Relay-Assisted Device-to-Device Communication over $\eta-\mu$ Channels

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Abstract- Device-to Devie (D2D) system for communication in regard to an amplify-and-forward (AF) relay-assistance over $\eta-\mu$ fading channels with its outage and success performance expression are presented in this work. The assumption for the presence of co-channel interference (CCI) at the relay and D2D receiver is made. To mitigate the fading conditions the selection combining (SC) scheme is also involved in the process. Characteristic approach function is used to derive the expressions for success and outage probabilities. The expressions depend on the path-loss of channels, distances between various nodes in the system and $\eta-\mu$ distribution parameters. The numerical analysis of the outage and success probability are presented under different conditions of the system.

Index Terms- Co-channel Interference signals, Device-to-Device Communication, $\eta-\mu$ fading, Outage Probability, Success Probability

I. Introduction

The augmentation in highly capable and intelligent communication devices has been triggered via evolution in various wireless communication technologies. These devices need significantly high data rate for services like multimedia sharing and online gaming etc. [1-2]. Communication between device is made sure by allowing two nearby devices to liaise via direct channel in substitution to routing through base station (BS). Device-to-device (D2D) can efficiently attain high bandwidth efficiency with low power consumption [3-4]. D2D also offloads the BS and increase transmission capacity. Due to the short range of D2D communication, a relay-assisted D2D system is required to fully exploit the potential of D2D communication system. Therefore, an amplify-and-forward (AF) relay-assisted D2D communication system is also considered. Co-channel interference (CCI) conditions are also considered in this work. Because in a cellular system with high density of D2D and various cellular devices, CCI may arise if there is a loss of coordination among them [5]. To minimize the co/cross-tier interferences between D2D and cellular communication, in [6], the author proposed a distributed resource allocation algorithm based on matching theory. In [7], the author presents an analysis over cooperative Device-to-Device communication system in an uplink cellular network. To maximize the total average achievable rate under the outage optimal spectrum and power allocation was entertained. To avoid the severe interference components for Device -to-Device communication, authors in [8], presents a case for multicell where he discussed a location-based power control technique. Area spectral efficiency analysis was performed using the proposed power control and cooperation approach. In [9], base the theory to introduce a mode selection scheme for maximum received signal strength for each user equipment to handle the Device-to-Device system interference. The author presents analysis based on the coverage probability and the area spectral efficiency.

Aside from the mentioned work, the main objective of this paper is to discuss the success probabilities and outage of a relay-assisted D2D communication environment in the presence of CCI over $\eta-\mu$ fading channels [10]. To our knowledge, this work has not been discussed in the literature. Non-line-of-sight fading scenarios are modeled after $\eta-\mu$ distribution. Special cases, namely Hoyt and Nakagami-m distributions are included in $\eta-\mu$ distribution. CCI is assumed to be initiated by different wireless devices in the system which causes the system to lose proper coordination. D2D and CCI signals are $\eta-\mu$ distribution faded. Incorporating selection combining (SC) diversity scheme the receiver alleviates the effect of fading. An assumption of having random values is made for the relay distance which can be located at different geographical points in the system [11]. To derive success and outage expression, characteristic function (CF) approach is used as a function of channel and CCI parameters. Section 2 holds the information to system model and analytic expressions, whereas section 3 advocates for Numerical analysis and section 4 concludes the work.

II. System Model

D2D system with amplify-and-forward (AF) relay-assisted is presented in Fig. 1. Near to the device communication system receiver lies L co-channel interferers at the relay and N CCI sources. CCI signals are independent and non-identically distributed. $\eta-\mu$ distributed fading channel [10] is considered for both types of signals. The relay over a $\eta-\mu$ distributed fading channel first receives a D2D signal from the source. The relay then performs amplification and forwards the CCI and the main signal to the receiver. Here, the assumption of no fading effects is made between relay to D2D receiver communication link. Taking into consideration that the maximum distance between the receiver device and the relay is to be Q meters. The relay-receiver distance, random values can be attested for x in range $0 < x < Q$ meters. As the distance x follows a linear distribution, the PDF of x can be written as [10],

$$f_X(x)=\frac{2x}{Q^2},\quad 0<x<Q$$

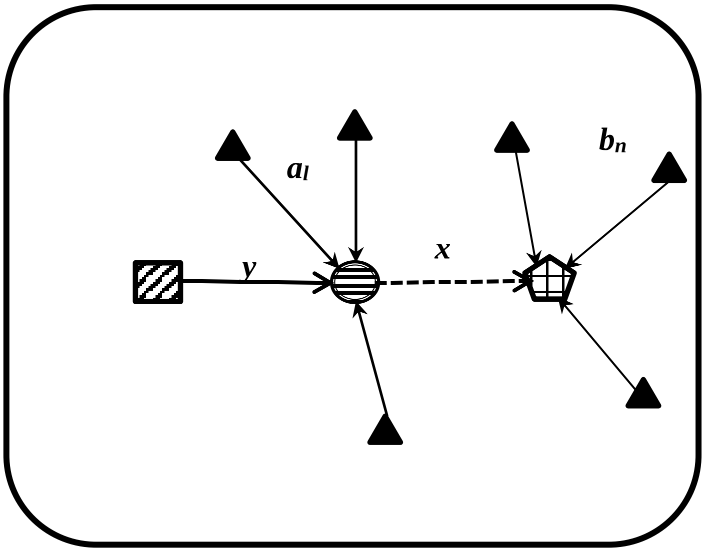

Fig.1. System Model

D2D source	
D2D receiver	
Relay	
Desired D2D signal from D2D source to relay	
Desired D2D signal from relay to D2D receiver	
Distance from D2D source to relay	***y***
Distance from relay to D2D receiver	***x***
Co-channel Interferers	
Signal of CCI	
$l-th$ CCI to relay link length	$\boldsymbol{a_l}$
$n-th$ CCI to receiver link length	$\boldsymbol{b_n}$

The signal-to-interference power ratio (SIR) at the receiver is,

$$\frac{S_d}{S_I}=\frac{MPy^{-c}x^{-q}\lambda}{Mx^{-q}\sum_{l=1}^{L}P_{I,l}a_l^{-k_l}\beta_l+\sum_{n=1}^{N}P_{I,n}b_n^{-v_n}\alpha_n}\qquad(1)$$

where S_d is the desired D2D signal power from relay, S_I is CCI power, transmitted D2D signal power is P, path-loss exponent of source-relay link is c and the $\eta-\mu$ distributed independent channel gain is λ for the source-relay channel. $l-th$ CCI power at the relay is $P_{I,n}$, $l-th$ CCI path-loss exponent is k_l, $l-th$ CCI $\eta-\mu$ independent variable is β_l and path-loss exponent for relay-receiver link is q. At the receiver node $n-th$ CCI path-loss exponent is v_n and α_n is an independent $\eta-\mu$ gain of the $n-th$ CCI. M is amplification factor of the relay

$$M=\frac{P_R}{Py^{-c}\Omega+\sum_{l=1}^{L}P_{I,l}a_l^{-k_l}\Omega_l}\qquad(2)$$

where P_R is the relay power, $\Omega=E[\lambda]$ and $\Omega_l=E[\beta_l]$ are average powers of D2D and $l-th$ CCI signals, respectively. Outage probability P_{out} with threshold R is $P_{out}=\Pr(RS_I>S_d)$ where $\Pr(.)$ is the probability. Consider, $\phi=RS_I-S_d$ where $\phi\begin{cases}>0 & Outage\\ \le 0 & Acceptable\ Transmission\end{cases}$. By using the CF based approach the P_{out} is derived. With the help of [12] the CF of ϕ is given,

$$\rho_\phi(\omega)=\frac{1}{\left(1+\frac{j\omega MPy^{-c}x^{-q}\Omega}{2\mu_d(h_d+H_d)}\right)^{\mu_d}\left(1+\frac{j\omega MPy^{-c}x^{-q}\Omega}{2\mu_d(h_d-H_d)}\right)^{\mu_d}}$$
$$\times\prod_{l=1}^{L}\frac{1}{\left(1-\frac{j\omega RMP_{I,l}a_l^{-k_l}x^{-q}\Omega_l}{2\mu_l(h_l+H_l)}\right)^{\mu_l}\left(1-\frac{j\omega RMP_{I,l}a_l^{-k_l}x^{-q}\Omega_l}{2\mu_l(h_l-H_l)}\right)^{\mu_l}}$$
$$\times\prod_{n=1}^{N}\frac{1}{\left(1-\frac{j\omega RP_{I,n}b_n^{-v_n}\Omega_n}{2\mu_n(h_n+H_n)}\right)^{\mu_n}\left(1-\frac{j\omega RP_{I,n}b_n^{-v_n}\Omega_n}{2\mu_n(h_n-H_n)}\right)^{\mu_n}}$$

where $\mu_d>0$ is the number of multi-path clusters. For D2D signal the $\eta-\mu$ format 1 parameters are, $0<\eta_d<\infty$ is the power ratio of the in-phase and quadrature scattered waves in each multipath cluster, $H_d=\frac{(\eta_d^{-1}-\eta_d)}{4}$ and $h_d=\frac{(2+\eta_d^{-1}-\eta_d)}{4}$. For D2D signal $\eta-\mu$ format 2 parameters are, $-1<\eta_d<1$ is the correlation coefficient between the in-phase and quadrature scattered waves in each multipath cluster, $H_d=\frac{\eta_d}{(1-\eta_d^2)}$ and $h_d=\frac{1}{(1-\eta_d^2)}$. For the $l-th$ CCI at the relay the $\eta-\mu$ format 1 parameters are, $0<\eta_l<\infty$, $H_l=\frac{(\eta_l^{-1}-\eta_l)}{4}$ and $h_l=\frac{(2+\eta_l^{-1}-\eta_l)}{4}$. For the $l-th$ CCI at the relay the $\eta-\mu$ format 2 parameters are, $-1<\eta_l<1$, $H_l=\frac{\eta_l}{(1-\eta_l^2)}$ and $h_l=\frac{1}{(1-\eta_l^2)}$. For the $n-th$ CCI at the receiver the $\eta-\mu$ format 1 parameters are, $0<\eta_n<\infty$, $H_n=\frac{(\eta_n^{-1}-\eta_n)}{4}$ and $h_n=\frac{(2+\eta_n^{-1}-\eta_n)}{4}$. For the $n-th$ CCI at the relay the $\eta-\mu$ format 2 parameters are, $-1<\eta_n<1$, $H_n=\frac{(\eta_n^{-1}-\eta_n)}{4}$ and $h_n=\frac{(2+\eta_n^{-1}-\eta_n)}{4}$. Based $\rho_\phi(\omega)$ on, outage probability is given as

$$P_{out}=\frac{1}{2}+\frac{1}{\pi}\int_0^\infty\int_0^Q\frac{\mathrm{Im}\left(\rho_\phi(\omega)\right)}{\omega}f_X(x)dx\,d\omega,$$

where $Im\,(.)$ is the imaginary part. The success probability P_S is the probability for which SIR exceeds threshold value R. The success probability is given as,

$$P_S=\frac{1}{2}-\frac{1}{\pi}\int_0^\infty\int_0^Q\frac{\mathrm{Im}\left(\rho_\phi(\omega)\right)}{\omega}f_X(x)dx\,d\omega.$$

The analysis with a Z branch SC diversity will be considered next. The SIR of the $z-th$ branch is,

$$\frac{S_{SC,z}}{S_I} = \frac{MPy^{-c}x^{-q}\lambda_z}{Mx^{-q}\sum_{l=1}^{L} P_{I,l}a_l^{-k_l}\beta_l + \sum_{n=1}^{N} P_{I,n}b_n^{-v_n}\alpha_n} \quad (4)$$

where $S_{SC,z}$ is the received power in the $z-th$ diversity branch, λ_z is the $\eta-\mu$ distributed gain in the $z-th$ branch. Outage probability P_{out} is $P_{out} = \Pr(RS_I > S_{SC,MAX})$ where $S_{SC,MAX} = \max_{z=1,2,\cdots,Z}(S_{SC,z})$. The CF of $\rho_\theta = RS_I - S_{SC,z}$ is given,

$$\rho_\theta(\omega) = \frac{1}{\left(1+\frac{j\omega MPy^{-c}x^{-q}\Omega_z}{2\mu_{d,z}(h_{d,z}+H_{d,z})}\right)^{\mu_{d,z}}\left(1+\frac{j\omega MPy^{-c}x^{-q}\Omega_z}{2\mu_{d,z}(h_{d,z}-H_{d,z})}\right)^{\mu_{d,z}}}$$
$$\times \prod_{l=1}^{L} \frac{1}{\left(1-\frac{j\omega RMP_{I,l}a_l^{-k_l}x^{-q}\Omega_l}{2\mu_l(h_l+H_l)}\right)^{\mu_l}\left(1-\frac{j\omega RMP_{I,l}a_l^{-k_l}x^{-q}\Omega_l}{2\mu_l(h_l-H_l)}\right)^{\mu_l}}$$
$$\times \prod_{n=1}^{N} \frac{1}{\left(1-\frac{j\omega RP_{I,n}b_n^{-v_n}\Omega_n}{2\mu_n(h_n+H_n)}\right)^{\mu_n}\left(1-\frac{j\omega RP_{I,n}b_n^{-v_n}\Omega_n}{2\mu_n(h_n-H_n)}\right)^{\mu_n}}$$

The D2D signal $\eta-\mu$ format 1 parameters are, $0 < \eta_{d,z} < \infty$, $H_{d,z} = \frac{(\eta_{d,z}^{-1}-\eta_{d,z})}{4}$ and $h_{d,z} = \frac{(2+\eta_{d,z}^{-1}-\eta_{d,z})}{4}$. For D2D signal $\eta-\mu$ format 2 parameters are, $-1 < \eta_{d,z} < 1$, $H_{d,z} = \frac{\eta_{d,z}}{(1-\eta_{d,z}^2)}$ and $h_{d,z} = \frac{1}{(1-\eta_{d,z}^2)}$. Based on $\rho_\theta(\omega)$ the outage probability of a SC based D2D system is,

$$P_{out,SC} = \sum_{z=1}^{Z}\left[\frac{1}{2}+\frac{1}{\pi}\int_0^\infty\int_0^Q \frac{\mathrm{Im}(\rho_\theta(\omega))}{\omega} f_X(x)dx\,d\omega\right].$$

Similarly, the success probability is,

$$P_{S,SC} = 1-\sum_{z=1}^{Z}\left[\frac{1}{2}+\frac{1}{\pi}\int_0^\infty\int_0^Q \frac{\mathrm{Im}(\rho_\theta(\omega))}{\omega} f_X(x)dx\,d\omega\right].$$

For an independent and identically distributed (IID) case the outage probability will be,

$$P_{out,SC} = \left[\frac{1}{2}+\frac{1}{\pi}\int_0^\infty\int_0^Q \frac{\mathrm{Im}(\rho_\theta(\omega))}{\omega} f_X(x)dx\,d\omega\right]^Z$$

Similarly, the success probability will be given as,

$$P_{out,SC} = 1-\left[\frac{1}{2}+\frac{1}{\pi}\int_0^\infty\int_0^Q \frac{\mathrm{Im}(\rho_\theta(\omega))}{\omega} f_X(x)dx\,d\omega\right]^Z.$$

The double integrals in the expressions of outage and success probabilities can be easily solved using MATLAB.

III. Numerical Analysis

Numerical analysis of relay-assisted D2D system over a $\eta-\mu$ distributed channel is presented. Expressions given in Section 2 are general. In this section, numerical analysis is presented based on assumption of various parameters and their values. Also, format 1 is considered. Table 1 includes all the parameters with fixed values for the numerical analysis.

Table 1. Fixed Valued Parameters

Parameters	Values
N	3
L	3
P_R	24.77 dBm
c	3
P	24.77 dBm
$P_{I,l}$	23.01 dBm, 20 dBm, 20.792 dBm
k_l	3, 3, 3.1
a_l	20 m, 25 m, 25 m
$P_{I,n}$	24.77 dBm, 23.01 dBm, 24.77 dBm
v_n	3.1, 3, 3.1
b_n	20 m, 30 m, 35 m

In Fig. 2 outage performance with varying source-relay distance is shown. Also, R = 20 dBm, Q = 25 m, q = 3, $\eta_{d,z}$ = [2, 0.8, 3], $\mu_{d,z}$ = [4, 3, 2], η_l = [3, 2, 0.7], μ_l = [2, 3, 2], η_n = [3, 2, 2] and μ_n = [2, 3, 5]. From the figure, it can be observed that the movement of the source away from the relay causes outage performance to deteriorate. Also, as the number of diversity branches are increased from Z = 1 to 3 the performance is improved. In the analysis to follow Z = 3 is considered.

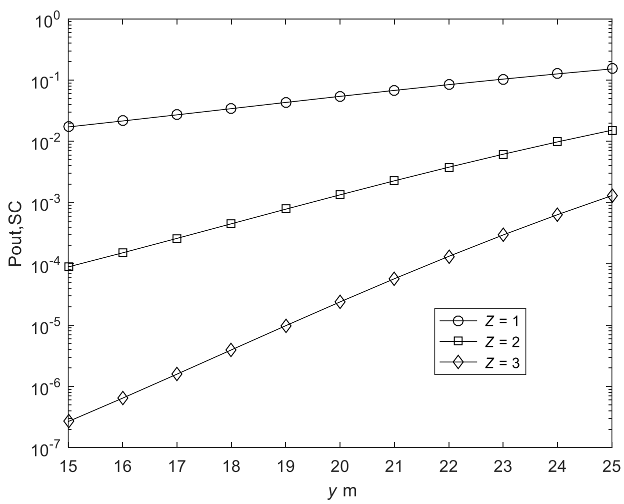

Fig. 2. Outage performance with various diversity branches.

Fig. 3 represents the outage performance of the D2D signal with variation in the values of $\eta_{d,z}$. Furthermore, R = 20 dBm, Q = 25 m, q = 3, $\mu_{d,z}$ = [4, 3, 2], η_l = [3, 2, 0.7], μ_l = [2, 3, 2], η_n = [3, 2, 2] and μ_n = [2, 3, 5]. From the figure, the observation can be made that the outage of the system degrades with the increasing values of $\eta_{d,z}$. In Fig. 4, results for outage performance with varying $\mu_{d,z}$ values of the D2D signal can be observed. With, R = 20 dBm, Q = 25 m, q = 3, $\eta_{d,z}$ = [3, 5, 8], η_l = [3, 2, 0.7], μ_l = [2, 3, 2], η_n = [3, 2, 2] and μ_n= [2, 3, 5]. It can be seen from the figure that the outage performance of the system is improved as the values of $\mu_{d,z}$ are increased. In Fig. 5, outage analysis with various η_l and η_n values of the CCI signals, is shown. Also, R = 20 dBm, Q = 25 m, q = 3, $\eta_{d,z}$ = [3, 5, 8], $\mu_{d,z}$ = [2, 4, 5], μ_l = [2, 3, 2] and μ_n = [2, 3, 5]. From the figure, it is clear that the variation in the values of η_l and η_n has negligible effect on the outage performance.

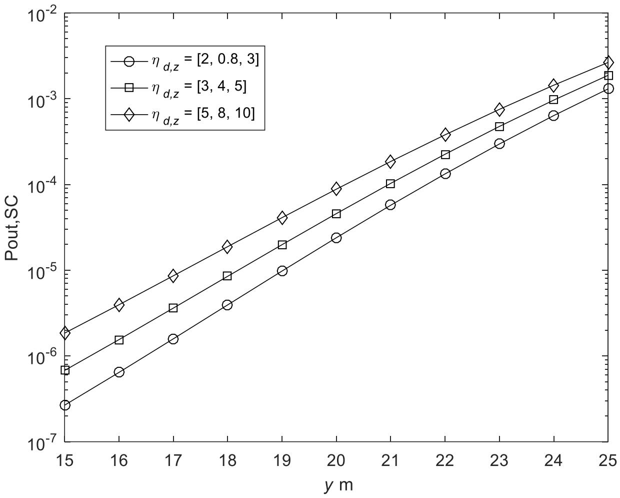

Fig. 3. Outage performance with various $\eta_{d,z}$ values of the D2D signal.

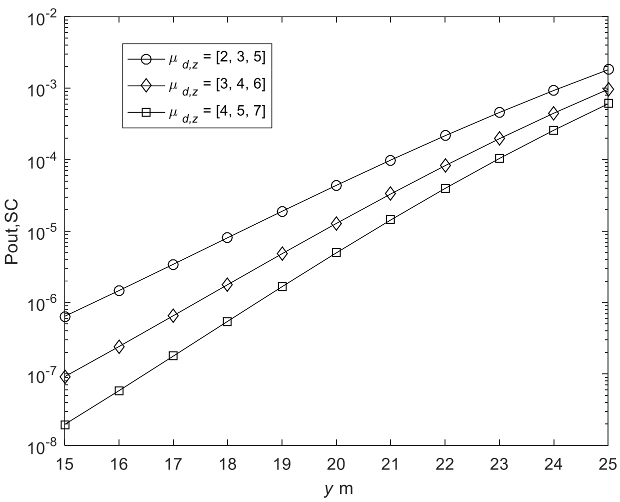

Fig. 4. Outage performance with various $\mu_{d,z}$ values of the D2D signal

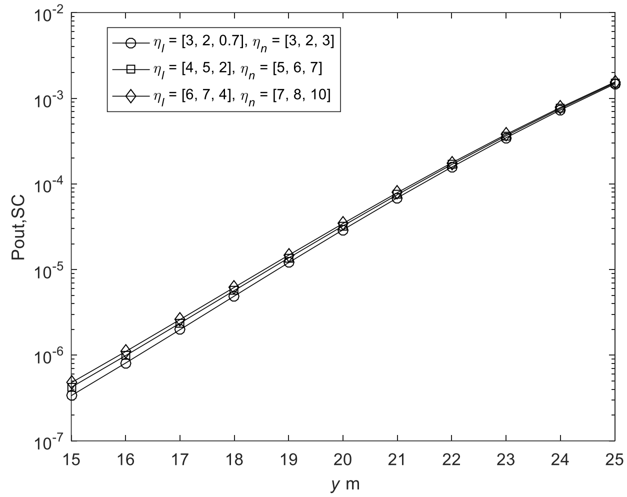

Fig. 5. Outage performance with various η_l and η_n values of CC1 signals.

Fig. 6 gives the outage analysis with various μ_l and $\mu_n$values of the CCI signals. With, R = 20 dBm, Q = 25 m, q = 3, $\eta_{d,z}$ = [3, 5, 8], $\mu_{d,z}$ = [2, 4, 5], η_l = [3, 4, 0.8] and η_n = [6, 5, 8]. From the figure, negligible effect is observed on the outage performance of the system when there is a change in the values of μ_l and μ_n. Fig. 7 gives the success analysis for the increasing value of R. With, Q = 20 m, q = 3.2, $\eta_{d,z}$ = [3, 5, 8], $\mu_{d,z}$ = [2, 4, 5], η_l = [3, 4, 0.8], μ_l = [4, 2, 5], μ_n = [3, 4, 6] and η_n = [6, 5, 8]. Figure 7 shows that the increase in the value of R causes the success performance of the system to degrade.

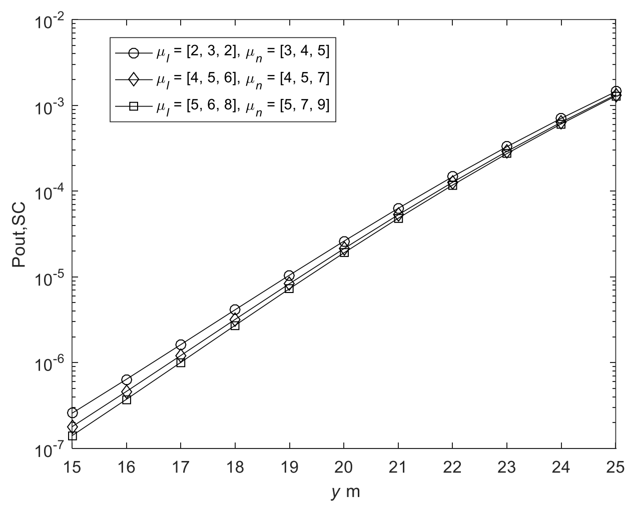

Fig. 6. Outage performance with various μ_l and μ_n values of the CCI signals.

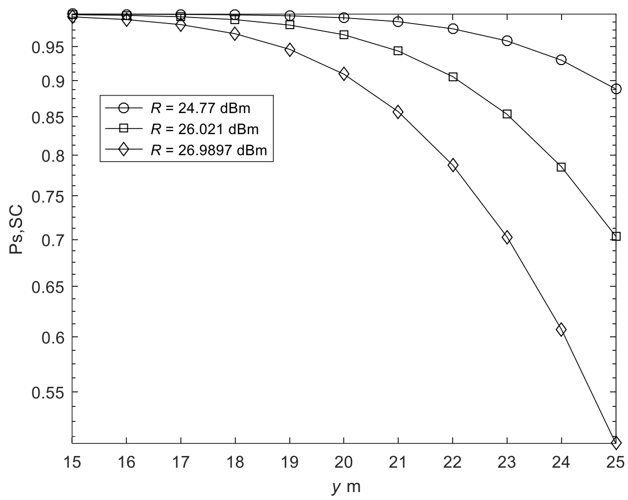

Fig. 7. Success performance with various values of R.

IV. CONCLUSION

The performance of success and outage of a relay-assisted D2D communication in the presence of CCI over a $\eta - \mu$ distributed channel is presented. In consideration are CCI at the relay and D2D receiver. Channel function (CF) based techniques are used to demonstrate the outage and success expression. Functions of various CCI parameters and channel conditions of D2D communication links guides to formulate the mentioned expressions. Numerical analysis shows that the outage performance degrades as the value of $\eta_{d,z}$ is increased and is improved as value of $\mu_{d,z}$ is increased. Furthermore, by changing the values of η_l, η_n, μ_l and μ_n outage of the system remains almost unaffected. Degradation in the success performance is noticed as value of R is increased.

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