D2D Relay-Assisted Communications over Lomax Fading Channels

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Abstract- A decode and forward relay-based device-to-device (D2D) system is analyzed over a novel Lomax fading channels. Co-channel interference (CCI) is also considered. Maximal ratio combining (MRC) techniques are present at relay and receiver to combat fading conditions. Analysis for outage, success and capacity with outage is done in this work. With the help of characteristic function approach all expressions are derived. These expressions are functions of Lomax fading parameters, path-loss, CCI conditions, diversity and distances between various devices in the system. Numerical results are presented and discussed under various scenarios of D2D system.

Index Terms- Co-Channel Interference, D2D Communication, Decode and Forward Relaying, Lomax Fading, Outage Probability

I. Introduction

DDevice-to-device (D2D) communication has opened new device-centric communication techniques that usually require no direct communication with the base stations. D2D communication has emerged as a key factor for improvement in cellular communication [1-3]. D2D nodes with the help of relays can enhance their range of communication. For example, in a decode and forward (DF) network an intermediate node can decode and forward the D2D signal to the end devices [4]. Due to ever competitive scenario of channel resources, issues like co-channel interference (CCI) take place. Hence, CCI is also considered in this work [5]. In [6], authors have presented the idea and address the challenges of the two-layer grid-based channel emulation technique to enable wireless channel emulator in the D2D. Authors in [7] presented an ultra-reliable and low-latency channel allocation for D2D networks in the presence of sporadic packet arrivals. In [8], authors discussed a reconfigurable intelligent surface aided D2D network to adjust its reflecting elements to improve D2D data rate as well as secrecy performance. In [9], authors have presented a resource allocation scheme to maximize the system sum rate, in the reconfigurable intelligent surface-assisted single-cell heterogeneous D2D communication scenario.

The aim of this paper is to present expressions of outage, success and capacity with outage [10] of a DF relay based D2D system with CCI. CCI is assumed to originate from wireless devices who have lost their coordination with our D2D system. The D2D and CCI channels follow a recently proposed Lomax distribution [11]. The main feature of Lomax distribution is its mathematically simpler form, which can be used to obtain mathematically tractable expressions. Characteristic function (CF) based technique is incorporated here to derive various analytical expressions. To the best of our knowledge, no work has incorporated the Lomax fading for the DF assisted D2D system in the presence of CCI. To combat fading conditions maximal ratio combining (MRC) techniques are present at relay and receiver. The rest of the paper is arranged as: The system model and analytical expressions are discussed in Section II. In Section III, numerical results are given, and finally paper is concluded in Section IV.

II. System Model

A DF relay-based D2D system over a recently proposed Lomax fading with CCI is presented in Fig. 1. In Table 1, Fig. 1 details are given. CCI signals are non-identically distributed and independent. There are L and M CCIs at relay and receiver, respectively. In DF scheme, D2D source first transmits a signal to relay, the relay decodes and re-encodes and forwards the information to receiver. Analysis is done for outage, success and capacity with outage.

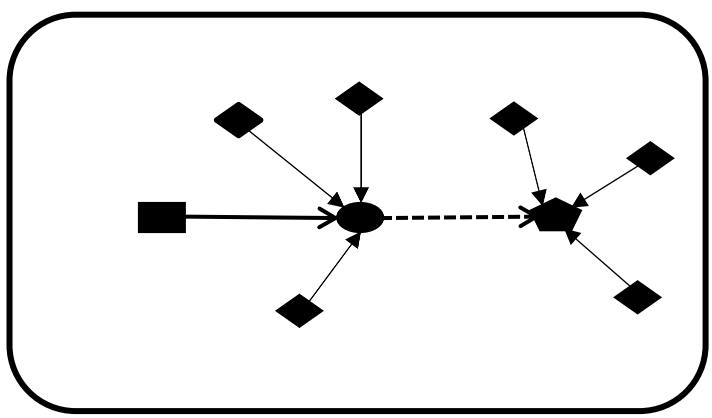
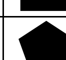
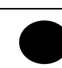


Fig.1. System Model

Table 1. Nomenclature for Fig. 1.

Source [D2D]	
Receiver [D2D]	
Relay	

D2D source-relay signal	→
Relay-D2D receiver signal	- →
D2D source-relay distance	x
Relay-D2D receiver distance	y
CCI	◆
CCI Signal	⟶
$l-th$ CCI-relay distance	q_l
$m-th$ CCI-receiver distance	s_m

For source to relay communications with Q branch MRC diversity at relay, signal-to-interference power ratio (SIR) is,

$$\frac{S_R}{S_{R,L}}=\frac{P_S x^a \sum_{q=1}^{Q}\alpha_q}{\sum_{l=1}^{L}P_{R,l}\,\beta_{R,l}q_l^{a_l}} \quad (1)$$

where S_R is D2D signal power at relay, $S_{R,L}$ is CCIs total power at relay, P_S is the power of transmitted D2D signal from the source,$P_{R,l}$ is the $l-th$ CCI's power at relay, a is the path-loss exponent of the source to relay channel and a_l is the $l-th$ CCI's path-loss exponent. α_q is the Lomax fading gain in the $q-th$ branch of relay and $\beta_{R,l}$ is the Lomax gain of $l-th$ CCI-relay channel. The outage occurs when the SIR falls below a defined threshold R, i.e.,$P_{out,R}=Pr(RS_{R,L}>S_R)$ where $Pr(.)$ is the probability. CF approach is considered in this work for the outage analysis. CF of decision parameter $\theta_R=R S_{R,L}-S_R$ is [11]

$$\phi_R(\omega)=E\left(e^{j\omega(RS_{R,L}-S_R)}\right)$$
$$=E\left(e^{j\omega RS_{R,L}}e^{j\omega(-S_R)}\right)$$
$$=E\left(e^{j\omega R\left[\sum_{l=1}^{L}P_{R,l}\beta_{R,l}q_l^{a_l}\right]}e^{-j\omega P_S x^a\sum_{q=1}^{Q}\alpha_q}\right)$$
$$=E\left(e^{-j\omega P_S x^a\sum_{q=1}^{Q}\alpha_q}\right)E\left(e^{j\omega R\left[\sum_{l=1}^{L}P_{R,l}\beta_{R,l}q_l^{a_l}\right]}\right)$$
$$=\prod_{q=1}^{Q}E\left(e^{-j\omega P_S x^a\alpha_q}\right)\prod_{l=1}^{L}E\left(e^{j\omega RP_{R,l}\beta_{R,l}q_l^{a_l}}\right)$$

$$\boldsymbol{\phi_R(\omega)=\prod_{q=1}^{Q}\lambda_q\,U\left(1,1-\lambda_q,-j\omega P_S x^a\Omega_q(1-\lambda_q)\right)}$$
$$\times\prod_{l=1}^{L}\boldsymbol{\lambda_{R,l}\,U\left(1,1-\lambda_{R,l},j\omega RP_{R,l}q_l^{a_l}\Omega_{R,l}(1-\lambda_{R,l})\right)} \quad (2)$$

where, $\lambda_q>1$ is the D2D signal's Lomax shape parameter [11] and $\Omega_q=E[\alpha_q]$ in the $q-th$ relay branch. $U(.,.,.)$ is the confluent hypergeometric function [12], $\lambda_{R,l}>1$ is the shape parameter and $\Omega_{R,l}=E[\beta_{R,l}]$ of $l-th$ CCI at relay. The outage probability at relay is,

$$P_{out,R}=\frac{1}{2}+\frac{1}{\pi}\int_0^{\infty}\frac{Im(\phi_R(\omega))}{\omega}d\omega \quad (3)$$

The integral in (3) can be solved with the help of MATLAB. For relay to receiver communications with N branch MRC diversity at receiver, SIR is,

$$\frac{S_D}{S_{D,M}}=\frac{P_R y^b\sum_{n=1}^{N}\alpha_{D,n}}{\sum_{m=1}^{M}P_{D,m}\beta_{D,m}s_m^{bm}} \quad (4)$$

where S_D is D2D signal power at receiver, $S_{D,m}$ is CCIs total power at receiver, P_R is the power of transmitted signal from relay,$P_{D,m}$ is the $m-th$ CCI's power at receiver, b is the path-loss exponent of the relay to receiver channel and b_m is the $m-th$ CCI's path-loss exponent. $\alpha_{D,n}$ is the D2D signal's Lomax fading gain in the $n-th$ branch of receiver and $\beta_{D,m}$ is the Lomax gain of $m-th$ CCI-receiver channel. Now,$P_{out,D}=Pr(RS_{D,M}>S_D)$, CF of $\theta_D=RS_{D,M}-S_D$ is,

$$\boldsymbol{\phi_D(\omega)=\prod_{n=1}^{N}\lambda_{D,n}\,U\left(1,1-\lambda_{D,n},-j\omega P_R y^b\Omega_{D,n}(1-\lambda_{D,n})\right)} \quad (5)$$
$$\times\prod_{m=1}^{M}\boldsymbol{\lambda_{D,m}\,U\left(1,1-\lambda_{D,m},j\omega RP_{D,m}s_m^{b_m}\Omega_{D,m}(1-\lambda_{D,m})\right)}$$

where $\lambda_{D,n}>1$ and $\Omega_{D,n}=E[\alpha_{D,n}]$ are Lomax parameters of D2D signal in the $n-th$ receiver branch. $\lambda_{D,m}>1$ and $\Omega_{D,m}=E[\beta_{D,m}]$ are Lomax parameters of $m-th$ CCI at receiver. The outage at receiver is,

$$P_{out,D}=\frac{1}{2}+\frac{1}{\pi}\int_0^{\infty}\frac{Im(\phi_D(\omega))}{\omega}d\omega \quad (6)$$

The overall outage of the system is,

$$P_T=P_{out,R}+P_{out,D}-P_{out,R}P_{out,D} \quad (7)$$

Success probability is the probability of SIR of the system exceeding threshold R. The overall success probability is of system is,

$$S_T=1-P_T \quad (8)$$

where P_T is given in (7). Overall capacity with outage [10] of the system is the rate correctly received over a channel, given as,

$$C_T=(1-P_T)\log_2(1+R)\ bps/Hz \quad (9)$$

III. NUMERICAL ANALYSIS

The numerical results based on the expressions of Section 2 are given here. Expressions derived in Section II are valid for arbitrary values. Table 2 shows the fixed parameter values.

Table 2. Fixed Valued Parameters

Parameters	Values
P_S	31.46 dBm
P_R	31.761 dBm
a	3
b	2.9
R	14.771 dBm
L	2
M	2
$P_{R,l}$	[29.031, 28.451] dBm
$P_{D,m}$	[29.5424, 29.031] dBm
q_l	[30, 35] m
s_m	[33, 36] m
a_l	[2.8, 3]
b_m	[2.7, 3.2]
Ω_q=$\Omega_{R,l}$=$\Omega_{D,n}$=$\Omega_{D,m}$	30 dBm

In Fig. 2, overall outage performance is shown for the varying distances between D2D source to relay and relay to D2D receiver. Parameters, a_l = [2.8, 3], b_m = [2.7, 3.2], λ_q= [3, 5], $\lambda_{R,l}$ = [2, 3], $\lambda_{D,n}$= [2, 7] and $\lambda_{D,m}$ = [3, 4]. The figure shows that by increasing the distances between source-relay and relay-receiver the outage performance degrades. It is also observed that outage performance is improved when the number of diversity branches is 2. Hence for the following analysis $Q = N = 2$.

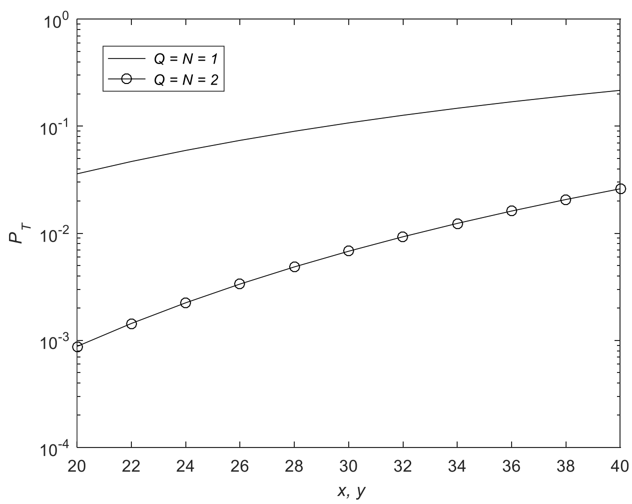


Fig. 2. Overall outage with varying distances between source-relay and relay-receiver.

In Fig. 3, outage analysis is shown for varying values of λ_q and $\lambda_{D,n}$. Parameters, a_l = [2.9, 3.1], b_m = [2.6, 3], $\lambda_{R,l}$ = [2, 3] and $\lambda_{D,m}$ = [3, 5]. From the figure it can be observed that as the values of λ_q and $\lambda_{D,n}$ are increased outage performance is improved. Because higher values of λ_q and $\lambda_{D,n}$ give low fading severity, however, for lower values of λ_q and $\lambda_{D,n}$, fading severity increases.

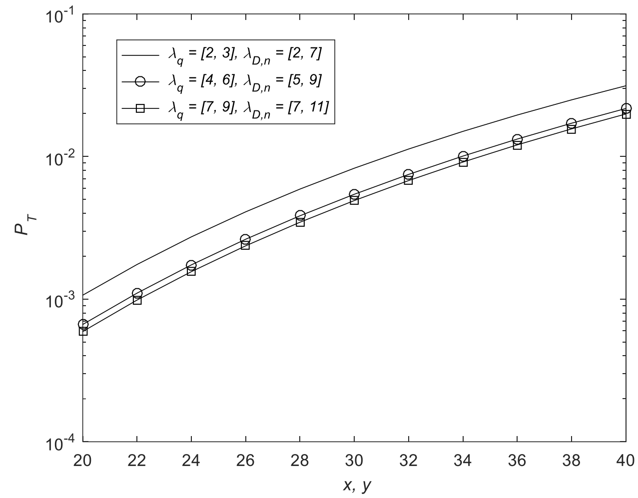


Fig. 3. Overall outage with varying values of λ_q and $\lambda_{D,n}$.

Fig. 4 shows the success analysis when the values of $\lambda_{R,l}$ and $\lambda_{D,m}$ are changed. Parameters, a_l = [2.9, 3.1], b_m = [2.6, 3], λ_q= [4, 5] and $\lambda_{D,n}$= [3, 4]. From the figure it is clear that the variation of CCIs parameters, $\lambda_{R,l}$ and $\lambda_{D,m}$, have negligible effect on the performance.

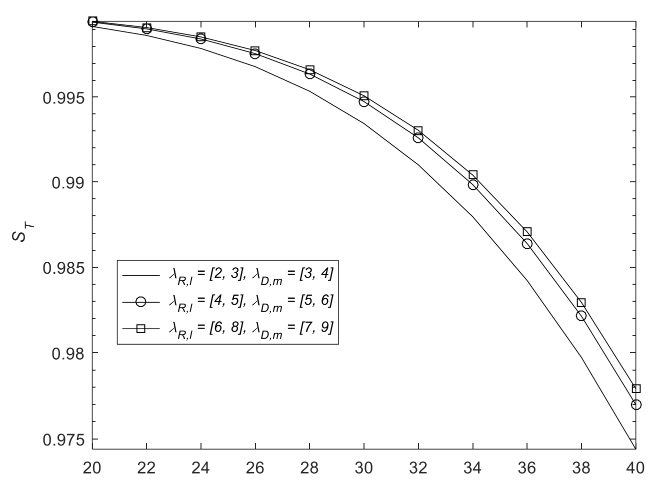


Fig. 4. Overall success analysis with varying CCIs parameters at relay and D2D receiver.

In Fig. 5, capacity with outage performance is given for various values of a_l and b_m. Now, λ_q= [4, 5], $\lambda_{R,l}$ = [5, 3], $\lambda_{D,n}$= [3, 4] and $\lambda_{D,m}$ = [6, 5]. It can be seen from the figure that as the values of CCIs path-loss at relay and receiver, a_l and b_m, increases capacity with outage performance of the system improves.

IV. CONCLUSION

Analysis of outage, success and capacity with outage is presented for DF relay-assisted D2D communication system over a recently proposed Lomax fading channel. To combat fading conditions MRC is present at relay and receiver. D2D system is also affected by CCI, which is present at relay and receiver. By using CF approach various expressions are derived. Numerical results showed the effects of Lomax channel parameters on the performance of D2D communications. However, Lomax parameters of CCI channels showed minimal effect on the system performance. Furthermore, by increasing the path-loss exponent of CCI improved system performance was observed.

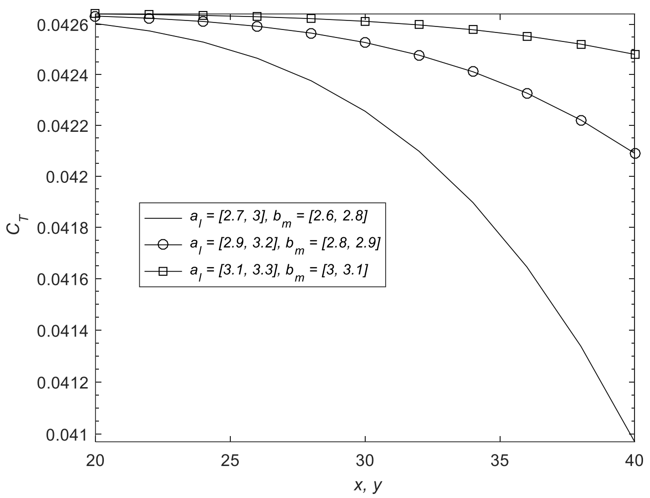


Fig. 5. Overall capacity with outage by varying a_l and b_m.

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