

## Mathematical study of the mean communication distances at lognormal shadow fading and Nakagami fading

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### ABSTRACT

Over some few decades, the communication distance and connectivity at wireless sensor network (WSN) has got noticeable attention from the researchers. In general, the communication process in WSN ad-hoc occurs without some wired infrastructure and, the communication process done through a 'single-hop' transmission, where the intermediate nodes called as relay nodes are used in long distance communication and the nodes are capable to transmit and receive the data packets. In this paper, we presented a computational analysis of communication distance in WSN in the presence of fading effects such as nakagami-m fading and lognormal fading. An extensive investigation at both nakagami-m fading and lognormal fading is carried out to provide optimize communication in ad-hoc WSN. In addition, individual wireless nodes have the similar range of communication, is assumed to get the precise communication distance and coverage area in a WSN, where it is required to get mean communication distance. In result analysis section, several validation parameters such as transmitted power, attenuation constant and different number of fading factor is considered to provide proper analytical view.

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## 1. INTRODUCTION

Ad hoc WSN is a multi-hop wireless network, which generally contains huge number of mobile system with wireless apparatuses such as transmitter and receiver. It is applied in wide range of applications; robotics exploration, wireless offices, and medical system etc. The technique of WSNs [1-3] is consider to be a field of science and communication, which have extraordinary potential and have gained lots of interest via scientific society and researchers in last few decades. Wireless Sensor Groups (WSGs) are special type of ad-hoc group, which generally exhibits hundreds to thousands number of active nodes and these nodes are capable for both transmission and receiving operation of data packets 'or' messages. While considering the advancement in the area of microelectronics and communication methodologies has ignited the development and research in the WSN and ad-hoc group network.

Usually the introspection wireless groups is called to be ad-hoc groups and it faces the performance degradation in terms of both capability and connection [4-6], which leads several researchers in order to improve the matrices association with considering group design that can enhance the performance of ad-hoc groups. The dominancy can be seen in research area, where the scientific society is focusing on enhancement of large scale introspection wireless group such as multi-hop ad-hoc group 'or' the packet radio groups. However, the rising attention towards the WSNs indicates the difficulty like execution of weird behavior and have many distinctive of the Ad hoc groups. This major difficulty is predominantly concerned at these type

of group network and the presentation of restrictive trueizable in the group connectivity, group coverage, group delay and group capacity [7-8]. The obtained outcome from one-dimensional case also can be functional to much higher dimensions in group in order to get the connectivity bounds and these type of bounds have not limitation, so there is focus on providing limitation at ad-hoc groups. While considering the one dimensional groups and uniformitarian of nodes, the appropriate formula for probability analysis of the groups is provided in [9-10]. However, the attenuation functions of power law, available data rate per node and connectivity scales is generally known to decrease the contrary, whenever the function of attenuation does not have consistently bounded and, singularity at the source. The connectivity between the nodes is used to analyze the performance, where some type of fading effect can be consider to provide the practice scenario such as nakagami fading, Rayleigh fading and Rician fading [11].

The connectivity performance in one dimensional group is performed and analyzed in [12]. However, the performance analysis of energy harvesting based on the two-way full-duplex relaying system at nakagami-m fading of channel is discussed in [13] and, spectrum sensing at a single channel and the multi-channel networks is provided in [14]. In [11], considered the equalization concept and afterwards perform the Rician flat fading effect on MIMO system. Moreover, it is further compared with Rayleigh flat fading and it also has been analyzed the system under the Rician flat fading effect. Through survey of state-of-art technique, we can say that the paper [15] has analyzed the communication range for the Rayleigh fading (RF) effect and lognormal superimposed RF. However, there are very less analysis on the mean communication range with considering Nakagami-m fading effect, which is more real-world scenario that present. In this paper, we have performed the computation at connective characteristics with considering high compact group. Considering the stratified fact of nakagami fading and shadowing fading, the achievable primitive of connectivity is shows the diversity [16], here we also investigated the acute range of transmission for connectivity in the ad hoc mobile groups. In the presence of obstacle free and bounded mobility we have provided the computation, afterwards we select our approximation in order to hold with optimize solution step. In addition, the scenario of mobile ad-hoc groups is considered in a random way for a point of mobility model [17-18], this study analyzed a fading effect capacity of nakagami-m channels with full CSI (channel state information) and shows the capacity of channel scalability, where m represent the fading parameter of Nakagami-m.

In this paper [19-20], proposed a homogeneous group of communication that features movements of nodes with respect to movement of random waypoint in a heterogeneous communication group scenario [21]. However in [22], researcher has proposed wider range of field simulation environment in order to perform the group connectivity process and the advancement in this technique is given in [23-24]. Though the appropriate scenario of real fading is necessary rather than the particular generic case, therefore the significance of communication range study with the nakagami-m fading model is much needed and can be done by study of mean communication distance for the lognormal superimposed fading and Rayleigh fading [25, 15]. Here, we highlighted the effect due to signify nodes of communication at overlaid lognormal shadow fading and nakagami-m fading. In addition, we assumed that individual wireless nodes have the similar range of communication, in order to get the precise communication distance and coverage area in a WSN, where it is required to get mean communication distance (mean CD). In the result analysis section we presented the average CD for all considered wireless nodes in a wireless network.

This paper is organized as follows; section 2 represent the preliminary assumptions and system model, section 3 shows the evaluation of signify mean communication distance, section 4 provides simulation result analysis followed by numerical values and, section 5 concludes our proposed analysis.

## 2. SYSTEM MODEL

The communication distance is a key word and it is also a physical explanation under a scenario of non-randomness channel prototype, to be in this support type only the random variable is considered and characterizes the node capability to provide a wide range of communication. In addition, we will presumed that the effect of fading in not changeable during transmission period of frame, where the subsequent fading are nothing but the block fading channels.

The signal is appropriately Trans received between two different points with differences  $e$ , under the likelihood state and can be given as [20, 26];

$$b(c \geq d) = \int_d^{\infty} f_c(e)de \quad (1)$$

Here,  $e$  denotes the internodes distance at CDF (Cumulative Distribution Function) and PDF (Probability Density Function). In order to provide signify communication, the transmission range can be given as;

$$G_F(e) = b[F \leq e] = 1 - b(F > e) \quad (2)$$

Whereas the computation of signify communication range is; {43-(46)}

$$H[F] = \int_0^\infty [1 - G_F(e)] de \quad (3)$$

It is very necessary to investigate the maximal ratio combining ('MRC') and best path selection ('BPS') stochastic organizations in comparative to the receiving antennas.

### 3. THE SIGNIFY COMMUNICATION DISTANCE FOR THE LOGNORMAL FADING AND NAKAGAMI-M FADING

Considering both the fading model such as; lognormal shadow channels and Nakagami-m fading model, here we provide the signify CD evaluation;

#### 3.1. Signify Communication Node Under Nakagami-M Fading Channel

While considering the maximum combining ratio, the signals of several antennas are collected in such manner that it increases the SNR outcome [15, 26]. Therefore, the methodology for the Nakagami-m fading and the PDF of "nakagami-m fading" for SNR is given by;

$$B_{S(\bar{c})} = \left(\frac{m}{\bar{c}}\right)^m \frac{c^{m-1}}{K(m)} \exp\left(\frac{mc}{\bar{c}}\right) \quad (4)$$

Therefore, the success probability ( $c \geq d$ ) can be given as;

$$B_{S(\bar{c})} = \frac{1}{K(m)} \int_{\frac{md}{\bar{c}}}^\infty t^{m-1} e^{-t} dt \quad (5)$$

$$B_{S(\bar{c})} = \frac{1}{K(m)} \cdot K\left(m, \frac{md}{\bar{c}}\right) \quad (6)$$

Where,

$$K\left(m, \frac{md}{\bar{c}}\right) = (m-1)! \exp\left(\frac{mc}{\bar{c}}\right) \sum_{p=0}^{m-1} \frac{\left(\frac{md}{\bar{c}}\right)^p}{p!} \quad (7)$$

Considering  $m$  to take values of only positive integer for the success probability. Therefore,  $P_{S(\bar{c})}$  is given as;

$$B_{S(\bar{c})} = \exp\left(\frac{mc}{\bar{c}}\right) \sum_{p=0}^{m-1} \frac{\left(\frac{md}{\bar{c}}\right)^p}{p!} \quad (8)$$

$$\bar{c} = \frac{B_r}{B_n}, \bar{c} = \frac{B_t a^{-q}}{B_n} \quad (9)$$

Through simplifying the (8) and (9) we got,

$$B_{S(\bar{c})} = \exp\left(\frac{mdu^q B_n}{B_{tx}}\right) \sum_{p=0}^{m-1} \frac{\left(\frac{mdu^q B_n}{B_{tx}}\right)^p}{p!} \quad (10)$$

The value of  $H[F]$  can be obtained by solving the (3) and (10)

$$H[F] = \int_0^\infty [1 - G_F(e)] de \quad (11)$$

Therefore,

$$\begin{aligned} 1 - G_F(e) &= 1 - [1 - B_{S(\bar{c})}] \\ 1 - G_F(e) &= B_{S(\bar{c})}[u = e] \end{aligned} \quad (12)$$

$$\int_0^\infty v^{w-1} \exp(-xv^b) dv = \frac{x^{\frac{w}{b}}}{|b|} K\left(\frac{w}{b}\right) \tag{13}$$

We can get  $H[F]$  by solving (11) and (13), the simplified expression is given in (14)

$$H[F] = \int_0^\infty \exp\left(\frac{mdu^q B_n}{B_{tx}}\right) \sum_{l=0}^{m-1} \frac{\left(\frac{mdu^q B_n}{B_{tx}}\right)^p}{p!} de \tag{14}$$

Through symplifing (13) and (14) we get ,

$$H[F] = \left(\frac{mdB_n}{B_{tx}}\right)^{\frac{-1}{q}} \frac{1}{q} \sum_{p=0}^{m-1} \frac{K\left(\frac{1}{q}+p\right)}{p!} \tag{15}$$

Here, (15) shows the determined node isolation probability in a system.

### 3.2. Signify Communication Distance at Lognormal Fading and Nakagami-M Fading Channel

Here, we will provide the analytical expression for signify communication distance at Nakagami-m fading and Lognormal fading Channel, considering from the above (10),

$$B_{S(\bar{c})} = \exp\left(\frac{mdu^q B_n}{B_{tx}}\right) \sum_{p=0}^{m-1} \frac{\left(\frac{mdu^q B_n}{B_{tx}}\right)^p}{p!} \tag{16}$$

$$G_F(e) = 1 - J\left(\frac{\ln \frac{dB_n e^q}{B_{tx}}}{l}\right) \tag{17}$$

$$G_F(e) = y\left(\frac{\ln \frac{dB_n e^q}{B_{tx}}}{l}\right)$$

The scenario of Rayleigh fading and superimposed lognormal shadowing is considered that leads towards the characterization of the network communication range statistic, the obtained signify communication [15] can be written as;

$$H[F] = \int_{-\infty}^\infty B_{S(\bar{c})} \frac{1}{\sqrt{2\pi}lv} e^{-\frac{1}{2}\left[\frac{\ln e - \ln z^{-q}}{l}\right]^2} dv \tag{18}$$

$$H[F] = \sum_{p=0}^{m-1} \frac{\left(\frac{mdu^q B_n}{B_{tx}}\right)^p}{p!} \left(\frac{mdB_n}{B_{tx}}\right)^{-\left(\frac{1}{q}+p\right)} \frac{1}{|q|} K\left(\frac{1}{q}+p\right) \frac{1}{\sqrt{2\pi}lv} e^{-\frac{1}{2}\left[\frac{\ln e - \ln z^{-q}}{l}\right]^2} \tag{19}$$

The above following procedure is adopted to solving and get  $H[F]$ , so it is given as;

$$H[F] = \left(\frac{mdB_n}{B_{tx}}\right)^{\frac{-1}{q}} \frac{1}{q} \sum_{p=0}^{m-1} \frac{K\left(\frac{1}{q}+p\right)}{p!} e^{\frac{l^2}{2q^2}} \tag{20}$$

## 4. RESULTS AND ANALYSIS

The mathematical analysis has performed and shown in above section, and their simulation has performed using MATLAB 2016b, under the system configuration of 4GB RAM, Intel i3 Processor, and Windows 10 Operating System. The numerical outcome has obtained using parameter such as;  $L = 10dB$ ,  $Btv = 1mW$ ,  $W = 0.01mW$ ,  $d = 1 Watt$ , moreover the constraints (i.e.,  $m, \lambda, q$ , and  $l$ ) are selected separately and the 100m x 100m dimension has consider in order to deploy network group. Figure 1 shows the bar graph of attenuation constant vs. Mean communication distance with considered fading factors (i.e.,  $m=2, 4$  and  $6$ ).

The obtained result describes the behavior of attenuation constant with mean CD of medium  $q$ , at several considered fading factor under Nakagami-m fading approach. Where the plot provide the impact conception attenuation constant on mean CD, from the graph we can say that the  $q$  attenuation constant at Nakagami model is having lower impact on the mean CD, while the fading factor at Nakagami model is

having higher impact on the mean CD. Which satisfy the conditional scenario with increasing the fading factor value and tends towards the appropriate channel condition. Though fading factor value  $m = 1$ , it gives result for Rayleigh fading and maximizing the fading factor value increases the performance of mean communication distance, therefore, we can conclude that Nakagami fading approach have improved performance than the Rayleigh fading.

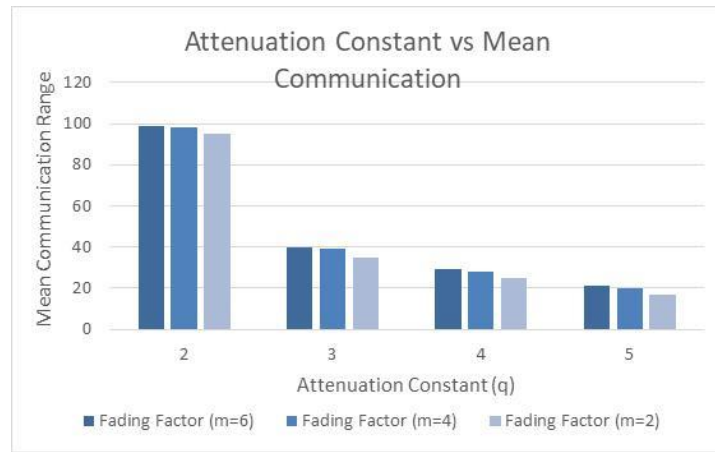


Figure 1. Mean communication distance vs. attenuation constant ( $m = 6, 4,$  and  $2$ )

Figure 2 shows the mean communication distance vs. fading factor  $m$  at  $q =$  two, four and six. This results clearly explain the performance of mean CD with the dissimilar attenuation constant value at diverse types of attenuated standard. While free medium is two with respect to attenuation constant, so from the graph analysis the performance conclusion can be made that the mean CD range provide better value for the free medium compare to attenuated medium.

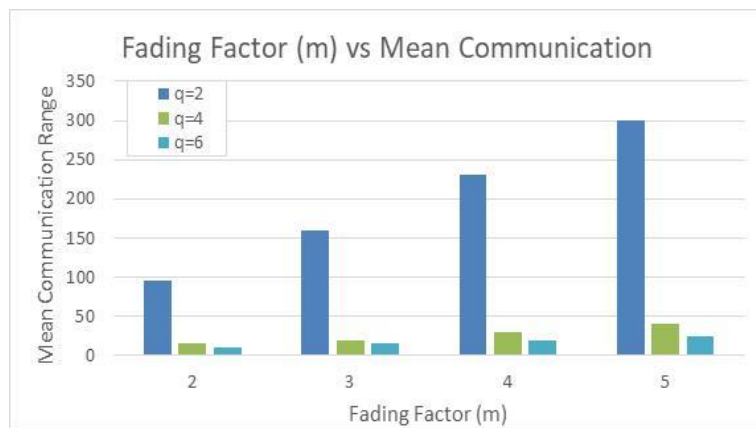


Figure 2. Mean communication distance vs. fading factor  $m$  ( $q =$  two, four and six)

Figure 3 shows the mean communication distance vs. transmitted power at  $q =$  three, four and six. This graph provide explanation for the behavior of mean communication distance at transmitted power, also the increment in the transmitted power will increase the performance in terms of link establishment, communication range and etc. The above plot justify the conditional scenario and provide explanation that the increment in mean communication distance with respect to transmitted power value will increase the performance, therefore we can say that the transmitted power provide progressive impact on the mean CD range.

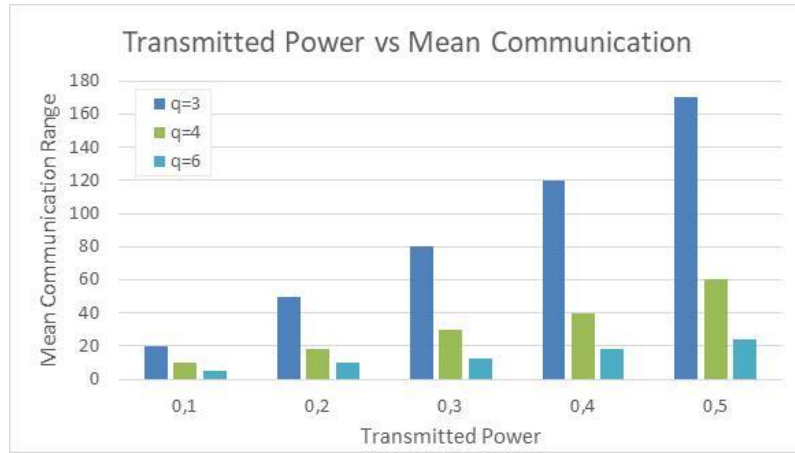


Figure 3. Mean communication distance vs. transmitted power at  $q =$  three, four and six

Figure 4 shows for the behavior of mean CD vs. standard deviation at the fading factor (i.e.,  $m =$  two and six), where the graph explains the behavioral analysis of mean CD at standard deviation, which will provide effect for the link establishment and communication range condition, in addition, from the graph the condition of standard deviation provide positive effect on the mean CD range (i.e., through increasing the standard mean CD value will tends to increase the performance), therefore, we can say the lognormal-shadowing Nakagami Fading (NF) provide direct impact on the mean CD.

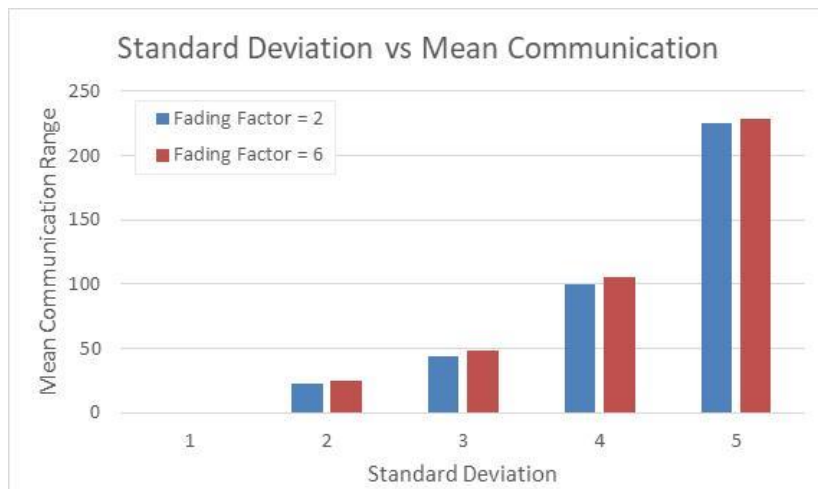


Figure 4. Mean communication distance vs. standard deviation at  $m =$  two and six

Figure 5 represent the outcome of mean communication distance vs. attenuation constant at SD one and two. Also this graph explains the performance of mean CD at attenuation constant  $q$  for the lognormal shadowing NF prototype and provides the view where increasing in the value of  $q$  attenuation constant, the decrement in the mean communication distance, therefore, it concludes the condition where the  $q$  attenuation constant provide negative effect on the mean communication range under a superimposed lognormal shadowing effect.

Figure 6 provide the graphical representation of mean communication distance vs. attenuation constant at SD = zero and two. Therefore, from the above graph we can conclude that the “lognormal shadowing NF” model provides enhanced performance than the NF model ‘or’ just we can say that the standard deviation of lognormal shadowing will tends to advance the mean communication distance performance.

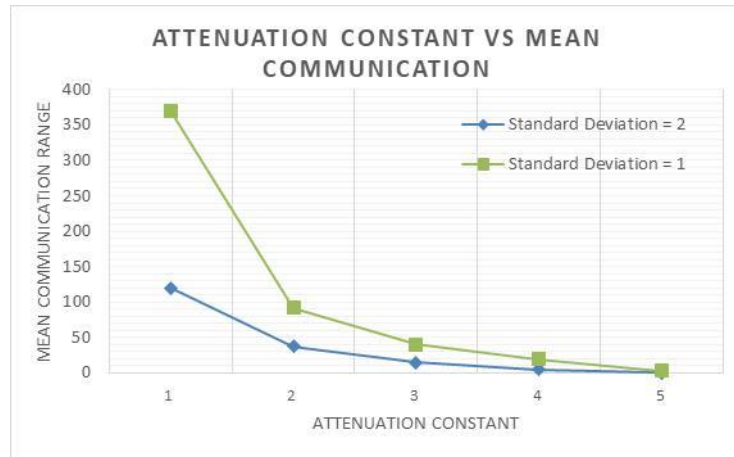


Figure 5. Mean communication distance vs. attenuation constant at SD (standard deviation) = two and one

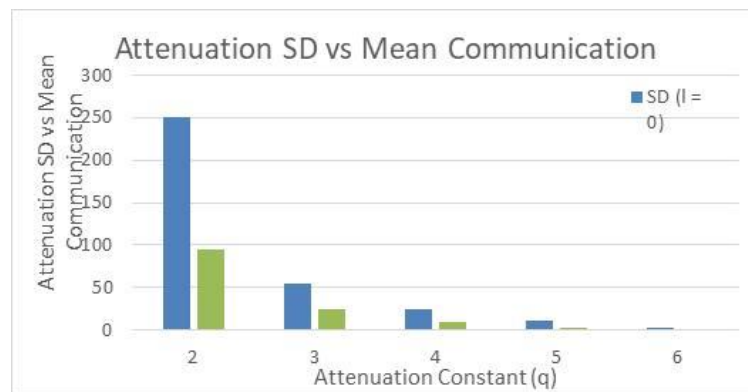


Figure 6. Mean communication distance vs. attenuation constant at SD = zero and two

## 5. CONCLUSION

It is important to analyse a fading effect capacity of Nakagami-m channels with full and shows the capacity of channel scalability, and this paper investigated the signify communication distance with respect to Nakagami m fading under a super-imposed lognormal shadow channel effect. Here we presented the more appropriate research work through considering the practice scenarios, also this study enhanced in terms of simulation and analysis in order to provide clear view and ease to develop a wireless sensor ad-hoc group more practically. This study has also applied on the fading effect and provide improvable study over the signify communication distance. In this paper, we have assumed that the CD range between each wireless nodes are same and to get the appropriate communication distance 'or' coverage distance in a wireless sensor network, the finding of mean communication distance is important. Therefore, we computed the average CD for all considered wireless node that present in a WSN and it is concluded that Nakagami fading approach have improved performance than the Rayleigh fading.

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