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Performance Simulation of Higher Frequency band Models for D2D application of 5G technology

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Abstract: The next generation of wireless transmission technology 5G is expected to support the development of high frequency channel models, so the interpretation of high frequency bands is the most important issue in radio propagation research. In this paper, multiple urban microcellular measurements have been carried out at 80 GHz. The collected data is uniformly analyzed to compare the simulation results of 5G MIMO models with the proposed algorithms using network Downlink Essentials 5G MIMO LTE-A and MIMO-OFDM. The 4×4 MIMO is an inwardly influential and 8×8 MIMO has accuracy of 89% for the frequencies 100 MHz to 80 GHz with bit-error-rate (BER) of 0.02323 which show that with less time-consumption, MIMO LTE-A and MIMO-OFDM provides better accuracy and demand on the network. It also shows that these new methods with 4×4 MIMO, 2×2 better MRC equalizer and ZF equalizer achieves reliability of 99.999%.

Keywords: 5G channel model, 60 GHz channel, Millimeter-wave, urban microcell

1 Introduction

To meet the challenges posed by the rise in traffic volumes in wireless communication, research on 5th generation networks is anticipated to intensify in the next decade [1]. 5G is the short for fifth generation, a mobile broadband technology that is in the early stages of works and likely to be in place six to seven years from now. A 5G network will be able to handle 10,000 times more call and data traffic than the current 3G or 4G network. Data download speed on 5G networks are likely to be several hundred times more than 4G. 5G mobile technology will change the means to use cell phones within very high bandwidth. Rapidly rising demand for radio communication and the explosion in the number of Device-to-Device (D2D) communication services have led to the need to optimize the development of 5G mobile communication systems [2]. In terms of developments in next generation mobile communication systems, performance verification of the development system is essential, for which it is necessary to estimate the exact wireless-space channel. This is because this channel is based on the exact model, including elements of the next-generation wireless transmission applications, such as frequency, time, space, and polarization [3]. Fifth generation mobile networks will need to make use of frequencies above 60 GHz for its potential to allow wider bandwidths [4] and the targeted frequency bands range up to 100 GHz [5].

Considerable effort is currently put into the refinement of channel models, since they are essential for accurately assessing the performance of future deployments. Most relevant work builds upon state-of-the-art three-dimensional (3D) geometry-based stochastic channel models (GSCMs) that have been developed recently for lower frequency bands. New model features and extended parameter tables have been proposed to fulfill the requirements for 5G millimeter-wave (mm-wave) channel models, which have to support a much wider frequency range, large antenna arrays, large bandwidth and high mobility [6]. Mobility performance and related enhancements are also important topics for mobile wireless systems. In research, mobility improvements are typically first assessed by simple analytical considerations, followed by more complex dynamic simulation campaigns, before implementing and testing in the field [7].

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This paper is organized into five sections as follows: Section 2 presents the factors and phenomena affecting the propagation in high frequency bands. Section 3 describes the studied channel models for 5G, while Section 4 presents the simulation results obtained for those models. Finally, Section 5 presents the conclusions.

2 Factors Affecting Propagation

Problems: If the problem is expected to run on ultra high frequency band of 5G service, then it can be used to compare low frequency bands, so that they can be better suited for better indoor coverage. High frequencies can be blocked from buildings and can lose strength over long distances. This means that providing a wide range of coverage will be a challenge.

Description: Direct D2D communication, controlled by the network, allows mobile devices to exchange packets between local devices.

Purpose: To integrate Direct D2D mode in one part of the MANET system.

Motivation:

(a) End-user benefits: Low power consumption; Enhanced potential geographical exploration of close activities;

(b) Carrier Advantage: Increasing spectral efficiency; Increase the coverage of more and more devices.

Fig. 1 summarizes factors expected to have a significant effect on propagation characteristics in high frequency bands. Of these, strong mobility effects, (1) rainfall attenuation and (2) losses due to trees and plants have been clarified in Inter-national Telecommunication Union, Radio communications Sector (ITU-R) reports [11]. Further, the effects of (2) shadowing by human bodies has been considered in a channel model proposal from the Millimeter-Wave Evolution for Backhaul and Access [12]. (MiWEBA) project, this model deals mainly with the 60 GHz band, and it will also be important to understand the characteristics of (3) rough surface diffusion.

3 Studied models

The METIS [4], MiWEBA [12] and NTT DOCOMO [11] channel models presented by articles [6] and [3] are well known research projects in Europe and Asia related to 5G.

3.1 METIS model

METIS has proposed a channel model called the Map-based Model, and calculates propagation characteristics using ray tracing. This model applies to frequencies of 100 GHz or less.

Fig. 1: Factors affecting propagation in high frequency bands [12].

It refers to propagation conditions in which the transmitter is situated much below the mean building height, in the sense that it lacks dominant visibility of the users and main propagation occurs by reflection between buildings.

For this case a detailed modeling of buildings is needed. The proposed model is based on the ITU-R UMi (urban microcell) path loss model for Manhattan grid layout [4].

In general, this model distinguishes the main street, where the transmission point is located, perpendicular streets, and parallel streets. Fig. 2 shows the geometry used.

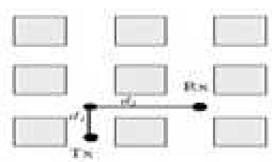

Fig. 2: Upright projection of the geometry [13].

If the receiver is in the main street, LoS path loss in decibels is calculated according to the following equation [13]:

$$PL(d) = 40\log_{10}(d) + 7.8 - 18\log_{10}(h'_{tx}) - 18\log_{10}(h'_{rx}) + 2\log_{10}(f_c) \quad (1)$$

where d is the distance in meters between transmitter and receiver, f_c is the frequency in GHz and h'_{tx} and h'_{rx} are the effective antenna heights in meters of transmitter and receiver, respectively. The effective antenna heights h'_{tx} and h'_{rx} are computed as follows:

$$h'_{tx} = h_{tx} - 1 \quad \text{and} \quad h'_{rx} = h_{rx} - 1 \quad (2)$$

where h_{tx} and h_{rx} are the actual antenna heights and the effective environment height in urban environments is assumed to be equal to 1 m. If the receiver is in a perpendicular street, then

$$PL = \min(PL(d_1, d_2), PL(d_2, d_1)) \quad (3)$$

where

$$PL(d_k, d_1) = PL_{LOS}(d_k) + 17.9 - 12.5n_j + 10n_j \log_{10}(d_1) + 3\log_{10}(f_c) \quad (4)$$

and

$$n_j = \max(2.8 - 0.0024d_k, 1.84). \quad (5)$$

For the sake of simplicity, the height used in the LoS formula will be the one of the receiver in Rx. It is worth noting that in case of being in a perpendicular street with distance less than 10 m between transmitter and receiver, then LoS conditions apply. Finally, for parallel streets, the path loss is assumed as infinite. Moreover, minimum coupling losses are set to 53 dB.

3.2 MIWEBA model

MiWEBA has proposed a model called the Quasi-Deterministic Model. This model uses paths computed using ray tracing and considers paths statistically, so it is a hybrid of the GSCM and Map-based Models from METIS. It is being used mainly for the 60 GHz band of frequencies, so care must be taken when applying it to other frequency bands.

The measurement snapshots were taken using Omni-directional antennas. When calculating the path loss of this basis all possible propagation paths between transmitter and receiver are taken into account. This is somewhat unrealistic as real millimeter-wave communication systems will most probably employ directional antennas to improve their link budget. Directional antennas imply that a spatial filtering of signals propagating towards the antenna is performed, depending on its orientation and antenna pattern. In order to replicate this behavior, a filter was applied to each channel impulse response from the measurement, before it was used to calculate the instantaneous path loss.

Only the line-of-sight component, the ground reflection and reflections from other objects very close to the line-of-sight path are taken into account.

The pass loss model is equal to [12]:

$$PL = \alpha + n\log_{10}\left(\frac{d}{d_0}\right) \quad (6)$$

where $\alpha = 82.02$ dB, $n = 2.36$, $d_0 = 5$ m and d is distance between transmitter and receiver.

3.3 NTT DOCOMO model

NTT DOCOMO has proposed a channel model which uses paths computed using ray tracing and considers paths statistically. Since high frequency bands are expected to be used with 5G, propagation characteristics must be elucidated for the 6 to 100 GHz range.

To adequately assess the performance of 5G systems, multi-frequency path loss (PL) models, LOS probability, and blockage models (NLOS) will need to be developed across the wide range of frequency bands and for operating scenarios.

It may also be noted that the intention is to have only one path loss model (per scenario and LOS/NLOS) but that choice is still open for discussion.

Table 1 shows the parameters of path loss models for different environments for Omni-directional antennas. It may be noted that the models presented here are multi-frequency models, and the parameters are invariant to carrier frequency and can be applied across the 0.5–100 GHz band.

The PL model is given as [10]:

$$PL(f,d) = FSPL(f, 1\text{ m}) + 10n\log_{10}\left(\frac{d}{1\text{ m}}\right) + X \quad (7)$$

where f is the frequency in Hertz (Hz), n is the PLE, d is the distance in meters, X is the shadow fading (SF) term in dB, and the free space path loss (FSPL) at 1 m, and frequency f is given as:

$$FSPL(f, 1\text{ m}) = 20n\log_{10}(4\pi f/c) \quad (8)$$

where c is the speed of light.

The parameters are given in Table 1.

Table 1: Path loss parameters for LOS and NLOS scenario [4].

Scenario	Parameters
UMi street canyon (Los)	$n = 1.98$, $X = 3.1$ dB
UMi street canyon (NLos)	$n = 3.19$, $X = 8.2$ dB

3.4 PL Model

In this model, the collected data is uniformly analyzed with focus on the path loss (PL), it reveals that the ground reflection has a dominant impact on the fading behavior, the PL shows a clear dependence on the scenario and strong distance dependence for street canyon.

The PL model is given by the equation (7), where d is the distance between transmitter and receiver.

Table 2: Path loss parameters [1].

Scenario	FSPL	n	X (dB)
SC-RA(Los)	67	2.07	2.53
SC-RA(NLos)	69.7	2.67	4.93

The PL (d_0) is the mean PL at the reference distance $d_0 = 5$ m, n is the PL exponent and X is a zero-mean Gaussian random variable (in dB) with standard deviation s, which accounts for shadow fading.

Measurements were performed in two locations: “street canyon, city center” and “street canyon, residential area”

The parameters are given in Table 2.

3.5 Model presented in [3]

This paper presents results of the analysis of radio propagation characteristics based on location variation in outdoor environments for small-cell 5G mobile systems shown in Fig. 3. Changes due to variation in location were measured using a channel sounder in a microcell environment with a 0.5 km radius in Korea.

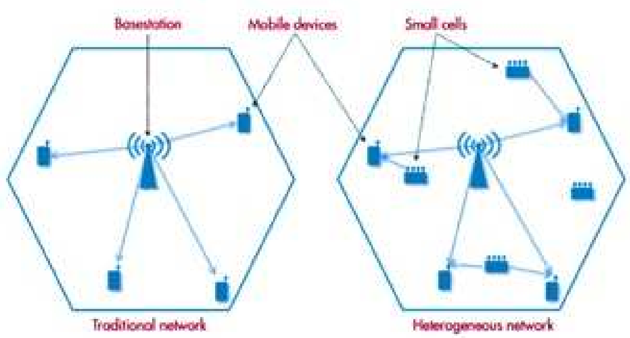

Fig. 3: Small-cell 5G generation mobile systems.

A comparison between measurements and three-dimensional ray-tracing simulation results confirmed the validity of the measurement result.

The path-loss value, which changes according to distance, appears to be along the following distribution given in (7). where $_0 = 20$ m. The parameters derived in each region are given in Table 3.

Table 3: Path loss parameters [2].

Scenario	FSPL	n	X (dB)
Los region	−15.05	1.63	5.76
NLos region	−19.59	4.79	19.1

4 Performance Evaluation

After studying some channel models and determining path loss for each model in the case of outdoor urban microcell scenario (UMi) we did a simulation with Matlab in order to compare the performance of those models, The results are presented in Figs. 4 and 5.

Curves show path loss in accordance with received distance. As distance increases, the value of path loss significantly distributes due to location variation for all models. For LoS scenario MIWEBA has the minimum path loss in comparison to METIS. In the case of NLOS scenario, the two regions (LOS and NLOS) are separated by a sharp attenuation, with a significant increase in loss. According to figures channel model presented in [3] presents the minimum path loss compared to the other models.

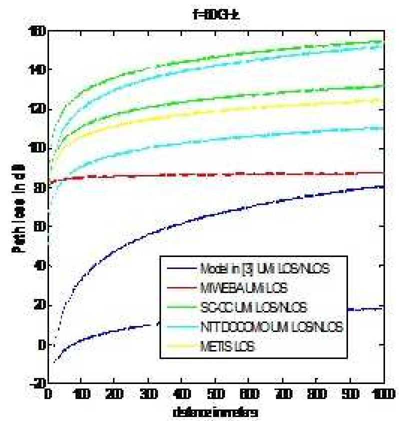

Fig. 4: Simulated path loss versus distance for the five models.

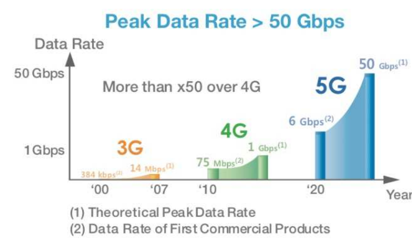

Fig. 5: Peak data rate > 50 Gbps.

4.1 High-level goals

1. 1000 times higher mobile data volume per area data rate.
2. 10 times to 100 times higher number of connected devices.
3. 10 times to 100 times higher typical user data rate.
4. 10 times longer battery life for low power Massive Machine Communication (MMC) devices.
5. 5 times reduced End-to-End (E2E) latency.
6. Data rate: TC1 (Virtual reality office)
7. 1 Gbps, TC2 (Dense information society): 300 Mpbs DL
8. Capacity: TC1: 36 TB/month/subscriber,TC2: 500 GB/month/subscriber
9. EP: 5GrEEn
10. Latency: TC5: 8ms, TC12: 5ms 99.999% reliability.

Table 4: Path Loss Processing.

5G		5G Observed MIMO OFDM							Grand Total	User's Accuracy
		4048	7124	7268	8429	8431	8442	2070/7233		
MIMO OFDM	4048	**5**	22	33	11	33	55	55	5	100%
	7124	2	**2**	44	33	55	77	77	2	100%
	7268	3	11	**22**	33	3	55	66	25	88%
	8429	4	33	55	**2**	55	77	77	2	100%
	8431	5	22	66	55	**10**	65	66	10	100%
	8442	6	12	77	44	55	**5**	88	5	100%
	2070/7233	44	66	66	55	44	5	**24**	30	80%
Grand Total:		5	2	23	3	13	10	24	79	
Producer's Accuracy:		100%	100%	96%	100%	77%	50%	100%		
Samples: 79 Overall Accuracy: 89% Reliability Statistic: 99.999%										

4.2 Proposed algorithms

MIMO MANET: Multiple transmitting and receiving radio broadcasts allow one channel outflow compensation.

MANET 5G: At the transmitter, the information source output is first divided into N parallel bit streams, each of which is independently encoded, interleaved, symbol mapped according to the MCS parameters which are fed back from the receiver. Symbol repetition is used only at low Signal to Noise Ratio (SNR) regions, the MCS parameter is determined per transmit antenna basis and is commonly shared by all sub-carriers. Each of the N data symbols are further time division multiplexed with pilot and control symbols and then allowed for Inverse Fourier Transformation (IFFT) to obtain the OFDM symbols with K sub-carriers. After GI is added, the resultant N signals are transmitted simultaneously.

MANET OFDM: Spatial multiplexing is combined with OFDM to effectively handle the complexity of this particular multiplexing technique.

5G MIMO LET-A: OFDM is a wideband system with many narrowband sub- carriers. The mathematical MIMO channel model is based on a narrow band non-frequency selective channel. The latter is supported by OFDM as well. Fading effects in wideband systems normally occur only at particular frequencies and interfere with few sub-carriers. The data is spread over all carriers, so that only a small amount of bits get lost, and these can be repaired by a forward error correction (FEC). OFDM provides a robust multi-path system suitable for MIMO. At the same time OFDM provides high spectral efficiency and a degree of freedom in spreading the time dimension of Space-Time Block Codes over several sub-carriers.

5G D2D: MIMO is also planned to be used in Mobile radio telephone standards such as recent 3GPP and 3GPP2. In 3GPP, High-Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standards take MIMO into account. Moreover, to fully support cellular environments MIMO research consortia including NILOS propose to develop advanced MIMO techniques, i.e., multi-user MIMO (MU-MIMO).

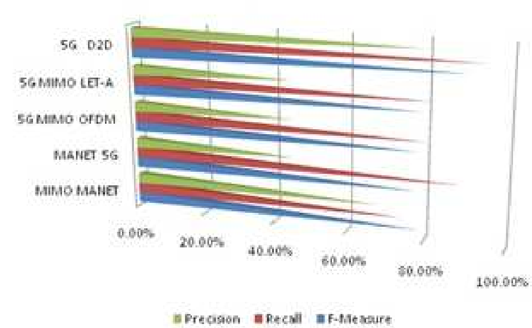

Fig. 6: F-Measure, Recall and Precision of the proposed algorithms.

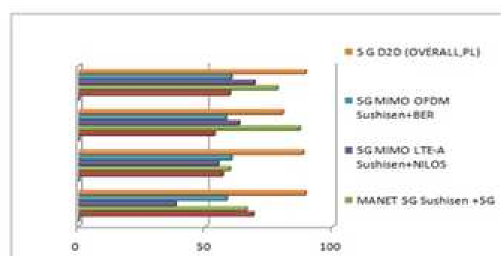

Fig. 7: Comparative analysis of proposed algorithms with the 5G Network.

The path loss processing of the system with two transmitting and one receiving antenna s are recorded in table 4 . The users are operated at a carrier frequency of 1.9 GHz, a symbol rate of 24.3 k symbols/sec, bandwidth of 30 kHz with MT = 8 and MR = 12. Results shown on Block-Error-Rate vs. average SNR (at one received antenna element); Block = 100 symbols; 20 symbols for training the result.

The F-Measure, Recall and Precision for the proposed algorithms are shown in Fig. 6. The 5G D2D algorithm amongst the proposed model gives the better performance.

The comparative analysis shown in Fig. 7 has been made with networks such as LAN,MAN,WAN and CAN. The 5G D2D provides accuracy of 89.01% in LAN, 88.01% in MAN, 80.11% inWAN and 89.10% in CAN.

5 Conclusion

5G will provide high speed packet transmission with maximum signal strength for mobile stations. It provides simultaneous connection to MANET, MIMO LTE- A, MIMO OFDM, and many other available technologies. It will be used to provide efficient productivity using beam division multiple access due to its limitations on time and frequency. Large-scale television assessment in MIMO OFDM is a great challenge to identify big characters and to increase the system capabilities. MIMO LTE-A 10 Hz increases the energy efficiency at the cost of 5G infrastructure. So, by reducing the transmitter and receiver signal processes the cost of infrastructure can be reduced. This is achieved using the Sushisen algorithm with 5G D2D and 2070/7233 period Multi-input multi-output (MIMO) radio communication system. The proposed model Increases communication capability and spectral efficiency with BRE of 0.02323, reliability of 99.999% and accuracy of 89%. The future work is to propose a new channel model with better performance and to underpin simulation results through suitable measurements.

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