Intensification and Interpretation of Performance in 5G Adopting Millimeter Wave: A Survey and Future Research Direction

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Abstract: *In context of high speed broadband communication, 5G optical communication has become a most stimulating and motivating domain in research. Recent cellular network LTE (4G) will not be adequate and effective to fulfill the needs of higher data rate, higher bandwidth, low latency and Quality of service.To achieve the above requirements and to address the challenges 5G optical communication have major considerations, the incorporation of Dense Wavelength Division Multiplexing (DWDM), Millimeter wave (mm-wave) communication, eMBB to make efficient decisions.This article summarize the empowering technology for DWDM, mm-wave signal communication and enhanced Mobile Broadband uses 5G optical communication as an evolution from 4G-LTE communication amenities, with fast communications, good throughput and high capacity, it is a successful aspirant for the increasing broadband communications. Such empowering technology, focused mainly on improving the network structure and efficiency, involves producing the mm-wave broadband signal with easy and cost adequate systems. This paper gives a thorough review on developing and empowering advancements identified with optical communication framework that can meet the huge data rate request of broadband. The article further addresses the research gaps and outlines the important future research direction for enhancing communication using DWDM.*

Keywords: *5G, DWDM, enhanced broadband, eMBB,mm-wave, radio over fiber*.

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1. Introduction

Telecommunication through high-speed Internet access and higher data rate now has a huge effect on our society. It plays a significant role in societal and global smart economic growth and digitization. Existing cellular networks such as 3rdGeneration, 4thGeneration unable to meet the specifications of 5G technology and cannot stand castoff for applications with low power wide area. Today, with a yearly development pace of around 25 percent, global Smartphone users are in millions and are projected to hit 80billion by year 2030 [6, 46]. System to System communication smart technology usher in the demand for more connected devices in high speed communication networks in future. Small base stations consisting of mm wave technology, Multiple Input Multiple Output (MIMO) antenna and more are used [3, 7].

The mm-Wave has radio spectrum, known as Extremely High Frequency, ranging from 30 to 300 GHz. It provides speed communication, higher data rate, high spectrum performance and greater consistency. This is also used as a Wireless short-range network. The high gain steering antenna array is used for compensating the path loss and obstructions.For transceivers the MIMO antennas are used to raise the efficiency of the wireless network. The MIMO has been switched by smart antenna technology and is too raising the Degree of Freedom. Such networks will offer high data rates, seamless high speed access and better coverage [44, 47]. Because of its higher availability (current spectrum congestion below 6 GHz) and future data-rate capabilities, millimetre wave band has been described as a possible broadband wireless access network candidate [8, 16, 32]. A preference in cell size decrease has advanced through the various developments in mobile connectivity along with carrier and data rate builds, and is also expected in 5G. The allocation of increasingly demanding resources and users would also need new approaches for front- and backhaul connections. Candidates for a heterogeneous 5G network topology are Mm-wave connections, Radio-over-Fibre (RoF) and Centralized-Internet Access Networks (C-RAN) [26, 40]. Because of the constraints on electronic components at these high frequencies, it is becoming generally recognized that photonic technologies must play key roles. Photonic technology offers fast, extreme great speed, small loss and stable communication for wireless networks of the next decade.Compared to untainted electronic switching technology, the limitations through functioning bandwidth, substituting speed and electromagnetic separation can be overcome by photonic microwave switching [9, 21]. A new photonic-based millimetre wavelength for wide bandwidth speeds and also allows switching noticeable for effective variation and high data rate over a wide range.

Enhanced broadband mobile communication is one of 5G's major obstacles, beyond cellular networks, demanding more bandwidth at higher frequencies [2, 10, 23, 24, 48]. Improved mobile broadband technology possibilities would involve pervasive artificial intelligence, virtual reality, augmented reality, high definition video (4k, 8k) bringing in an enormous network flow requiring high data rate. It is therefore stimulating to examine how data communication can be carried out at as high data rate as potential. Millimetre wave band 30GHz-300GHz is one of the hopeful aspirants for 5G, because its enormous bandwidth can support high data rate [18, 25, 33, 49, 50]. From the time when 2010, a great speed optical transceiver with 100 GB/s for every channel dependent on rational detection has been commonly used in everyday optical systems besides networks [52]. Such systems and networks use quadrature amplitude modulation on the transmitter end and logical detection on the receiver end to achieve good spectrum efficiency and transmission of extended distance signals. In addition, photonic devices, such as peripheral optical modulator have wide ranging bandwidth and devices through a bandwidth of>70GHz are already accessible. Related to the restricted bandwidth electrical In-Phase/Quadrature (I/Q) mixer, the optical I/Q modulator will escalate the bandwidth by 40GHz [36]. As a result, the use of photonic supported telecommunications to resolve the bandwidth constraint of millimetre wave communication is a natural choice.

The major contribution of this review article is listed below:

- IMT 2020 Requirements, Challenges and vision of 5G Technology is presented.
- New Generation Techniques for 5G Communication systems are presented in detail.
- Presentation of 5G usage scenario and traffic estimation 2020 to 2030.
- Presentation of wide range application domain in 5G Communication.
- Research gaps and future direction for enhancing broadband in 5G is provided.

The rest of the article is organized as follows, In section 2, Challenges and vision of IMT-2020, they include the requirements of International Mobile Telecommunication IMT- 2020, listed the Challenges and vision for enhancing broadband communication in optical communication. In section 3, the New Generation Techniques for optical Communication systems are presented in detail .The usage scenario and traffic estimates for 2020 to 2030 is briefly represented in section 4. Presentation of wide range application domain in optical Communication in section 5. Finally, conclude with what has been learned through this research survey and presentation of the futureresearch direction for enhancing broadband communications in sections 6 and 7.

2. Challenges and Vision of IMT-2020

The International Telecommunications Union Radio communications Standardization Sector decided on the IMT-2020 specifications for 5G, which are related to our review (ITU-R). The Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), and ultra-reliable low latency communication were three specific uses that the 5G criteria for IMT-2020 mentioned. Reduced-capability and user equipment, non-terrestrial network, multicast, and broadcast service are the main components of 3Gpp release 17. Beam management, multiple Transmission And Reception Point (mTRP) for Ultra-Reliable, Low-Latency Communication (URLLC), mTRP for improved mobile broadband (eMBB), and TDD and FDD reciprocity are the four areas that 3GPP Release 17 MIMO innovations address [20, 34]. Table 1 discussed the performance of technical stipulations for 2020-IMT

Table 1. Technical performance stipulations for 2020-IMT [27, 39].

Performance Illustrator	Value
Highest data rate (eMBB)	DLnk 20Gbps, ULnk 10Gbps
Peak spectral efficiency	DLnk 30bps / Hz (presuming 8 spatial streams), ULnk 15 bps / Hz (presuming 4 spatial streams)
5th percentile User experienced data rate	Dense urban eMBB: DLnk 100Mbps, ULnk 50Mbps
User spectral efficiency in Transmitter Point (TRP)	Indoor hotspot: DLnk 0.3bps / Hz / TRP, ULnk 0.21bps / Hz / TRP Dense Urban: DLnk 0.225bps / Hz / TRP, ULnk 0.15bps / Hz / TRP Rural: DLnk 0.12bps /Hz / TRP, ULnk 0.045bps / Hz / TRP
Average spectral efficiency	Indoor hotspot: DLnk 9bps / Hz / TRP, ULnk 6.75bps / Hz / TRP Dense urban: DLnk 7.8bps / Hz / TRP, ULnk 5.4bps / Hz / TRP Rural: DLnk 3.3bps / Hz / TRP, ULnk 1.6bps / Hz / TRP
Area traffic capacity	Spectral effectiveness and site density must be matched; the objective value targeted for indoor hotspots is 10 Mbps / m^2.
User-plane latency	4 ms for eMBB, 1 ms for URLLC
Control plane latency	20 ms (recommended 10 ms)
Connection density	106/km^2 for mMTC
Energy efficiency	a) Effectual transmission of data in power limited case and b) Low energy ingestion when there is no data.
Mobility interruption time	0 ms for eMBB
Bandwidth	Partially 100 MHz; Till 1 GHz frequency bands beyond 6 GHz

IMT-2020's key performance statistics are: Data Rate: This requirement provisions enhanced mobile broadband data rates for Uplink (ULnk) and Downlink (DLnk) latency: User plane latency within 4 ms for enhanced mobile broadband and 1ms for URLLC services is required to support enhanced mobile broadband and URLLC service. Density: The link density (total number of devices per sq.km) offering the requirement for QoS is set to support mMTC. The minimal expected link density is 1,000,000 devices/km^2. Energy Efficiency: Energy efficiency is considered in two respects to understand the greener perspective of future 5G networks:

1. Energy-efficient transmission of data in charged cases
2. Low energy ingestion in idle situations, categorised by the sleep ratio and period of sleep. IMT-2020's other criteria are huge reliability, provision for high speed (120–500 km /h^{-1}) agility of vehicles and disruption of mobility. Now, we are discussing the obstacles and potential solutions to fulfilling the above requirements [13].

2.1. Challenges of Optical Communication

To meet these targets, there are several technological challenges ahead. Potential developments are the large deployment of small cells, massive MIMO, beam forming, and mm-wave communication, to improve data rates and cell capacity. The features of mm-wave propagation determine its use for the limited spaces. Cumulating the amount of small cells, due to frequency reuse, will also improve the spectrum output and cell capacities. Small cell deployments with mm-wave will boost performance even further. Separating user and control planes, assigning signals and controls to macro Base Stations (BSs) and transmitting data to small base stations, mitigates the frequent hand-off issue. Despite the widely talked about benefits of massive MIMO, this system poses several challenges. Pilot pollution is the most evident problem; several terminals routine the same pilot series, initiating interference. Furthermore, antennas for massive low frequency MIMO require huge physical structures, which might not be possible anywhere. One new area of research is the dual use of beam forming with mMIMO and mm-wave [5]. A potential approach to minimize latency is contact between Device-To-Device (D2D) in-band and out-of-band. Additionally, taking the storage and processing resources to the edge of the network also helps to reduce latency. The principle of Network Slicing (NS) facilitated by Software Defined Networks (SDNs) and Network Functions Virtualization (NFV) has a significant role to play in supporting the various services. The paradigm of mobile edge computing is also necessary for relieving the core network from the enormous traffic burden created by the huge amount of IoT devices. The greener viewpoint of future wireless networks is another thing to consider. As per the study, the research problems related to 5G technology concentrate primarily on the following issues.

1. 1~10 GBPS data rate in actual networks: data transmission need to be 10X higher than current technologies [22].
2. Latency: compared with LTE networks, this will be 10X smaller [1].
3. Huge bandwidth and spectrum proficiency: 5G technologies require good bandwidth and perhaps accomplished by using MIMO antenna and mm wave technologies, and cognitive radio can achieve spectrum efficiency, allowing the consumer to use both licensed and non-licensed spectrum bands [29].
4. Low cost: internet of Things should look at low cost sensors, tools, and expense of deployment [4].
5. More number of connected devices: when trade with the Internet of Things system it is estimated that about 80 billion Internet of Things devices are associated over a network [30].
6. Greater battery lifespan: as the devices are supposed to be smart, and more power consumption is needed, and I should be more in charge storage and battery backup [40].
7. Reduce energy consumption by nearly 90 percent: energy reduction in 5G can be attained through the deployment of green technologies and can be competent in high connectivity and data rate [41].

I may increase the resonance wavelength when constructing the demultiplexer utilizing a ring resonator, and by doing so, I can increase the BER and bandwidth of my DWDM system in 5G compared to 4G technology. With regard to 4G technology, the demultiplexer design must be used to increase the bandwidth and bit rate in 5G.

2.2.Vision of Optical Communication

From the 7 major challenges listed above in 5G Internet of Things, wireless communications industries and research development institutes are cooperating and beginning research actions in various phases of 5G. Table 2 [11, 31] shows 5G's vision of different network providers and operators and its current research activities. Many of the leading telecommunications, semiconductor firms and service suppliers with outstanding research amenities are steering research and field prosecutions to make 5G wireless technology available by 2030. Many research organizations engaged in 5G study and studies with world-class laboratory facilities. The modern advance and elevation in cellular technology promises to light the demand for greater data speeds, improved spectrum efficiency, extended distance communication, improved battery lifespan and connecting billions and billions of devices. 5G cellular technology will be available in several countries within 2030 according to study. Table 2 explains the different research industries vision of the 5G broadband.

Table 2. Vision of 5G broadband: industry and research perception.

Research Industries	5GBroadband Key Vision
Intel	• The essential technology for cheap cost, longer battery life, and improved coverage, NB-IoT, has been standardised in large part because to Intel. • In light of industry 4.0, Intel is collaborating with Honeywell on IoT products and technology for robots, robotic internet, and factory automation.
ZTE	The 5G Multiple Input Multiple Output (MIMO) antenna developed by ZTE has effectively showcased the newest technology and won numerous prizes on various international platforms. ZTE's key contributions to the Internet of Things (IoT) market include software defined radio (SDR), 5G New Radio, and orthogonal frequency division multiple access (OFDMA).
Huawei	Recently, Huawei tested 5G NR in the 2.6GHz frequency band with success. The company's test experiments with IMT 2020's assistance have demonstrated that 2.6 GHz is an appropriate spectrum range for operators to deploy 5G in both SA and NSA mode [11].
Qualcomm	With sub-ms latency and 99.99% dependability, Qualcomm is planning to provide URLLC service for the Internet of Things [31]. Below is a list of Qualcomm's contributions to the standardisation of 3GPP Release 16. Time-sensitive networks: It can handle enhanced quality of service (QoS), microsecond time congestion, and Ethernet switch tasks. Qualcomm is making a real attempt to use unlicensed or shared spectrum for 5G NR.

Throughout today's technical era, the internet plays an important role in communicating various systems and devices that we utilize without human intervention in everyday life. This review article aims to deliver systematic knowledge and direction of future research in 5G communication.

5G standards:

- With a focus on improved mobile broadband, ultra-reliability, and low latency, the 3GPP is developing 5G architecture and 5G New Radio.
- To enhance Internet Protocol (IP) protocols, the Internet Engineering Task Force (IETF) develops network function virtualization technology.
- The International Telecommunication Union (ITU) is working on what radio interface technologies and radio frequency bands 5G networks can employ.

3. 5G Usage Scenarios and Traffic Estimation

Article ITU M.2083-0 [38] describes the structure and general goals of the “IMT for 2020 and beyond” strategic growth in order to meet the essentials of the future network. This is envisioned that IMT-2020 will extend to accommodate numerous implementation cases to presentations that will endure outside the existing 2020-IMT.

Massive Machine Type Communications (mMTC), usually transferring comparatively limited amounts of non-suspension critical data rate such as smart grid, home, cities, etc., for environments of a huge number of linked devices. Since unexpected ways of usage are likely to occur in the near term, 5G networks need to have stability to meet these emerging uses. High data rates are necessary for improved mobile broadband, mMTC requires high connection capacity for wide rollouts, and URLLC need extremely low latency. The study details the network topology, measurement parameters (in terms of system criteria, deployment device, usability, and traffic models), antenna features, and channel prototypes for the following five evaluation scenarios:

- Mobile broadband indoor hotspots upgrades.
- Dense mobile broadband increased in urban areas.
- Wireless broadband extended in remote areas.
- Macro Regional mMTC.
- Macro urban URLLC.

In the case of progressive mobile broadband, which is the conceptual progression of traditional 4G network networks, three common scenarios (outdoor urban and rural, and indoor hotspot) are considered. To this end, the ITU-R M.2370-0 [37] study analyzes patterns impacting projected development of IMT traffic flow yonder the year 2020. This research also forecasts the traffic demands for the 2020-2030 periods. The key factors affecting the development of potential IMT traffic according to this study are:

- *Video usage*: high-resolution (HD/UHD) video-on-demand platforms can account for two thirds of all internet traffic.
- *Propagation of devices*: additional1.4 billion smart phones and tabs are expected.
- *Application endorsement*: it is predicted to download more than 270 billion apps.

4. Research Gaps and Future Research Direction

One of the furthermost energizing duties in 5G Broadband correspondence is high transfer speed and range productivity. Due to its high Inter-Channel Interference (ICI), high Inter-Symbol Interference (ISI) and high Peak to Average Power Ratio (PAPR), LTE does not meet the demands of people as high-speed mobile broadband in crowded areas, enabling customers to enjoy high-speed streaming to grow at home. Such weaknesses are seen as the research obstacle for rising 5G broadband. The following are the primary solutions to the bandwidth demand issue: Small cell deployment, the use of higher frequency bands like millimetre wave bands, and multiplexing techniques that increase spectral efficiency are all examples of frequency reuse. Frequency reuse can be done more frequently by reducing cell size. Wireless connectivity to Gbps can be provided in lower frequency bands such millimetre wave bands; however the transmission range is constrained. In order to improve the effectiveness of the cellular system, small cell architecture (picocell/femto cell) in combination with RoF offers a superior option [28, 42, 43]. The sophisticated modulation formats and multiplexing technologies offer the necessary spectrum efficiency to supply the appropriate power to the end user. The system will operate in a narrow band and provide a good bandwidth when I go from Wavelength Division Multiplexing (WDM) to Dense Wavelength Division Multiplexing (DWDM), depending on the demultiplexer design. Demultiplexers can be created depending on the application. We can increase the bit rate and bandwidth in 5G compared to 4G technology when I use demultiplexer design in DWDM system as per the varied applications.

According to a thorough investigation, power consumption has become a crucial element in the construction of the 5G wireless connection network. For 5G progression, billions of devices are projected to join with more base station in single network architecture compared to current Long term Evolution (LTE) network. Therefore the need for energy effective system model and action to handle these enormous devices is a significant requirement. The utilization of small cell base stations is one issue that can be resolved through energy conservation. Its purpose is to increase capacity in locations with high consumer density. Additionally, it improves coverage, boosts data rates, and lengthens battery life by consuming less power. The small cells that can be further examined include the pico cell, femto cell, and micro cell [14, 17, 45].

The energy efficiency can be improved by deployment of network. The following system will help to improve energy efficiency.

In this work, I choose a demultiplexer design for a 5G application. As I was developing the demultiplexer, I moved the waveguide so that the receiver's response time would be in the pico second range. In a pico second, the receiver will therefore receive the information.

- Round trip delay-1ms.
- Bandwidth is 1000 per unit area.
- Number of connected devices 10-100.
- (Perception of) 99.999% availability.
- (Perception of) 100% coverage.

It is challenging to imagine a new technology that could simultaneously satisfy all of these requirements because they are stated from many angles and do not form a completely coherent. Table 3 deliver the research gap in existing work and imminent proposal with (filter) in 5G technologies.

Table 3. Research Gap and Imminent Proposal to meet the demands of High data rate, more bandwidth.

Paper Title	Enabling Technologies / Performance Measures	Research Gap	Imminent Proposal
A New Hybrid Architecture of Radio over Fiber/Wavelength Division Multiplexing in Optical Network [12]	1) RoF 2) WDM 3) mm-wave a) Power b) BER c) Q-Factor d) OSNR	✓ Using WDM technique, the input signal should be increased on the same cable ✓ In addition, the broadband network would be improved by addressing several issues that directly affect device performance quality	These take (DWDM) devices into account, which use optical multiplexing techniques to increase the efficiency of the fiber network beyond the rates reached by time division multiplexing.
Hybrid ARoF-WDM PON Infrastructure for 5G Millimeter wave Interface & Broadband Internet Service [35]	1) ARoF 2)WDM-PON 3) mm-wave 1) Spectral and 2) Energy efficiency 3) BER	40 Gigabit capable WDM-PON standards offering a solution for hybrid fiber optic systems, but after 40 km of transmission through the received broadband internet signal with 10Gbit/s bit rate, crosstalk and chromatic dispersion are mainly affected.	A-RoF-PON segment with DWDM channel frequency grid (50 GHz), optimized to the next generation PON standard, offering a novel solution for hybrid fiber optical networks that will function as the next step for future 5G wireless network.
Design of WDM-RoF-PON Based on Improved OFDM Mechanism and Optical Coherent Technology [15]	1) RoF 2)WDM-PON 3) OFDM a) BER b) Coverage c) Bandwidth	RZ-OFDM format has the same transmitting property and the same bandwidth as the NRZ-OFDM but it uses half of the RZ-OFDM signal bandwidth.	The use of RoF-DWDM-PON in OFDM system and Coherent technology can achieve high bandwidth and low BER performance.
Experimental Demonstration of a WDM RoF Based Mobile Fronthaul With f-OFDM Signals by Using Directly Modulated 3s-DBR Laser [51]	1) ROF 2) WDM 3) F- OFDM 4) 3s-DBR a) high bandwidth b) ultralow latency	✓ Due to the radio frequency authority fading brought on by the interaction among laser chirp and fiber dispersion. ✓ A single wavelength for each Remote Radio Head that facilitates the delivery of high bandwidth services needed for future 5G communications	✓ Different channels of wavelength are selected for transmission to verify performance across different DWDM channels. ✓ Direct modulation of the 3s-DBR laser tunable, multiband f-OFDM signal transmission with different wavelength
D-band Millimeter Wave Generation and Transmission Though Radio- Over-Fiber System [19]	1) RoF 2)Intensity & Quadrature modulator a) mm-wave generation b) BER	Under the current state of technology, it is still feasible and cost-effective to generate D-band mm-wave vector signals, which can be applied to long-distance fiber wireless integration systems.	Using RoF-DWDM with modulators can achieve a high efficiency in bandwidth and low BER.

4.1. Future Research Constraints

- Simple stations work in mm-wave bands (and can be wired together using high-capacity mm-wave connections) delivering multi Gb/s services to customers. I still have plans to use DWDM for long haul application to advance 5G technology in the future by reducing its latency and improving bandwidth.
- Withdrawal by subscriber/service or dependent on usage.
- Intelligent resource distribution dependent on traffic variability.
- Reduce transportation loads and central processing units.
- Consensus between industry and regulatory body on the use of mm-wave spectrum for emerging mobile broadband radio systems.
- Management and exchange of dynamic spectrum (sensing, exchanging, trading) between operators.

5. Conclusions

5G broadband vision and mission is to enhance user expectations by empowering new kinds of experiences, enabling new services, connecting new industries and connecting multiple device numbers within the same network architecture. 5G communication technology will be a great social service for developed nations and for the world. Protection, data traffic management, broadband networks and many 5G physical level investigation containing MIMO and photonics assisted broadband millimeter wave communication signal can be research domain in 5G. Many advanced 5G technologies such as intelligence cities, smart manufacturing, smart farming and smart healthcare are contributing to a revolution in speed and bandwidth. These enormous ranges of smart devices are supposed to be provided under the same roof of 5G networking with massive high speed connectivity. Highlight the most important application cases for 5G and possible traffic forecasting. We assume that this survey will form the basis for designing, standardizing and finalizing communication systems in order to meet the challenges of enhancing 5G broadband. Finally, on this revolutionary technology, they delivered some research challenges and track for analysis. The future research imperatives are being reviewed and broadly intellectualized to sustain such vast challenges. Nevertheless, the efficient monitoring and management of scalability and the implementation of new technologies in 5G also pose various challenges. Lastly, we explored how and what kind of work is contributed by different industrial spectrum in 5G, which this analysis will aid as a future research standard in 5G communication.

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