to mismatch in the timings. The signal which is transmitted does not require CP. Spectral efficiency is more than OFDM. Due to multipath fading, it suffers from ISI. Complex equalization. Usage of 2N point FFT results in enhancement of noise which in turn degrades the performance
GFDM	Spectral efficiency is improved. Loose synchronization. It is compatible with MIMO. It ensures ISI protection	Complex receivers are required to remove ICI & ISI. Computational complexity is more. The detection and decoding starts once the entire block is received so GFDM suffers from decoding latency. Sensitive to CFO. High BER
NOMA	Spectral efficiency improves. Compatibility with other techniques of multiple access. Compatibility with MIMO. It's a new domain of multiplexing	Requires perfect synchronization. Computational complexity
Filtered OFDM	F-OFDM is flexible. Compatible with MIMO. All sub bands gets filtered in parallel using different filters. Unlimited filter length. Various services are placed in the different sub bands. OOB interferences and emission can be reduced by proper filter design. Energy consumed by guard band is minimized. The length of filter is unlimited. It is MIMO compatible & flexible	It requires extra filters at transmitting and receiving end. In comparison to CPOFDM, computational complexity is more. Efficiency of spectrum is less in comparison with FBMC and UFMC. It is also having ICI. By using full band filtering it cannot be eliminated.
Windowed OFDM	Reduces OOB emissions. OOB attenuation is better. It is MIMO compatible. WOFDM design is a settlement among ISI & ICI. ICI localization also improves as window length increases. With long delay spread, the robustness towards channel decreases. Reduced sensitivity to separation of sub channel. With low modulation it offers better performance.	Copied data addendum amidst the successive and ensuing OFDM symbols results in data collision

Result Analysis:

The aim is to find a novel improved OFDM based waveform for future networks. FBMC is used in cognitive radio applications. UFMC is used in mMTC, URLLC and IoT applications. GFDM is used in wireless networks and IoT applications. Different sub bands are used for providing multiple services in F-OFDM. Hybrid WF-OFDM is best choice among all other waveforms, as it achieves OOB emission performance in comparison to OFDM. Highest priority is given to FBMC. After that F-OFDM is preferred. UFMC is third choice. At the end GFDM and W-OFDM are preferred. FBMC, GFDM and UFMC are complex. W-OFDM, F-OFDM & WF-OFDM are also complex but to some extent only. W-OFDM, F-OFDM & Hybrid WF-OFDM are best waveforms as they are compatible with the network and flexible. Various types of waveform contenders are discussed to replace the existing OFDM by the best available and suitable alternative. This is necessary to meet the 5G requirements. The improved waveforms contender with windowing & filtering produces good results as compared to OFDM. These candidate waveforms are compatible with technologies such as multiple access schemes, modulation and coding. The performance comparisons of different waveforms are done to prototype & implement this technical aspect in 5G. Based on above result analysis and discussions a new waveform is proposed which overcomes the disadvantages of previous waveforms in use.

V. CONCLUSION

Roadmap of correlation of different generations of mobile from 1G towards 5G, features of different generations are given along with their performance, advantages, and disadvantages. Literature Survey and work done by different research groups, development towards 5G, performance comparison of the candidate waveforms, multiple access techniques, 5G features**,** merits & demerits are discussed. Architecture, emerging applications, issues and challenges in 5G is highlighted. 5G is very fast and reliable and is able to satisfy rapid wireless traffic growth. It provided recent initiatives towards flexible, green 5G communication standards. Challenges such as reduction in consumption of energy and more spectrum requirement which cannot be accommodated by 4G are resolved in 5G. 5G enables cloud based services, offering flexibility features and accessibility. 5G provides higher data rate, very low almost zero latency, improved system capability, improved spectral efficiency, superior throughput, improved energy and cost efficiency, lesser delays, improved quality of service. This paper presents recent research initiatives towards flexible and green 5G mobile communication standards. An improved alternate for OFDMA is proposed. For critical machine communication and services like massive IoT it should offer flexible platform. 5G supports all kind of services almost everything using new spectrum, cloud computing, beam forming, massive MIMO, network slicing and edge computing. Technologies which increase the bandwidth such as mm-wave, dual connectivity, spectrum sharing and carrier aggregation are discussed. The technologies like massive MIMO, flexible air interface, NOMA, different OFDM variants, alternative waveforms which increases efficiency of spectrum are highlighted. The strengths and weaknesses of these technologies are analyzed in detail. The open problems identified needs to be resolved. This research will act as a guideline for future work being carried out in 5G. Performance comparison of the candidate waveforms is summarized. Multiple access techniques, merits and demerits are analyzed and highlighted, challenges and limitations are noted which needs to be catered. Demerits of OFDM need to be overcome. Based on above result analysis and discussions a new waveform is proposed which overcomes the disadvantages of previous waveforms in use. An improved alternative waveform and multiple access technique proposed is a good initiative. Better results are possible by combining these two methods Windowed & Filtered OFDM. WFOFDM supports MQAM modulation. Hybrid WFOFDM is a good waveform contender resulting in improved performance, reduced OOB emission in shorter (6 or 8) window length, increased spectrum efficiency. This proposed new improved waveform is flexible and is also compatible with new multiple access technique and new modulation scheme**.**

REFERENCES

1. Zaidi A., Athley F., Medbo J., Gustavsson U., Durisi Gi., Chen X., (2018), 5G physical layer: principles, models and technology components
2. Internet Resource, Ericsson, http://www.ericsson.com/openarticle/mwc-connected-devices 1686565587c
3. Mehta H., Patel D., Joshi B., Modi H., 0G to 5G Mobile Technology, A Survey, Journal of Basic and Applied Engineering Research, Volume 1, Number 6, PP 56-60, October, 2014
4. Mir M. M., Kumar S., Evolution of Mobile Wireless Technology from 0G to 5G, International Journal of Computer Science and Information Technology, Volume 6 (3), PP 2545-2551, 2015
5. Ms. Anju Uttam Gawas, an Overview on Evolution of Mobile Wireless Communication Networks, 1G-6G, JRITCC, Volume 3, Issue 5, 2015
6. Meenal G. Kachhavay, International Journal of Computer Science and Mobile Computing, Volume 3, Issue 3, 2014
7. J.G. Andrews, What will 5G be?, IEEE, J. Sel. Areas Comm. 32, PP 1065–1082,2014
8. Satinder, Babbar V., 3G, 4G & 5G wireless mobile networks, A comparative study, ICSTM, PP 2381-2390, 2015
9. Akhil Gupta, Rakesh Kumar Jha, A Survey of 5G Network, Architecture and Emerging Technologies, IEEE, 2169-3536 (c), 2015
10. Kwadwo, P. Agyapong, Design considerations for 5G network architecture. IEEE Comm. Mag. 52(11), 65, 2014
11. DMC R&D Center, 5G Vision White Paper, http://www.samsung.com/global/business images/insights/2015/samsung5GVision0.pdf, 2015
12. Bego Blanco, technology architecture of future pillars in the 5G mobile networks: NFV, MEC and SDN, November 2017
13. R. Henderson, M. Langridge, What is 5G?, When is it coming and why do we need it?, http://www.pocket-lint.com/news/128938-what-is-5g-when-is-it-coming-and-why-do-we-need-it, Jan 2017
14. Chaudhary R. R., A Network Overview of Massive MIMO for 5G Wireless Cellular System Model and Potentials, International Journal of Engineering Research and General Science, Volume 2, Issue 4, PP 338 – 347, 2014
15. Kwadwo P.A., Iwamura M., Staehle D., Kiess W., Design Considerations for a 5G Network Architecture, IEEE Communications Magazine, PP 65 - 75, November 2014
16. Larsson E.G., Edfors O., Tufvesson F., Marzetta T. L., Massive MIMO for Next Generation Wireless Systems, IEEE Communications Magazine, (52), PP 186-195, February 2014
17. Eduardo Castaneda, Adao Silva, Atılio Gameiro, and Marios Kountouris, an Overview on Resource Allocation Techniques for Multi-User MIMO Systems, IEEE, 1553-877X (c), 2016
18. Carolina Fortuna, Software interfaces for control, optimization and update of 5G machine type communication networks, December 2017
19. Zoraida Frias, 5G networks, Will technology and policy collide?, July 2017
20. Jing Wang, Chih Lin, Recent advances and future challenges for massive MIMO channel measurements and models, science china, Vol. 59 021301:1–021301:16, February 2016
21. Erik Dahlman, New 5G Radio Access Technology, 2016
22. Garg S., A New Wireless Communication Technology, Radio over Fiber, KIET International Journal of Communications & Electronics, Volume No. 3, Issue No.1, PP 24-27, March 2015
23. Ian F. Akyildiz, 5G roadmap, 10 key enabling technologies, September 2016
24. Shahid Mumtaz, A survey of 5G technologies, regulatory, standardization and industrial perspectives, September 2017
25. Pablo Salva Garcia, 5G-UHD, Design prototyping and empirical evaluation of adaptive Ultra High Definition video streaming based on scalable H.265 in virtualized 5G networks, December 2017
26. Jiasong Muan, Improved AODV routing for the ZigBee heterogeneous networks in 5G environment, April 2017
27. S. Zhang, 5G towards energy-efficient, low-latency and high reliable communications networks, IEEE, ICCS, PP 197–201, 2014
28. Akhil Gupta, Rakesh Kumar Jha, A Survey of 5G Network, Architecture and Emerging Technologies, IEEE, 2169-3536(c), 2015
29. Gaikwad, Vaibhav Vitthal, Bhor Pooja Vijay, Review of Light fidelity, International Journal for Scientific Research & Development,| Volume 4, Issue 02, ISSN (online): 2321-0613, 2016
30. S. Jia, Analyzing and relieving the impact of FCD traffic in LTE-VANET heterogeneous network, in: IEEE Int. Conference on Telecommunications, PP 88–92, 2014
31. Mamun A.A., Anwar S., Ali H., 4G and 5G Mobile Communication Networks, Features, Analysis, Comparison and Proposed Architecture", IJCST, Volume 7, Issue 2, PP 154-160, 2016
32. Farris, Federated IoT services leveraging 5G technologies at the edge, January 2018

33. A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, O. Queseth, M. Schellmann, H. Schotten, H. Taoka, H. Tullberg, M. Uusitalo, B. Timus, Fallgren, Scenarios for 5G mobile and wireless communications: the vision of the METIS project, IEEE Commun. Mag. 52 (5), PP 26–35, 2014 doi: 10.1109/ MCOM.2014.6815890.
34. Additional Knowhow on FP7 Internet Resource, http://ec.europa.eu/research/fp7/index en.cfm
35. FP7 Integrating Project METIS (ICT 317669). [Online] Available: https://www.metis 2020.com/documents/deliverables
36. D.S. Baum, J. Hansen, J. Salo, An interim channel model for beyond 3G systems: extending the 3GPP spatial channel model (SCM), in: 2005 IEEE 61st Vehicular Technology Conference, Volume 5, IEEE, PP 3132–3136, 2005
37. Y.J. Bultitude, T. Rautiainen, IST-4-027756 WINNER II D1. 1.2 V1. 2 WINNER II Channel Models
38. J. Medbo, K. Borner, K. Haneda, V. Hovinen, T. Imai, J. Jarvelainen, T. Jamsa, Karttunen, K. Kusume, J. Kyrolainen, P. Kyosti, J. Meinila, V. Nurmela, Raschkowski, A. Roivainen, J. Ylitalo, Channel modeling for the fifth generation mobile communications, in: 2014 8th European Conference on Antennas and Propagation (EuCAP), PP 219–223, 2014, doi:10.1109/ EuCAP.2014. 6901730
39. The Institute of Electrical and Electronics Engineers (IEEE), IEEE Standard for Information technology–Telecommunications and information exchange between systems–Local and metropolitan area networks–Specific requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 3: Enhancements for Very High Through-put in the 60 GHz Band, IEEE Std 802.11ad-2012 (Amendment to IEEE Std 802.11-2012, as amended by IEEE Std 802.11ae-2012 and IEEE Std 802.11aa-2012) PP 1–628, 2012, doi:10.1109/IEEESTD.2012.6392842
40. METIS II Project, Preliminary Views and Initial Considerations on 5G RAN Architecture and Functional Design, 2015, https://metis-ii.5g-ppp.eu
41. mmMAGIC Project, mmMAGIC: Millimetre-Wave Based Mobile Radio Ac-cess Network for Fifth Generation Integrated Communications, 2015, https://5g-ppp.eu/mmmagic
42. The 5G Infrastructure Public Private Partnership [Online]. Available: http://5g-ppp.eu
43. G. Wunder, P. Jung, M. Kasparick, T. Wild, F. Schaich, Y. Chen, S. Brink, I. Gas-par, N. Michailow, A. Festag, L. Mendes, N. Cassiau, D. Ktenas, M. Dryjanski, S. Pietrzyk, B. Eged, P. Vago, F. Weidman, 5GNOW: non-orthogonal, asynchronous waveforms for future mobile applications, IEEE Commun. Mag. 52(3), PP 97–105, 2014 doi:10.1109/MCOM.2014.6736749.
44. Internet Resource, 5GNOW Deliverable2.2: http://www.5gnow.eu/download/5GNOW D2.2 v1.0.pdf
45. 5th Generation Public Private Partnership, mmMAGIC: Millimeter-Wave Based Mobile Radio Access Network for Fifth Generation Integrated Communications, 2015 http://5g-ppp.eu.
46. 5th Generation Public Private Partnership, mmMAGIC: Millimeter-Wave Based Mobile Radio Access Network for Fifth Generation Integrated Communications, 2015 http://5g-ppp.eu.
47. Internet Resource, EMPhAtiC Deliverable 4.1: http://www.ictemphatic.eu/ images/ deliverables/deliverable d4.1 final.pdf
48. M. Olsson, C. Cavdar, P. Frenger, S. Tombaz, D. Sabella, R. Jantti, 5G Green: towards green 5G mobile networks, in: 2013 IEEE 9th International Conference on Wireless and Mobile Computing, Networking and Communications, WiMob, PP 212–216, 2013, doi:10.1109/WiMOB.2013.6673363
49. Internet Resource, NEWCOM Deliverable 23.3: http://www.newcomproject.eu/ images/deliverable/D23.3 secondreportontoolsandtheirintegration on the experimentalsetups.pdf
50. T.S. Rappaport, Millimeter wave mobile communications for 5G cellular, It will work, IEEE, Access 1, 335–349, 2013
51. Internet Resource, 5GIC: http://www.surrey.ac.uk/5gic
52. Internet Resource: https://www.etri.re.kr/eng/sub6/sub6 0101.etri? DepartCode=6
53. .S. Bae, Architecture and performance evaluation of MmWave based 5G mobile communication systems, IEEE, ICTC 2014, PP 847–851, 2014
54. T. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. Wong, J. Schulz, M. Samimi, F. Gutierrez, Millimeter wave mobile communications for 5G cellular: it will work!, IEEE Access 1 (2013) 335–349, doi: 10.1109/ACCESS.2013. 2260813
55. A. Alkhateeb, O. El Ayach, G. Leus, R. Heath, Channel estimation and hybrid precoding for millimeter wave cellular systems, IEEE J. Sel. Topics Signal Process. 8 (5) (2014) 831–846, doi: 10.1109/JSTSP.2014.2334278
56. I.F. Akyildiz, P. Wang, S.C. Lin, Soft Air, Software defined networking architecture for 5G wireless systems, Computer Networks 85 (C), PP 1–18, 2015
57. Qualcomm, 5G - Vision for the next generation of connectivity, White Paper, 2015, https://www.qualcomm.com/ invention/technologies/5g
58. Samsung Electronics, Samsung Electronics Sets 5G Speed Record at 7.5Gbps, Over 30 Times Faster Than 4G LTE, 2014, http://www.samsung.com/ global/ business/networks/insights/news
59. AT&T, AT&T Unveils 5G Roadmap Including Trials In 2016. http://about.att.com/ story/unveils 5G roadmap.html
60. Huawei, 5G: New Air Interface and Radio Access Virtualization, Technical Report, 2015
61. NTT DoCoMo, 5G – Future Core Network, Presentation at GSMA Mobile World Congress 2016, Barcelona, 2016, Available at: https://www.nttdocomo.co.jp/english/info/ media center/event/mwc2016/pdf/about future core network.pdf
62. C. L. I. C. Rowell, S. Han, Z. Xu, G. Li, Z. Pan, Toward green and soft: a 5G perspective, IEEE Commun. Mag. 52 (2) (2014) 66–73, doi: 10.1109/MCOM.2014. 6736745
63. Pekka Pirinen, A brief overview of 5G research activities, IEEE, International Conference on 5G for Ubiquitous Connectivity, PP 17–22, 2014
64. T. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. Wong, J. Schulz, M. Samimi, F. Gutierrez, Millimeter wave mobile communications for 5G cellular, it will work!, IEEE Access 1, PP 335–349, 2013 doi:10.1109/ACCESS.2013. 2260813
65. T. Levanen, Radio interface design for ultra low latency millimeter wave communications in 5G era, Globecom Workshop, Ultra-Low Latency and Ultra-High Reliability in Wireless Communications, PP 1420–1426, 2014
66. J.S. Bae, Architecture and performance evaluation of MmWave based 5G mobile communication system, in: IEEE ICTC 2014, 2014, pp. 847–851.
67. L. Baochun, X. Hong, Resource allocation with flexible channel cooperation in cognitive radio networks, IEEE Transactions, Mobile Computing, 12 (5), PP 957–970, 2013
68. F. Schaich, T. Wild, Waveform contenders for 5G-OFDM vs. FBMC vs. UFMC, 6th International Symposium on Communications, Control and Signal Processing, ISCCSP, 2014, PP 457–460, 2014
69. 5GNow Deliverables online resources: http://www.5gnow.eu/wp-content/uploads/ 2015/04/5GNOW D3.2 v1.3. pdf
70. G. Fettweis, M. Krondorf, S. Bittner, GFDM-generalized frequency division multiplexing, 69th Vehicular Technology Conference, IEEE, PP 1–4, 2009
71. M. Mukherjee, reduced out of band radiation based filter optimization for UFMC systems in 5G, Wireless Communications and Mobile Computing Conference, IWCMC, 2015, PP 1150–1155, 2015
72. N. Vander Neut, PAPR reduction in FBMC systems using a smart gradient project active constellation extension method, 21st International Conference on Telecommunications, ICT 2014, PP 134–139, 2014
73. G. Wunder, S.A. Gorgani, S.S. Ahmed, Waveform optimization using trapezoidal pulses for 5G random access with short message support, IEEE, 16th International Workshop on Signal Processing, Advances in Wireless Communications, PP 76–80, 2015
74. D. Sabella, Energy efficiency benefits of RAN-as-a-service concept for a cloud-based 5G mobile network infrastructure, IEEE, Access 2, PP 1586–1597, 2014
75. V. Jungnickel, Software-defined open architecture for front- and backhaul in 5G mobile networks, in: IEEE International Conference on Transparent Optical Networks, ICTON, PP 1- 4, 2014
76. J. Costa-Requena, Software defined 5G mobile backhaul, in: IEEE International Conference on SG for Ubiquitous Connectivity, PP 258 - 263, 2014
77. S. Tombaz, K.W. Sung, J. Zander, Impact of densification on energy efficiency in wireless access networks, in: The 8th Broadband Wireless Access Workshop, PP 57 - 62, 2012
78. S. Zhang, 5G: towards energy-efficient, low-latency and high reliable communications networks, in: Proceedings of the IEEE ICCS, 2014, pp. 197–201

79. M. Olsson, 5G Green: towards green 5G mobile networks, in: International Workshop on Green Optimized Wireless Networks, PP 212–216, 2013
80. B. Li, H. Xu, Anchor: A Versatile and efficient framework for resource management in the cloud, IEEE Trans. Parallel Distrib. Syst. 24 (6), PP 1066–1076, 2013
81. A. Gohil, 5G technology of mobile communication: A Survey, in: International Conference on Intelligent Systems and Signal Processing, PP 288–292, 2013
82. LTE Direct Workshop White Paper- Qualcomm Inc.
83. J. Qiao, Enabling device-to-device communications in millimeter wave 5G cellular networks, IEEE Comm. Mag. 209–215, 2015
84. T. Abdelzaher, Media Scope: Selective on-demand media retrieval from mobile devices, in: IEEE IPSN, PP 289–300, 2013
85. J. Domme, 5G in space: PHY-layer design for satellite communications using non-orthogonal multi-carrier transmission, in: Advanced Satellite Multimedia Systems Conference and the 13th Signal Processing for Space Communications Workshop, ASMS/SPSC, PP 190–196, 2014
86. J. Bingham, Multicarrier modulation for data transmission, an idea whose time has come, IEEE Commun. Mag. 28 (5), PP 5–14, 1990
87. M. Schwartz, Mobile Wireless Communications, Cambridge University Press, 2004
88. Bellanger M., (2011), FBMC physical layer-principle. www.ict-phydyas.org
89. Vakilian V. (2013), Universal-filtered multi-carrier technique for wireless systems beyond LTE". In: Globecom 2013 workshop
90. Fettweis G., Krondorf M., Bittner S,. (2009), GFDM - generalized frequency division multiplexing In: 2009 IEEE 69th vehicular technology conference, VTC Spring 2009, Barcelona, pp 1–4
91. Abdoli J., Jia M., Ma J., (2015), Filtered OFDM: a new waveform for future wireless systems. In: 2015 IEEE 16th international workshop on IEEE signal processing advances in wireless communications (SPAWC), pp 66–70
92. Zayani R., Medjahdi Y., Shaiek H., Roviras D., (2016), WOLA-OFDM: a potential candidate for asynchronous 5G. In: 2016 IEEE Globecom workshops (GC Wkshps), Washington, DC, pp 1–5
93. An C., Kim B., Ryu H., (2017), WF-OFDM (windowing and filtering OFDM) system for the 5G new radio waveform. In: 2017 IEEE XXIV international conference on electronics, electrical engineering and computing (INTERCON), Cusco, pp 1–4

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