Satellite Communications in the New Space Era: A Survey and Future Challenges

Fayik Ali A, Dr Balusamy R, Dr Nalini P, Rumana N, Dr Sivakumar C

Al-Ameen Engineering College (Autonomous), Erode, Tamilnadu, India.
Ensafe Technologies, Salem, Tamilnadu, India.

Abstract:

In order to address the continuously expanding demand for mobile data, the millimetre wave (mmWave) bands supply new capabilities with a large amount of spectrum to fifth-generation (5G) mobile communication networks. Conventional methods and mmWave telecommunications differ significantly in terms of directivity, obstruction sensitivity, and maximum transmission loss. Some of the issues that mmWave raises in transmission are anti-blocking, interference management, spatial recycling, dynamic regulate, and systems engineering for maximum efficiency. In this paper, we investigated solutions and standards for these issues, as well as architectural and protocol design proposals for mmWave communications. The millimetre wave spectrum has already been investigated in the literature to see if it could be used in 5G small cell access, mobile access, and mobile backhaul.In addition, we discussed the potential use of mmWave zones in 5G.

Introduction

One of the fastest growing segments of the communications business is mobile communications. The explosion of mobile data traffic has been fueled by the advancement of wireless large datasets and the growing popularity of smart devices, posing significant problems for mobile operators [1]. By 2020, it is expected that mobile usage will have increased 1000-fold due to the Internet of Things (IoT) and real UHD services. This dramatic increase necessitates a significant increase in mobile available bandwidth beyond today's 3G/4G networks to the next era of cellular radio technologies [1]. The next 5th generation (5G) is viewed as an appropriate technologies that unites the existing transceivers, such as Wi-Fi and LTE, into a single new system.In general, new network needs are projected to emerge as a result of the large increase in devices connected planned in the coming years, and also the substantial increase in traffic volume. KPIs are used to identify alternatives that analyse radio link needs based on core technical problems arising from user-related issues. Traffic volume concentration, latency, dependability, experienced end-user bandwidth, and reliability are among the requirements used to define these KPIs [2]. New systems that effectively integrate developed technology and incorporate fresh methodologies, in fact, are the ones that will lay the groundwork for 5G.

The vastly expanded bandwidth, parallel processing transmission, and ultra-dense systems are the 3 most important prospective technologies for boosting the effectiveness of 5G mobile networks [2]. The majority of today's mobile communications operate in the sub-3GHz band, which is notoriously congested. The focus of radio system developers has shifted to higher bands in order to deliver the requisite download speeds and capacity while avoiding congestion. The mmWave range (30 to 300 GHz) contains a large amount of spectrum, with approximately 100 GHz of it usable for communication devices.mmWaves, when combined with Massive MIMO and femtocells, could be the key to eventual 5G mobile connectivity. However, in order for such a structure to become an actuality, various difficulties and questions should be addressed.

The constraint between frequency limits and capacity demands has become more evident as traffic information demands grow at a rapid pace. Wireless bandwidth chokepoints become a key challenge for 5G telecommunication. In contrast, multi-gigabit transmissions such as HDTV and UHDV are being suggested for mmWave with great capacity from 3 Khz to 300 ghz GHz, which are expected to be leading uses of 5G [1-2]. Actual studies have been conducted in frequencies of 20, 34, 59, 60-65, and 79-67 GHz. Technology, like CMOS radio frequency gear in mmWave frequencies, is predicted to progress quickly [3-4].

The properties of mmWave transmission were first summarised. Because of the high carrier signal, MmWave transmissions suffer from significant propagation loss. Furthermore, BF is used as a fundamental approach, indicating that mmWave transmissions are inherently directed. Furthermore, due to its low diffraction capability, mmWave communications are susceptible to obstruction by barriers such as humans and furniture. In contrast to scientific studies in the MmWave field, the following benchmarks of this study's achievements are presented: • We conducted a more thorough examination and summary of mmwave, including its properties, comparisons to other wireless systems, and applications. • Due to the rapid advancement of mmWave technology, a plethora of mmWave study has recently been developed.

The rapid expansion of mobile data and the widespread usage of smartphones are presenting wireless service providers with unprecedented hurdles in overcoming a global capacity deficit [1], [2]. Today's cellular operators are restricted to a carrier frequency band in order to generate quality, poor video and multimedia apps to wireless devices. As illustrated in Table 1, the total worldwide spectrum data transmission rates for all mobile communications does not surpass 780 MHz, with each cellular communications operator having around 200 MHz available throughout all mobile bands. The concurrent management of several devices in the same band-limited frequency is required to service legacy users with older ineffective cellphones and also clients with modern smartphones.Currently, operators' allocated spectrum is divided into discontinuous frequency bands, each of which has its own radio network with differing transmission properties and structure penetration rates. This implies that ground station designs should support a wide range of bands across many cell sites, with various ground stations for each wavelength or technology, such as 3rd generation (3G), 4th generation (4G), and Longer - term Evolution - Advanced (LTE-A) [3], [4]. Obtaining new spectrum can require a decade of administration through regulatory agencies like the ITU and the FCC in the United States. When spectrum is ultimately licenced, existing users will have to be relocated off the spectrum, generating additional delays and expenditures.

II. Attributes & Spreading of MMWAVES

Millimeter-wave (mmWave) cellular systems, which run in the 40-400 GHz band, appear to be a promising contender for the next 5G communication network, which are predicted to offer multiple Gb/s data rates. However, using mmWave necessitates dealing with the ultrasonic bands' propagation characteristics and channel limitations. Higher route loss resulting in higher carrier signal, lower scattering, which lowers available diversification, and greater effect of blockage due to a decline non-line-of-sight routes are all major hurdles to mmWave propagation. Furthermore, because of the use of higher bandwidths, the influence of noise figure is more apparent.

Path Loss

The carrier rate fc affects the free space route loss. The antenna length will be reduced as the carrier frequency is increased. As a consequence, the directional antennas functional aperture increases by a ratio of two 4, while the free storage path loss increases by fc 2. As a result, raising the carrier signal fc from Three to 24ghz will result in a 20 dB power loss, independent of the distance between the transmitter and receiver. Maintaining a consistent antenna diameter at one end of the link, on the other hand, will keep the free propagation loss from altering as the frequency is increased. Additionally, maintaining the antenna diameter constant for both ends reduces the free propagation loss with fc 2 by a startling amount.

Blockage

As per the absence and presence of line-of-sight, this will lead in a roughly bimodal channel. According to recent studies [4,] route loss rises to 20 dB/decade with increasing transmission and reception distance for line-of-sight transmission, but decreases to 40 dB/decade with an extra blocking effect of 15-40 dB for non-line of vision propagation. As a result, depending on the existence of obstructions, the link set will change from useable to useless. This will lead to a large disadvantage that small-scale variety will not be able to overcome.

Rain and Atmospheric Absorption

Attenuation caused by rain, foliage, and air uptake is a key stumbling block for radio communication. Environmental attenuation caused by transfer of oxygen or heavy rain may range from 10 to 20 decibels per kilometre. The absorption owing to air and rain, for example, is considerable in the 60-GHz range, particularly the 15 dB/km oxygen retention [2] [4]. However, as explained in section III, this problem can be avoided by using small size cells. Table I illustrates the path loss factor (PLE) under Nlos routes, rain absorption at 200 m, and oxygen uptake at 200 m for radio communication in various bands.Rain absorption and oxygen uptake are minimal in the 28 GHz and 38 GHz bands at 200 m, but they are considerable in the 60 GHz and 73 GHz bands [4]. In all four categories, it can also be demonstrated that the NLOS broadcast has more propagation loss than the LOS broadcast [4].

III. SOLUTIONS IN PLACE AND FUTURE DIRECTIONS

It is necessary to consider a remedy to the issues mentioned. Researchers discovered that combining mmWave with 2 other compatible technologies, Mu - mimo and femto cells, can result in a very reliable system.

Beamforming with Massive MIMO

mmWave networks should use electronically directional antenna arrays with high gain to provide a high signal (SNR) consistently throughout a cell, which means they must pre-code or girder data on massive antenna arrays. Because of the tiny wavelength, feasible arrays will be able to hold orders of magnitude more bits than existing arrays. This will give sufficient gain to overcome route loss and ensure higher SNR result [5] [6]. B. Networks with Extreme Density (small cell deployment) mmWave networks could also be made very thick to overcome obstructions, and can profit from the recent trend of migrating cellular systems to a more diverse network that includes cell sites and relays, when combined with the usage of adaptive directional arrays.

In fact, the mmWave's absorptivity characteristics will effectively boost cell isolation by attenuating interferences from more remote base stations [4] [6]. Future developments include a more in-depth investigation of the Massive MIMO system, which will need to tackle a number of problems: Hardware design and analysis, software - defined architecture, method of control, and heterogeneous connectivity are all examples of hybrid (analogue and digital) beam-forming.

FEATURES OF MMWAVE COMMUNICATION

When creating network topologies and procedures to adapt lots of wideband, the special qualities of MmWave communication should be taken account. The subsections that follow summarise and present the features of MmWave communications. Measurements in the Channel mmWave bands have a higher pathloss than traditional systems with lower carrier frequencies. As seen in Fig. 1, environmental and molecular bsorptions limit the applicability of radio communication. The transmission loss of the cells, however, was observed insignificantly when the distance between the transmitter and the receiver was less than 200 m. Insertion loss and bandwidth efficiency are in the same boat [13].mmWave communications can thus provide backhaul, small cell access, and interior applications. In the 60 GHz band, significant research has been done on mmWave dispersion.

In Manhattan, another inspection and test was made [22]. Due to impediments, the signal was detected with a 57 percent degradation within 200 metres. The antenna strengths must be raised and the route loss exponent must be decreased to reach the overall coverage range. In a strongly obstructed environment, 200 m. is considered as a limit range when the gain of the antenna is 49 dB. Absorption and reflection rates on brick columns and coloured glass were also observed at 28 GHz. The coefficients of reflection of outdoor substances were found to be higher than those of interior materials [23]. In addition, the angles of entry and exit in cities were measured.It was detected multipath with a mean of 2.5 signal lobes at any reception position using highly focused directional horn transmitters [24]. At the bands of 28 and 73 GHz in New York, spatial statistical models of channels were constructed, which included channel metrics.

Strong indications extending from 98 to 199 m from possible cellular regions may be recognised even in extremely NLOS situations, and variety and channel coding are enabled in many places where several path clusters have been acquired. Using spinning antenna arrays, another study of wideband dispersion was made at 73 GHz, and an actual ray-tracing design was developed to predict propagation features [26]. Using beam tracer to get the elevation parameters of the model, a prototype 3GPP-style 3D mmWave modeling software was improved based on the measurement data [27].

This has been demonstrated that the RMS delay is greater than the antenna gain. In an outage survey, the shorter the base station's height, the greater the service, and the majority of outages occurred more than 200 metres from the base. According to the findings, AOAs are most common when the RX angle of inclination is between 20° and the related to gun of the TX azimuth [28]. Table 1 shows the characteristics of mmwave in various bands..

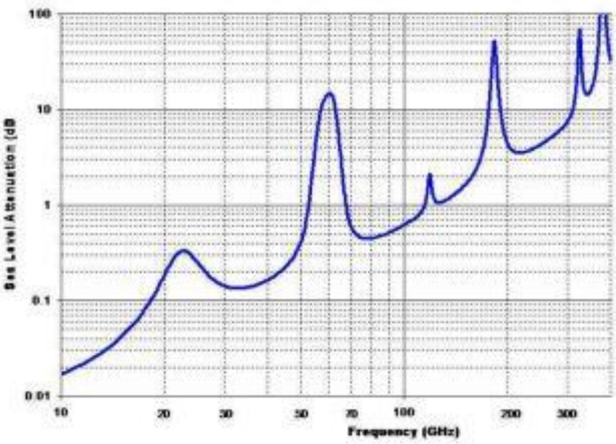

Fig. 1 Molecular attenuation at mmWave frequencies

Angle

Millimeter wave links have inherent and directional propagation. As a result, directional antennas guided by electrical impulses can be created as metal designs on a circuit [30]. Furthermore, the period of each antenna broadcasting signal could be electronically directed in any direction, resulting in a low yield in all directions while achieving a large gain in this path. Beam training is needed to direct the beam from the transmitter to a receiver, and different beam training algorithms have been developed to decrease beam time training [31-32].

Blockage Sensitivity

When the wavelength of electromagnetic waves is greater than the width of the obstruction, they can diffract significantly. Small wavelengths in the 60 GHz spectrum are subject to being obstructed by obstructions. The loss of physical obstruction, for example, was recorded at 20-30 dB [33]. In a realistic interior environment, Collonge et al. [34] measured propagation in the existence of human activity. In terms of measures, 1-5 persons lose roughly 1% to 2% of their body weight. The mmWave connectivity are scant when compared to human movement. As a result, providing a stable connection will cause the applications to be delayed.

III. SMALL CELL ACCESS APPLICATIONS OF MMWAVE IN COMMUNICATION

WLANs or WPANs, which are supported by tiny cells, are widely seen as possible alternatives for meeting 5G demand. Wideband multimedia applications, such as high-speed data transmission with multi-gigabit rates capacity, can be supported by mmWave tiny cells. mmWave tiny cells can also provide real-time streaming for HDTV, gigabit ethernet, and wireless gaming. The case for using the mmWave frequencies for improved local area (eLA) access in 5G, specifically bands was made.

With massive bandwidth, the eLA system delivers high data rates of more than 10 Gbps and edge download speeds of more than 100 Mbps. It is proposed that a mmWave system be used to produce HD video at speeds of up to 3 Gb/s [39]. Critical metrics were used to describe multimedia QoScharacterisation, and a QoSaware multimodal planning method was created to overcome the complexity while maintaining optimal performance.

TABLE I MMWAVE Transmission Attributes .

Frequency Band		25 GHz	38 GHz	60 GHz	73 GHz
Path loss exponent	**LOS Scenario**	1.8-1.9	1.9-2.0	2.23	2
	NLOS Scenario	4.5-4.6	2.7-3.8	4.19	2.45-2.69
Rain attenuation at 200 m	**5 mm/h**	1.23 dB	1.24dB	1.43 dB	01.4 dB
	25 mm/h	1.4 dB	1.8 dB	3 dB	4.3 dB
Oxygen absorption at 200 m		1.21 dB	1.24 dB	4.3 dB	1.34 dB

Cellular Access

The much greater bandwidth of mmWave opens up a lot of possibilities for 5G cellular connection. The coverage and connectivity potential of mmWave-based cellular networks are estimated to be higher, as long as the equipment is heavily implemented in [41]. The cell size of 200 metres at 28 GHz and 38 GHz demonstrates the viability and effectiveness of using mmWave transmission in cellular service, depending on spacious dispersion measurement studies at the millimeter waves. These capacity improvements in case antenna arrays are prospective in the most strong transmission and receiving directions, particularly for power savings and evolving bandwidth efficiency for communications. It must be turned on in mmWave cellular networks in order to encourage sensetive activities to the source, such as recognizing and interacting wi. surrounding objects.

Two D2D modes could be engaged when the mobile cells are heavily distributed in the system. It also includes D2D transmissions between cells and inside cells. Backhaul, intra-cellular, access, and inter-cell D2D connectivity are among the services available. To fully exploit the capability, effective and adaptable radio management techniques are necessary, including broadcast scheduling, voltage regulation, user identification, and access control.

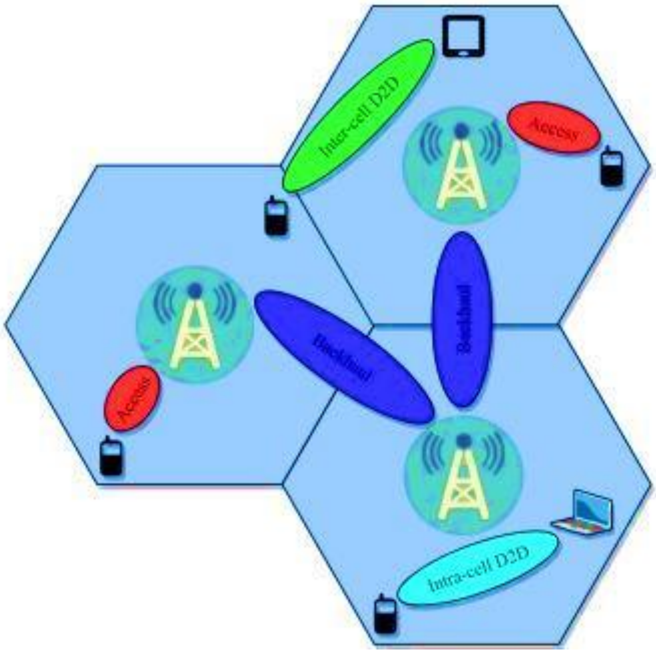

Fig.2 mmWave 5G cellular network architecture, with D2D communications

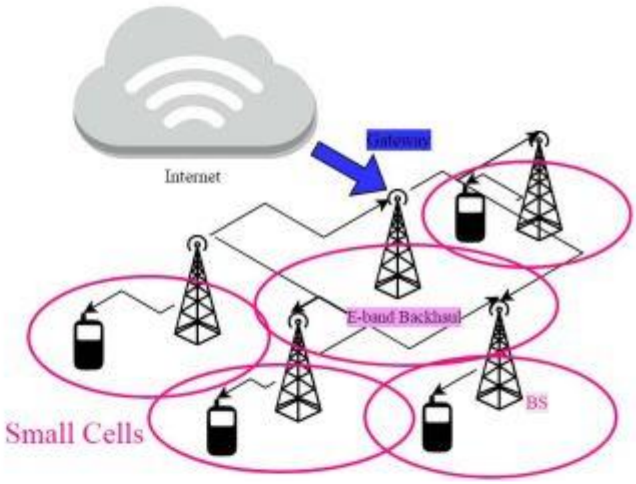

Fig. 3Cells that are tiny Backhaul in the E-band is widely employed.

Backhaul via wireless

Small cells are widely employed in 5G, also known as next era. Because 5G uses fiber-based backhaul, linking base stations to one another and to the internet is expensive [43]. Furthermore, linking via wireless broadband is more convenient, adaptable, and cost-effective to implement. With existing high-bandwidth wireless broadband in mmWave wavelengths, bands like 60, 71–76, and 81–86 GHz can deliver a few Gbps data speeds. As a result, it could be a viable solution for tiny cells. As demonstrated in Fig. 3, the E-band backhaul enables communication between BSs and gateways or small cell BSs. To develop a low-cost and flexible backhaul system, in-band radio backhaul is used.

In-band backhaul allocation of resources will be further optimised due to a single backhaul and access architecture [45]. A unified transmission planning framework for communication systems and transport of small cells at 60 GHz has recently been developed. D2DMAC was a path selection algorithm that tries to increase performance while also allowing D2D transmissions [43]. Table II shows the characteristics of works by frequency range, scenario, and principal application. In the 60 GHz range, there have been numerous studies on interior WLAN / WPAN applications.

TABLE II. mmwave telecommunication applications in many bands

Frequency Band (GHz)	Application	Scenario
28	in-band backhaul	outdoor cellular
$28,38,71-76,81-86$	access and backhaul	urban street
60	HD video	WPAN
60	access, backhaul and D2D	small cells in heterogeneous networks
60	uplink channel access	WLAN

60,70	Multimedia	indoor
Not specified	Access, backhaul and D2D	outdoor cellular

Conclusions:

MmWave telecommunication techniques are gaining traction as a potential 5G platform, offering higher capacity than existing communication networks. In this study, we conducted a poll on multimedia traffic for 5G. To encourage the redesign of methods and structures by addressing the issues and characteristics of mmwave, like congestion control and spatial re-use, dynamism owing to mobility electrical parts and technology requirements, and anti-blockage. Traditional solutions were first assessed and compared in term of performance, efficiency, and intricacy. Two key wireless transmission protocols, and also mmWave devices, were compared and contrasted. Additionally, possible 5G mmWave technological devices were examined.

Reference:

1. Rappaport, Theodore S., et al. "Overview of millimeter wave communications for fifth-generation (5G) wireless networks—With a focus on propagation models." *IEEE Transactions on antennas and propagation* 65.12 (2017): 6213-6230.
2. Balaji G., Vengataasalam S., Sekar S.”Numerical investigation of second order singular system using single-term haar wavelet series method” *Research Journal of Applied Sciences*(2013).
3. Sun, Shu, George R. MacCartney, and Theodore S. Rappaport. "A novel millimeter-wave channel simulator and applications for 5G wireless communications." *2017 IEEE International Conference on Communications (ICC)*. IEEE, 2017.
4. Sakthivel R., Sundareswari K., Mathiyalagan K., Santra S.”Reliable H∞ Stabilization of Fuzzy Systems with Random Delay Via Nonlinear Retarded Control” *Circuits, Systems, and Signal Processing*(2016).
5. Hong, Wonbin, Kwang-Hyun Baek, and SeungtaeKo. "Millimeter-wave 5G antennas for smartphones: Overview and experimental demonstration." *IEEE Transactions on Antennas and Propagation* 65.12 (2017): 6250-6261.
6. Yang, Binqi, et al. "Compact tapered slot antenna array for 5G millimeter-wave massive MIMO systems." *IEEE Transactions on Antennas and Propagation* 65.12 (2017): 6721-6727.
7. Shahmansoori, Arash, et al. "Position and orientation estimation through millimeter-wave MIMO in 5G systems." *IEEE Transactions on Wireless Communications* 17.3 (2017): 1822-1835.
8. Xiao, Ming, et al. "Millimeter wave communications for future mobile networks." *IEEE Journal on Selected Areas in Communications* 35.9 (2017): 1909-1935.

9. He, Danping, et al. "Channel measurement, simulation, and analysis for high-speed railway communications in 5G millimeter-wave band." *IEEE Transactions on Intelligent Transportation Systems* 19.10 (2017): 3144-3158.

10. Imbert, Marc, et al. "Assessment of LTCC-based dielectric flat lens antennas and switched-beam arrays for future 5G millimeter-wave communication systems." *IEEE Transactions on Antennas and Propagation* 65.12 (2017): 6453-6473.

11. Busari, SherifAdeshina, et al. "Millimeter-wave massive MIMO communication for future wireless systems: A survey." *IEEE Communications Surveys & Tutorials* 20.2 (2017): 836-869.

12. Jilani, SyedaFizzah, and AkramAlomainy. "A multiband millimeter-wave 2-D array based on enhanced Franklin antenna for 5G wireless systems." *IEEE Antennas and Wireless Propagation Letters* 16 (2017): 2983-2986.

13. Rappaport, Theodore S., et al. "Small-scale, local area, and transitional millimeter wave propagation for 5G communications." *IEEE Transactions on Antennas and Propagation* 65.12 (2017): 6474-6490.

14. Jayapandian N., Rahman A.M.J.M.Z., Poornima U., Padmavathy P.”Efficient online solar energy monitoring and electricity sharing in home using cloud system” *IC-GET 2015 - Proceedings of 2015 Online International Conference on Green Engineering and Technologies*(2016).

15. Gu, Xiaoxiong, et al. "Antenna-in-package design and module integration for millimeter-wave communication and 5G." *2018 International Symposium on VLSI Design, Automation and Test (VLSI-DAT)*. IEEE, 2018.

16. Lam, H. Y., et al. "Impact of rain attenuation on 5G millimeter wave communication systems in equatorial Malaysia investigated through disdrometer data." *2017 11th European Conference on Antennas and Propagation (EUCAP)*. IEEE, 2017.

17. Giordani, Marco, Andrea Zanella, and Michele Zorzi. "Millimeter wave communication in vehicular networks: Challenges and opportunities." *2017 6th International Conference on Modern Circuits and Systems Technologies (MOCAST)*. IEEE, 2017.

18. Li, Yilin, et al. "Radio resource management considerations for 5G millimeter wave backhaul and access networks." *IEEE Communications Magazine* 55.6 (2017): 86-92.