International Journal for Rapid Research in Engineering Technology & Applied Science
Vol IX Issue III March 2023
ISSN Online :- (2455-4723)

Review on Coverage and capacity improvement of millimeter wave 5G network

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Abstract- Many of the technologies driving both the global economy and societal development, such as the Internet of Things, Industry 4.0 and Smart Healthcare, depend on adequate capacity and coverage of digital connectivity. It is therefore essential that wireless connectivity can be delivered in a cost-efficient way by Mobile Network Operators, for the benefit of all digital ecosystem actors. The contribution of this paper is to analyze the capacity, coverage and cost of different enhanced Mobile Broadband (eMBB) infrastructure strategies, as the industry moves towards integrating new 5G spectrum bands and identifying existing networks. Both a supply-driven and demand-driven investment analysis is undertaken using a case study of the Netherlands As the number of internet user is increasing exponentially, demand of bandwidth, speed and carrier frequencies are also raising proportionally. To meet the users demand, existing 4G is not enough, hence the requirement of high speed and superior quality internet leads 5G network. The technology of 5G network needs huge number of devices and unmatched numbers of antennae which must support many number of new applications with lots of enhanced features in terms of speed, data rate, latency, coverage capacity, spectral efficiency etc. This paper reviewed some of the general aspects 5G network and focus on two important features namely spectral efficiency and coverage capacity

Keywords: 5G; millimeter wave (mmW); massive multiple input and multiple output (MIMO); small cell; mobile edge computing (MEC); beam forming;

I INTRODUCTION

Cellular and Mobile communication is quickly emerging finished an excellent developed voice communication as well as tremendous improvement in data streaming. Radio technologies promote of the equivalent cellular structure in the year of 1980's.That growth we seen in 1G, 2G, 3G to 4Gare Presently we are learning about 5G system. Since it provides more speed than other earlier generations. Here from the beginning of 1stgeneration 1G in 1980, second generation 2G in 1990, third generation 3G in 2000, fourth generation 4G in 2010 and finally the fifth generation 5G under the planning and development launch in present market of 2020. Difference Between 4G AND 5G: here in present scenario the 4G systems are LTE-A and Wi-Max, 3G systems are UMTS and LTE and 2G system is GSM. Beyond these systems 5G radio access system uses together novel radio access technologies RAT and also the current wireless technologies LTE, HSPA, GSM and finally the Wi-Fi With the advancement of every generation (i.e., starting from the voice-only systems to today's intelligent communication systems), the mobile network introduces new use cases and services, shown in Table 1 [1–4]. Until the 5G networks, all the new use cases and services were introduced to attract more human users to the mobile network. However, the 5G networks open up a new horizon and promise that the mobile network will be used for human-centric applications. It will also interconnect billions of smart devices autonomously while ensuring security and privacy [5,6]. The 5G network will enable the emerging services that include remote monitoring and real-time control of a diverse range of smart devices. It will support machine-to-machine (M2M) services and Internet of Things (IoT), such as connected cars, connected homes, moving robots, and sensors, etc. [7,8]. The 5G network evolution is well underway, and it has progressed swiftly since the 3GPP standardized the first 5G NR (New Radio) release (release 15) in mid-2018, shown in Figure 1 [9]. The leading mobile network operators (MNOs) in several regions of the world have already launched the first commercial 5G NR networks with mid-bands (i.e., 3–6 GHz) with the existing 4G cell sites, resulting in a significant performance boost [9–11].

However, the 5G network is projected to reach 40 percent population coverage and 1.9 billion subscriptions by 2024, corresponding to 20 percent of all mobile subscriptions [8]. These figures indicate that it will be the fastest global rollout so far. Moreover, smartphones generated data traffic is about 90 percent and is estimated to reach 95 percent by the end of 2024 [10]. With the continued growth of smartphone usage, the worldwide mobile data traffic is predicted to reach about 130 exabytes per month, which is four times higher than the corresponding figure for 2019, and 35 percent of the traffic will be carried by 5G networks [11,12].

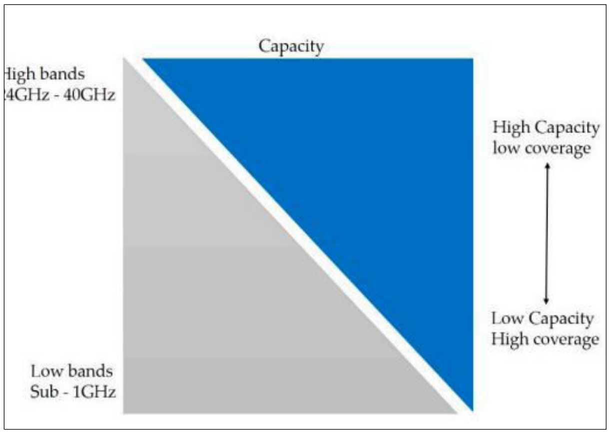

Figure 1. Coverage and capacity characteristics of 5G radio frequency ranges.

This ever-growing data demand and massive data traffic requirements can be met with the additional spectrum offered by the high-bands (i.e., 24 GHz–40 GHz) of 5G NR (new radio). The current 4G network can offer the carrier bandwidth from 5 MHz, 10 MHz, and 20 MHz, but the 5G mid-bands can offer 50 MHz and 100 MHz, whereas the 5G high-band can offer 400~800 MHz [12]. Since the wider band provides a shorter transmission time interval, it will enable lower network latency [13]. The 5G NR deployment in high bands (i.e., 24 GHz–40 GHz) offers more spectrum, which can boost the network capacity and the data rate by several folds [14]. In higher frequency bands, the signal propagation loss is too high; that will significantly reduce the individual cell site coverage, as shown in Figure 2 [13,15]. The individual cell site coverage will be around 100 m (in radius) in higher frequency bands (i.e., 24 GHz–40 GHz) compared to several kilometers in 4G networks [14,16]. Therefore, the MNO must deploy hundreds of new small cells (e.g., 100 m cell radius) compared to one large cell site (e.g., Macrocell will have several km in radius) to ensure the end-users' connectivity for the same area. The 5G network will require a very high level of network availability (i.e., 99.999%) and very high network reliability (i.e., 99.99%) that will require 100% network coverage [4,17,18], meaning that the 5G network coverage planning will be one of the main priorities for the MNO. It will ensure 5G connectivity and meet all the 5G network key performance indicators (KPI) (e.g., 99.99% network availability, 99.99% network reliability, highest bitrates (~20 Gb/s), and lowest latencies, etc.)

To deploy the 5G network and test the KPI of the networks for any deployment he MNO will have the following two options: 1. the first option begins with deploying all the required cell sites without priors is (e.g., each cell site location and cell site parameters, etc.). Then test the radials disperse throughout the deployment area and update the cell site para(e.g., antenna height, transmit power, power supply, backhaul connections, accordingly to meet the 5G network KPI requirements.

5G-gives certain specifications such as data rate must be equal to10 Gbps i.e. approximately 10 to 100x over an development of 4G and 4.5G networks, 1 ms potential with 1000x bandwidth per unit area, an amount of 100x associated devices per unit area over 4G LTE by99.99% availability and 100% attention,90% drop-in network energy procedure with 10 year battery life for low power IoT devices. Fig. 1; Features of 5GThe next generation mobile networks (5G) have started to endure to grow globally In addition to speed gains, the fourth generation network has a number of other advantages. The present LTE frequency range (600 MHz to 6 GHz) as well as millimetre wave (mmWave) bands (24–86 GHz) will be used for 5G. ITU IMT-2020 and/or 3GPP Release 15 standards must be met by 5G technologies Despite the fact that IMT-2020 calls for data rates of 20 Gbit/s, 5G speeds in sub-6 GHz bands are comparable to 4G.[3][4].5G is broadly accepted to be more astute, quicker and more productive than 4G allowing table examines4G against5G improvements and notices distinction anywhere in the range of 4G 5G remote advances.

Macro Cell in a Network -The macrocell networks are defined as the combining of micro cells in huge numbers. It is also called as mitigation network. These micro cells are used in the advanced techniques which have special characteristics (Eg: JT Comp) like low transmit power and different radio propagation. In a very short time there is no direct contact between a micro cell and the macro base station. Hence for a 5G network the simplest solution is micro and macro cells that use a robust method which is kept for different and independent frequency layers that works parallel. Hence the performance analysis in 5G shows that high spectral efficiency is obtained by the reusability of full frequency in micro cells which maintains the Integrity of specifications.

Massive MIMO. -Massive MIMO indicates the usage of more number of antennae per cell than the normal

MIMO system. The number of antennae in massive MIMO is 10 times more than normal MIMO system [10, 11]. Due to Improving Spectral Efficiency And Coverage Capacity OF this structure, the upper bound is set on spectral efficiency where the parallel services can be possible and the beam forming gains are achieved. This system actually requires orthogonal channels for the error estimation. For non-linear systems, the estimation of error propagation is minor since it has high signal to Interference pulse noise ratio. The major drawback of MIMO its cost which is more and hence the complexity in the circuit is also more.

5G Spectrums -In this section, an integrated approach of three technologies: JT CoMP, Massive MIMO and Micro cell to improve spectral efficiency and coverage capacity is presented. 6.1. An improved coverage in indoor using MIMO. A thorough knowledge of many number of antennas at typical outdoor hotspot locations helps in making better replacement of network capacity. The continuous use of frequencies in the network will lead to a high speed data coverage making of better improvement and the increased network range of different things for the hotspot location. Apart from this, the shorter distances between base stations and terminals and a higher line of sight (LOS) also makes advantageous.

Method of combining cells- 5G integrated approaches are used to improve the spectral efficiency. For this method the mobile nodes shares the spectrum of data such that the coordination among the network is maintained. This is done basically by distributed joint signal or processing centralized processing. A high spectral efficiency with high capacity, high speed and low latency are required for a back haul to interconnect the number of base stations and to deliver the amounts of data the number, a backhaul with high speed is needed to interconnect. Thus both high capacity and low latency are required for obtaining a high spectral efficiency in the proposed architecture [6]

II STATE-OF-THE-ART APPROACHES

Plenty of approaches were proposed to resolve the issues of conventional MIMO [7]. The MIMO multirate, feed-forward controller is suggested by Mae et al. [46]. In the simulation, the proposed model generates the smooth control input, unlike the conventional MIMO, which generates oscillated control inputs. It also outperformed concerning the error rate. However, a combination of multirate and single rate can be used for better results. The performance of stand-alone MIMO, distributed MIMO with and without corporation MIMO, was investigated by Panzner et al. [11].

In addition, an idea about the integration of large scale in the 5G technology was also presented. In the experimental analysis, different MIMO configurations are considered. The variation in the ratio of overall transmit antennas to spatial is deemed step-wise from equality to ten. The simulation of massive MIMO noncooperative and cooperative systems for downlink behavior was performed by He et al. [12]. It depends on present LTE systems, which deal with various antennas in the base station set-up. It was observed that collaboration in different BS improves the system behaviors, whereas throughput is reduced slightly in this approach. However, a new method can be developed which can enhance both system behavior and throughput.

In [13], different approaches that increased the energy efficiency benefits provided by massive MIMO were presented. They analyzed the massive MIMO technology and described the detailed design of the energy consumption model for massive MIMO systems. This article has explored several techniques to enhance massive MIMO systems' energy efficiency (EE) gains. This paper reviews standard EE-maximization approaches for the conventional massive MIMO systems, namely, scaling number of antennas, real-time implementing low-complexity operations at the base station (BS), power amplifier losses minimization, and radio frequency (RF) chain minimization requirements. In addition, open research direction is also identified.

In [14], various existing approaches based on different antenna selection and scheduling, user selection and scheduling, and joint antenna and user scheduling methods adopted in massive MIMO systems are presented in this paper. The objective of this survey article was to make awareness about the current research and future research direction in MIMO for systems. They analyzed that complete utilization of resources and bandwidth was the most crucial factor which enhances the sum rate.

In [15], authors discussed the development of various techniques for pilot contamination. To calculate the impact of pilot contamination in time division duplex (TDD) massive MIMO system, TDD and frequency division duplexing FDD patterns in massive MIMO techniques are used. They discussed different issues in pilot contamination in TDD massive MIMO systems with all the possible future directions of research. They also classified various techniques to generate the channel information for both pilot-based and subspace-based approaches.

In [16], the authors defined the uplink and downlink services for a massive MIMO system. In addition, it maintains a performance matrix that measures the impact of pilot contamination on different performances. They also examined the various application of massive MIMO such as small cells, orthogonal frequency-division multiplexing (OFDM) schemes, massive MIMO IEEE 802, 3rd generation partnership project (3GPP) specifications, and higher frequency bands. They considered their research work crucial for cutting edge massive MIMO and covered many issues like system throughput performance and channel state acquisition at higher frequencies.

In [17], various approaches were suggested for MIMO future generation wireless communication. They made a comparative study based on performance indicators such as peak data rate, energy efficiency, latency, throughput, etc. The key findings of this survey are as follows:
(1) Spatial multiplexing improves the energy efficiency;
(2) Design of MIMO play a vital role in the enhancement of throughput;
(3) Enhancement of mMIMO focusing on energy & spectral performance;
(4) Discussed the future challenges to improve the system design.

In [18], the study of large-scale MIMO systems for an energy-efficient system sharing method was presented. For the resource allocation, circuit energy and transmit energy expenditures were taken into consideration. In addition, the optimization techniques were applied for an energy-efficient resource sharing system to enlarge the energy efficiency for individual QoS and energy constraints. The author also examined the BS configuration, which includes homogeneous and heterogeneous UEs. While simulating, they discussed that the total number of transmit antennas plays a vital role in boosting energy efficiency. They highlighted that the highest energy efficiency was obtained when the BS was set up with 100 antennas that serve 20 UEs.

In [19], the authors considered the suitability of the mmWave band for 5G cellular systems. They suggested a resource allocation system for concurrent D2D communications in mmWave 5G cellular systems, and it improves network efficiency and maintains network connectivity. This research article can serve as guidance for simulating D2D communications in mmWave 5G cellular systems. Massive mmWave BS may be set up to obtain a high delivery rate and aggregate efficiency. Therefore, many wireless users can hand off frequently between the mmWave base terminals, and it emerges the demand to search the neighbor having better network connectivity.

In [20], the authors provided a brief description of the cellular spectrum which ranges from 1 GHz to 3 GHz and is very crowed. In addition, they presented various noteworthy factors to set up mmWave communications in 5G, namely, channel characteristics regarding mmWave signal attenuation due to free space propagation, atmospheric gaseous, and rain. In addition, hybrid beam forming architecture in the mmWave technique is analyzed. They also suggested methods for the blockage effect in mmWave communications due to penetration damage. Finally, the authors have studied designing the mmWave transmission with small beams in no orthogonal device-to-device communication.

Talib Abbas et.al. 2017 [21] in this paper, we analyze the end-to-end (e2e) performance of a millimeter-wave (mmWave) multi-hop relay network. The relays in it are decode-and-forward (DF) type. As appropriate for mmWave bands, we incorporate path loss and blockages considering the links to be either line of sight (LOS) or non line of sight (NLOS). The links also experience Nakagami-m fading with different m-parameters for the LOS and NLOS states. We consider two scenarios, namely sparse and dense deployments. In the sparse case, the nodes (relays and the destination) are limited by additive noise only. We derive closed-form expressions for the distribution of equivalent e2e signal-to-noise-ratio (SNR), coverage probability, ergodic capacity, and symbol error rate (SER) for the three classes of digital modulation schemes, namely, binary phase shift keying (BPSK), differential BPSK (DBPSK), and square-quadrature amplitude modulation (QAM). In the dense case, the nodes are limited by interference only. Here, we consider two situations: 1) interference powers are independent and identically distributed (i.i.d.) and 2) they are independent but not identically distributed (i.n.i.d.). For the latter situation, closed-form analysis is exceedingly difficult. Therefore, we use the Welch-Satterthwaite Approximation for the sum of Gamma variables to derive the distribution of the total interference. For both situations, we derive the distribution of signal-to-interference ratio (SIR), coverage probability, ergodic capacity, and SERs for the DBPSK and BPSK. We study how these measures are affected by the number of hops. The accuracy of the analytical results is verified via Monte-Carlo simulation. We show that multi-hop relaying provides significant coverage improvements in blockage-prone mmWave networks.

Khagendra Belbase et.al. 2017[22] The recent advancement in the 5G wireless technologies is demanding higher bandwidth, which is a challenging task to fulfill with the existing frequency spectrum i.e. below 6 GHz. It forces operators and researchers to go for higher frequency millimeter-wave (mm-wave) spectrum in order to achieve greater bandwidth. Enabling mm-wave, however, will come with various path losses, scattering, fading, coverage limitation, penetration loss and various different signal attenuation issues. Optimizing the propagation path is much essential in order to identify the behavior of channel response of the wireless channel before it is implemented in the real-world scenario. In this paper, we have analyzed the potential ability of mm-wave frequency band such as 28 and 73 GHz and compare our results with the existing 2.14 GHz LTE-A frequency band. We utilize the most current potential Alpha Beta Gama (ABG) propagation path loss model for designing urban microcell line of sight (LOS) scenario. We investigate the network performance by estimating average user throughput, average cell throughput, cell-edge user's throughput, peak user throughput, spectral efficiency and fairness index with respect to different user's capacity. The results express the significant improvement in spectrum efficiency of up to 95% for 28 GHz and 180% for 73 GHz is achieved in comparison with 2.14 GHz. It results also show that the 28 and 73 GHz frequency band is able to deliver up to 80 and 170% of enormous improvement in average cell throughput respectively as compared to currently LTE-A frequency band.

Chiranjib Saha et.al. 2019[23] with the emergence of integrated access and backhaul (IAB) in the fifth generation (5G) of cellular networks, backhaul is no longer just a passive capacity constraint in cellular network design. In fact, this tight integration of access and backhaul is one of the key ways in which 5G millimeter wave (mm-wave) heterogeneous cellular networks (HetNets) differ from traditional settings where the backhaul network was designed independently from the radio access network (RAN). With the goal of elucidating key design trends for this new paradigm, we develop a stochastic geometry-based analytical framework for a millimeter wave (mm-wave) two-tier HetNet with IAB where only the macro BSs (MBSs) have fiber access to the core network and the small cell BSs (SBSs) are wirelessly backhauled by the MBSs over mm-wave links. For this network, we derive the downlink rate coverage probability for two types of resource allocations at the MBS: 1) integrated resource allocation (IRA): where the total bandwidth (BW) is dynamically split between access and backhaul, and 2) orthogonal resource allocation (ORA): where a static partition is defined for the access and backhaul communications. Our analysis concretely demonstrates that offloading users from the MBSs to SBSs may not provide similar rate improvements in an IAB setting as it would in a HetNet with fiber-backhauled SBS. Our analysis also shows that it is not possible to improve the user rate in an IAB setting by simply densifying the SBSs due to the bottleneck on the rate of wireless backhaul links between MBS and SBS.

Ahmed Elshafiy; 2017[24] In order to achieve higher transmission rates and system capacity, fifth-generation cellular (SG) and 802.11ad/ay wireless systems will use higher frequency bands (24GHz-70GHz), the so-called millimeter wave frequencies. These systems rely on using large antenna arrays and narrow beam forming to counter the large path-loss experienced. Narrow beam forming maximizes array gain but results in a significant increase in beam management complexity, and the number of beams which are required to maintain the desired cell coverage as well. Hence, beam-broadening algorithms are suggested as a countermeasure, where a trade-off between high transmission quality and robustness to dynamics could be achieved. In this paper, a novel beam-steering algorithm is proposed to achieve improved coverage for a defined codebook size. Additionally, indoor office system performance is evaluated for different beam forming techniques. Numerical results show up to 1.5 dB improvement in system Signal-to-Interference-plus-Noise Ratio (SINR) via the proposed beam-steering approach when compared to conventional methods. The SINR gains could be converted to a 35% reduction in codebook size. These improvements are attained at zero additional cost.

III CONCLUSIONS

This survey article illustrates the emergence of 5G, its evolution from 1G to 5G mobile network, applications, different research groups, their work, and the key features of 5G. It is not just a mobile broadband network, different from all the previous mobile network generations; it offers services like IoT, V2X, and Industry 4.0. This paper covers a detailed survey from multiple authors on different technologies in 5G, such as massive MIMO, Non-Orthogonal Multiple Access (NOMA), millimeter wave, small cell, MEC (Mobile Edge Computing), beamforming, optimization, and machine learning in 5G. After each section, a tabular comparison covers all the state-of-the-research held in these technologies. This survey also shows the importance of these newly added technologies and building a flexible, scalable, and reliable 5G network

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