TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 4, August 2020, pp. 1828~1833
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i4.13716

Outage probability analysis in DF power-splitting full-duplex relaying network with impact of Co-channel interference at the destination

Phu Tran Tin[1], Duy Hung Ha[2], Minh Tran[3]
[1]Faculty of Electronics Technology, Industrial University of Ho Chi Minh City, Ho Chi Minh City, Vietnam
[2]Wireless Communications Research Group, Faculty of Electrical and Electronics Engineering,
Ton Duc Thang University, Ho Chi Minh City, Vietnam
[3]Optoelectronics Research Group, Faculty of Electrical and Electronics Engineering,
Ton Duc Thang University, Ho Chi Minh City, Vietnam

Article Info

Article history:

Received Jul 24, 2019
Revised Feb 25, 2020
Accepted Mar 18, 2020

Keywords:

Co-channel interference
Energy harvesting
Full-duplex
Outage probability

ABSTRACT

Nowadays, improving the WPCN efficiency problem is the leading research direction in the communication network. In this research, the outage probability (OP) analysis in DF power-splitting (PS) full-duplex (FD) Relaying Network with Impact of Co-channel interference at the destination is proposed and investigated. In the system model section, we present the DF PS FD Relaying Network with Impact of Co-channel interference at the destination. Then in the system performance section, we analyze and derive the closed-form expression of the OP and investigate the effect of the main system parameters on the system network performance. Then, we perform the Monte Carlo simulation to verify the analytical section. This research can provide a new recommendation for the communication network.

Corresponding Author:

Duy Hung Ha,
Wireless Communications Research Group,
Faculty of Electrical and Electronics Engineering,
Ton Duc Thang University,
Ho Chi Minh City, Vietnam.
Email: haduyhung@tdtu.edu.vn

1. INTRODUCTION

Recently, a wireless- powered communication network (WPCN) has been considered as the critical research direction based on the fact that its capability to deal with the energy scarcity in energy- constrained wireless networks [1-6]. In the latest researches, the energy harvesting (EH) and information transmission (IT) in WPCN with its advantages were presented in [7, 8]. Authors in [9] proposed the partial network-level cooperation for EH networks and resolved its problems. In [10], wireless EH and IT in cognitive relay networks were intensely investigated. Moreover, the WPCN with two TSP and PSP protocols have been popularly studied in recent researches, as shown in [11-15].

In this research, the outage probability (OP) analysis in DF power-splitting (PS) full-duplex (FD) relaying network with impact of Co-channel interference at the destination is proposed and investigated. In the system model section, we present the DF PS FD relaying network with impact of Co-channel interference at the destination. Then in the system performance section, we analyze and derive the closed-form expression of the OP and investigate the effect of the main system parameters on the system network performance. Then, we perform the Monte Carlo simulation to verify the analytical section. This research can provide a new

recommendation for a communication network. The main contribution of this paper can be drawn as the follows;
– The DF PS FD Relaying Network with Impact of Co-Channel Interference at the Destination is presented.
– The closed-form expression of the system OP is derived and investigated in the influence of the primary system parameters.
– The Monte Carlo simulation convinces all the results.

2. SYSTEM MODEL

The DF PS FD relaying network with impact of Co-channel interference at the destination is drawn in Figure 1. The energy harvesting (EH) and information transferring (IT) phases of the system model are drawn in Figure 2 [16-21]. In the transmission phase, the received signal at the R can be formulated as (1).

$$y_r = \sqrt{\rho} h_{sr} x_s + h_{rr} x_r + n_r \tag{1}$$

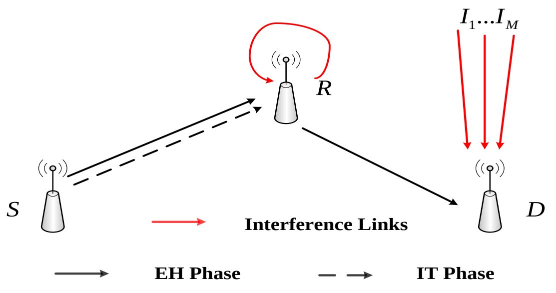

Figure 1. System model

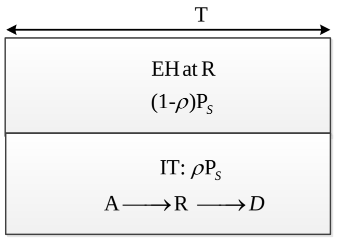

Figure 2. The EH and IT phases

The remaining power $\sqrt{1-\rho} P_s$ of the source will be employed for EH at the lay. Hence, the harvested power at the R can be obtained as (2).

$$P_r = \frac{E_h}{T} = \frac{\eta(1-\rho)P_s |h_{sr}|^2 T}{T} = \eta(1-\rho)P_s |h_{sr}|^2 \tag{2}$$

The received signal at the D can be given as (3):

$$y_D = h_{rd} x_r + \sum_{n=1}^{M} x_{I_n} h_{I_n D} + n_d \tag{3}$$

from (1), the signal to noise ratio (SNR) at the R can be formulated as the (4).

$$\gamma_1 = \frac{\rho |h_{sr}|^2 P_s}{|h_{rr}|^2 P_r + N_0} \tag{4}$$

From these (2) and (4), and using the fact that $N_0 << P_s$, the (4) can be rewritten as;

$$\gamma_1 \approx \frac{\rho}{\eta(1-\rho)|h_{rr}|^2} = \frac{\rho}{\eta(1-\rho)X} \tag{5}$$

where $X = |h_{rr}|^2$. Then the SNR at the D can be given by;

$$\gamma_2 = \frac{P_r \left|h_{rd}\right|^2}{N_0 + \sum_{n=1}^{M} P_{I_n} \left|h_{I_n D}\right|^2} = \frac{\eta(1-\rho) P_s \left|h_{sr}\right|^2 \left|h_{rd}\right|^2}{N_0 + \sum_{n=1}^{M} P_{I_n} \left|h_{I_n D}\right|^2}$$
$$= \frac{\eta(1-\rho)\psi \left|h_{sr}\right|^2 \left|h_{rd}\right|^2}{1 + \Delta \sum_{n=1}^{M} \left|h_{I_n D}\right|^2} = \frac{\eta(1-\rho)\psi Y}{1 + \Delta Z} \tag{6}$$

where $\psi = \frac{P_s}{N_0}$, $\Delta = \frac{P_I}{N_0}$, $Y = \left|h_{sr}\right|^2 \left|h_{rd}\right|^2$ and $Z = \sum_{n=1}^{M} \left|h_{I_n D}\right|^2$. Finally, the end to end SNR can be given by;

$$\gamma_{DF} = \min\left(\gamma_1, \gamma_2\right) \tag{7}$$

3. OUTAGE PROBABILITY ANALYSIS

- Remark 1:
  The probability density function (PDF) of random variable (RV) Z can be obtained as the following;

$$f_Z(t) = \frac{(\lambda_4)^M}{(M-1)!} t^{M-1} \exp(-\lambda_4 t) \tag{8}$$

- Outage probability (OP)

$$OP = \Pr\left(\gamma_{DF} < \gamma_{th}\right) = \Pr\left[\min\left(\gamma_1, \gamma_2\right) < \gamma_{th}\right]$$
$$= \Pr\left[\min\left(\frac{\rho}{\eta(1-\rho)X}, \frac{\eta(1-\rho)\psi Y}{1+\Delta Z}\right) < \gamma_{th}\right] \tag{9}$$

where $\gamma_{th} = 2^R - 1$ is the threshold of system, and R is the target rate. In (9) can be reformulated as the (10).

$$OP = 1 - \Pr\left[\frac{\rho}{\eta(1-\rho)X} \geq \gamma_{th}\right] \Pr\left[\frac{\eta(1-\rho)\psi Y}{1+\Delta Z} \geq \gamma_{th}\right] \tag{10}$$

The first term of (10) can be calculated as (11),

$$P_1 = \Pr\left[\frac{\rho}{\eta(1-\rho)X} \geq \gamma_{th}\right] = \Pr\left[X \leq \frac{\rho}{\eta(1-\rho)\gamma_{th}}\right] = 1 - \exp\left[-\frac{\lambda_1 \rho}{\eta(1-\rho)\gamma_{th}}\right] \tag{11}$$

where λ_1 is the mean of RV $\left|h_{rr}\right|^2$. The second term from (10) can be obtained by (12).

$$P_2 = \Pr\left[\frac{\eta(1-\rho)\psi Y}{1+\Delta Z} \geq \gamma_{th}\right] = 1 - \Pr\left[\eta(1-\rho)\psi Y < \gamma_{th}(1+\Delta Z)\right]$$
$$= 1 - \Pr\left[Y < \frac{\gamma_{th}(1+\Delta Z)}{\eta(1-\rho)\psi}\right]$$
$$= 1 - \int_0^\infty F_Y\left(\frac{\gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi} \mid Z = z\right) \times f_Z(z) dz \tag{12}$$

Next, the cumulative distribution function (CDF) of Y can be computed as (13).

$$F_Y(y) = \Pr(|h_{sr}|^2 |h_{rd}|^2 < y) = \Pr\left(|h_{sr}|^2 < \frac{y}{|h_{rd}|^2}\right)$$
$$= \int_0^\infty F_{|h_{sr}|^2}\left(\frac{y}{a} \,|\, |h_{rd}|^2 = a\right) \times f_{|h_{rd}|^2}(a)da \tag{13}$$
$$= 1 - \lambda_3 \int_0^\infty \exp\left(-\frac{\lambda_2 y}{a}\right) \times \exp(-\lambda_3 a)\, da$$

Applying eq (3.324,1) of the table of integral, (13) can be reformulated by (14).

$$F_Y(y) = 1 - 2\sqrt{\lambda_2\lambda_3 y} \times K_1\left(2\sqrt{\lambda_2\lambda_3 y}\right) \tag{14}$$

Using (14) and substituting (8) into (12), P_2 can be obtained as (15).

$$P_2 = 2\int_0^\infty \sqrt{\frac{\lambda_2\lambda_3\gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}} \times K_1\left(2\sqrt{\frac{\lambda_2\lambda_3\gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}}\right) \times \frac{(\lambda_4)^M}{(M-1)!} z^{M-1} \exp(-\lambda_4 z)dz \tag{15}$$

Substituting (11) and (15) into (10), the OP can be claimed by;

$$OP = 1 - 2\left(1 - \exp\left[-\frac{\lambda_1\rho}{\eta(1-\rho)\gamma_{th}}\right]\right) \times \left\{ \begin{array}{l} \int_0^\infty \sqrt{\frac{\lambda_2\lambda_3\gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}} \times K_1\left(2\sqrt{\frac{\lambda_2\lambda_3\gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}}\right) \\ \times \frac{(\lambda_4)^M}{(M-1)!} z^{M-1} \exp(-\lambda_4 z)dz \end{array} \right\} \tag{16}$$

4. NUMERICAL RESULTS AND DISCUSSION

In this section, we propose and investigate the influence of the primary system parameters on the OP of the proposed model system [21-25]. The influence of ψ and Δ on the system OP are drawn in Figures 3 and 4. In these Figures 3 and 4, we vary ψ from 5 to 25 dB and Δ from 0 to 25 dB. The main system parameters are set as R= 0.25 bps/Hz, ρ=0.5, η=0.8. From the results, as shown in Figure 3, we can see that the system OP crucially falls from 10 to 0 with the rising of ψ. In addition, the system OP has a massive increase from 0 to 1 with an increase of Δ. From the Figures 3 and 4, all the simulations are the same as the analytical results.

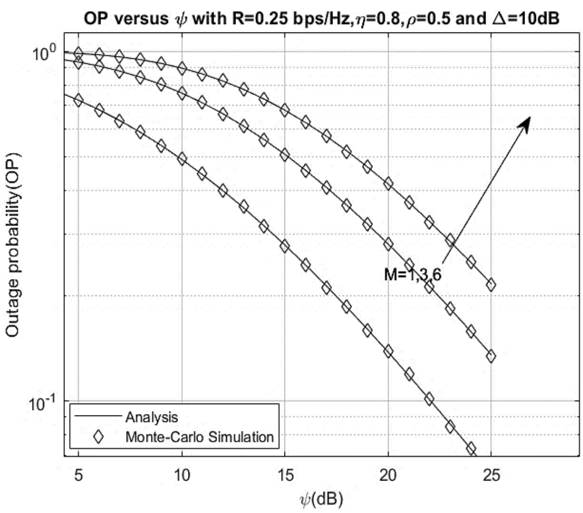

Figure 3. OP versus ψ

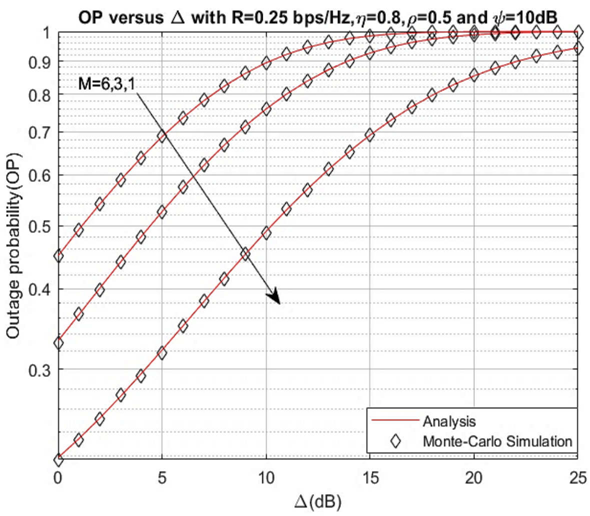

Figure 4. OP versus Δ

Moreover, the effect of ρ, R, and M on the system OP are proposed in Figures 5-7 with the main system parameters, as shown in Figures 5-7. In Figure 5, the system OP decreases when ρ varies from 0 to 0.3, and then has a considerable rise while ρ increases to 1. The optimal value of the system OP can be obtained with ρ from 0.2 to 0.3. Furthermore, the system OP increases significantly when R and M increase, as shown in Figures 6 and 7. In all figures the simulation and analytical results have a good agreement.

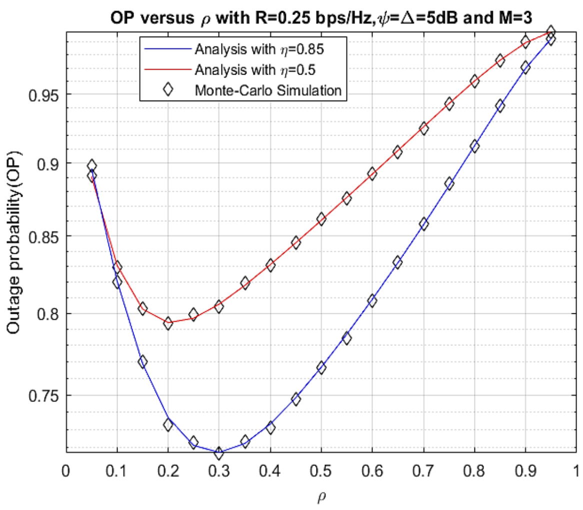

Figure 5. OP versus ρ

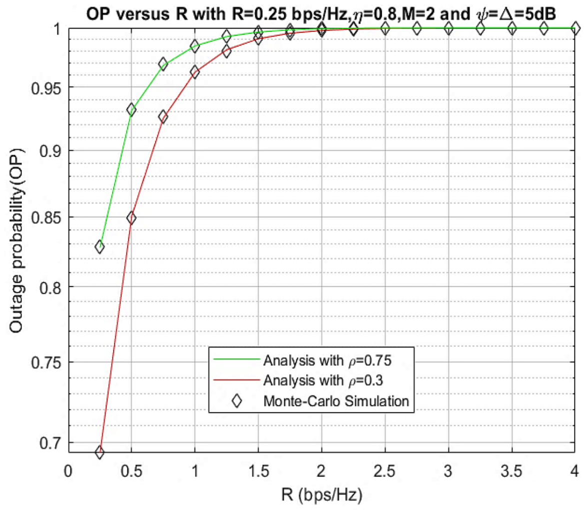

Figure 6. OP versus R

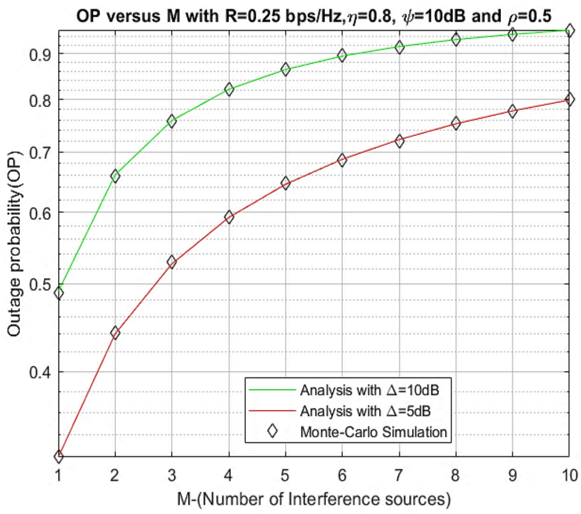

Figure 7. OP versus M

5. CONCLUSION

In this research, the OP Analysis in DF PS FD Relaying Network with Impact of Co-Channel Interference at the Destination is proposed and investigated. In the system model section, we present the DF PS FD Relaying Network with Impact of Co-Channel Interference at the Destination. Then in the system performance section, we analyze and derive the closed-form expression of the OP and investigate the effect of the main system parameters on the system network performance. Then, we perform the Monte Carlo simulation to verify the analytical section. This research can provide a new recommendation for a communication network.

REFERENCES

[1] Chen He, Chao Zhai, Yonghui Li, and Branka Vucetic, "Cooperative Strategies for Wireless-Powered Communications: An Overview," *IEEE Wireless Communications*, vol. 25, no. 4, pp. 112-19, 2018.

[2] Yu H., Lee H., & Jeon H., "What is 5G? Emerging 5G Mobile Services and Network Requirements," *Sustainability*, vol. 9, no. 10, 2017.

[3] Sharma V., & Karmakar P., "A Novel Method of Opportunistic Wireless Energy Harvesting in Cognitive Radio Networks," *7th International Conference on Computational Intelligence, Communication Systems and Networks*, 2015.

[4] Boccardi, Federico, Robert Heath, Angel Lozano, Thomas Marzetta, and Petar Popovski, "Five Disruptive Technology Directions for 5G," *IEEE Communications Magazine*, vol. 52, no. 2, pp. 74-80, 2014.

[5] Dai, Linglong, Bichai Wang, Yifei Yuan, Shuangfeng Han, Chih-Lin I, and Zhaocheng Wang, "Non-orthogonal Multiple Access for 5G: Solutions, Challenges, Opportunities, and Future Research Trends," *IEEE Communications Magazine*, vol. 53, no. 9, pp. 74-81, 2015.

[6] Saito, Yuya, Yoshihisa Kishiyama, Anass Benjebbour, Takehiro Nakamura, Anxin Li, and Kenichi Higuchi, "Non-Orthogonal Multiple Access (NOMA) for Cellular Future Radio Access," *2013 IEEE 77th Vehicular Technology Conference (VTC Spring)*, 2013.

[7] Varshney, Lav R., "Transporting Information and Energy Simultaneously," *2008 IEEE International Symposium on Information Theory*, 2008.

[8] Zhou, Xun, Rui Zhang, and Chin Keong Ho., "Wireless Information and Power Transfer: Architecture Design and Rate-energy Tradeoff," *2012 IEEE Global Communications Conference (GLOBECOM)*, 2012.

[9] Kashef, Mohamed, and Anthony Ephremides, "Optimal Partial Relaying for Energy-Harvesting Wireless Networks," *IEEE/ACM Transactions on Networking*, vol. 24, no. 1, pp. 113-22, 2016.

[10] Wang, Zihao, Zhiyong Chen, Yao Yao, Bin Xia, and Hui Liu, "Wireless Energy Harvesting and Information Transfer in Cognitive Two-way Relay Networks," *2014 IEEE Global Communications Conference*, 2014.

[11] Ju Minchul, Kyu-Min Kang, Kyu-Sung Hwang, and Cheol Jeong, "Maximum Transmission Rate of PSR/TSR Protocols in Wireless Energy Harvesting DF-Based Relay Networks," *IEEE Journal on Selected Areas in Communications*, vol. 33, no. 12, pp. 2701-717, 2015.

[12] Nguyen T. N., Do D. T., Tran P. T., and Voznak M., "Time Switching for Wireless Communications with Full-Duplex Relaying in Imperfect CSI Condition," *KSII Transactions on Internet and Information Systems*, vol. 10, no. 9, pp. 4223-4239, 2016.

[13] Gu Yanju, and Sonia Aissa, "RF-Based Energy Harvesting in Decode-and-Forward Relaying Systems: Ergodic and Outage Capacities," *IEEE Transactions on Wireless Communications*, vol. 14, no. 11, pp. 6425-434, 2015.

[14] Zhou, Zheng, Mugen Peng, Zhongyuan Zhao, and Yong Li, "Joint Power Splitting and Antenna Selection in Energy Harvesting Relay Channels," *IEEE Signal Processing Letters*, vol. 22, no. 7, pp. 823-27, 2015.

[15] Phu Tran Tin, Minh Tran, Tan N. Nguyen, Thanh-Long Nguyen, "System performance analysis of hybrid timepower switching protocol of EH bidirectional relaying network in amplify-and-forward mode," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 14, no. 1, pp. 2123-131, 2019.

[16] Tan N. Nguyen, T. H. Q. Minh, Phuong T., Tran and Miroslav Voznak, "Adaptive Energy Harvesting Relaying Protocol for Two-Way Half Duplex System Network over Rician Fading Channel," *Wireless Communications and Mobile Computing*, vol. 2018, pp. 1-10, 2018.

[17] Tin Phu Tran, Tran Hoang Quang Minh, Tan N. Nguyen, and Miroslav Voznak, "System Performance Analysis of Half-Duplex Relay Network over Rician Fading Channel," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 16, no. 1, pp. 189-199, 2018.

[18] Van-Duc Phan, Phu Tran Tin, Minh Tran, Tran Thanh Trang, "Outage probability analysis of DF PSR energy harvesting full-duplex relaying network with presence of the direct link using MRC technique," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 1, no. 2, pp. 606-613, 2019.

[19] Van-Duc Phan, Phu Tran Tin, Minh Tran, Tran Thanh Trang, "User selection protocols in FD PSP EH cooperative network over rayleigh fading channel: outage and intercept probability," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 10., no. 4, pp. 2130-2137, 2019.

[20] C. Zhong, H. Suraweera, G. Zheng, I. Krikidis, and Z. Zhang, "Wireless information and power transfer with full duplex relaying," *IEEE Trans. Commun*., vol. 62, no. 10, pp. 3447-3461, 2014.

[21] Daniel Zwillinger and Victor Moll, "Table of Integrals, Series, and Products," *Academic Press*, 2015.

[22] Nguyen T., Quang Minh T., Tran P., Vozňák M., "Energy Harvesting over Rician Fading Channel: A Performance Analysis for Half-Duplex Bidirectional Sensor Networks under Hardware Impairments," *Sensors*, vol. 18, no. 6, pp. 1-22, 2018.

[23] Tan N. Nguyen, T. H. Q. Minh, Phuong T. Tran, Miroslav Voznak, T. T. Duy, Thanh-Long Nguyen and Phu Tran Tin, "Performance Enhancement for Energy Harvesting Based Two-Way Relay Protocols in Wireless Ad-hoc Networks with Partial and Full Relay Selection Methods," *Ad hoc networks*, vol 84, pp. 178-187, 2019.

[24] Nguyen T. N., Minh T. H. Q., Nguyen T. L., Ha D. H., Voznak M., "Performance Analysis of User Selection Protocol in Cooperative Networks with Power Splitting Protocol Based Energy Harvesting Over Nakagami-m/Rayleigh Channel," *Electronics*, vol. 8, no. 448, pp. 1-14, 2019.

[25] Nguyen T. N., Minh T. H. Q., Nguyen T. L., Ha D. H., Voznak M., "Multi-Source Power Splitting Energy Harvesting Relaying Network in Half-Duplex System Over Block Rayleigh Fading Channel: System Performance Analysis," Electronics, vol. 8, no. 67, pp. 1-15, 2019.