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5G Millimeter Wave Propagation with Intelligent Grid Selection for Obstacle Avoidance

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Abstract: **Recently, millimeter wave (mmWave) frequencies are under research for providing high speed data spectrum for upcoming 5th Generation (5G) communication system by 2020 with Device-to-Device (D2D) data exchange facility. Due to high frequency spectrum in 5G, the mmWave frequencies suffer with high propagation attenuation in the channel due to various obstacle or blockages. There is a demand and need in 5G world to have an effective method for efficient mmWave propagation in the wireless channel. In this research paper, we propose an innovative method for intelligently selecting a grid or group of grids having minimal mmWave propagation attenuation from a virtual grid face. This grid selection for mmWave propagation is described to overcome the various effects of obstacles by forming virtual grid face around the transmission antenna. The simulation for the same has been performed for the proposed 5G D2D mmWave link. Further, one grid (or group of grids) is selected from the virtual face based on the minimal attenuation value the for the mmWave propagation. Minimal attenuation grid can be used in several manner in the 5G D2D wireless communication system like for line of Sight (LoS) link, transmission power link budget analysis, transmission power control, beamforming, Shannon channel capacity analysis, cell planning and etc. This paper shows smart intelligent method for minimal attenuation grid-forming for the mmWave based communication link. It significantly improves the 5G system performance by saving the transmitter power radiation for mmWave propagation through the selected grid having minimal attenuation.**

Keywords: millimeter wave (mmWave), 5th generation (5G), Federal Communications Commission (FCC), Cellular-Internet of Things (C-IoT).

I. Introduction

Recent consideration of mmWave with 5G wireless communication system is attracting researcher's attraction worldwide for deep wireless channel propagation research and investigation. 5G mmWave communication system will use mmWave frequency bands of 3 GHz to 300 GHz [1]-[3]. 5G mmWave frequency bands provide capacity to have high data rate with high data capacity. High frequencies of mmWave frequency bands are having small wavelength which makes mmWave frequencies bands more prone to attenuation. 5G D2D mmWave communication allows mobile devices to connect directly and also an important connection in Cellular internet of Things (C-IoT) environment [3]-[8]. Wireless channel is really responsible for mmWave transmission power losses due to various obstructions in the channel. The mmWave frequencies suffer with channel attenuation in the wireless medium due to various channel impairments like atmosphere, seasons, vegetation, urban and etc. The mmWave propagates with high losses in the mmWave frequency bands and requires high research attention to make more effective system [8]-[12].

As per 5G system for shifting towards high frequency spectrum; it becomes part of research to have certain fixed or proposed frequencies for research and development from high frequency. Recently, Federal Communications Commission (FCC) has announced 5G mmWave high carrier frequencies along with the bands information. FCC mmWave frequencies bands are 28 GHz band, 37 GHz band and 39 GHz band. For the above mentioned mmWave carrier frequencies, 5G system research is in development worldwide [11]-[15]. In this research paper, we have used FCC recommended frequency for forming and identifying minimal mmWave propagation attenuation intelligent grids as well as for identifying the right zones (set of two or more grids) for the same. The intelligent grids are selected from the virtual face grid which is formed in a virtual manner on the face of the transmitting antenna. The virtual face consists obstacles and non-obstacles area which are identified and mapped the grids.

The mmWave spectrum is promising for 5G communication systems with high bandwidth for users along with various advance services. Extensive research is in progress for mmWave propagation in the environment of various channel obstructions. The mmWave propagation channel obstructions are like; vegetation, atmosphere, building/ urban and etc. Research for mmWave is in progress for getting characteristics of mmWave propagation [10]-[15]. It is required to have characteristics of mmWave propagation based on various atmospheric, seasons and obstructions for a particular site conditions. Literature discusses mmWave communication systems with various types of attenuations measurements and models to get the characteristics of mmWave propagation [13]-[17]. In this research paper we are discussing intelligent grids for mmWave propagation to provide minimal channel losses during propagation. These smart intelligent such grids will show that mmWave systems can have high quality signal strength by using proposed grids. We also represent that the grids can be used in an effective manner for mmWave path loss estimation while 5G cell planning [13]-[19].

This paper provides mmWave propagation effect due to various obstructions for the experimental simulation site. Our work considers a variety of mmWave propagation channel obstructions like building, vegetation in-leaf, vegetation out-leaf, atmospheric impairments and seasonal atmosphere with 5G transmitter. Various types of channel obstructions are considered to calculate the mmWave channel propagation losses. Delhi Technological University (DTU), previously known as Delhi College of Engineering (DCE), New Delhi, India has been considered as calculation experimental site [20]-[26]. The idea of using grids-forming for 5G transmitters with millimeter-wave spectrum is shown with the results in later sections of this paper.

In this research, we calculate the mmWave propagation losses due to vegetation in 5G wireless communication system, it is considered that both devices transmitter and receiver are situated in the DTU area. As per literature several vegetation propagation attenuation models are proposed. Here, we have used fitted radio international telecommunication union (FITU-R) model to calculate the vegetation propagation attenuation with the reason that this model is applicable to mmWave frequency range and provide with-leaf and with out-leaf attenuation values which can be used with the varied seasons[21]-[25]. Further, mmWave propagation losses due to buildings (urban area) in 5G system are calculated and details are in description section(s). As per literature several methods are available to calculate the urban area propagation attenuations. Here, we have used geometrical optics (GO) and a uniform theory of diffraction (UTD) to calculate urban area mmWave propagation attenuation with the reason that this model is applicable to mmWave frequency range and provide reliable prediction for the proposed site [23]-[25]. Also in this research paper, we have calculated mmWave propagation losses due to atmosphere in 5G wireless communication system. As per literature, we have used ITU recommended models to calculate the atmospheric mmWave propagation attenuation. This model is applicable to mmWave frequency range and provides reliable prediction for the proposed site. Here we have simulated results along with the performance and validations of the results for the frequency 28 GHz [12]-[15],[21]-[25].

This research paper is structured as follows: Section II presents the prior art related work described in literature. Section III presents the motivation and section IV discusses mmWave attenuation grid formation and selection for 5G wireless communication system. In Section IV we are presenting and discussing intelligent attenuation grid formation and selection. Section V discusses DTU campus mmWave attenuation and the calculation experimental site DTU which is having obstructions of urban-site buildings and vegetation. In Section VI we discuss, DTU campus grids site grid for 5G transmitter with mmWave attenuations for various obstructions. In Section VII based on calculation we demonstrate the performance result along with the discussion. Section VIII shows validation and discussion along with section IX as final the research work.

II. Related Work

D2D 5G wireless communications with mmWave frequencies is one of the main important aspect of the networks. The propagation losses are known in the literature due to several propagation impairments and as well as discussed in the prior art literature. 5G mmWave propagation attenuation due to various obstructions plays major role in the wireless transmitter performance and mmWave wireless propagation paths. As per literature; it is important to plan the mmWave transmission in the urban area as the transmission losses are high due to propagation attenuation. Some of the prior art discusses using omni-directional transmissions with the mmWave communication and which causes large amount of propagation attenuation and loads transmitter with extra transmission power [23]-[28]. At transmission end beamforming and beam deviation methods have been proposed to avoid channel blockages or obstacles; however prior art does not specifically discusses forming intelligent grids and selecting optimum grids for mmWave transmission. It is quite important to have directional mmWave transmissions in D2D communication and need to solve problem of transmission in the existence of blockages [28]-[32].

Prior art discusses that major propagation impairment of channels are weather or atmospheric effects for mmWave frequencies. Building and vegetation also adds high value propagation mmWave attenuation for mmWave frequencies. So, it is very important and necessary to have the information of the various blockage effects at transmitter end so that transmitter can decide transmission accordingly [23]-[28]. In this research paper; we have proposed efficient method for transmitter to avoid blockage effect by avoiding obstacles. In the literature, wireless channel propagation has been discussed with various types of blockage conditions. The blockage conditions discussed and considered are atmosphere, seasons, building, tree, vegetation and etc. The atmospheric impairments are rain, water vapor, oxygen, fog and etc. The attenuation due to building and vegetation plays a high significant role in the mmWave propagation and due to which channel capacity also degrades [21]-[34].

Prior art discusses for wireless sensor networks in three-dimensional (3D) environment obstacles avoidance. As per prior art the mobile anchor trajectory path shall avoid collision with obstacles [34]. In this paper, the proposal focuses on intelligently finding and selecting minimal attenuation grid or group of grids from the virtual face at the transmitter end to provide efficient mmWave propagation through wireless channel. In prior art, an obstacle avoidance approach using path planning has been discussed and it uses graph approach along with a depth-first-search based algorithm with greedy strategy [31]-[34].

In prior art, it has been discussed to deal with obstacle obstructions and avoid the losses in channel. However, the prior art literature does not specifically discuss forming virtual face and selecting optimum grids for transmission based on minimal attenuation [29]-[34]. Such optimum grids provide efficient power transmission and etc.

III. Motivation

The Recent research is focusing on obstacle free transmission approach to provide high directivity power signal transmission. With respect to the related prior art literature [31]-[34], in this paper we jointly found several issues in mmWave transmission. 5G transmission can be done efficiently which are covered in our proposal and we propose the following novel elements:

- We propose, creating and selecting a virtual face for a transmitting antenna
- We Create grids in square metrix form on the selected face and map with the obstructions/ blockages on that particular face
- We calculate attenuation for each grid based on type of obstructions/ blockage
- We select one grid or group of grids from amongst the grids as a minimal attenuation grid by comparing with the rest of other grids attenuation values
- We propose efficient millimeter wave transmission passing through selected grid based on the intelligently selected grid by comparing, calculating , validating the performance with Shannon channel capacity

We have tried best to address blockage avoidance issue in mmWave propagation and as per proposed approach such issue can be resolved. By using the proposed approach the efficient mmWave transmission can take place. This research deals with the obstacle avoidance problem and provides clear approach to have low loss transmission. Further, we have tried to show through simulations that the proposed obstacle avoidance approach has high quality mmWave transmission performance with respect to without obstacle avoidance approach.

IV. Intelligent Attenuation Grid Formation and Selection

As per Figure 1, flow diagram has been shown for a virtual face which is created around a static D2D transmitting antenna. The grids are created on the selected virtual face. The grids divide a face of the virtual shape into an n by n matrix. At least one grid from amongst the grids is selected as an optimum grid based on the minimal mmWave attenuation value. The 5G controller includes a grid creator and selector. It creates the grids on at least one selected face and selects at least one grid based on the minimal mmWave attenuation value. Further, beam is formed based on least attenuation grid which is one optimum grid as selected. Beam forming is used to direct and steer an antenna's directivity beam in a particular direction. Shannon channel capacity can be calculated in the obstacle free grids and obstacle based grids.

At least one optimum grid allows power transmission in a direction of a particular location with minimal attenuation/losses, thereby allows power control over shaping and steering of antenna's beam directivity pattern. Thus, formation of the at least one beam based on at least one optimum grid generates a high directional and efficient beam with minimal losses and overheads. System includes a beam-forming unit and forms beam in accordance with the input one optimum grid which is provided by the system. As per this approach system controls and performs a function of transmitting a signal to the receiving antenna through the minimum attenuation grid and transmitting antenna transmits the signal in the direction of the receiving antenna.

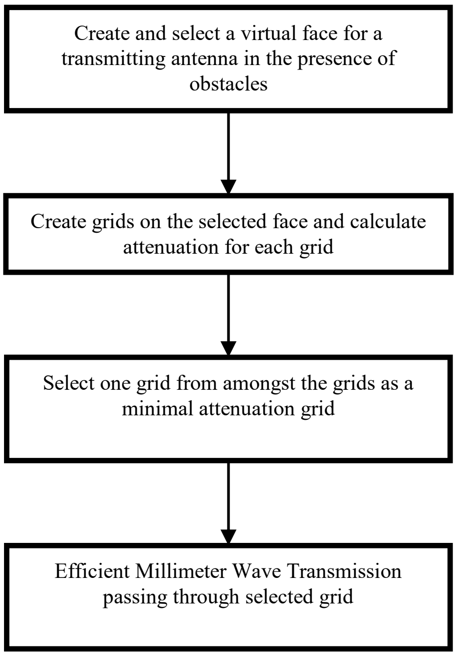

Figure 1. 5G mmWave grid selection for 5G transmitting antenna

As per figure 2, device-to-device grid selection for 5G mmWave communication system is shown for one of the transmitting device. As per our work; it is considered that the transmitting, receiving device and obstacles are stationary. 5G grid attenuation controller includes a location detection modular to detect the antenna location and it dynamically detects the current location of the transmitting antenna. The transmitting antenna is part of D2D communication system [4]-[5], [33]. The system has storage unit to store the data pertaining to obstructions as obstruction data.

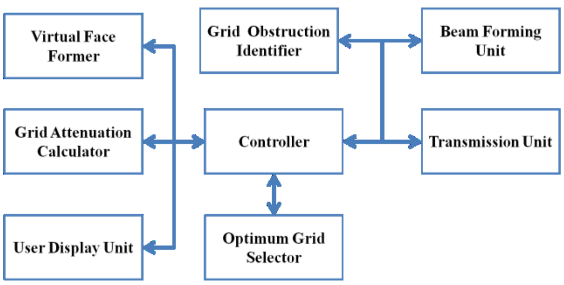

Figure 2. 5G mmWave intelligent grid selection and obstacle avoidance system

The obstruction data can be determined, evaluated or processed and such processing can take place for various terminals/devices/systems used by the various users or antennas. Further obstruction data can be obtained from system. The system can predict /forecast obstruction details such as future building projects and weather conditions. System creates the virtual face based on the received data. The virtual shape or layer is selected and created such that the transmitting antenna is at centre of the virtual face.

Further, controller creates the one or more grids on the selected face in nxn metrix form. Accordingly, based on the values of obstructions and the received stored data, the controller divides the selected face of the virtual mode into an n by n matrix that forms the grids. The controller obtains the attenuation values of the obstructions which are received data from the storage and run time calculations as per the mapped grids with obstructions or obstacles. The controller calculates the grid attenuation and forms the low or high zone attenuation grids and selects the minimal attenuation zone for the beamforming or channel capacity or link power budget or line of sight path for mmWave transmission.

V. DTU Campus mmWave Attenuation

In this proposed research simulation, we have considered DTU campus which is formerly known as DCE, located in New Delhi, India. Figure 3, illustrates 5G mmWave site for DTU; having vegetation and building area [20]. DTU campus has sports ground, various outdoor game grounds, indoor game complex, library, academic block, administrative and hostel blocks in the campus. DTU also has high vegetation area. DTU site is rich with all of the mixture of buildings, equal air distribution and vegetation. Based on the variety of obstructions and site richness; we are using this area for our simulations. Here we have identified a position of the 5G stationary transmitter which is near the following hostel blocks and sports ground:

- Sir C. V. Raman Hostel
- Sir J.C. Bose Hostel

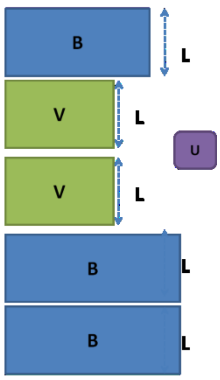

Figure 3. 5G mmWave site of DTU; having vegetation, atmosphere and building area

At this 5G transmitter location, we are calculating attenuations due to obstacles and considering calculation experimental site for grid selection based on vegetation, seasonal atmosphere and building attenuation calculations. This site has buildings, open air and average size Indian vegetation area. The calculations are performed for the university campus by considering equi-probable summation of the attenuation and also we have considered full vegetation for the summer and rainy season [22]-[24]. In winter season we have considered no vegetation or can say out of leaf vegetation attenuation; such type of attenuation is due to branches or trunk of the vegetation. In this calculation experiment we have taken average vegetation density as 10 meter vegetation depth for mmWave propagation along with the consideration equal spaced, equal densed vegetation. DTU site also consists of small vegetation, buildings, concrete roads, soil, sand and grass. This calculation also takes into account no-air to have calculation and results meaningful so that it can be used by the power planning engineer in 5G communication system [16].

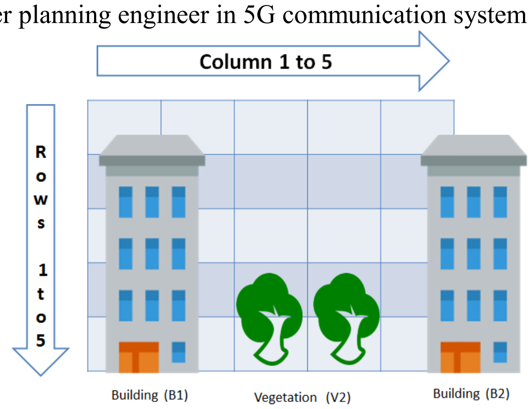

Figure 4. 5G mmWave grid for DTU (having vegetation, atmosphere and building area)

As shown in figure 4 this site DTU consists vegetation and building area along with open area in the boys hostel area to have D2D 5G transmitter. This figure 4 shows side view of the site (based on virtual face) where; we are calculating grid based attenuation and optimum grid selection for transmission. This side view is shown along with 5x5 metrix having grids which are equally spaced. The grids are mapped with the type of obstructions/ blockage (vegetation, building and atmosphere).

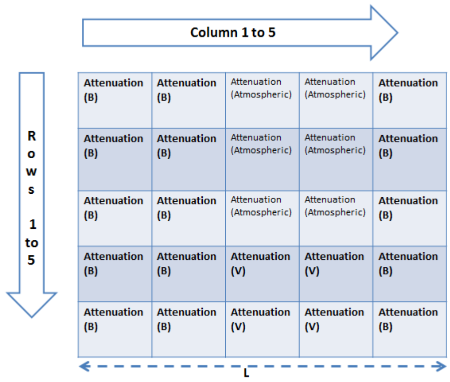

Figure 5. 5G mmWave grid with type of attenuations for DTU; having atmospheric, vegetation and building area

Referring to figure 5, the grids are created on the selected virtual face and it is considered that row and column shall be equal (here 5x5) for less complex calculations. 5G grid creator and selector module divides the selected virtual face of the virtual dimensional shape into m by m matrix. This matrix forms grids inside virtual face. In this virtual face; user can also enter number of rows or column for the virtual face.

Further system identifies the type of the obstructions for each grid based on the system blockage mapping or obstruction identifications. Each grid is calculated with the attenuation values as per identified type of obstructions. As per proposal; attenuation values are identified based on type of obstructions. Further, calculations are performed by considering the type of obstructions and minimal attenuation value grid is identified by comparing the rest of the grids for efficient transmission.

For the identified vegetation blockage, we have used the simulation model through software coding. As per Fitted-International Telecommunication Union (FITU-R) model the vegetation attenuation Av is given by equation (1) [21]-[25] :

$$A_v = 0.39 f^{0.39} * d^{0.25} (in - leaf) ....(1.1)$$

$$A_v = 0.37 f^{0.18} * d^{0.59} (out - of - leaf) ..(1.2)$$

Here w.r.t. FITU−R, Av is the mmWave vegetation loss in dB, f is the mmWave frequency in MHz and d is the depth of the vegetation in meters as per equations (1.1) and (1.2).

For the identified building blockage, simulation is performed through software coding. D2D 5G total urban mmWave propagation path loss (AUrban) in dB is given below for the buildings in DTU area as per equation (2) [20]-[25]:

$$A_{urban} = 20\log\left(\frac{\lambda \,|\, E_{Total} \,|}{4\pi \,|\, E_o \,|}\right) ....(2.1)$$

Here, λ is the wavelength of the transmitted mmWave signal, E0 is the emitted electric field from the 5G D2D transmitter. ETotal is the vector addition of the received electric field components at D2D unit in DTU building area as per equation (2.1). Further, Lambda is mmWave wavelength.

For the identified atmosphere blockage, we have used ITU recommended methods for simulation. For atmospheric attenuation, the total value is equi- probable sum of water vapour attenuation and oxygen attenuation. Water vapor attenuation Aw is expressed as equation (3) [22]:

$$A_w = \left[\frac{h_w \gamma_w}{\sin\ \theta}\right] ....(\theta > 10°).....(3.1)$$

$$A_w = \left[\frac{\gamma_w \sqrt{R_e h_w}}{\cos\ \theta} F(\tan\theta \sqrt{R_e / h_w})\right] ...(\theta =< 10°)...(3.2)$$

Water vapor specific attenuation γw is frequency dependent and measured in dB/km. Here, hw is the equivalent height of water vapor in km. Re is the effective earth radius, θ is the elevation angle and F(x) is a function as per literature in equation (3.1) and (3.2). For atmospheric oxygen attenuation Ao; attenuation in dB is given by the following equation (4) [22]:

$$A_o = \left[\frac{h_o \gamma_o}{\sin\ \theta}\right] ....(\theta > 10°).....(4.1)$$

$$A_o = \left[\frac{\gamma_o \sqrt{R_e h_o}}{\cos\ \theta} F(\tan\theta \sqrt{R_e / h_o})\right] ...(\theta =< 10°)...(4.2)$$

In equation 4.1 and 4.2 oxygen specific attenuation is γo . Here, *ho* is the equivalent height of the oxygen layer. Re is the effective earth radius, θ is the elevation angle and F(x) is a function as per literature [22].

VI. DTU Campus Grids

As per DTU site calculation example; for finding out minimal attenuation path during mmWave propagation and to calculate the mmWave propagation losses due to atmosphere in 5G wireless communication system, it is considered that both devices transmitter and receiver are stationary in DTU area. Referring to Figure 5 grids are created inside a virtual face as side view is also illustrated for obstructions like building, vegetation and atmospheric attenuation.

As per calculations; attenuation values are identified as per type of obstructions atmosphere, vegetation and building. Attenuation values for atmosphere, vegetation and building are calculated by considering type of obstructions. Further minimal attenuation value grid is identified for optimum transmission path as considering blockage avoidance based on relative attenuation values comparison among other grid attenuation values.

Ab+As	Ab+As	As	As	Ab+As
Ab+As	Ab+As	As	As	Ab+As
Ab+As	Ab+As	As	As	Ab+As
Ab+As	Ab+As	As	As	Ab+As
Ab+As	Ab+As	Avi+As	Avi+As	Ab+As
Ab+As	Ab+As	Avi+As	Avi+As	Ab+As

Figure 6. 5G mmWave grids with type of attenuations for summer season.

Ab+Ar	Ab+Ar	Ar	Ar	Ab+Ar
Ab+Ar	Ab+Ar	Ar	Ar	Ab+Ar
Ab+Ar	Ab+Ar	Ar	Ar	Ab+Ar
Ab+Ar	Ab+Ar	Ar	Ar	Ab+Ar
Ab+Ar	Ab+Ar	Avi+Ar	Avi+Ar	Ab+Ar
Ab+Ar	Ab+Ar	Avi+Ar	Avi+Ar	Ab+Ar

Figure 7. 5G mmWave grids with type of attenuations for rainy season.

Ab+Aw	Ab+Aw	Aw	Aw	Ab+Aw
Ab+Aw	Ab+Aw	Aw	Aw	Ab+Aw
Ab+Aw	Ab+Aw	Aw	Aw	Ab+Aw
Ab+Aw	Ab+Aw	Aw	Aw	Ab+Aw
Ab+Aw	Ab+Aw	Avi+Aw	Avi+Aw	Ab+Aw
Ab+Aw	Ab+Aw	Avi+Aw	Avi+Aw	Ab+Aw

Figure 8. 5G mmWave grids with type of attenuations for winter season.

Further, 5G mmWave grid attenuation causes for 5X5 matrix are shown in figure 6-8. These figures indicate type of grid attenuations causes for different seasons of India like summer, rain and winter. The figure shows the type of the obstructions for each grid as per 5G transmitter antenna location in DTU site having mixture of atmosphere, vegetation and building. Further, the grids will have two factor attenuation due to the one of obstruction vegetation or building and additional with atmosphere as atmosphere attenuation which will be in all grids. Figures 6-8 show the grids for 5G mmWave propagation with the type of attenuations for summer, rain and winter seasons as Atmospheric attenuation: Summer (As), Rain (Ar), Winter (Aw); Building Attenuation (Ab); Vegetation Attenuation: In-Leaf (Avi); Vegetation Attenuation: Out-Leaf (Avo). Figures 6-8 indicates the causes of the blockage along with the notation of the attenuations. Below are the notation used to depict in figures 6-8:

1. Atmospheric attenuation
   a. Summer (As)
   b. Rain (Ar)
   c. Winter (Aw)
2. Building Attenuation (Ab)
3. Vegetation Attenuation
   a. In-Leaf (Avi)
   b. Out-Leaf (Avo)

Obstruction data can be obtained by calculating obstruction details such as building, vegetation and weather condition at later instance of time. Here we have used software simulation coding to calculate the values and run the program along with the following assumptions:

- Heights of buildings = 20 meter
- Vegetation heights = 2/5 * building height = 8 meter
- Depth of vegetation = 10 meters
- Angle building elevation = 45 degree
- Ab = Building Attenuation
- Aas = Summer Atmosphere Attenuation
- Aar = Rainy Atmosphere Attenuation
- Aaw = Winter Atmosphere Attenuation
- As = Aas
- Ar=Aar+rain
- Aw=Ar=Aar+ winter fog
- Avi = in leaf Vegetation Attenuation (summer rain)
- Avo = out leaf Vegetation Attenuation (winter)

69.25	69.25	0.82	0.82	69.25
69.25	69.25	0.82	0.82	69.25
69.25	69.25	0.82	0.82	69.25
69.25	69.25	0.82	0.82	69.25
69.25	69.25	28.66	28.66	69.25
69.25	69.25	28.66	28.66	69.25

Figure 9. 5G mmWave grids with values of attenuations (atmospheric, vegetation in-leaf and building) in summer season for 28 GHz

We have used FITU-R model to calculate vegetation propagation attenuation for in-leaf and out-of-leaf attenuation with the various seasons. FITU-R model is employed to calculate vegetation propagation attenuation for the frequency 28 GHz and simulated with the same. For calculating urban area attenuation for 5G mmWave communication; we are using geometrical optics (GO) and a uniform theory of diffraction (UTD) to calculate urban area mmWave propagation attenuation. GO and UTD are applicable to mmWave frequency range and provide reliable prediction for the simulation frequency [19]-[25].

70.23	70.23	1.8	1.8	70.23
70.23	70.23	1.8	1.8	70.23
70.23	70.23	1.8	1.8	70.23
70.23	70.23	1.8	1.8	70.23
70.23	70.23	29.64	29.64	70.23
70.23	70.23	29.64	29.64	70.23

Figure 10. 5G mmWave grids with values of attenuations (atmospheric, vegetation in-leaf and building) in rain season for 28 GHz

69.73	69.73	1.3	1.3	69.73
69.73	69.73	1.3	1.3	69.73
69.73	69.73	1.3	1.3	69.73
69.73	69.73	1.3	1.3	69.73
69.73	69.73	5.77	5.77	69.73
69.73	69.73	5.77	5.77	69.73

Figure 11. 5G mmWave grids with values of attenuations (atmospheric, vegetation out-leaf and building) in winter season for 28 GHz

As per literature, we have used ITU recommended models to calculate the atmospheric mmWave propagation attenuation [22]. This model is applicable to mmWave frequency range and provides reliable prediction for the proposed site. Here we have simulated results and calculations are performed for the frequencies 28 GHz. Figures 9-11 show the grids with blockage attenuations values (vegetation in-leaf, vegetation no-leaf, atmospheric and building) with type of attenuations for summer, rain and winter seasons for the frequency 28 GHz. In these figures, consolidated attenuation values are shown after summing atmospheric attenuation with respect to vegetation attenuation or building attenuation as per seasons summer, rain and winter for the mentioned frequency as shown and discussed here.

VII. Performance Result & Discussion

Based on the previous section findings of the grids having attenuation values due to various blockage or obstructions; in this section we will intelligently select the minimal attenuation grid by avoiding the obstructions or blockage to have efficient power transmission. Here, we classify and identifies zones as attenuation low (Al) or attenuation high (Ah). We have used threshold value (~15dB) based deciding factor for attenuation low (Al) and attenuation high (Ah) to fill the grids/ metrix accordingly. As per simulation results and based on threshold value the attenuation values are classified in Ah and Al categories. The classified attenuation values are mapped with the grid values for the performance results evaluation and discussion to identify the optimum zone or set of grids for mmWave transmission. Figures 12-14 show the grids attenuation values for the frequency 28 GHz for DTU. Figure 12-14 show mmWave attenuation values for various grids for 5G mmWave channel having building, atmosphere and vegetation as obstructions. It is clear that low attenuation zone has significant amount of less attenuation as compare to high attenuation zone values. It is shown that the grids with values of attenuations (low/ high) zones for 5G mmWave with type of intensity for the frequencies 28 GHz.

Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Ah	Ah	Ah
Ah	Ah	Ah	Ah	Ah

Figure 12. 5G mmWave grids with zones of Attenuation high (Ah) and attenuation low (Al) in summer season for 28 GHz

Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Ah	Ah	Ah
Ah	Ah	Ah	Ah	Ah

Figure 13. 5G mmWave grids with zones of Attenuation high (Ah) and attenuation low (Al) in rain season for 28 GHz

Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Al	Al	Ah
Ah	Ah	Ah	Ah	Ah
Ah	Ah	Ah	Ah	Ah

Figure 14. 5G mmWave grids with zones of Attenuation high (Ah) and attenuation low (Al) in winter season for 28 GHz

The 5G grid creator creates the grids on the at least one selected face and selects the at least one grid based with the minimal mmWave attenuation value by using low and high attenuation zones as shown in figures. The grids are created for the frequencies 28 GHz for DTU. Further, beam can be formed based on least attenuation value grid by avoiding obstruction/ blockage (high attenuation values) which is one optimum grid as selected. By having minimal attenuation grid or grids; the 5G system can avoid high attenuation blockage from the mmWave propagation path.

At least one optimum grid allows formation of the beam in a direction of a particular location with minimal attenuation/losses, thereby allowing control over shape and steering of antenna's directivity pattern. Thus, formation of the at least one beam based on the at least one optimum grid generates a high directional and efficient beam with minimal losses and overheads. Beam-forming unit forms beam in accordance with the minimal attenuation zone which is provided by the system. As per this approach system controls and performs a function of transmitting a signal to the receiving antenna through at least one formed beam and transmitting antenna transmits the signal in the direction of the receiving antenna by avoiding high attenuation obstacles.

VIII. Validation & Discussion

5G D2D provides wireless communication among nearby electronics devices using mmWave frequencies. This research carries importance especially in Cellular-Internet of Things (C-IoT) environment; where transmission power control is really important [1]-[5]. These minimal propagation attenuation grids are selected by avoiding obstacle(s). This grids-forming is done for mmWave 5G communication by considering obstruction attenuation into account and grid(s) selection for propagation path. Based on intelligent grid selection for optimal mmWave transmission; channel capacity has been calculated and validated with the obstacle and no-obstacle situation. The comparative Shannon channel capacity validates the performance of the 5G D2D propagation [3]-[5]. Shannon channel capacity per unit bandwidth (C/B) can be defined by the equation (5) as below [23]-[25]:

$$\frac{C}{B} = \log_2\left(1 + \frac{S}{N}\right) \qquad (5)$$

In equation 5, B is the 5G bandwidth in Hz, and S/N is the signal-to-noise ratio (SNR) of received mmWave signal power. The channel capacity per unit bandwidth C/B here is refereed as the 5G channel capacity [21]-[25]. Based on the intelligent selection of minimal attenuation grid; the 5G D2D application on the same for the minimal attenuation grids is shown here with channel capacity simulation result.

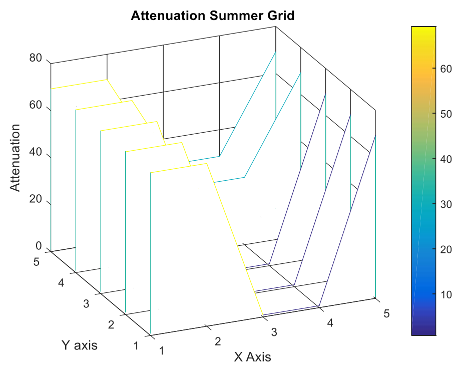

Figure 15. 5G mmWave grids attenuation values for atmospheric, vegetation in-leaf and building in summer season for 28 GHz.

Figure 15 shows the grid attenuation values in a graph form for atmospheric, vegetation in-leaf and building in summer season for 28 GHz. In summer season only attenuation is due to water vapor and oxygen and in this time or season the water vapour moisture is less as compare to rain or winter. X axis and Y axis in figure 15 indicates the number of grids and z axis indicates the attenuation values for the summer season. It is clear from the figure that the low attenuation values show the valley which indicates the low attenuation zone / or grids around grid 3 to 4.

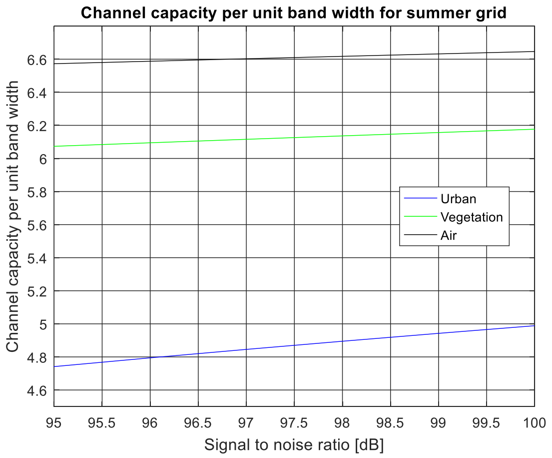

Figure 16. 5G mmWave channel capacity in summer season for 28 GHz.

Figure 16 indicates 5G mmWave channel capacity in summer season for 28 GHz for urban, vegetation and atmospheric season summer. It is clear from figure 16 that the minimal attenuation grids provide the highest channel capacity by avoiding the obstacles in that virtual face. The figure 16, validates the simulation that air / summer atmospheric grids show the highest channel capacity by avoiding the obstructions/ blockage.

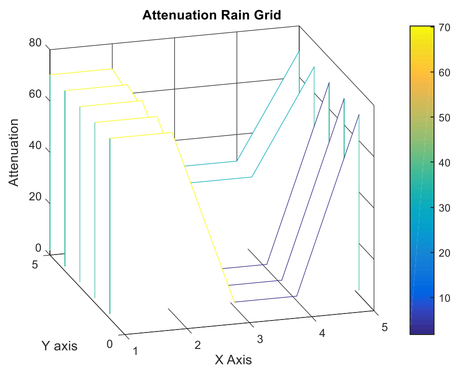

Figure 17. 5G mmWave grids attenuation values for atmospheric, vegetation in-leaf and building in rain season for 28 GHz.

Figure 17 shows the grid attenuation values in a graph form for atmospheric, vegetation in-leaf and building in rain season for 28 GHz. It is clear from the figure that the low attenuation values show the valley which indicates the low attenuation zone around grid 3 to 4. In rain season air attenuation is due to water vapor, oxygen and rain. Figure 18 indicates 5G mmWave channel capacity in rain season for 28 GHz for urban, vegetation and atmospheric rain. It is clear from figure 18 that the minimal attenuation grids provide the highest channel capacity by avoiding the obstacles in that virtual face. This figure 18 validates the simulation that air / rain atmospheric grids show the highest channel capacity by avoiding the obstructions/ blockage. Beam forming is used to direct and steer an antenna's directivity beam in a particular direction of minimal attenuation.

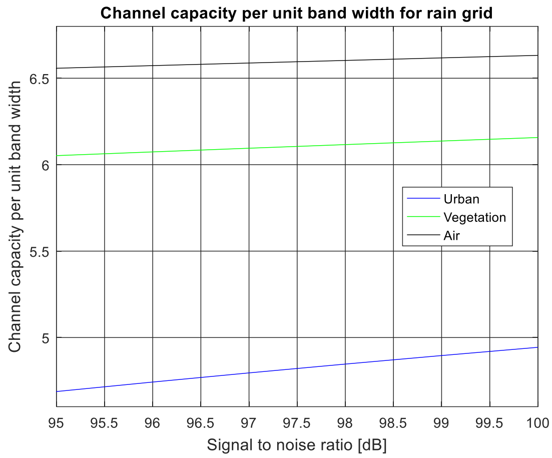

Figure 18. 5G mmWave channel capacity in rain season for 28 GHz

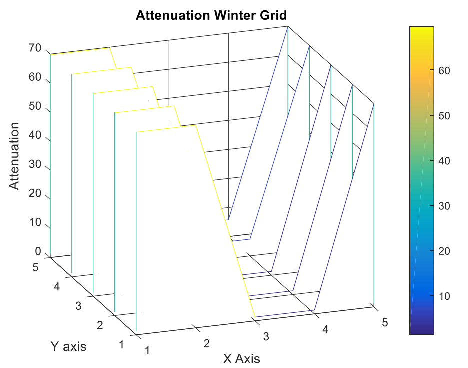

Figure 19. 5G mmWave grids attenuation values for atmospheric, vegetation in-leaf and building in winter season for 28 GHz.

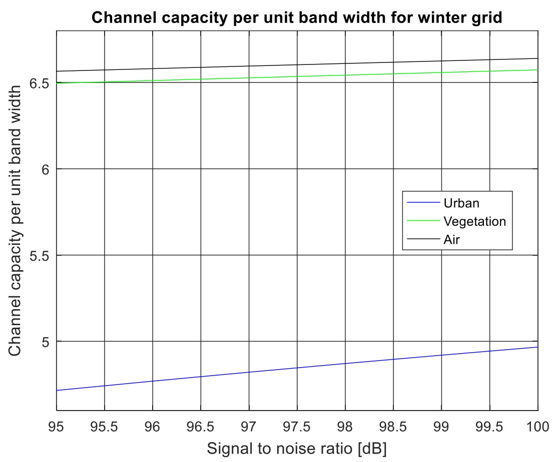

Figure 20. 5G mmWave channel capacity in winter season for 28 GHz.

Figure 19 shows the grid attenuation values in a graph form for atmospheric, vegetation in-leaf and building in winter season for 28 GHz. Figure 20 indicates 5G mmWave channel capacity in winter season for 28 GHz for urban, vegetation and atmospheric rain. It is clear from the figure 19, that the low attenuation values show the valley which indicates the low attenuation zone / or grids around grid 3 to 4. In winter season air attenuation is due to water vapor, oxygen and fog takes place. It is clear from figure 20 that the minimal attenuation grids provide the highest channel capacity by avoiding the obstacles in that virtual face. This figure 20 validates the simulation that air / winter atmospheric grids show the highest channel capacity by avoiding the obstructions/ blockage.

In summer season mmWave attenuation is due to water vapor and oxygen. In summer time or season the water vapour moisture is less as compare to rain or winter. In rainy season attenuation is due to water vapor, oxygen and rain drops. In rainy time or season the water vapour moisture is very high as compare to rain or winter. In winter season attenuation is due to water vapor, oxygen and fog. In winter season the water vapour moisture is high as compare to summers. Such additional or extra air moisture also adds attenuation in mmWave propagation which is clear from the simulation results.

Capacity	Air	Veg.	Building
Summer	6.64	6.17	4.98
Rain	6.63	6.15	4.94
Winter	6.63	6.57	4.96

Table 1. 5G mmWave channel capacity in various seasons for 28 GHz

Such additional losses or attenuation effects the channel capacity by lowering the values. It is also clear from the table 1 that the summer air shows the highest channel capacity due to minimal atmosphere attenuation and vegetation as well as urban shows the significant high attenuation values. Hence, it becomes important to avoid obstacles in mmWave propagation.

IX. Conclusion

In this research, we discussed minimal attenuation grid for 5G millimeter wave (mmWave) D2D devices in DTU campus area which is having open air, vegetation and building area. 5G mmWave antenna forms grids and calculates the minimal attenuation grids for atleast one of the purposes like; beamforming, minimal loss path, line of Sight (LoS), power planning, link budget planning and etc. The method effectively selects at least one grid from amongst the grids as an optimum grid based on the minimal attenuation. Here we have simulated results and calculations are performed for the frequencies 28 GHz. Further, Shannon channel capacity has also been calculated for various seasons and respectively for vegetation and building. It is clear from simulation results and validation that the Shannon channel capacity in atmospheric impairments is higher as compare to other mentioned grid values.

The purpose of this analysis is to review the impact of the obstacles like; atmosphere, seasons, vegetation and urban-site attenuation and choose the minimum attenuation grid as minimum attenuation path for mmWaves in 5G communication system. This method is useful in many ways for 5G millimeter wave (mmWave) communication system. This further reduces complexity of the 5G millimeter wave communication systems and optimizes performance parameters. Further, time, load, and power consumption for beam forming is considerably reduced, as the beam is formed based on the selected grid rather than linear scanning.

This research provides solution to have minimal attenuation path for the 5G transmitter under various type of obstructions like vegetation or urban/ buildings. However, many additional measurements / calculations are needed to detect the type of obstructions for having quality grid attenuation values. This research provides an easy direction for low channel losses especially in dense obstruction areas. The future work simulates the 2D and 3D beamfoming for mobile users by considering the impact of assorted obstructions.

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