Calculating the Capacity of Wireless Network with Directed Energy Links In The Presence of Arbitrarily Obstacles

1. B.Himabindu, 2. K.Chandra Mouli
Student, Lecturer in ECE department
Electronics and Communication Engineering
Jawaharlal Nehru Technological University, Anantapur, India

Abstract— Wireless networks grants implementing communication by applying standard network protocols. It is the communication without the use of cables. Today, mobile applications are growing exponentially and putting great pressure on the wireless spectrum. To mitigate such pressure, the FCC freshly made available E-band (71-76 and 81-86 GHz). The 10 GHz spectrum of E-band is 50-times that of the entire cellular spectrum. The E-band links can be called as a directed energy (DE) links because of its highly focused nature called “pencil beam”. The performance of DE links is exclusively perceptible to the presence of the obstacles. The DE links can be blocked by natural or artificial obstacles, which affects the probability distribution of DE links, and it may affect the scale-invariance property. The shapes of the obstacles are takes as simple shapes like circle, square, rectangle. The DE links of arbitrarily shaped obstacles has found the throughput capacity for the arbitrarily shape.

***Index Terms*— Arbitrarily Obstacles, Directed energy links, Arbitrarily shapes, Cellular spectrum, Scale-invariance, Performance analysis and modeling**

I. INTRODUCTION

The WRC-2000 allotted the 81-86 GHz band to the Radio Astronomy Service (RAS) 16 on an fundamental assertion. Keeping in mind as the RAS allocation from satellite downlinks in the 81-84 GHz band is harmful, so it is avoided and the Mobile-Satellite Service (MSS) and Fixed-Satellite Service (FSS) uplink allotments in the 71-74 GHz band were returned with the MSS and FSS downlink allocations in the 81-84 GHz band. The WRC-2000 can also additionally removed the 72.77-72.91 GHz band from resources 5.149 and 5.55617 and incorporated in the RAS designations over the 76 GHZ [1].

In this research the obstacles are involved to find the capacity in terms of wireless networks with the Directed Energy (DE) links combination. The previous work is happened without the involvement of obstacles. The physical obstacle is an any blockage that excludes the physical presence of a node. The communication obstacle is a barrier that avoids the nodes from communicating with each other by stopping the communication channels. The obstacle shapes used in this research are random shaped obstacles. In this research the deterministic obstacles are considered, where the obstacles are existed and remains constant throughout the time of simulation. These obstacle presence shows that they are in the network area [2].

II. RELATED WORK

The capacity of large-scale wireless networks characteristic is mainly depends on mobile wireless networks. The communication links of the networks differs in its time variation of particular channel strength [3]. The variation of time can be occurred due to the multiple time scales and path loss by the obstacles from the involvement of other users. The impact of time variation is appeared on the design of wireless networks in the overall network layers [4].

2.1ASSUMPTIONS

This research has been analyzed the following assumptions:

- Dense network model: where the *n* nodes are randomly and regularly expanded.
- Physical and communication obstacle models both are used. By using the physical obstacle model, any node positioned over an obstacle area is relocated in a network area, see figure1. Where the communication obstacle models are used to block the absence of obstacles of some DE links,
- Throughout the simulation and time duration the obstacles are remains unchanged.
- The aggregate of a obstacles in an network area is fraction γ as given in table 1.
- The asymptotic behavior of a network can be identified by *n* nodes and *k* obstacles.

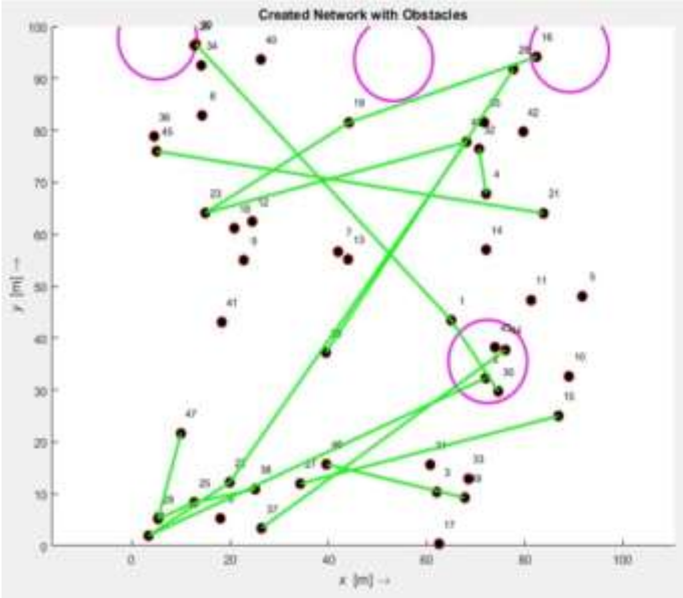

Figure1: Network with obstacles

2.2 CIRCULAR OBSTACLES

The circular obstacle is defined as, whenever the obstacle is in circular shape the blocking area is the rectangle centered on the line of sight (LOS) in between the two end nodes of the DE link with *r* as a length of the link. The width of the rectangle is $2r_b$, where it can be treated as two times the obstacle radius [5]. The center of a circular obstacle is within the r_b, the LOS distance from both side. The blocking area of the circular obstacle is shown in the below figure 2.

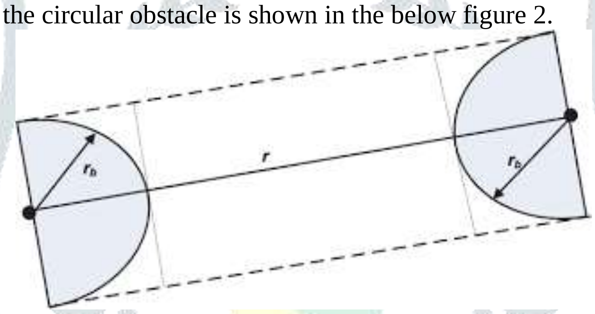

Figure 2: Blocking area of circular obstacle.

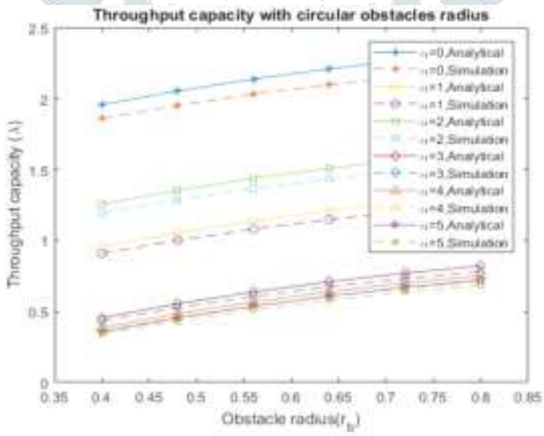

Figure3: Throughput capacity of circular obstacles

The throughput capacity of a circular obstacle is calculated with the probability distribution function[2]. The simulation result of throughput capacity of circular obstacles is shown in figure3.

Table 1: Variable definitions

Variable	Description
n	Number of nodes in the network.
k	Number of obstacles in the network.
p	Probability that a node has a DE link.
A_n	Area of the network (A_n = 1).
A_o	Area of an obstacle.
A_b	Blocking Area.
$\bar{A}_b$	Average blocking Area.
	Percentage of the network area covered by all obstacles.
r_b	Radius of the circular obstacle.
a; b	Dimensions of the square and rectangle obstacles.
	Orientation angle for square and rectangle obstacles.
	Angle that determines the shape of a rectangular obstacle.
P_b	Probability that an obstacle blocks a particular DE link.
P_{nb}	Probability that an obstacle does not block a particular DE links - single obstacle.
P_{NB}	Probability that no obstacle blocks a particular DE link - k obstacles.
$f_o(r)$	Probability that there exists a DE link between two nodes separated by a distance r, i.e., $f_o(r) = f(r)P_{NB}$, where f(r) is the probability that a DE link exists in the absence of obstacles.
r	distance of a DE link.
r_A	Average DE link distance.

2.3 SQUARE OBSTACLES

The square obstacles are used to determine the blocking area by considering the orientation of obstacles and the obstacle orientation is calculated by the random angle θ, it varies in between the radius of the square and the LOS [6]. To reproduce the obstacle orientation the range of θ is between 0 and the $\pi/2$. The square obstacle is represented in the below figure 4 clearly. Let l_1 be the radius of the square and $2l_1 sin(\theta)$ be the height of the parallelogram.

The throughput capacity of a square obstacle is calculated with the probability distribution function [2]. The simulation result of throughput capacity of square obstacles is shown in figure5.

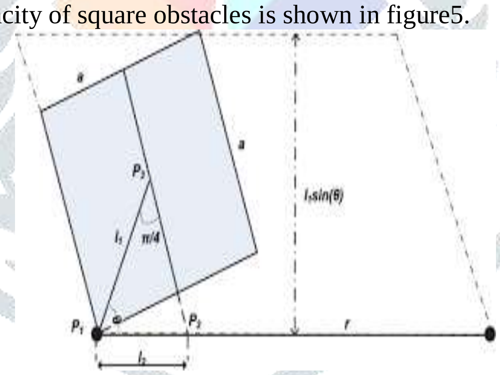

Figure 4: Blocking area of a square obstacle

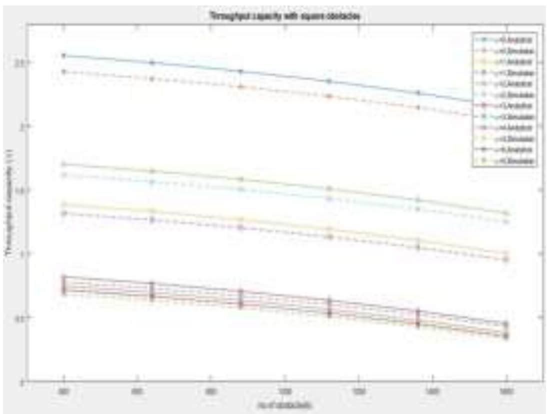

Figure5: Throughput capacity of square obstacles

2.4 RECTANGULAR OBSTACLES

The two important variables should be considered in the rectangular obstacles they are obstacle orientation and the obstacle aspect ratio. The obstacle orientation is described with the random angle $\theta \in [0, \pi/2]$ which is equal to the square obstacle [7]. The obstacle aspect ratio is stated by the β and it regulates the ratio in between length and height of the rectangular obstacle. The below figure6 shows the rectangular obstacles in a detailed manner.

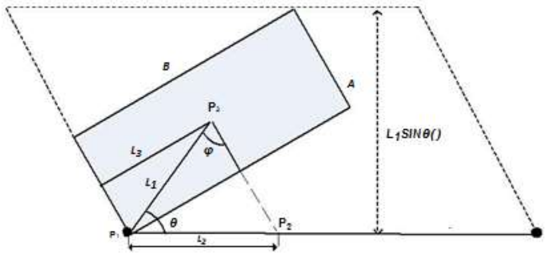

Figure 6: Blocking area of a rectangular obstacle

For square and rectangular obstructions, crossing point with the DE connections can be identified utilizing the Sweep Line Algorithm (SLA) [8] [9]. The SLA is portrayed in Algorithm1. The calculation essentially clears from left to right in the system region to identify crossing points between DE joins and the obstacles.

Algorithm 1 SLA Algorithm

```
Input: An array of line segments S of size s.
[label; EP _Status] = Sort _EP _LR(S).
label : An array of labels for leftmost endpoints.
EP Status : Binary array of endpoints status, 1 for left
endpoint, 0 for right endpoint.
for j = 1 : 2s do
    l    label[j]
    if (EP _Status(j) == 1) then
        Insert (l)              . Insert l in the right position
        if Intersect (S(l); S(above(l))) then
            return True
        end if
        if Intersect (S(l); S(below(l))) then
            return True
        end if
    else
        if Intersect (S(above(l); S(below(l))) then
            return True
            Delete (label(j))
        end if
    end if
end for
```

The line sections imply to the DE joins, thus S is the arrangement of all DE joins. The capacity Sort _EP_LR(S) is in charge of arranging the portions endpoints from left to right dependent on their x-coordinates; the capacity returns two clusters: one exhibit is for relegating marks to the endpoints; the other cluster is for determining a left or right endpoint.

Function insert () is used to insert an endpoint label in its right position ordered by its y-coordinate. Function intersect () is used to check if two line segments intersect. Functions above () and below ()are used to retrieve the line segment labels which are above or below the current label. Finally function delete () is used to delete a right endpoint label. For details, please refer to [8], [9].

The throughput capacity of a rectangle obstacle is calculated with the probability distribution function [2]. The simulation result of throughput capacity of rectangular obstacles is shown in figure7.

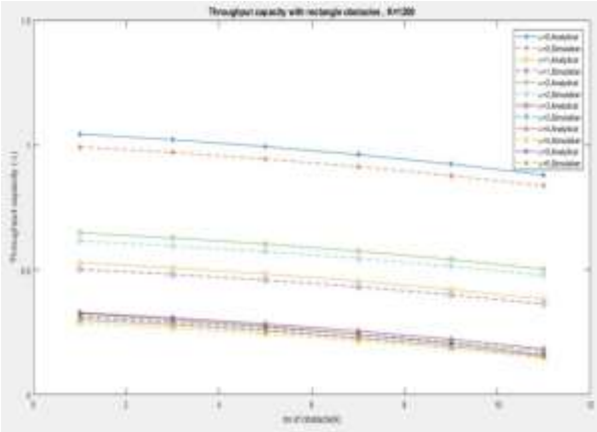

Figure7: Throughput capacity of rectangle obstacles

III. PROPOSED WORK

Using MATLAB and utilizing a similar network configuration setting found in the Simulation. The arbitrarily shape obstacles found the throughput limit λ_{rand} for various number of obstacles (k). The arbitrarily shapes produced are basically a mix of the fundamental shapes. When at least two fundamental shapes overlap, we remove some essential shapes so that there is no overlap. Presently, we permit fundamental shapes overlap. The outcome demonstrates some complicated looking, arbitrarily shaped obstacles. At that point, the irregular shapes secured with basic shapes presented in the paper (circles, squares and square shapes). The process of covering the irregular shapes with fundamental shapes depends on the least area rule. In this standard, a specific basic shape is chosen to cover an arbitrarily shape in the event that it covers the irregular shape altogether, and has least area among other basic shapes. After that we processed the hypothetical throughput limit λ_{th}using the accompanying condition.

$$\lambda_{th} = \omega_c * \lambda_c + \omega_s * \lambda_s + \omega_{r1} * \lambda_{r1} + \cdots + \omega_{rm} * \lambda_{rm}$$

Where, ω_c,ω_s,ω_{r1},...,ω_{rm} speak to the fraction of obstacles that are secured by circles, squares, and square shapes with m number of aspect ratio β individually, to such an extent that:

$$\omega_c + \omega_s + \omega_{r1} + \cdots + \omega_{rm} = 1$$

m is a finite number of the aspect ratio β. In this simulation we utilized four for the estimation of m which compares to four angles (ϕ ∈ [5,15,30,45]) that decides the aspect ratio (β ∈ [11.25,3.73,1.73,1]) individually. The estimations of $\lambda_c, , \lambda_s, \lambda_{r1}, \dots \dots \dots .. \lambda_{rm}$speak to the theoretical throughput limits of circles, squares, and rectangle shapes with various aspect ratios separately. the throughput capacity of arbitrarily shapes is constantly higher than the theoretical limit, this is on account of the area involved by the covered obstacles is more noteworthy than the total area possessed by the uncovered arbitrarily shapes, and more obstacles zone implies more DE connections will be blocked. Here the arbitrarily obstacle is covered with mostly rectangle shapes with different aspect ratiosβ_s. The figure represents the throughput capacity of arbitrarily shaped obstacles.

IV. RESULTS

Simulator is created by using MATLAB. It fundamentally creates a network of n nodes as indicated by the intense network model[3],as shown in figure8, it additionally produces DE interfaces between nodes as per the inverse power law with various values of clustering exponent α, and finally it creates shifting quantities of obstacles with changing shapes. As the quantity of obstacles k increments, or proportionately, the area of a obstacle Ao decrements (since the total obstacle area γ is consistent), the obstacle measurements liker_b of a circle, a of a square, and a,b of a rectangle wind up littler. Accordingly, λ decrements as more obstacles will stop more DE links, as appeared in the figures. Moreover, Fig. 7 demonstrates that, for rectangular obstacles, as ϕ diminishes, the rectangular obstacles turn out to be increasingly compacted, more like a line, and the aspect ratio β between the rectangular measurements builds, which will with high likelihood blocks more DE connects particularly when α is 0 or 1.

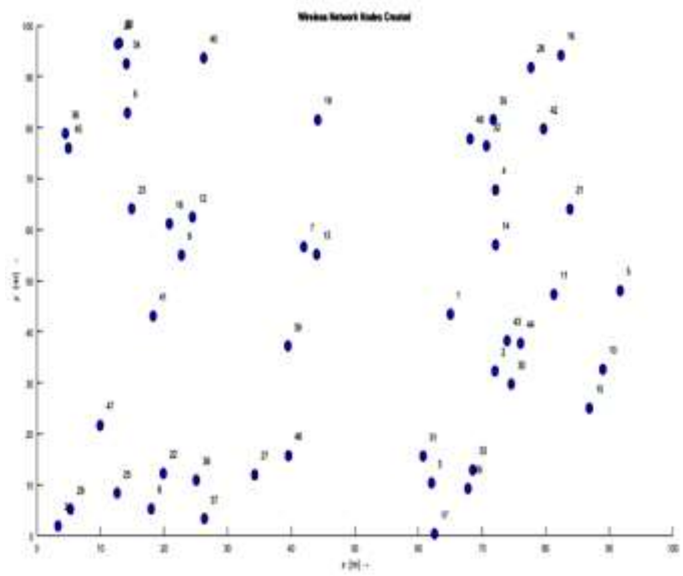

Figure8: Network with nodes

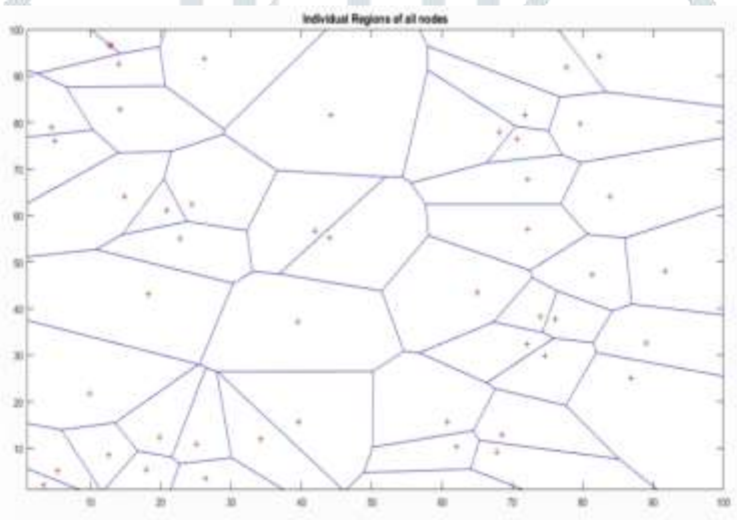

Figure9: Individual region of networks

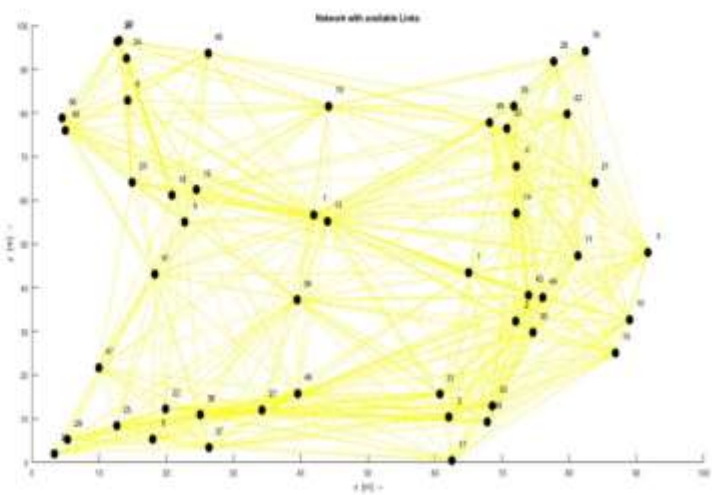

Figure10: Network with available DE links

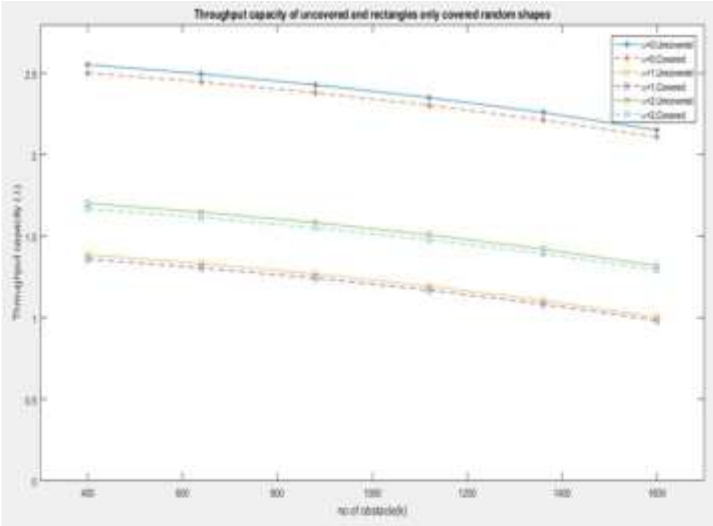

Figure11: Throughput capacity with uncovered and rectangles only covered random shapes

V. CONCLUSION

This work proposed such a way to provide the throughput capacity for the random shapes with the usage of DE links. We study the effect of arbitrarily obstacles found in network area on DE link probability distribution. It is noticed that:

- Two major factors affect the average DE link lengthr_A, and as a result affect the capacity of a wireless network. The first factor is the number of obstacles k, as more obstacles block more DE links. The second factor is the obstacle shape, as an obstacle of rectangular shape with high aspect ratio blocks more DE links than obstacles with other shapes.
- The average DE link length r_A is more robust and has a small reduction in length when α is 2 compared to when α is 0 or 1, this is because of the scale invariance property.

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