

Performance Analysis of Communication System with Fluctuating Beckmann Fading

Zakir Hussain, Asim ur Rehman Khan, Haider Mehdi and Aamir Ali

Abstract—In this paper, performance of device-to-device (D2D) communication system over Fluctuating Beckmann (FB) fading channels is analyzed. FB fading model is a novel generalized fading model that unifies various fading models such as Rayleigh, Nakagami, one-sided Gaussian, Rician, Rician shadowed, κ - μ , κ - μ shadowed, η - μ and Beckmann. The considered D2D system is assumed to be affected by various FB faded co-channel interferers. Using the characteristic function (CF) approach outage probability and success probability expressions are given. These expressions are functions of D2D and interference path-loss exponents, distance between the D2D devices, distances between interferers and the D2D receiver and, interference and D2D fading channel conditions. Maximum ratio combining (MRC) and selection combining (SC) based diversity schemes are considered to mitigate channel fading effects. D2D communication system under various conditions of channel fading and interference is numerically analyzed and discussed.

Index Terms— Co-channel Interference, Device-to-Device, Fluctuating Beckmann, Outage Probability, Success Probability

I. INTRODUCTION

An explosive growth in high data rate demand on cellular communication systems is expected in near future. This demand is due to the popularity of online gaming, HD video streaming and other social media services. Device-to-device (D2D) communication system has emerged as one of the promising technologies to overcome this problem [1-2]. It is considered to be one of the dynamic techniques of the 5th generation (5G) cellular communication standard. D2D communication is defined as the direct communication of devices with each other, when are in proximity, without involvement of base station (BS). D2D system can enhance the data rate, spectrum utilization and, the energy efficiency of the user devices and the networks [3-4]. Despite many advantages, D2D communication brings some challenges as well. Due to insufficient wireless channel bandwidth and the loss of coordination between wireless devices, co-channel interference (CCI) problem arises [5]. Therefore, effects of CCI should be considered for the analysis of D2D systems. In this paper, performance of the D2D communication system is analyzed with the help of outage probability and success probability. Outage probability performance of D2D communication system using stochastic geometry is studied by authors in [6]. Authors in [6], have not considered any diversity scheme for the system. In [7], authors studied outage performance of D2D system under optimal spectrum allocation strategy. Authors has discussed resource

sharing method for user in the system. Authors in [8], discussed outage probability of D2D communication in a cellular network from a general threshold-based perspective. Success probability of D2D communication system over Rician fading channel under the distributed random-access control scheme is analyzed by authors in [9].

Outage and success performance analysis of D2D system in the presence of CCI is the aim of this work. The co-channel interference signals are considered to originate from any wireless device with which the system has lost coordination. The channel for the D2D and CCI signals are assumed to follow Fluctuating Beckmann (FB) distribution. FB fading model is a generalized fading model which includes many fading models as special case [10]. The one-sided Gaussian, Rayleigh, Nakagami, η - μ , κ - μ , κ - μ shadowed, Rician, Rician Shadowed and the Beckmann distribution are the special cases of FB model [10]. The κ - μ shadowed fading model [11] manages to capture propagation conditions like clustering and LoS fluctuation. However, it fails when there is power imbalance in the LoS and NLoS components. Fluctuating Beckmann (FB) fading model which is an extended κ - μ shadowed model is introduced in [10]. FB model effectively captures such scenarios. FB model is a generalization of Beckmann fading model by considering the effects of line-of-sight (LoS) fluctuation and clustering. It also takes into account the effects of power imbalance in the LoS and non-LoS components [10]. CCI effects on the performance of D2D communication system is analyzed. Use of generalized FB model has enabled us to present analytical expressions that can be used to analyze various fading conditions. The SC and MRC based diversity schemes are also considered to combat fading effects. Path loss conditions are also included in the analysis. Outage and success probability expressions for the non-identically distributed D2D and CCI signals are presented. Numerical analysis under various channel and CCI conditions are presented and discussed. Numerical results from these expressions are obtained with the help of MATLAB. The rest of paper is structured as follows: the system model is discussed in Section II. Also analytical expressions for outage probability and success probability are presented in Section II. In Section III, numerical results are presented and discussed. Finally, paper is concluded in Section IV.

II. SYSTEM MODEL

A device-to-device (D2D) communication system in an interference limited environment is considered here. The system model is illustrated in Fig. 1. There are N co-channel interferers that are affecting the D2D communication system. The D2D signals and co-channel interference (CCI) signals are considered to be independent and non-identically distributed. The co-channel interferers are assumed to be at different distances from the receiver of the D2D pair. The channels for D2D and CCI signals are assumed to be Fluctuating Beckmann (FB) distributed. Path-loss is a significant factor in performance degradation of any communication system. In this paper, a simplified path-loss model is considered [12]. To reduce the effects of fading maximal ratio combining (MRC) and selection combining (SC) based diversity techniques with D branches are considered in the system.

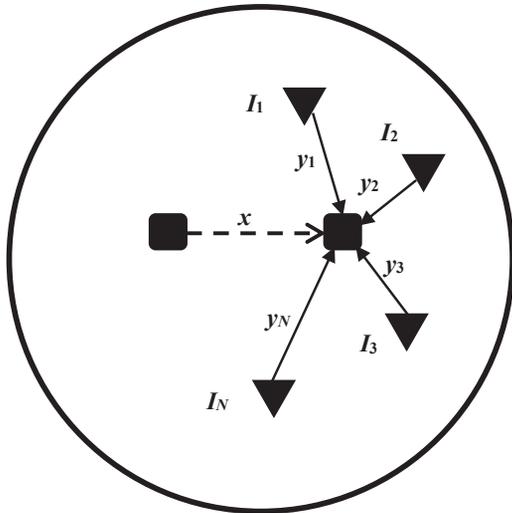


Fig. 1. System Model

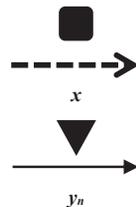
D2D device

Desired D2D Signal

Distance between D2D devices

 n -th Co-channel Interferer

Co-channel Interference Signal

 Distance between the n -th Co-channel Interferer and
the D2D Receiver


A. Selection Combining (SC) Scheme

The signal-to-interference ratio (SIR) at the d -th diversity branch of the selection combining (SC) based D2D system is

$$\frac{S_{S-SC,d}}{S_I} = \frac{P_1 \left(\frac{x_0^{u-2}}{x^u} \right) h_d}{\sum_{n=1}^N P_{I,n} \left(\frac{y_{0,n}^{v_n-2}}{y_n^{v_n}} \right) \beta_n} \quad (1)$$

where $S_{S-SC,d}$ is the received power at the d -th diversity branch of D2D receiver, P_1 is the power of the D2D signal, x is the distance between desired D2D devices, u is path-loss exponent for the D2D signal, x_0 is the reference distance and h_d is an independent FB fading variable in the d -th diversity branch. Similarly, S_I is the received power of CCI signals, $P_{I,n}$ is the power of the n -th CCI signal which is originated from a device at a distance y_n from the D2D receiver, $y_{0,n}$ is the reference distance, v_n is the path-loss exponent of the n -th co-channel interferer and β_n is an independent FB fading variable of the n -th CCI signal. The outage probability is defined as the probability that the instantaneous SIR of the communication system falls below a predefined threshold R . The outage probability for the D2D system is

$$P_{out,SC} = \Pr(RS_I > S_{S-SC,MAX}) \quad (2)$$

where $S_{S-SC,MAX} = \max_{d=1,\dots,D} (S_{S-SC,d})$ and $\Pr(\cdot)$ is probability.

Based on (2), a decision variable $\hat{\delta}$ is defined as

$$\hat{\delta} = RS_I - S_{S-SC,MAX} \quad (3)$$

For a successful reception, the value of $\hat{\delta}$ must be less than zero, otherwise outage will occur. Mathematically,

$$\hat{\delta} \begin{cases} > 0 & \text{Outage} \\ \leq 0 & \text{Successful Transmission} \end{cases} \quad (4)$$

In this study, a characteristic function (CF) based approach is used for the outage analysis. The CF expression for the decision variable is obtained with the help of [10] and is given as,

$$\phi_{\hat{\delta}}(\omega) = \frac{\left[1 + \frac{1}{m_d} \left(\frac{j\omega C_d}{G_d + j\omega E_d} + \frac{j\omega F_d}{G_d + j\omega H_d} \right) \right]^{-m_d}}{\left[(1 + j\omega A_d)(1 + j\omega B_d) \right]^{\frac{m_d}{2}}} \quad (5)$$

$$\times \prod_{n=1}^N \left[\frac{\left[1 - \frac{1}{m_n} \left(\frac{j\omega C_n}{G_n - j\omega E_n} + \frac{j\omega F_n}{G_n - j\omega H_n} \right) \right]^{-m_n}}{\left[(1 - j\omega A_n)(1 - j\omega B_n) \right]^{\frac{m_n}{2}}} \right]$$

$$\text{where } A_d = \frac{2\eta_d \Omega_d \delta_d}{\mu_d (1 + \eta_d)(1 + \kappa_d)}, \quad B_d = \frac{2\Omega_d \delta_d}{\mu_d (1 + \eta_d)(1 + \kappa_d)},$$

$$C_d = \mu_d \kappa_d \left(\frac{\zeta_d^2}{1 + \zeta_d^2} \right) (1 + \eta_d) \Omega_d \delta_d, \quad E_d = 2\eta_d \Omega_d \delta_d,$$

$$G_d = (1 + \eta_d)(1 + \kappa_d)\mu_d, \quad H_d = 2\Omega_d\delta_d,$$

$$F_d = \mu_d\kappa_d \left(\frac{1}{1 + \zeta_d^2} \right) (1 + \eta_d)\Omega_d\delta_d \text{ and } A_n = \frac{2\eta_n\Omega_n\delta_n}{\mu_n(1 + \eta_n)(1 + \kappa_n)},$$

$$B_n = \frac{2\Omega_n\delta_n}{\mu_n(1 + \eta_n)(1 + \kappa_n)}, \quad C_n = \mu_n\kappa_n \left(\frac{\zeta_n^2}{1 + \zeta_n^2} \right) (1 + \eta_n)\Omega_n\delta_n,$$

$$E_n = 2\eta_n\Omega_n\delta_n, \quad F_n = \mu_n\kappa_n \left(\frac{1}{1 + \zeta_n^2} \right) (1 + \eta_n)\Omega_n\delta_n, \quad H_n = 2\Omega_n\delta_n,$$

$G_n = (1 + \eta_n)(1 + \kappa_n)\mu_n$, where μ_d and μ_n represent number of clusters of the d -th branch D2D signal and n -th CCI signal, respectively. κ_d and κ_n are related to the strength of line-of-sight (LoS) component, η_d and η_n are the in-phase/quadrature power imbalance in the non-LoS components of the d -th branch D2D signal and n -th CCI signal, respectively. ζ_d^2 and ζ_n^2 are the in-phase/quadrature power imbalance in the LoS components, m_d and m_n accounts the fluctuation in LoS components, and, Ω_d and Ω_n are average power of the d -th branch D2D signal and n -th CCI signal, respectively. Moreover,

$$\delta_d = P_1 \left(\frac{x_0^{u-2}}{x^u} \right) \text{ and } \delta_n = RP_{I,n} \left(\frac{y_{0,n}^{v_n-2}}{x^{v_n}} \right).$$

Outage probability of the D2D system is obtained by using the identity, $P_{out} = \frac{1}{2} + \frac{1}{\pi} \int_0^\infty \frac{\text{Im}(\phi_\theta(\omega))}{\omega} d\omega$, where $\text{Im}(\cdot)$ gives the imaginary part. The outage probability for the SC diversity based D2D system is

$$P_{out,SC} = \prod_{d=1}^D \left[\frac{1}{2} + \frac{1}{\pi} \int_0^\infty \frac{\text{Im}(\phi_\theta(\omega))}{\omega} d\omega \right] \quad (6)$$

The outage expression in (6) is for the independent but non-identically distributed D2D and CCI signals. The outage probability for independent and identically distributed case is

$$P_{out,SC} = \left[\frac{1}{2} + \frac{1}{\pi} \int_0^\infty \frac{\text{Im}(\phi_\theta(\omega))}{\omega} d\omega \right]^D \quad (7)$$

Success probability is defined as the probability that the SIR of the communication system remains above a predefined threshold R . The expression for the success probability of SC diversity based D2D system is

$$P_{S,SC} = 1 - \prod_{d=1}^D \left[\frac{1}{2} + \frac{1}{\pi} \int_0^\infty \frac{\text{Im}(\phi_\theta(\omega))}{\omega} d\omega \right] \quad (8)$$

The success probability expression presented in (8) is for the independent but non-identically distributed D2D and CCI signals. The success probability expression for the independent and identically distributed case is

$$P_{S,SC} = 1 - \left[\frac{1}{2} + \frac{1}{\pi} \int_0^\infty \frac{\text{Im}(\phi_\theta(\omega))}{\omega} d\omega \right]^D \quad (9)$$

B. Maximal Ratio Combining (MRC) Scheme

The SIR of the D2D system at the output of D branches MRC combiner is

$$\frac{S_{S,MRC}}{S_I} = \frac{P_1 \left(\frac{x_0^{u-2}}{x^u} \right) \sum_{d=1}^D h_d}{\sum_{n=1}^N P_{I,n} \left(\frac{y_{0,n}^{v_n-2}}{y_n^{v_n}} \right) \beta_n} \quad (10)$$

where $S_{S,MRC}$ is the received power of the D2D signal. The outage probability for the MRC based D2D system is

$$P_{out,MRC} = \Pr(RS_I > S_{S,MRC}) \quad (11)$$

Using the expression given in (11), a decision variable θ is defined as

$$\theta = RS_I - S_{S,MRC} \quad (12)$$

For a satisfactory desired D2D signal quality, the value of θ has to be negative. Otherwise, outage will happen. Mathematically,

$$\theta \begin{cases} > 0 & \text{Outage} \\ \leq 0 & \text{Acceptable Transmission} \end{cases} \quad (13)$$

The CF of the decision variable θ is given as

$$\phi_\theta(\omega) = \prod_{d=1}^D \left[\frac{1 + \left(\frac{j\omega C_d}{G_d + j\omega E_d} + \frac{j\omega F_d}{G_d + j\omega H_d} \right)^{-m_d}}{\left[(1 + j\omega A_d)(1 + j\omega B_d) \right]^{\frac{m_d}{2}}} \right]$$

$$\times \prod_{n=1}^N \left[\frac{1 - \left(\frac{j\omega C_n}{G_n - j\omega E_n} + \frac{j\omega F_n}{G_n - j\omega H_n} \right)}{m_n} \right]^{-m_n} \left[(1 - j\omega A_n)(1 - j\omega B_n) \right]^{\frac{\mu_n}{2}} \quad (14)$$

Based on (13) and (14), the outage probability expression for independent but non-identically distributed D2D and CCI signals is

$$P_{out,MRC} = \frac{1}{2} + \frac{1}{\pi} \int_0^{\infty} \frac{\text{Im}(\phi_{\theta}(\omega))}{\omega} d\omega \quad (15)$$

The outage probability expression for independent and identically distributed system is

$$P_{out,MRC} = \frac{1}{2} + \frac{1}{\pi} \int_0^{\infty} \frac{\text{Im}([X_d]^D [Y_n]^N)}{\omega} d\omega \quad (16)$$

where

$$X_d = \frac{\left[1 + \frac{1}{m_d} \left(\frac{j\omega C_d}{G_d + j\omega E_d} + \frac{j\omega F_d}{G_d + j\omega H_d} \right) \right]^{-m_d}}{(1 + j\omega A_d)^{\frac{\mu_d}{2}} (1 + j\omega B_d)^{\frac{\mu_d}{2}}}$$

and

$$Y_n = \frac{\left[1 - \frac{1}{m_n} \left(\frac{j\omega C_n}{G_n - j\omega E_n} + \frac{j\omega F_n}{G_n - j\omega H_n} \right) \right]^{-m_n}}{(1 - j\omega A_n)^{\frac{\mu_n}{2}} (1 - j\omega B_n)^{\frac{\mu_n}{2}}}$$

The success probability expression for the independent and non-identically distributed system is

$$P_{S,MRC} = \frac{1}{2} - \frac{1}{\pi} \int_0^{\infty} \frac{\text{Im}(\phi_{\theta}(\omega))}{\omega} d\omega \quad (17)$$

The success probability expression for the independent and identically distributed case is

$$P_{S,MRC} = \frac{1}{2} - \frac{1}{\pi} \int_0^{\infty} \frac{\text{Im}([X_d]^D [Y_n]^N)}{\omega} d\omega \quad (18)$$

III. NUMERICAL RESULTS AND ANALYSIS

In this section, the performance of FB faded D2D system based on the expressions derived in Section II is presented. The reference distances x_0 and $y_{0,n}$ are assumed to be 1 meter. Fig. 2 shows the outage performance of D2D system with the various number of diversity branches for both SC and MRC schemes. The values for D2D signals parameters for number of diversity branches $D = 2$ and 3, and CCI signals parameters are shown in Table 1.

Table 1.

Parameters	Values	Parameters	Values
u	3.4	$P_{i,n}$	[16.98, 17.78, 18.45, 19.03, 20] dBm
x	15 meters	v_n	[2.7, 2.8, 2.9, 3.0, 2.6]
μ_d	[10,7] & [10, 7, 1]	y_n	[45, 40, 35, 30, 25] meters
κ_d	[10, 3] & [10, 3, 8]	μ_n	[1, 3, 7, 3, 4]
ζ_d^2	[0.1, 0.01] & [0.1, 0.01, 1]	ζ_n^2	[0.01, 0.1, 0.001, 1, 2]
η_d	[10, 5] & [10, 5, 6]	κ_n	[1, 5, 6, 4, 5]
m_d	[3, 2] & [3, 2, 7]	η_n	[1, 2, 7, 2, 3]
R	16.98	m_n	[1, 3, 4, 2, 6]

From the figure, it is clear that as the number of branches is increased for the SC and MRC schemes outage performance improves. It is because of the improved SIR conditions of the system. Furthermore, it is seen that the increase in power of the D2D signal improves the outage performance of the system. Analytical and simulation of Outage performance of D2D communication system with various values μ_d and x is shown in Fig. 3. The values for D2D signals parameters and CCI signals parameters are shown in Table 2.

Table 2.

Parameters	Values	Parameters	Values
P_i	20 dBm	v_n	[3, 3.1, 3.2, 3.3, 3]
u	2.6	μ_n	[1, 3, 7, 3, 4]
κ_d	[0, 0]	κ_n	[0, 0, 0, 0, 0]
η_d	[0, 0]	η_n	[0, 0, 0, 0, 0]
m_d	[0, 0]	m_n	[0, 0, 0, 0, 0]
ζ_d^2	[0, 0]	ζ_n^2	[0, 0, 0, 0, 0]
$P_{i,n}$	[20, 23.01, 24.77, 26.02, 26.99] dBm	y_n	[45, 40, 35, 30, 30] meters

From the figure, it is observed that the outage probability of the system is less for higher values fading parameter μ_d . It is because of the fading condition of D2D signals which results in an improved outage performance of the D2D system. Moreover, the increase in distance between D2D devices degrades the outage performance of the system. It is because of the path-loss phenomena. Outage performance of D2D system for various values of v_n and x is shown in Fig. 4. The values for the three branches of MRC based D2D signal parameters and CCI signal Parameters are given in Table 3.

Table 3.

Parameters	Values	Parameters	Values
P_1	20 dBm	$P_{I,n}$	[16.98, 17.78, 18.45, 19.03, 20] dBm
u	3.2	μ_n	[1, 3, 4, 3, 2]
κ_d	[10, 3, 8]	κ_n	[1, 2, 3, 4, 1]
η_d	[10, 5, 6]	η_n	[1, 2, 3, 2, 3]
m_d	[6, 5, 7]	m_n	[1, 3, 4, 2, 3]
ζ_d^2	[0.1, 0.01, 1]	ζ_n^2	[0.01, 0.1, 0.001, 0.5, 1]
μ_d	[10, 7, 1]	y_n	[25, 30, 35, 40, 45] meters

From the figure, it is observed that the outage probability of the system is less for higher values CCI path-loss exponents. It is because of the weakening of CCI signals which results in an improved outage performance of the D2D system. Moreover, the increase in distance between D2D devices degrades the outage performance of the system.

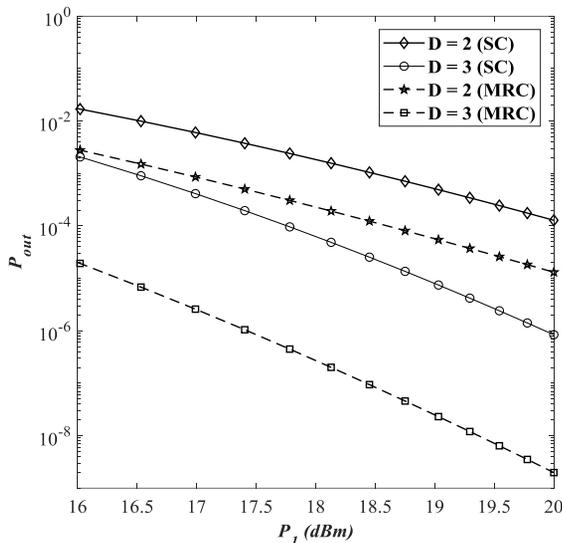


Fig. 2. Outage probability for various numbers of SC and MRC branches

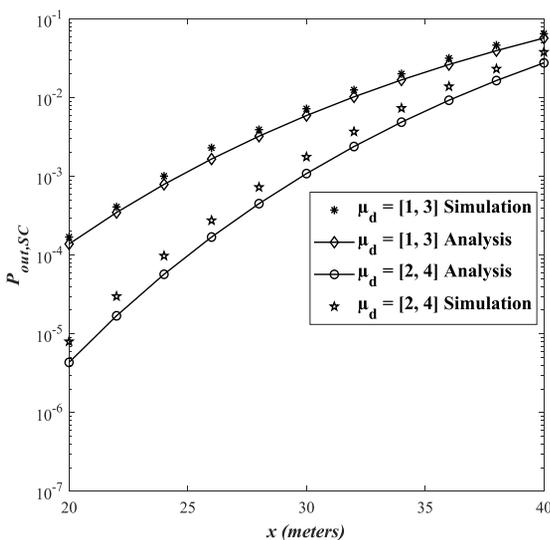


Fig. 3. Outage Probability for various values of fading parameter

In Fig. 5, outage performance of D2D system for various values of u and m_d is shown. The values for the three branches of SC based D2D signal parameters and CCI signal parameters are given in Table 4.

Table 4.

Parameters	Values	Parameters	Values
P_1	20 dBm	$P_{I,n}$	[16.98, 17.78, 18.45, 19.03, 20] dBm
x	19 meters	μ_n	[1, 3, 7, 3, 4]
κ_d	[10, 3, 8]	κ_n	[1, 5, 6, 4, 5]
η_d	[10, 5, 6]	η_n	[1, 2, 7, 2, 3]
μ_d	[10, 7, 1]	m_n	[1, 3, 4, 2, 3]
ζ_d^2	[0.1, 0.01, 1]	ζ_n^2	{0.01, 0.1, 0.001, 1, 2}
v_n	[2.7, 2.8, 2.9, 3, 2.6]	y_n	[25, 30, 35, 40, 45] meters

From the figure, it is observed that the outage probability of the system is worse for the higher values of the u . It is due to the weakened D2D signal due to the path-loss effects. Moreover, from the figure it can also be seen that the outage performance of the system improves as the values of m_d is increased. It is because of the better shadowing conditions of the D2D communication channel.

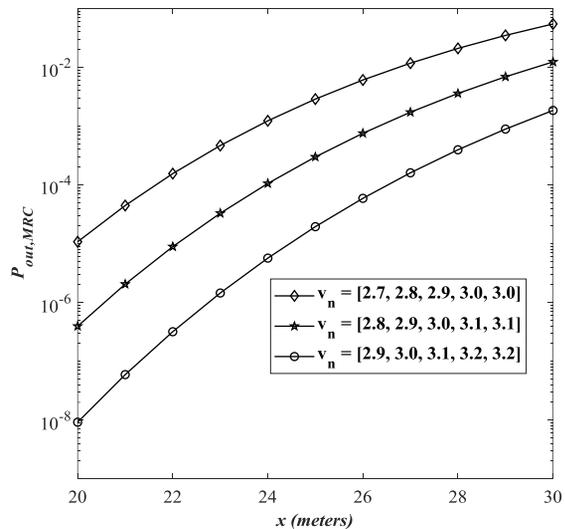


Fig. 4. Outage performance of MRC based D2D system with varying path-loss exponents of CCI signals

Fig. 6 presents outage performance of D2D communication system with varying values of m_n . The values for $P_1, P_{I,n}, x, y_n, u, v_n, \mu_d, \mu_n, \kappa_d, \kappa_n, \eta_d, \eta_n, \zeta_d^2, \zeta_n^2$ and R are considered to be 20 dBm, 16.98 dBm, 15 meters, 35 meters, 3.3, 2.7, 2, 2, 5, 4, 0.1, 0.1, 0.01, 0.01 and 20 dBm, respectively. From the figure it is observed that the outage performance is almost insensitive to the variations of m_n . Furthermore, it is also observed that the outage performance improves as the values of m_d is increased.

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Outage performance of D2D system for the varying values of ζ_n^2 and η_n in a scenario with $\mu_n = 1$ and μ_d is shown in Fig. 7. The values for $P_1, P_{L,n}, x, y_n, u, v_n, \kappa_d, \kappa_n, \eta_d, m_d, m_n, \zeta_d^2$ and R are set to be 20 dBm, 16.98 dBm, 15 meters, 40 meters, 3.5, 2.5, 10, 1, 10, 3, 5, 0.1, and 16.98 dBm, respectively. From the figure it is observed that outage performance of the system is better for the higher values of η_n . Moreover, from the figure it can be seen that the outage performance improves as the number of clusters of desired D2D signal increases.

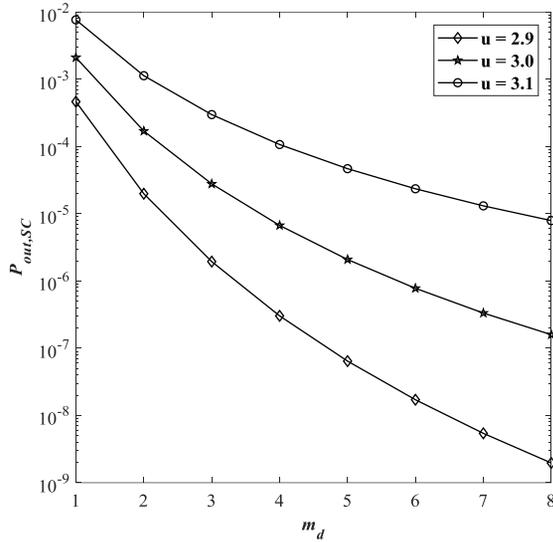


Fig. 5. Outage performance of SC based D2D system for various values of path-loss exponent u

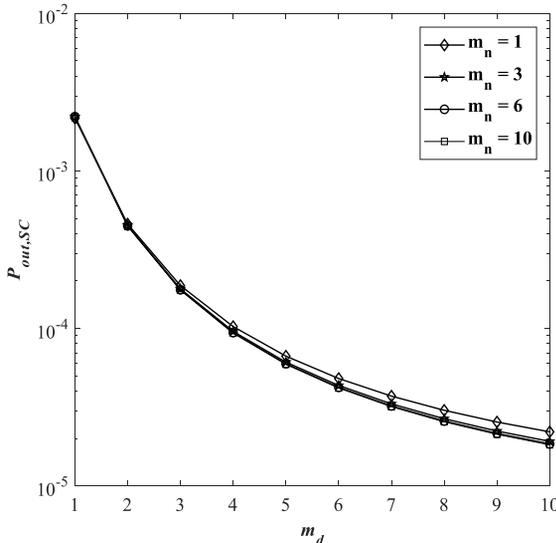


Fig. 6. Outage performance of SC based D2D system for various values of m_n

Success probability performance of D2D system for κ_n and κ_d is shown in Fig. 8. The values for $P_1, P_{L,n}, x, y_n, u, v_n, \eta_d, \eta_n, m_d, m_n, \mu_d, \mu_n, \zeta_d^2, \zeta_n^2$ and R are set to be 20 dBm, 16.98 dBm, 15 meters, 30 meters, 3.8, 2.5, 2, 2, 3, 1, 2, 2, 0.01, 0.01 and 16.98

dBm, respectively. From the figure it is observed that success probability performance of the system is better for the lower values κ_n . It is because of degraded CCI signals which results in an improved the SIR performance of the system, and hence better success probability performance of the system. It can also be seen that the success probability of the system increases as the values of κ_d increases. In Fig. 9, success probability performance of D2D communication system with varying values of η_n and ζ_n^2 is shown. $P_1, P_{L,n}, x, y_n, u, v_n, \kappa_d, \kappa_n, \eta_d, \eta_n, m_d, m_n, \mu_d, \mu_n$ and R are fixed at 20 dBm, 16.98 dBm, 16 meters, 25 meters, 3.5, 2.5, 1, 5, 10, 2, 1, 1, 3, 3 and 20 dBm, respectively. From the figure, it can be seen that the success probability does not show much variation when ζ_n^2 is varied. Furthermore, it is also observed that the success probability performance of the system deteriorates as ζ_d^2 is increased.

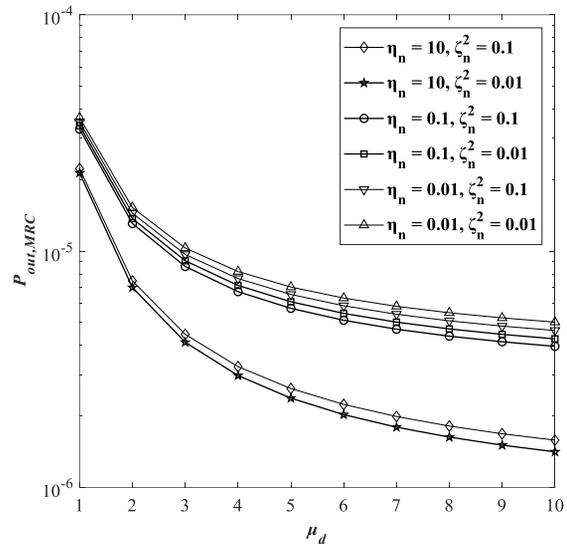


Fig. 7. Outage performance of MRC based D2D system for various values of η_n and ζ_n^2

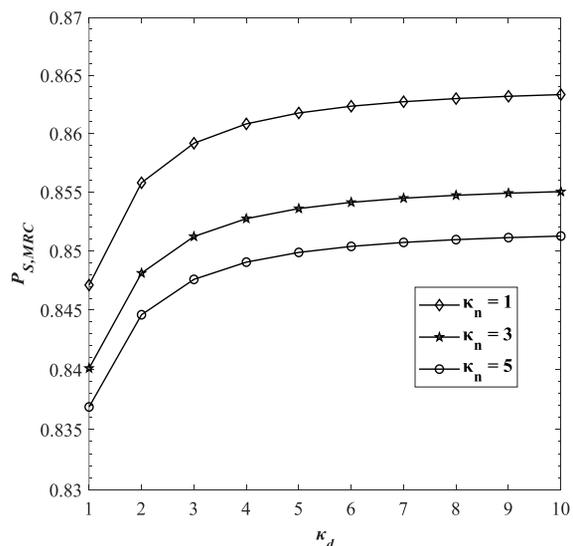


Fig. 8. Success probability performance of MRC based D2D system for various κ_n

Success probability performance of the D2D system with varying values μ_n and the distance y is analyzed in Fig. 10. Here, the values for parameters $P_1, P_{I,n}, x, u, v_n, \kappa_d, \kappa_n, \eta_d, \eta_n, m_d, m_n, \zeta_d^2, \zeta_n^2$ and μ_n are fixed at 20 dBm, 17.78 dBm, 16 meters, 3.5, 2.5, 1, 5, 10, 5, 1, 10, 10, 0.1 and 2, respectively. From the figure, it is evident that the success probability performance of the system is almost insensitive to the change in the values of μ_n . Moreover, from the figure it is also seen that the success probability of the system improves as the distance y is increased. It is because of the improved SIR conditions of the system due to weakening of CCI signals by the path-loss.

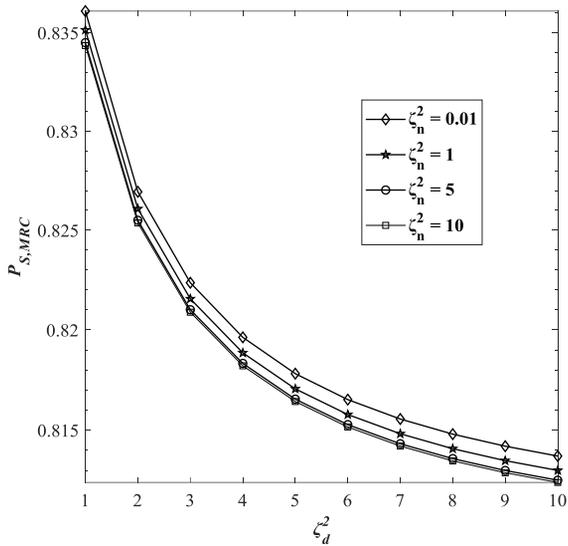


Fig. 9. Success probability performance of MRC based D2D system with varying values of ζ_n^2

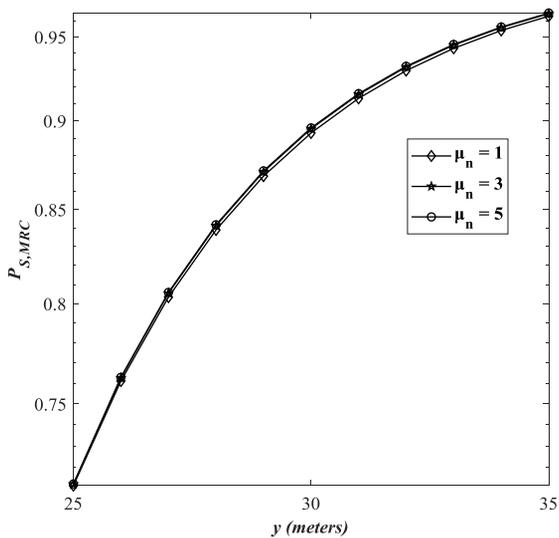


Fig. 10. Success Probability of MRC based D2D system with varying values of μ_n

IV. CONCLUSION

In this paper, outage and success performances of a D2D communication system over a Fluctuating Beckmann (FB) fading channel in an interference limited scenario is analyzed. The FB distribution generalizes various distributions. Expressions of outage and success probabilities using characteristic function (CF) based approach is presented. Effects of co-channel interference, FB channel conditions and the path-loss on the outage and success probabilities of the system are presented and discussed. MRC and SC diversity schemes are also incorporated to mitigate fading conditions. It is observed that path-loss significantly effects performance of D2D system. It is also observed that the system performance improves as the number of clusters in the D2D signal is increased. However, system performance is almost insensitive to the variations in the number of clusters of CCI.

APPENDIX A
PROOF OF EQ. NO. 5

$$\partial = RS_I - S_{S,SC,MAX}$$

$$\begin{aligned} \phi_o(\omega) &= E \left(e^{j\omega (RS_I - S_{S,SC,MAX})} \right) \\ &= E \left(e^{j\omega (RS_I)} e^{j\omega (-S_{S,SC,MAX})} \right) \\ &= E \left(e^{j\omega \left(\sum_{n=1}^N \delta_n \beta_n \right)} e^{j\omega (-\delta_d h_d)} \right) \\ &= E \left(e^{j\omega \left(\sum_{n=1}^N \delta_n \beta_n \right)} \right) E \left(e^{j\omega (-\delta_d h_d)} \right) \\ &= E \left(e^{j\omega (-\delta_d h_d)} \right) \prod_{n=1}^N E \left(e^{j\omega \delta_n \beta_n} \right) \\ &= \phi_d(-\omega \delta_d h_d) \prod_{n=1}^N \phi_l(\omega \delta_n \beta_n) \end{aligned}$$

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