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A Review on Comparative Study of Indoor Propagation Model Below and Above 6 GHz for 5G Wireless Networks

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Abstract

To satisfy the demand for ever-increasing data rates in the mobile networks, and that the high demands for the future applications in the 5G system require more capacity. In the microwave band below 6 GHz, most of the available bands are occupied; hence, the microwave band above 6 GHz and mmWave band can be used for the 5G system to cover the bandwidth required for all 5G applications. In this paper, the propagation characteristics at three different bands above 6 GHz (19, 28, and 38 GHz) are investigated in an indoor corridor environment for line of sight (LOS) and non-LOS (NLOS) scenarios. Five different path loss models are studied for this environment, namely, close-in (CI) free space path loss, floating-intercept (FI), frequency attenuation (FA) path loss, alpha-beta-gamma (ABG), and close-in free space reference distance with frequency weighting (CIF) models. Important statistical properties, such as power delay profile (PDP), root mean square (RMS) delay spread, and azimuth angle spread, are obtained and compared for different bands. The paper studied and discusses the comparative propagation model below and above 6 GHz characteristics for 5G wireless networks channels at two different frequency bands. In which two different wireless networks models have been proposed and analyzed to study the loss due to the diffraction from wall edge and the loss of high frequency band. The wideband measurements were summarized and conducted at 3.5 GHz and 28 GHz using a 5G channel sounder including the gains of antennas, with a high chip rate of 1000 Mcps. All the key system parameters are summarized for path loss; excess delay and power delay profile were calculated. The frequency response of the entire system and signal loss due to the edge shadow and high frequency was monitored, investigated and discussed accordingly. Two separate models have been proposed to study and calculate the loss due to the diffraction from wall edge and the loss of high frequency band/ antennas. The wideband including waveguide horn antenna measurements were conducted and calculated at 3.5 GHz and 28 GHz using a 5G channel sounder including the gains of antennas with a high chip rate of 1000 Mcps. The 5G channel parameters for path loss, excess delay and power delay profile were investigated, summarized and calculated. The signal loss due to the edge shadow and high frequency was also investigated.

Keywords: 5G Networks, Propagation Model Below 6GHz, Propagation Model Above 6GHz, 5G Wireless Networks, frequency bands.

1.1 Introduction

With ever-increasing data rates and the rapid development of green lighting technology, visible light-based indoor localization has attracted a dramatic of attention. Visible light-based indoor positioning technology leverages a light propagation model to pinpoint target location. Compared with the radio localization technology, visible light-based indoor positioning not only can achieve higher location accuracy, but also no electromagnetic interference (Wang et al., 2018). 5G is an incremental advance on 4G.The previous four generations "of cellular technology has each been a major paradigm shift that has broken backward compatibility. Indeed, 5G will need to be a paradigm shift that includes very high carrier frequencies with massive bandwidths, extreme base station and device densities, and unprecedented numbers of antennas". (Andrews et al, 2014). Many researchers have it in mind that the performance of the next generation based wireless for mobile and smart city networks should meet a high transmission speed on the order of 1000 times more than that of the current cellular communication of 1g, 2g or 3g communication wireless systems. "The frequency bands above 6GHz have received significant attention lately as a prospective band for next generation 5G systems" which is an improvement over the below 6Ghz frequency of wireless communication networks (Al-Samman et al., 2019). However channel modeling for frequency bands above 6 GHz is gaining momentum. (Rodriguez, Nguyen, Kovács, Sørensen, & Mogensen, 2016). It was discovered from the research that the power delay profile and root mean square "(RMS) delay spread indicate that these parameters are comparable for frequency bands below and above 6 GHz". A typical smartphone nowadays is equipped with an array of embedded sensors (e.g., GPS, accelerometers, gyroscopes, RFID readers, cameras, and microphones) along with different communication interfaces (e.g. Cellular, WiFi, Bluetooth, etc.). Thus, a smartphone is a significant provider for sensory data that awaits the utilization in many critical application (Ghosh, Majmundar, & Novlan, 2018).

2.0 Evaluation

5G communication technology system is one of the rapidly changing developments today. Part of its rapid changing development resulted in the International Mobile Telecommunications (IMT)-Advancement and Specifications of the frequency bands above 6GHz Terrestrial Mobile Telecommunication System.

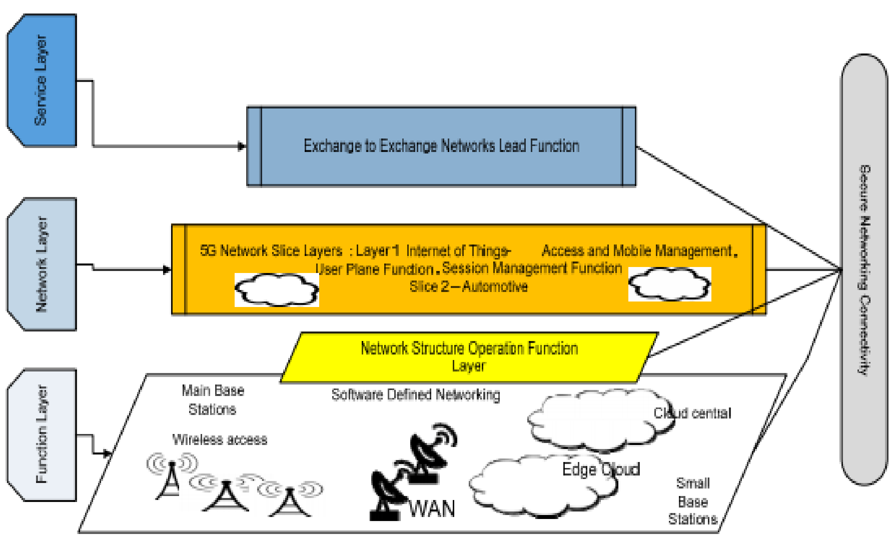

Figure 1: Overview of 5G network (Al-Samman, A., Al-Hadhrami, T., Daho, A., Hindia, M., Azmi, M., Dimyati, K., & Alazab, M., 2019).)

"However, a lot of debate surrounded the implementation of new generations' Wireless network technology and its devices currently referred as 5G wireless network. In the last fifteen years, mobile and wireless networks made significant growth which impacted peoples' life positively. In the present days, mobile phones are equipped with WLAN and WiMAX adapters in addition to 3G and 4G technologies. The 5G network architecture was designed to support present and future infrastructure implementation modules and was aimed at achieving high data rate, low latency, low power consumption, improved system capacity and the most important thing; more device connectivity". (Sai, Sato, Takeda, Yabukami, & Yamaguchi, 2018).

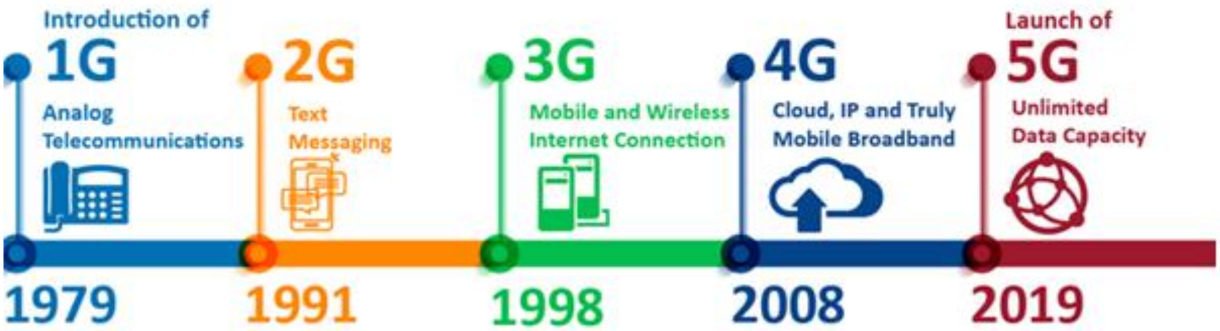

Figure 2: Evolution of 5G Network (Al-Samman, A., Al-Hadhrami, T., Daho, A., Hindia, M., Azmi, M., Dimyati, K., & Alazab, M., 2019).)

- The 5G networks are expected to establish a greater scale upon which to pivot to the fourth industrial revolution. It provides a convergence of pervasive broadband, sensing, and intelligence, which causes greater change in society and industrial markets. Moving into new wireless communication networks can bring the Internet of Things (IoT) into future power markets, providing greater benefits to the utilities and the consumers. The development of new communication infrastructure with the existing wireless technologies can be more advantageous in smart grids. Over the past few decades, the world has seen a gradual and steady growth of communication networks, starting from the first generation and moving towards the fourth generation.. Five different path loss models are studied for this environment, namely, close-in (CI) free space path loss, floating-intercept (FI), frequency attenuation (FA) path loss, alpha-beta-gamma (ABG), and close-in free space reference distance with frequency weighting (CIF) models. Important statistical properties, such as power delay profile (PDP), root mean square (RMS) delay spread, and azimuth angle spread, are obtained and compared for different bands(Parvez, Rahmati, Guvenc, Sarwat, & Dai, 2018). For the NLOS scenario, the angle of arrival (AOA) is extensively investigated, and the results indicated that the channel propagation for 5G using high directional antenna should be used in the beam forming technique to receive the signal and collect all multipath components from different angles in a particular mobile location(Sachs, Wikstrom, Dudda, Baldemair, & Kittichokechai, 2018). There are several applications where 5G networks provide a tremendous advantage, such as in IoT, healthcare systems, energy sectors, financial technology, and many more.

3.0 Contributions

- "Firstly, the propagation characteristics for the 5G channel at frequencies of 3.5 GHz and 28 GHz are compared in an indoor environment. The line of sight (LOS) and non-LOS (NLOS) measurements were performed using the ultra-wideband correlation channel sounder with a higher chip rate of 1000 Megachips-per-second (Mcps) as well as a higher resolution of 1ns". (A. Al-Samman et al., 2019)
- Secondly, two different physically based models were used to investigate and calculate the single loss and multi-frequency statistical path loss, respectively. Which are the close-in (CI) free space reference and the CI model with a frequency-weighted path loss exponent (CIF). Also the floating intercept (FI) and alpha-beta-gamma (ABG) models are two deferments 3GPP path loss models used to investigate the propagation characteristic for a single and multi-frequency statistical models, respectively. (A. Al-Samman et al., 2019)
- "Thirdly, DL and FD are used to investigate the signal degradation due to the shadow edge effect and high operating frequency". (A. Al-Samman et al., 2019)
- "In the last, the power delay profile, root mean square (RMS) delay spread and mean excess (MN-EX) delay, are considered to characterize the time dispersion parameters for both frequency bands". (A. Al-Samman et al., 2019). The researchers consulted 26 sources which all of them are relevant to the subject area.

- It is understood that the main problem for 5G wireless networks is that a huge amount of data and massive antennas will be required more than before, which will be congested at the radio-frequency spectrum below 6 GHz. This implies and shows that slower service due to low frequency with less antennas bring about more occurrence of dropped connections due to the low bandwidth. Hence, the millimeter wave (mm-wave) band have been selected as a potential candidate for the next generation wireless networks, i.e., 5G, where more bandwidths and antennas are available with up to 10 times the capacity of today's cellular networks (A. Al-Samman et al., 2019)

- "The path loss is the main parameter that can be used to describe the large-scale effects of the propagation channel on the received signal. The RMS delay spread is the main parameter for wideband channel characterization, as it is a good measure of multipath time dispersion. Based on the signal bandwidth, the RMS delay spread provides a good knowledge of the potential severity of inter symbol interference (ISI). The time dispersion characteristics and analysis of such properties can serve for the indoor mm-wave communications systems design". (A. Al-Samman et al., 2019)

Table 1. Measurement Parameters.

Parameter	Value	Value
Carrier Frequency (GHz)	3.5	28
Transmit Power	0 dBm	0 dBm
Polarization	Vertical	Vertical
Antenna Gain (dB)	9	11.6
Tx and Rx Antenna /HPBW (degree)	58.97	44.8
Tx /Rx Antenna Height (m)	1.5/1.5	1.5/1.5

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4.0 Results and Discussion

In order to satisfy an extremely high demand for ever-increasing data rates in the mobile networks and smart city, the new millimeter wave band (20 - 30 GHz) has been selected by 5GPPP (Public Private Partnership) (A. Gupta and R. K. Jha., 2015) to be used in the emerging fifth-generation (5G) mobile/smart city networks. The vision of 5G networks poses a lot of challenges, for it plans to reach ultra-low latency of 1 ms, 10 Gbps maximal throughput and covering more than 100 billion devices (A. Checko, H. L. Christiansen, Y. Ying, L. Scolari, G. Kardaras, M. S. Berger and L. Dittmannal., 2015).

“5G has high demand as it is expected to deliver high amount of data rate, which is useful to design an IoT based smart city as well as mobile networks”. (Sai et al., 2018). The use of more mm-wave frequency band and antennas in 5G network bring about various scattering, fading and penetration of losses problems, especially in indoor environment. “These problems and or issues can be mitigated easily if we can predict the propagation channel, where the signal is propagating. The Path loss is one of the important elements to define any channel behavior used for wireless communication. It can depend on many transmission devices/equipment factors, for instance, transmitter power, antenna type and its gain, channel structure and its reflection, refraction and diffraction effect”. (Busari, Mumtaz, Al-Rubaye, & Rodriguez, 2018; Sachs et al., 2018).

“The reason for path loss modeling is to evaluate the magnitude of attenuation observed by broadcasting radio signals over a distance, which is an integral for designing of 5G communications systems”. (Wang, C.; Bian, J.; Sun, J.; Zhang,W. , A 2018). The section provides an insight and the results for analysis of path loss, diffraction, frequency drop, power delay profile and time dispersion parameters. “To make an appropriate comparative study for the two measured frequencies, 3.5 GHz (below 6 GHz) and 28 GHz (above 6 GHz), the results of the parameters for both bands are explored in the same figure in each analysis”. (Prasad, Uusitalo, Navrátil, & Säily, 2018). “5G is currently being standardized and addresses, among other things, new URLLC services. These are characterized by the need to support reliable communication, where successful data transmission can be guaranteed within low latency bounds, like 1 ms, at a low failure rate” (Sachs et al., 2018). The mentioned 20 - 30 GHz ‘pioneer’ spectral band is the first to be used in mobile and smart city networks above 6 GHz, requiring a number of challenges and issues to be addressed including a significantly high attenuation (i.e. ~ 3 dB/m) when the radio frequency (RF) signal is transmitted over metallic cables, which limits the transmission span. To address this, the radio over fiber (RoF) technology was proposed (H. Al-Raweshidy and S. Komaki., 2002), (D. Pham Tien, A. Kanno and T. Kawanishi., 2015)., e.g. for usage between a central office and the pico- or femto-cell base stations. In [M. Uysal, C. Capsoni, Z. Ghassemlooy, A. Boucouvalas and E. Udvary., 2016)., an alternative concept of radio over free-space optics (FSO) (RoFSO) transmission was proposed for deployment in dense urban areas, where installation of new optical fiber cables is not cost effective.

5.0 Conclusions

This review discussed and presented the comparative propagation characteristics for the 5G channel at two different frequency bands. Two different models have been proposed and studied the loss due to the diffraction from wall edge and the loss of high frequency bands. The wideband measurements were investigated, presented and conducted at 3.5 GHz and 28 GHz using a 5G channel sounder and antennas with a high chip rate of 1000 Mcps. The 5G channel parameters for path loss, excess delay and power delay profile also analyzed and calculated. The signal loss due to the edge shadow and high frequency was investigated. "The path loss exponent values for the LOS scenario were 1.6 and 1.3 at 3.5 and 28 GHz, respectively. However, the received power was dropped in the NLOS scenario, where the PLE values were 2.7 and 3.6 at 3.5 GHz and 28 GHz, respectively. The 3GPP models i.e., FI and ABG provided reliable performance for path loss for both single and multi-frequency models in LOS scenario. Based on the proposed models, the average diffraction loss values were 11.11 dB and 23.37 dB at 3.5 GHz and 28 GHz respectively (Qamar, Hindia, Abbas, Dimyati, & Amiri, 2019). The loss due to frequency, termed frequency drop was 19.73 dB for the LOS scenario and 32.00 for the NLOS scenario. The RMS delay spread values were less than 8 ns and 12 ns at both frequency bands, for the LOS and NLOS scenarios, respectively. These results indicate that the 5G channel has good performance in term of path loss with very low delay spread. The findings in this study are useful to test and implement for real environment and gives a sight for the next-generation IoT based smart city 5G network. This also implies that the future 5G wireless networks can support a high data rate with low latency using high directive antenna to provide high gain power with small cell size: (A. Al-Samman et al., 2019) . According to (A. M. Al-Samman, Abd Rahman, & Azmi, 2018). "Software-Defined Networking (SDN) is transforming the networking ecosystem. SDN allows network operators to easily and quickly introduce new services and flexibly adapt to their requirements, while simplifying the network management to reduce the cost of operation, maintenance and deployment. On the other hand, mobility is a key aspect for the future mobile networks. In this context, Distributed Mobility Management (DMM) has been recently introduced as a new trend to overcome the limitations of the today's mobility management protocols which are highly centralized and hierarchical. Driven from the fact that DMM and SDN share the same principle in which the data and control plane are decoupled, we propose a DMM solution based on SDN architecture called S-DMM". This solution offers a lot of advantages including no need to deploy any mobility-related component at the access router, independence of the underlying technologies, and per-flow mobility support. On one hand, the numerical results prove that S-DMM is more scalable than the legacy DMM (Nguyen, Bonnet, & Harri, 2016).

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