TABLE I
VLC CHANNEL MODELING PARAMETERS

Parameters	Values
Field of View (FOV)	60°
Incident (ϖ) and Radiation angle (θ)	0°and 30°
Optical concentrator gain $g(\varpi)$	1
Refractive index (n)	1.5
Detection area of PD (A_k)	1 cm^2
Optical filter gain $(\tau(\varpi))$	1
Euclidean distance of PD (d_k)	1m
PD responsivity (ζ)	0.4 A/W
Lambertian emission order (m)	1
DC bias offset I_{DC}	700 mA
Minimum DC offset I_L	600 mA
Maximum DC offset I_H	800 mA

Fig. 3. OP comparison of RSMA and NOMA-based VLC over Rayleigh and Rician fading channels

Now, the CEE is accounted for the outage analysis over the Rician distribution which is also modeled as i.i.d and its closed-form is mathematically realized as in (28). Also, the combined effect of CEE and residual noise can be analyzed for studying the system vulnerability towards outage and its final expression can be obtained as in (29). [Refer Appendix for equations (26)-(29)]. From the obtained final expressions of outage for the common part and private part, analyses with various key parameters are performed for RSMA-based VLC system under the impact of ICSI and ISIC in the upcoming section.

V. Results and Discussions

In this section, the analytical expressions of OP for downlink RSMA scenario aided through VLC is validated through MC simulation in MATLAB R2021b version for 10^6 iterations. An analysis is performed with both perfect and imperfect CSI and SIC over Rayleigh and Rician PDF, respectively. Also, the outage performance is analyzed for various threshold values with fixed transmit SNR. The power allocated for the common, private user 1, and private user 2 parts are $0.4,\ 0.3$ and 0.3

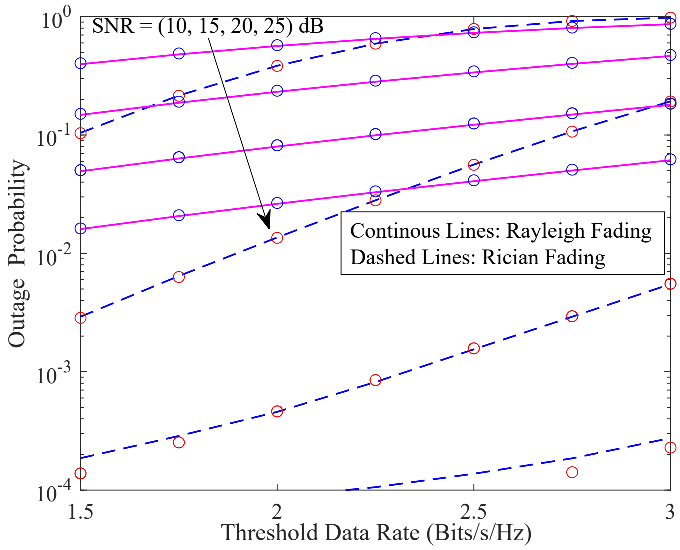

Fig. 4. OP of RSMA-based VLC for various threshold rates

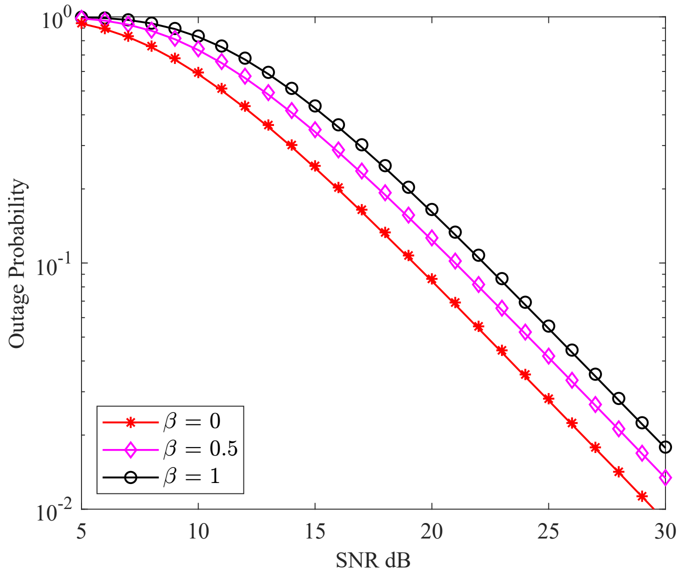

Fig. 5. OP of Rayleigh channel with various residual noise

respectively, with the threshold data rate of 2 $bits/s/Hz$. The parameters considered for VLC channel coefficient generation modeled through Lambertian emission to simulate the RSMA-based VLC system are listed in Table 1. Fig. 3 traces the OP of RSMA-based VLC system with transmit SNR varying from 10 to 30 dB for Rayleigh and Rician fading channels. Inference shows that as SNR approaches higher values, the system is less outage for both the fading channels due to high signal power. Since the Rician channel considers only LOS path and VLC scenario is aided, its performance is better compared to Rayleigh which accounts for LOS and NLOS paths. Furthermore, it is observed that an average of 10 dB gain is achieved with the Rician channel at a high SNR regime in the VLC-based communication.The analytical closed form expressions derived for OP are validated through MC simulation. Also, the OP of NOMA-based VLC system

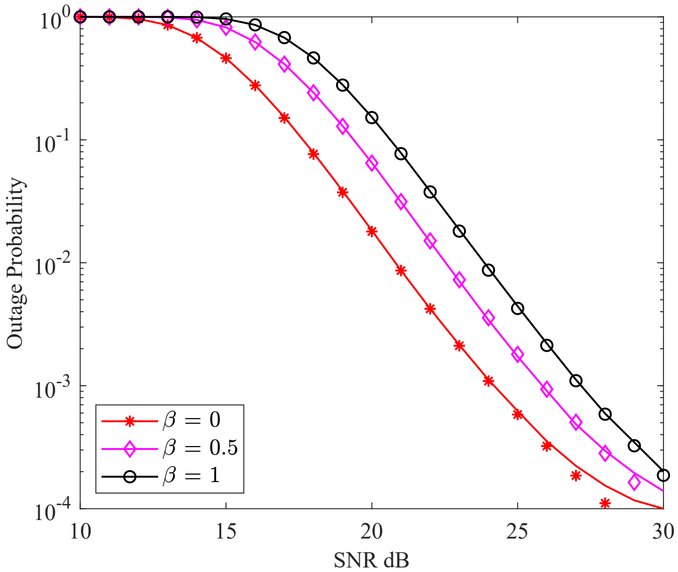

Fig. 6. OP of Rician channel with various residual noise

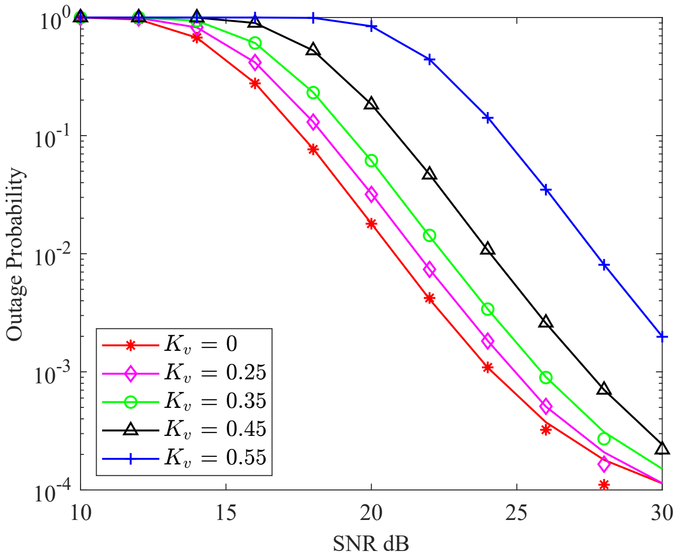

Fig. 8. OP for various ICSI over Rician fading channel

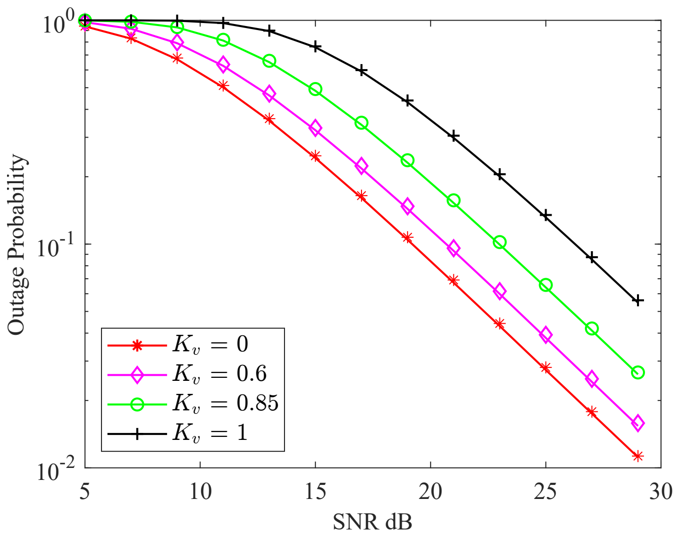

Fig. 7. OP for various ICSI over Rayleigh fading channel

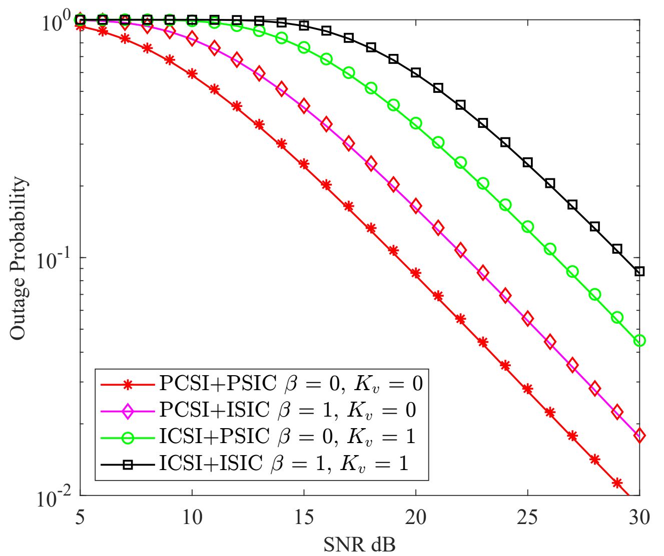

Fig. 9. OP for various ICSI and ISIC over Rayleigh channel

is traced out and contrast with RSMA which shows that a substantial gain is achieved by RSMA over the NOMA. For an outage of 10^{-2}, the RSMA system achieves a gain of $2\ dB$ and $4\ dB$ for Rayleigh and Rician fading channels respectively over the NOMA system. The effect on OP with varying threshold data rates for specific SNR values $(10, 15, 20, 25)\ dB$ over Rayleigh and Rician fading channels is shown in Fig. 4. At a high SNR regime, it is perceptible that OP is more in Rayleigh channel and comparatively performs inferior to Rician fading channel due to dominant LOS path. Moreover, as the threshold rate increases, the system outage increases because the reliability decreases for any fixed transmit SNR. Thus, optimal selection of threshold rate is necessary to make the system less outage.

Outage analysis of RSMA-based VLC system with various residual noise $(\beta = 0,\ 0.5,\ 1)$ over Rayleigh and Rician channels is performed and results are displayed in Fig. 5 and 6, respectively. An immediate observation is that at a low SNR regime, the system remains outage for both the fading environments as the signal power is weak and as SNR increases, the outage decreases and better performance is noted in the Rician channel. However, as residual noise increases, OP also increases due to the imperfection in SIC which contributes to additional noise at the PD.

Outage performance of the system under ICSI and perfect SIC over Rayleigh and Rician fading channels is depicted in Fig. 7 and Fig. 8 respectively. Inference reveals that as K_v increases, OP increases i.e., system performance gets degraded due to the CEE. Rayleigh fading channel provides high outage when compared to Rician fading channel due to presence of NLOS component. Finally, the performance of the system with ICSI and ISIC over Rayleigh and Rician fading channels is shown in Fig. 9 and Fig. 10 respectively. The residual noise and CEE parameters are varied within

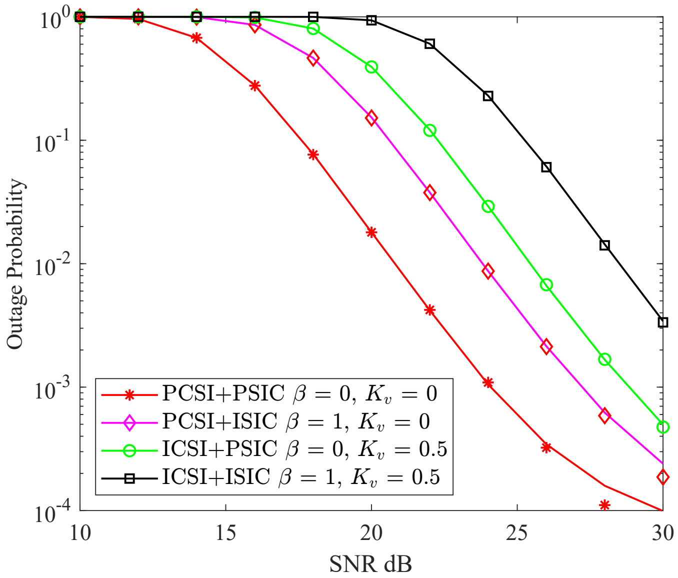

Fig. 10. OP for various ICSI and ISIC over Rician channel

the interval $0 \leq \beta, K_v \leq 1$ for investigation and inferred that OP increases with an increase in β and K_v due to additional noise during SIC and error in channel estimated conditions, respectively. Furthermore, it is evident that Rician fading performance is superior to the Rayleigh channel due to the strong LoS component.

VI. Conclusion

In this paper, an investigation on RSMA-based VLC for downlink scenario is performed. Firstly, we have derived the closed-form OP expressions for Rayleigh and Rician fading channels by considering its corresponding PDF under perfect and imperfect SIC and CSI, respectively. The derived analytical expressions are validated through MC simulations for verifying its correctness. Moreover, the OP analyses is carried out for various key parameters viz., threshold rate, PSIC, PCSI, ISIC and ICSI over Rayleigh and Rician fading channels. From the results of the analyses, it is shown that system outage is less for perfect SIC and CSI values in both the fading channels due to the absence of CEE and residual noise. Furthermore, it is evident that the QoS of RSMA-based VLC system improves with Rician channel due to the LOS component and more outage is observed in the Rayleigh fading channel. Also, the RSMA-based VLC system is compared with NOMA in terms of outage which enacts that RSMA outperforms NOMA-based VLC system. Thus, RSMA-based VLC system aids for indoor communication with enhanced QoS paving the way to 5GB applications with wider bandwidth and unlicensed spectrum. Extension to this work can be optimizing the VLC parameters viz., Lambertian emission order, the optical concentrator gain, detection area of the PD and the optical filter gain for modeling the channel in indoor environment, thereby enhancing the QoS.

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APPENDIX

$$P_{\text{out, private}} = 1 - Y_{\frac{1}{2}} \left(\sqrt{\frac{1+K}{\bar{\gamma}} \max\left\{ \frac{\gamma_t}{\rho \left[\mathbf{P}_k^2 - \gamma_t \mathbf{P}_{\mathcal{K}}^2\right]}, \frac{\gamma_t}{\rho \left[\mathbf{P}_{12}^2 - \gamma_t \left(\mathbf{P}_1^2 + \mathbf{P}_2^2\right)\right]} \right\}} \right) \tag{26}$$

$$P_{out,\ ISIC} \ = \ 1 - Y_{\frac{1}{2}} \left(2\sqrt{K}, \ \sqrt{\frac{1+K}{\bar{\gamma}} \ max\left\{ \frac{\gamma_t(\beta+1)}{\rho \left[\mathbf{P}_k^2 - \gamma_t \mathbf{P}_{\mathcal{K}}^2\right]} \ , \ \frac{\gamma_t(\beta+1)}{\rho \left[\mathbf{P}_{12}^2 - \gamma_t \left(\mathbf{P}_1^2 + \mathbf{P}_2^2\right)\right]} \right\}} \right). \tag{27}$$

$$P_{out,ICSI} = 1 - Y_{\frac{1}{2}} \left(2\sqrt{K}, \sqrt{\frac{1+K}{\bar{\gamma}} \ max\left\{ \frac{\gamma_t}{\rho \left[\mathbf{P}_k^2 - \gamma_t \ \left(\left(\mathbf{P}_{\mathcal{K}}\right)^2 + \left(K_v\right)^2 \right)\right]} \ , \ \frac{\gamma_t}{\rho \left[\mathbf{P}_{12}^2 - \gamma_t \left(\mathbf{P}_1^2 + \mathbf{P}_2^2 + \left(K_v\right)^2\right)\right]} \right\}} \right). \tag{28}$$

$$P_{out,ICSI,ISIC} = 1 - Y_{\frac{1}{2}} \left(2\sqrt{K}, \sqrt{\frac{1+K}{\bar{\gamma}} max\left\{ \frac{\gamma_t\left(\beta+1\right)}{\rho \left[\mathbf{P}_k^2 - \gamma_t \left(\left(\mathbf{P}_{\mathcal{K}}\right)^2 + \left(K_v\right)^2 \right) \right]}, \frac{\gamma_t\left(\beta+1\right)}{\rho \left[\mathbf{P}_{12}^2 - \gamma_t \left(\mathbf{P}_1^2 + \mathbf{P}_2^2 + \left(K_v\right)^2\right)\right]} \right\}} \right). \tag{29}$$

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