Improved mm Wave Massive MIMO Channel Measurements and Characterization by Bayesian optimization in 5G Wireless Communication Systems

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Abstract- Fifth generation (5G) of cellular technology is expected to address the ever-increasing traffic requirements of the digital society. Delivering these higher data rates, higher bandwidth is required, thus, moving to the higher frequency millimetre wave (mmWave) spectrum is needed. However, to overcome the high isotropic propagation loss experienced at these frequencies, base station (BS) and the user equipment (UE) need to have highly directional antennas. Therefore, BS and UE are required to find the correct transmission (Tx) and reception (Rx) beam pair that align with each other. Achieving these fine alignment of beams at the initial access phase is quite challenging due to the unavailability of location information about BS and UE. In mmWave small cells, signals are blocked by obstacles. Hence, signal transmissions may not reach users. Also, some directions may have higher user density while some directions have lower or no user density. Therefore, an intelligent cell search is needed for initial access, which can steer its beams to a known populated area for UEs instead of wasting time and resources emitting towards an obstacle or unpopulated directions.

Keywords- *5g, mmwave, Bayesian, optimization*

I. INTRODUCTION

Millimetre wave (mmWave) communication has been considered as a key technology for the fifth generation (5G) wireless communications, e.g., for wideband cellular communication (hotspot and small cell), wireless backhaul, indoor, and device-to-device (D2D) communications [21, 40]. MmWave generally corresponds to30–300 GHz frequency bands, but sometimes 10–30 GHz bands are also included as they share some similar propagation characteristics. Compared with sub-6 GHz frequency bands, mmWave bands have large available bandwidths but suffer from additional high path loss. Recently, many groups and standardization organizations including METIS, MiWEBA, mmMAGIC, 5GCM, 3GPP 38.900, IEEE 802.11 NG60, and NYU Wireless [6] have tried to develop mmWave channel models for the frequency range of 6–100 GHz. Various channel measurements have been conducted at some popular mmWave bands, such as 11, 15, 28, 38, 45, 60, and73 GHz bands. In [25], 11 GHz outdoor urban cellular channel measurements were conducted by using a 24×24 multiple-input-multiple-output (MIMO) channel sounder with 400 MHz bandwidth and dual-polarized 12-element uniform circular arrays. Path loss, shadowing, cell coverage, polarization properties, and root mean square (RMS) delay spread (DS)were obtained. In [20], 15 GHz channel measurements were conducted in two indoor corridor environments by using a vector network analyzer (VNA) and a spectrum analyser 1 GHz bandwidth. The large-scale fading, K-factor, and RMS DS were obtained. In [33], a VNA and two high gain horn antennas were used to measure the 28 GHz indoor environments with 1 GHz bandwidth. Power delay profile (PDP), path loss, RMS DS, and power angular profile were obtained. In [24], a sliding correlator-based directions can-sounding method was used to measure 28 GHz indoor office environments with 500 MHz bandwidth. Both line-of-sight (LOS) and non-line-of-sight (NLOS) scenarios were considered, and the space-alternating generalized expectation maximization (SAGE) algorithm was applied to estimate delay and angular parameters of multipath components (MPCs). Hur *et al.* [26] conducted 28 GHz measurements in an urban environment with 250 MHz bandwidth. The transmitter (Tx) antenna was scanned in both azimuth and elevation angle domains. The omni-directional PDPs were synthesized. In [27], a commercial backhaul equipment was used to conduct 38 GHz measurements in urban outdoor and outdoor-to-indoor environments. The LOS propagation, reflection, scattering, diffraction, transmission, as well as polarization effects were studied.

However, most of the channel measurements were conducted with different configurations, including measurement environments, channel sounders, antennas, and even postprocessing methods, which may have large impacts on propagation channel characteristics. It is hard to have a fair evaluation of different measurement results, though it is very important for the development of a unified channel model framework for large mm Wave bands. The comparison of channel propagation characteristics at different mmWave bands is also scarce. Moreover, mmWave massive MIMO channel measurements are scarce in the literature.

Massive MIMO or large antenna array system has the capability of greatly improving spectral efficiency, energy efficiency, and system robustness [14, 18]. In a typical massive MIMO system, single-antenna mobile stations (MSs)communicate with a base station (BS) equipped with a large number of antennas. Due to the increasing number of antennas, the propagation channel characteristics have some new properties and should be measured. In [42], 2.6 GHz outdoor channel measurements were conducted for a 128-element real cylindrical patch antenna array with a RUSK channel sounder, and for a 128-elementvirtual ULA with a VNA. In [23], 3.33 GHz outdoor channel measurements were conducted by using a signal generator, a spectrum analyser, and a 64-element virtual ULA. The non-stationarity of the channel over the array was identified in both delay and spatial domains.

Table 1.1: Different Properties Between mmWAVE massive MIMO channels and conventional wireless channels

Properties	Conventional wireless	MmWave massive MIMO channel
Bandwidth	< 100MHz	On the order of GHz
Frequency	<6GHz	6-100 GHz
Wavefornt	Plane	Spherical
Antenna elements	Usually less than 10	Up to 1000
Stationary	Wide stationary	Non=stationary

The combination of mmWave and massive MIMO has the potential to dramatically improve wireless access and throughput performance. Such systems benefit from large available signal bandwidth and small antenna form factor. The systems also have advantages in terms of compact dimensions, energy efficiency, flexibility, and adaptivity that would make them ideally suited for 5G communication systems [12, 32] including high-speed railway systems. As shown in [35], large antenna arrays can be used in mmWave systems to keep the antenna aperture constant, eliminate the frequency dependence of path loss relative to omnidirectional antennas, and provide array gains to counter the larger thermal noise bandwidth. The combination also brings new challenges to channel modeling. Table I shows the main different properties between mmWave massive MIMO channels and conventional wireless channels.

- **5G Evoloution**

This journey began with 1G, followed by 2G, 3G, the currently deployed4G and the newly emerging 5G technologies. A new generation has appeared every ten years since 1981 and has followed its own evolutionary path towards achieving higher speeds and better performance, as the global market of mobile and wireless communication has increased exponentially [1].

1G: The first generation (1G) used the analog transmission to fulfil basic mobile voice transmission. The 2G systems used digitally enhanced multiple access technologies such as TDMA (Time Division Multiple Access) and CDMA (Code División Multiple Access) leading towards early data services and enhanced spectral efficiency, under the Enhanced Data for Global Evolution (EDGE)standard. However, the standards were found to differ globally, and a network was developed where the design standards would not differ and be independent of the technology platform. And hence 3G was implemented [36, 39].

3G: In 3G, technologies such as Wideband Code Division Multiple Access (W–CDMA) and High–Speed Packet Access (HSPA) resulted in enhanced improvements within video and audio streaming capabilities by supporting information transfer rate of at least 2Mbps. 3G was a family of standards working together to meet the IMT–2000 technical standards [38]. Universal Terrestrial Mobile System (UMTS) was adopted in Europe, while the American 3G technology is named as cdma2000 and both were developed by the Third Generation Partnership Project (3GPP). 3GPP also developed the Long–Term Evolution (LTE) to offer a complete 4G capable mobile broadband and an upgrade to the existing 3G network. LTE uses Orthogonal Frequency–Division Multiplexing (OFDM) to support a transmission bandwidth of 20 MHz, while also supporting MIMO antenna arrays. These combined with dynamic channel allocation and channel–dependent scheduling allows for the utilization of propagation via multiple paths, in order to improve signal performance, spectral efficiency and diversity [38]. The predicted increase in mobile broadband demands is up to a thousand-fold by the year 2020, which has led to the motivation behind research in alternate spectrums beyond the 4G standard.

5G is the latest generation to be developing in the wireless revolution. It promises speeds of up to 10 Gbps, 100 times faster than 4G. It has low latency of 1 ms or less, and mobility with larger coverage areas. The higher data rates will allow services beyond cell phones, and base stations will provide the necessary bandwidth for office and home usage, which was not possible in previous generations [1].

- **mmWAVE Technologies**

mmWave communication has been considered as key innovation for 5G. The EHF range of 30-300 GHz corresponds to mmWave region of the electromagnetic spectrum, but 10- 30 GHz bands also included as they share some comparable propagation characteristics. One of the best uses of mmWaves is in transmitting a lot of information, and it have substantial accessible data transfer capacity. mmWave permit expansive data transfer capacity, other frequencies, infrared and optical wavelengths, allow high data rates and narrow bandwidths. Unlike mmWave, these shorter wavelength signals suffer from ingestion by fog, tidy and smoke, so it is preferred to use optical fiber as a wave directing medium since it is less affected by mist or other air conditions. There are numerous circumstances where optical fibers can't be utilized in light of the fact that the transmitters or collectors are portable, (for example, cell telephones or satellite communication) so radio wave interchanges including mmWaves, is generally the best decisions

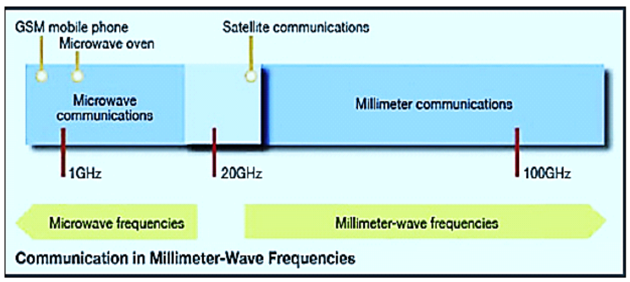

Figure 1.1: Communication in mmWave Frequencies [4]

- **Massive MIMO**

The explosive growth of wireless data service, especially more and more requirement for high-definition videos, demands higher capacities of future wireless communication system to meet this trend. Conventional MIMO is not a scalable technology. Massive MIMO means the use of a very large number of several antenna, large number of users are served simultaneously. Massive MIMO increases the capacity 10 times or more and simultaneously improves the radiated energy efficiency 100 times [4]. It can be built with inexpensive, low power components and it also enables a significant reduction of latency on the air interface.

Figure 1.2: Massive MIMO [4]

Massive MIMO or huge antenna array system has the functionality of substantially enhancing spectral performance, strength efficiency and system robustness [14] in an exceedingly typical massive MIMO system, single antenna mobile stations (MSs) communicate with a BS prepared with a large number of antennas. Because of the increasing variety of antennas, the propagation channel characteristics have a few new properties that must be measured. The combination of mmWave and massive mimo has the ability to dramatically:

- Improve wireless access & Throughput performance.
- Systems benefit from large available signal bandwidth and small antenna form factor.

The systems also have advantages in terms of:

- Compact dimensions
- Energy efficiency
- Flexibility Adaptivity

II. RELATED WORK

Bhatti, S. [1] looks at the 5G revolution, its advantage over 4G, the incorporation between 5G and mmWave technologies, and MIMO antenna design considerations. It will also highlight the challenges facing the above technologies, and some new technologies such as Ultra Dense Networks (UDN), smart cities and Li-Fi which will incorporate mmWave, MIMO and 5G technology.

Santos, R., et al. [2] developed an SDN based approach to enable such a dynamic backhaul reconfiguration and use real-world mmWave equipment to setup a SDN-enabled mmWave testbed to conduct various reconfiguration experiments. In our approach, the SDN control plane is not only responsible for configuring the forwarding plane but also for the link configuration, antenna alignment, and adaptive mesh node power on/off operations. We implement the SDN-based reconfiguration operations in a testbed with four nodes, each equipped with multiple mmWave interfaces that can be mechanically steered to connect to different neighbors.

Seraj, A. S. [3] presents large-scale characteristics of mmWave such as path loss, delay spread and power delay profile for both line-of-sight (LOS) and non-line-of-sight (NLOS) cases. The work also compares directional and omnidirectional propagation in a relatively smaller microcell with 5 times larger cell to observe the performance differences and characteristics of different mmWave frequencies with the increase in the Tx-Rx distance.

Mathew, R. A., & George, R. M. [4] provided a detailed analysis of Circular Rayline Array and mmWave Massive MIMO channel measurements at 11, 16, 28, and 38 GHz bands has been carried out. A recently proposed Space-Alternating Generalized Expectation- Maximization (SAGE) algorithm is applied to process the measured data. Important statistical properties, such as Average Power Delay Profile (APDP), Average Azimuth Profile (AAP), Average Elevation Profile (AEP), Root Mean Square Delay Spread (RMS DS), Elevation Angular Spread (EAS), Power Delay Profile (PDP) and their correlation properties are analysed.

Gao, X., et al. [5] investigate low RF-complexity technologies to solve this bottleneck. We first review the evolution of low RF-complexity technologies from microwave frequencies to mmWave frequencies. Then, we discuss two promising low RF-complexity technologies for mmWave MIMO systems in detail, that is PAHP and LAHP, including their principles, advantages, challenges, and recent results.

Huang, J., et al. [6] carry out mmWave massive MIMO channel measurements at 11-, 16-, 28-, and 38-GHz bands in indoor environments. The space-alternating generalized expectation-maximization algorithm is applied to process the measurement data. Important statistical properties, such as average power delay profile, power azimuth profile, power elevation profile, root mean square delay spread, azimuth angular spread, elevation angular spread, and their cumulative distribution functions and correlation properties, are obtained and compared for different bands.

Semiari, O., et al. [6] proposed a novel dual-mode scheduling framework is proposed that jointly performs user applications (UAs) selection and scheduling over µW and mmW bands. The proposed scheduling framework allows multiple UAs to run simultaneously on each user equipment (UE) and utilizes a set of context information, including the channel state information per UE, the delay tolerance and required load per UA, and the uncertainty of mmW channels, to maximize the quality-of-service (QoS) per UA. The dual-mode scheduling problem is then formulated as an optimization problem with minimum unsatisfied relations problem, which is shown to be challenging to solve.

Kuo, P. H., et al. [8] discusses two different approaches of CSI acquisition for massive MIMO in FDD, as well as a downlink precoding method that does not require CSI feedback. First, by noting that a spatially correlating MIMO channel can have a sparse representation via certain linear transformations, a feedback load reduction method based on compressive sensing theory is introduced. Secondly expound a practical and efficient CSI feedback mechanism utilizing multistage beamforming, wherein the pilot symbols are transmitted on angular-domain beams. Last, a downlink precoding technique based on angles-of-arrival knowledge of propagation paths instead of CSI is investigated in detail.

Busari, S. A., et al. [9] present the preliminary outcomes of extensive research on mmWave massive MIMO and highlight emerging trends together with their respective benefits, challenges, and proposed solutions. The survey spans broad areas in the field of wireless communications, and the objective is to point out current trends, evolving research issues and future directions on mmWave massive MIMO as a technology that will open up new frontiers of services and applications for next-generation cellular networks.

Hemadeh, I. A., et al. [10] present a survey of the mmWave propagation characteristics, channel modeling, and design guidelines, such as system and antenna design considerations for mmWave, including the link budget of the network, which are essential for mmWave communication systems. The researchers commence by introducing the main channel propagation characteristics of mmWaves followed by channel modeling and design guidelines. Then, they report on the main measurement and modeling campaigns conducted in order to understand the mmWave band's properties and present the associated channel models. They survey the different channel models focusing on the channel models available for the 28, 38, 60, and 73 GHz frequency bands.

Sakaguchi, K., et al. [11] gives four 5G mmWave deployment examples and describes in chronological order the scenarios and use cases of their probable deployment, including expected system architectures and hardware prototypes. The first example is a 28 GHz outdoor backhauling for fixed wireless access and moving hotspots, which will be demonstrated at the PyeongChang Winter Olympic Games in 2018. The second deployment example is a 60 GHz unlicensed indoor access system at the Tokyo-Narita airport, which is combined with Mobile Edge Computing (MEC) to enable ultra-high-speed content download with low latency. The third example is mmWave mesh network to be used as a micro Radio Access Network (μ-RAN), for cost-effective backhauling of small-cell Base Stations (BSs) in dense urban scenarios.

Wang, X., et al. [12] investigates the problem of the coexistence of LTE and Wi-Fi in 5 GHz unlicensed bands. The researchers first introduce the current rules for the 5 GHz unlicensed bands and the carrier aggregation technique. Then they discuss four deployment scenarios and two LTE-unlicensed (LTE-U) coexistence scenarios. Further, we provide a feature comparison between LTE and Wi-Fi in the PHY/MAC layers, and review the coexistence methods for LTE-U and Wi-Fi without or with the Listen- Before-Talk (LBT) mechanism. This paper is concluded by an examination of Wi-Fi link aggregation and in-device coexistence issues.

III. THE PROPOSED METHOD

Control the phases of signals with the single data stream in order to realize optimal antenna array gain and effective SNR. With perfect knowledge of the CSI available at both the BS and the UE, the analog beamformer employs N antennas at the BS with only one RF chain to send a single data stream to a terminal (i.e., UE) with M antennas and only one RF chain too. This concept is also called beam steering and aims at the design of the analog beamformer vector $\boldsymbol{f}$ and analog combiner $\boldsymbol{w}$ which maximizes the effective SNR, using the conditions in

However, perfect CSI is unrealistic in practical systems, thus necessitating beam training where both the UE and the BS collaborate in selecting the best beamformer (at the BS end) and combiner (at the user end) pair ($|\boldsymbol{f}|$-$|\boldsymbol{w}|$ pair) from pre-defined codebooks in order to optimize performance [9]. For mmWave massive MIMO systems, the codebook sizes could be very large due to a large number of antennas, together with the accompanying huge overheads.

An algorithm based on Bayesian approach is proposed for congestion control which is executed as explained in the steps below and flowchart 1 represents these steps in a graphical way for better considerate of the planned scheme.

PROPOSED WORK

The process of proposed technique is given as steps below:

Step 1: The initialization of protocol is deploying Massive -mimo.

Step 2: After deploying, then start making cluster.

Step 3: Then each cluster has multiple queues, then define the priority.

Step 4: After definition, change priorities according to the data.

Step 5: Then select time stamp for every node.

Step 6: The next step is initializing the likelihood.

Step 7: After this, define the new threshold.

Step 8: Then the prediction of threshold is done using Bayesian Approach.

Bayesian Approach is a catalyst which boosts to use the instructions as a right path to establish energy minimization algorithm. It gives top most performance for the minimum consumption of energy by determining optimum parameters which are required for pre-deployment of sensor nodes and ensures best detection of fault.[13]

Step 9: Change the priorities.

Step 10: After Changing priorities, optimization process is started. If optimization is successful, then drop the packet collision else go to the step 6.

Hyper parameter tuning is a kind of Bayesian optimization: minimize a function f (θ), but you only get to query values, not compute gradients Input θ: a configuration of hyper parameters Function value f (θ): error on the validation set Each evaluation is expensive. Given a fixed adaptive buffer of evaluations, the performance of an optimizer is quantified by the improvement obtained at the end of the optimization, i.e., when the evaluation buffer is consumed. Thus, at each iteration n, the best Bayesian optimization algorithm evaluates the buffer leading, at the end of the optimization, to the maximum expected feasible improvement. To define this optimal Bayesian optimization algorithm, it is first necessary to characterize how a design evaluated at iteration n is likely to affect the following iterations under an optimization policy. An optimization policy is a mapping from a training set D to a design to evaluate x. Using GPs as generative models. Combined with an optimization policy, this defines a mechanism that simulates the possible future steps of the optimization. Each possible buffer has a known probability of occurrence characterized by the statistical model. Thus, for a given optimization policy, the expected improvement obtained at the end of the optimization can be quantified with this simulation machinery. The optimal Bayesian optimization algorithm corresponds to the (unknown) best optimization policy which is the solution of an intractable dynamic programming (DP) problem.

Algorithm 1: Bayesian Approach
Input: Deploy nodes in WLAN Output: Optimize queue length for avoiding collision.

1). Deploy nodes with 5g network.

2). Deploy nodes, calculate distance and make clusters.

3). In every cluster there are multiple nodes and every node has queue and total queue.

4). Initialize queue priority according to number of packets. If packets are same then choose randomly.

5). From step 4 Initialize Bayesian approach

/)= /) 1

)

= new priority of queue.

) = Initialize priority of queue.

6). Step 5 Start giving prediction of priority and .

6.1 /) = ()* P(/) 2

∑ P()

/)= iterative queue priority on Packet

6.2 = ∑ /)

n

7). Analyze probability and coreelation

IV. RESULT ANALYSIS

4.1 Result Analysis

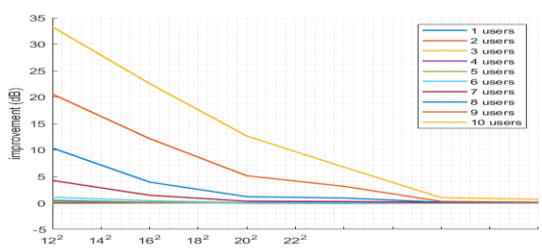

Figure 5.1 Number of users in proposed Bayesian approach

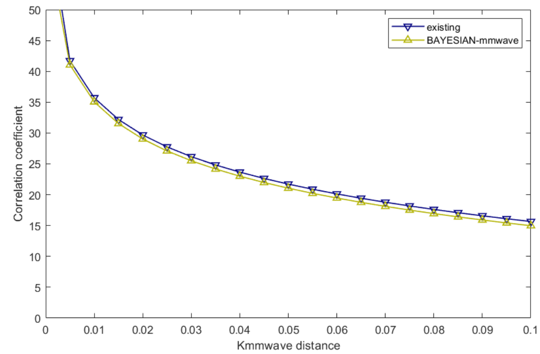

Figure 5.2 correlation at T*3

The above given Figure 5.2 represents Tx3 location for the four bands, respectively. As shown in), the DS can vary in the range of 3 ns over the array. shows that the azimuth AS can vary 20° over the arrayshows that the elevation AS variations are in the range of about 5° over the array. All the results indicate that the mmWave massive MIMO channel shows the non-stationarity property over the array and should not be seen as a WSS channel.

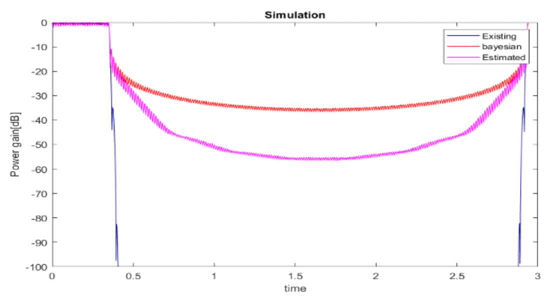

Figure 5.3 Measured and estimated power

The above given Figure 5.3 represents each frequency band, the LOS path arrives with azimuth angle of −17◦, −16◦, 0°, and 70° at the four Tx locations, respectively. By using the spatial lobe algorithm in [41] with 30 dB power threshold with respect to the maximum peak power, an average of four spatial lobes of MPCs are obtained for the four bands. Because height differences between Tx and Rx antennas are the same for the four Tx locations, and the Tx–Rx distances on horizontal plane are close, the elevation angles show almost the same properties for different Tx locations.

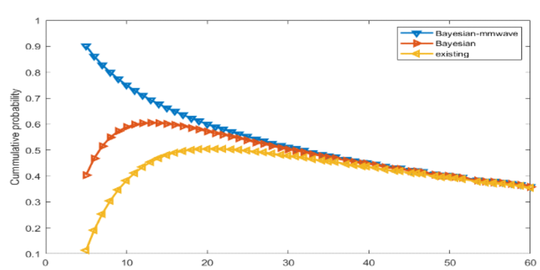

Figure 5.3 CDF and EAAS

The above given Figure 5.4 represents antennas increases to hundreds, the aperture of the antenna array becomes much larger. The Tx–Rx may be within the Rayleigh distance, and the far field or plane wave front may be violated. Because the SAGE algorithm is based on plane wave front assumption, it is impossible to process the large antenna array measurement data. To deal with the problem, the large array is divided into several sub-arrays. For each sub-array, the calculated Rayleigh distance is smaller than the Tx–Rx distance, and the SAGE algorithm is applied. A sliding window is used over the array on Y axis

V. CONCLUSION

Millimeter Wave communication is a key enabling technological for the realization of the Internet of Things in the 5G and beyond networks. In this thesis, we studied the propagation characteristics of mmWave in a dense urban environment for a heterogenous 5G network. The results in this study show that mmWave has the capabilities to be used in the 5G cellular outdoor networks by overcoming some propagation challenges for the massive connectivity in the dense urban areas. We reviewed the propagation characteristics of millimeter wave and highlighted the differences that mmWaves show in terms of higher rain and atmosphere attenuation and more sensitivity to blockage, compared to traditional wireless communications. The efforts for mmWave channel modeling was discussed and some developed channel models were introduced. We also described the details of the considered channel model for urban dense environments.

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