Indonesian Journal of Electrical Engineering and Computer Science
Vol. 19, No. 2, August 2020, pp. 1095~1104
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v19.i2.pp1095-1104

Physical layer security in hybrid TPSR two-way half-duplex relaying networks over rayleigh fading channel: non-zero secrecy probability analysis

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 27, 2019
Revised Dec 4, 2019
Accepted Feb 1, 2020

Keywords:

Energy harvesting (EH)
Half-duplex (HD)
Monte carlo simulation
Non-zero secrecy probability (NZSP)
Relaying network

ABSTRACT

In this paper, we proposed and investigated the Hybrid TPSR Two-Way Half-Duplex (HD) Relaying Communication Networks Over Rayleigh Fading Channel in the presence of the Eavesdropper (E). The system model consists of two sources A and B communicate with each other with helping of intermediate Relay (R). For the system performance analysis, we analyzed and derived the exact and approximate integral-form of the system Non-zero secrecy probability (NZSP) in the case that the E uses the MRC (maximal ratio combining) technique. In addition, the effect of the main system parameters on the system performance is investigated. Finally, all the research results are convinced by the Monte Carlo Simulation. This paper can provide a novel recommendation for relaying communication network manufacture.

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

Radio frequency (RF) signals with excellent advantages, such as small dimensions, low cost, and independence concerning time and location in urban areas can be considered as electrical sources for cooperative network devices. In addition, RF signals can provide both information and energy in the communication network nodes through a well-known technique in the communication cooperative network called wireless powered networks (WPNs) [1-10]. The security issue is increasingly considered as the main study and improvements in wireless communications, especially the physical layer. Studies on the information exchange security have always been extensively performed for the upper layers, but currently, the security provided in the physical layer has gained significant importance. Physical-layer security (PLS) has recently attracted considerable attention since these approaches can prevent eavesdropping without data encryption in the upper layer [10-18].

In this paper, we proposed and investigated the Hybrid TPSR Two-Way Half-Duplex (HD) Relaying Communication Networks Over Rayleigh Fading Channel in the presence of the Eavesdropper (E). The system model consists of two sources A and B communicate with each other with helping of intermediate Relay (R). For the system performance analysis, we analyzed and derived the exact and approximate integral-form of the system Non-zero secrecy probability (NSP) in the case that the E uses the MRC (maximal ratio combining) technique. In addition, the effect of the main system parameters on the system performance is investigated. Finally, all the research results are convinced by the Monte Carlo Simulation.

2. SYSTEM MODEL

In this section, the system model is drawn in Figure 1 with two sources A and B communicate with each other with helping of intermediate Relay (R) in the presence of the Eavesdropper (E). The energy harvesting (EH) and information processing (IT) of the system model are proposed in Figure 2 as in [19-25].

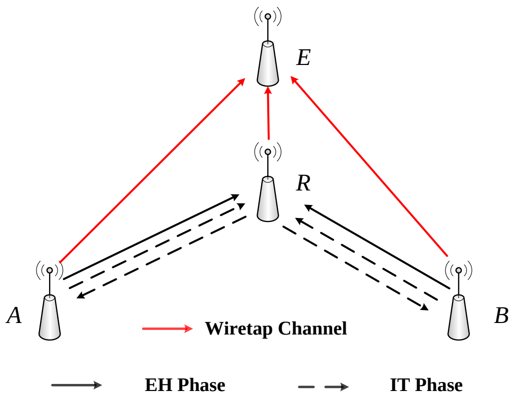

Figure 1. System model

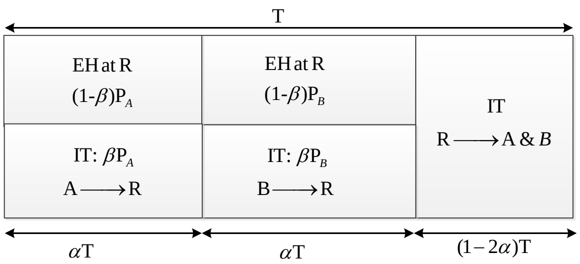

Figure 2. The EH and IT phases

2.1. Energy harvesting phase

In the first phase αT , A will transmit the message x_A with the power P_A and the signal received at R can be given by:

$$y_{AR} = \sqrt{\beta} h_{AR} x_A + n_R^1 \tag{1}$$

where n_R^1 is additive white Gaussian noise (AWGN) with variance δ_1^2 and h_{AR} is channel gain of A-R link and $\mathrm{E}\left\{|x_A|^2\right\} = P_A$ in which $\mathrm{E}\{\bullet\}$ is the expectation operator.

The EH relay employs a fixed power-splitting factor β to split the received RF power into two parts: $\sqrt{\beta}\left(h_{AR}x_A + n_R\right)$ is used for information transmission, and remaining power $\sqrt{1-\beta}\left(h_{AR}x_A + n_R\right)$ is used for EH. The amount of harvested energy during the first and second phase can be obtained as:

$$E_R = \eta(1-\beta)\alpha T\left(P_A|h_{AR}|^2 + P_B|h_{BR}|^2\right) \tag{2}$$

where $0 < \eta \le 1$ is energy conversion efficiency, P_B is the average transmitted power at the source B, and h_{BR} are the channel gain of B-R link. Moreover, $0 \le \beta < 1$ and $0 \le \alpha < 0.5$ is the power splitting and time-switching factor, respectively. We assume that $P_A = P_B = P$, (2) can be rewritten as

$$E_R = \eta(1-\beta)\alpha TP\left(|h_{AR}|^2 + |h_{BR}|^2\right) \tag{3}$$

The average transmitted power at the relay can be obtained as:

$$P_R = \frac{E_R}{T(1-2\alpha)} = \frac{\eta(1-\beta)\alpha TP\left(|h_{AR}|^2 + |h_{BR}|^2\right)}{T(1-2\alpha)} = \kappa P\left(|h_{AR}|^2 + |h_{BR}|^2\right) \tag{4}$$

where $\kappa = \frac{\eta(1-\beta)\alpha}{1-2\alpha}$

2.2. Information transmission phase

In the first phase, after doing EH, A will broadcast the information to relay node and B with remaining power βP_A . Hence, the received signal at R can be expressed as, respectively.

$$y_{AR} = \sqrt{\beta} h_{AR} x_A + n_R^1 \tag{5}$$

Similar to the first phase, the received signal at R can be given in the second phase,

$$y_{BR} = \sqrt{\beta} h_{BR} x_B + n_R^2 \tag{6}$$

where h_{BR} is channel gain of B-R link and $\mathrm{E}\left\{|x_B|^2\right\} = P_B$ and n_R^2 is AWGN with variance δ_2^2 Hence, the total received signal at R after A and B node transmit their signal can be expressed by:

$$y_R = \sqrt{\beta} h_{AR} x_A + \sqrt{\beta} h_{BR} x_B + n_R \tag{7}$$

where $n_R = n_R^1 + n_R^2$ denoted the total AWGN at R with variance N_0. Finally, in the third phase, the received signal at A and B node can be expressed as, respectively.

$$\begin{aligned} y_A &= h_{RA} x_R + n_A, \\ y_B &= h_{RB} x_R + n_B \end{aligned} \tag{8}$$

where h_{RA}, h_{RB} is channel gain of R-B link and R-A link, respectively, n_A, n_B is AWGN with variance N_0 at A and B node and $\mathrm{E}\left\{|x_R|^2\right\} = P_R$. In our proposed model, we will consider amplify and forward (AF) mode. In order to ensure that the transmission power at *R* is P_R, the amplifying coefficient μ can be chosen as,

$$\mu = \frac{x_R}{y_R} = \sqrt{\frac{\mathrm{P}_R}{\beta\left[P_A|h_{AR}|^2 + P_B|h_{BR}|^2\right] + N_0}} = \sqrt{\frac{\mathrm{P}_R}{\beta P\left[|h_{AR}|^2 + |h_{BR}|^2\right] + N_0}} \tag{9}$$

From (7) and combine with (5), (6), the received signal at A node can be rewritten as,

$$y_A = h_{RA}\mu\left(y_{AR} + y_{BR}\right) + n_A \tag{10}$$

Substituting (7) into (10), we can obtain as follows:

$$y_A = h_{RA}\mu\left(\sqrt{\beta}h_{AR}x_A + \sqrt{\beta}h_{BR}x_B + n_R\right) + n_A = \underbrace{h_{RA}\mu\sqrt{\beta}h_{BR}x_B}_{signal} + \underbrace{h_{RA}\mu\sqrt{\beta}h_{AR}x_A}_{self-interference} + \underbrace{h_{RA}\mu n_R + n_A}_{noise} \quad (11)$$

This signal contains both messages x_A and x_B, while only x_B is the desired signal at A. Since node A perfectly knows its own transmitted symbol x_A, it can eliminate the corresponding the self-interference term $h_{RA}\mu\sqrt{\beta}h_{AR}x_A$ from y_A Therefore, equation (11) can be rewritten by

$$y_A = \underbrace{h_{RA}\mu\sqrt{\beta}h_{BR}x_B}_{signal} + \underbrace{h_{RA}\mu n_R + n_A}_{noise} \quad (12)$$

The signal to noise ratio (SNR) at A node can be calculated by:

$$\gamma_A = \frac{\mathrm{E}\left\{|signal|^2\right\}}{\mathrm{E}\left\{|noise|^2\right\}} = \frac{|h_{RA}|^2|h_{BR}|^2\mu^2\beta P}{|h_{RA}|^2\mu^2 N_0 + N_0} \quad (13)$$

Substituting (5) into (9) and then doing some algebra, we have:

$$\gamma_A \approx \frac{\kappa\beta\Psi|h_{RA}|^2|h_{BR}|^2}{\kappa|h_{RA}|^2 + \beta} \quad (14)$$

where $\Psi = \dfrac{P}{N_0}$

In the total information transmission phase, while R will receive both legitimated message x_A and x_B from source node A and B, E will also overhear the information transmitted by A and B node. Thus, the received signal at E can be obtained as

$$y_E^1 = h_{AE}x_A + h_{BE}x_B + n_E \quad (15)$$

where h_{AE}, h_{BE} are the channel gain of A-E and B-E links, respectively and n_E is AWGN with variance N_0. During the broadcast signal phase, E also overhears the information from R. Hence, the received signal at E can be given by

$$\begin{aligned} y_E^2 &= h_{RE}x_R + n_E = h_{RE}\mu y_R + n_E \\ &= h_{RE}\mu\left(\sqrt{\beta}h_{AR}x_A + \sqrt{\beta}h_{BR}x_B + n_R\right) + n_E \end{aligned} \quad (16)$$

In our model, we will analyze the intercept (IP), non-zero secrecy (NZSP) and secrecy outage probability (SOP) at node A because our system model is symmetry and we can analyze at node A or node B. Therefore, from (15) and (16), the SNR at E to decode successful message of node A in two different phases can be claimed as, respectively.

$$\gamma_E^1 = \frac{|h_{AE}|^2 P_A}{|h_{BE}|^2 P_B + N_0} = \frac{|h_{AE}|^2\Psi}{|h_{BE}|^2\Psi + 1} \quad (17)$$

$$\gamma_E^2 = \frac{|h_{RE}|^2\mu^2\beta|h_{AR}|^2 P_A}{|h_{RE}|^2\mu^2\beta|h_{BR}|^2 P_B + |h_{RE}|^2\mu^2 N_0 + N_0} \approx \frac{\beta|h_{AR}|^2 P_A}{\beta|h_{BR}|^2 P_B + N_0} = \frac{\beta|h_{AR}|^2\Psi}{\beta|h_{BR}|^2\Psi + 1} \quad (18)$$

3. SYSTEM PERFORMANCE ANALYSIS

With MRC technique, E combines SNR from (17) and (18). Hence, the end to end SNR at E can be obtained by

$$\gamma_E^{MRC} = \gamma_E^1 + \gamma_E^2 = \frac{|h_{AE}|^2 \Psi}{|h_{BE}|^2 \Psi + 1} + \frac{\beta |h_{AR}|^2 \Psi}{\beta |h_{BR}|^2 \Psi + 1} \tag{19}$$

From (14) and (19), we can claim the capacities at nodes A and E, respectively.

$$C_A = \frac{(1-2\alpha)T}{3} \times \log_2 \left(1+\gamma_A\right),$$
$$C_E^{MRC} = \frac{(1-2\alpha)T}{3} \times \log_2 \left(1+\gamma_E^{MRC}\right) \tag{20}$$

3.1. Non-zero secrecy probability (NZSP) analysis

From (20), the secrecy capacity can be obtained by

$$C_{e2e}^{\text{Sec}} = \max\left[0, C_A - C_E^{MRC}\right] \tag{21}$$

The NZSP of the system can be formulated as followings after combine with (14) and (19):

$$\begin{aligned} NZSP &= \Pr\left(C_{e2e}^{\text{Sec}} > 0\right) = \Pr\left(C_A > C_E^{MRC}\right) = \Pr\left(\gamma_A > \gamma_E^{MRC}\right) \\ &= \Pr\left(\frac{\kappa\beta\Psi |h_{RA}|^2 |h_{BR}|^2}{\kappa |h_{RA}|^2 + \beta} > \frac{|h_{AE}|^2 \Psi}{|h_{BE}|^2 \Psi + 1} + \frac{\beta |h_{AR}|^2 \Psi}{\beta |h_{BR}|^2 \Psi + 1}\right) \\ &= \int_0^\infty \Pr\left(\tilde{\gamma}_E^{MRC} < \tilde{\gamma}_A\right) f_{|h_{BR}|^2}(y)dy \end{aligned} \tag{22}$$

where $\tilde{\gamma}_E^{MRC} = \frac{|h_{AE}|^2 \Psi}{|h_{BE}|^2 \Psi + 1} + \frac{\beta |h_{AR}|^2 \Psi}{\beta y \Psi + 1}$ and $\tilde{\gamma}_A = \frac{\kappa\beta\Psi |h_{RA}|^2 y}{\kappa |h_{RA}|^2 + \beta}$

3.2. Lemma 1. Exact analysis for NZSP

In (22), we have to define $\Pr\left(\tilde{\gamma}_E^{MRC} < \tilde{\gamma}_A\right)$

$$\Pr\left(\tilde{\gamma}_E^{MRC} < \tilde{\gamma}_A\right) = \int_0^\infty F_{\tilde{\gamma}_E^{MRC}}(\tilde{\gamma}_A \mid \tilde{\gamma}_A = x) f_{\tilde{\gamma}_A}(x)dx \tag{23}$$

The CDF of $\tilde{\gamma}_E^{MRC}$ and PDF of $\tilde{\gamma}_A$ can be calculated by:

$$\begin{aligned} F_{\tilde{\gamma}_E^{MRC}}(x) &= \Pr\left(\tilde{\gamma}_E^{MRC} < x\right) = \Pr\left(\frac{|h_{AE}|^2 \Psi}{|h_{BE}|^2 \Psi + 1} + \frac{\beta |h_{AR}|^2 \Psi}{\beta y \Psi + 1} < x\right) \\ &= \Pr\left(X + \tilde{Y} < x\right) = \int_0^x F_X(x - \tilde{Y} \mid \tilde{Y} = t) f_{\tilde{Y}}(t)dt \end{aligned} \tag{24}$$

where $X = \frac{|h_{AE}|^2 \Psi}{|h_{BE}|^2 \Psi + 1}$ and $\tilde{Y} = \frac{\beta |h_{AR}|^2 \Psi}{\beta y \Psi + 1}$

In (24), the CDF of X and $\tilde{Y}$ can be computed as, respectively.

$$
\begin{aligned}
F_X(x) &= \Pr\left(X < x\right) = \Pr\left(\frac{|h_{AE}|^2\Psi}{|h_{BE}|^2\Psi+1} < x\right) \\
&= \Pr\left(|h_{AE}|^2 < x|h_{BE}|^2 + \frac{x}{\Psi}\right) = \int_0^\infty F_{|h_{AE}|^2}\left(x|h_{BE}|^2 + \frac{x}{\Psi} \,|\, |h_{BE}|^2 = t\right)\times f_{|h_{BE}|^2}(t)dt \\
&= 1-\lambda_{BE}\times\exp\left[-\frac{\lambda_{AE}x}{\Psi}\right]\int_0^\infty \exp\left(-\lambda_{BE}t\right)\times\exp\left(-x\lambda_{AE}t\right)dt \\
&= 1-\frac{\lambda_{BE}\times\exp\left[-\frac{\lambda_{AE}x}{\Psi}\right]}{\lambda_{BE}+x\lambda_{AE}}
\end{aligned} \tag{25}
$$

$$
\begin{aligned}
F_{\tilde{Y}}(t) &= \Pr\left(\tilde{Y} < t\right) = \Pr\left(\frac{\beta|h_{AR}|^2\Psi}{\beta y\Psi+1} < t\right) = \Pr\left(|h_{AR}|^2 < \frac{t(\beta y\Psi+1)}{\beta\Psi}\right) \\
&= 1-\exp\left(-\frac{\lambda_{AR}t(\beta y\Psi+1)}{\beta\Psi}\right)
\end{aligned} \tag{26}
$$

Applying result from (25) and (26), we have as followings:

$$
F_X(x-t) = 1-\frac{\lambda_{BE}\times\exp\left[-\frac{\lambda_{AE}(x-t)}{\Psi}\right]}{\lambda_{BE}+(x-t)\lambda_{AE}} \tag{27}
$$

$$
f_{\tilde{Y}}(t) = \frac{\partial F_{\tilde{Y}}(t)}{\partial t} = \frac{\lambda_{AR}(\beta y\Psi+1)}{\beta\Psi}\times\exp\left(-\frac{\lambda_{AR}t(\beta y\Psi+1)}{\beta\Psi}\right) \tag{28}
$$

Substituting (27) and (28) into (24):

$$
\begin{aligned}
F_{\tilde{\gamma}_E^{MRC}}(x) &= \frac{\lambda_{AR}(\beta y\Psi+1)}{\beta\Psi}\int_0^x\left\{1-\frac{\lambda_{BE}\times\exp\left[-\frac{\lambda_{AE}(x-t)}{\Psi}\right]}{\lambda_{BE}+(x-t)\lambda_{AE}}\right\}\times\exp\left(-\frac{\lambda_{AR}t(\beta y\Psi+1)}{\beta\Psi}\right)dt \\
&= 1-\exp\left(-x\times r(y)\right)-r(y)\int_0^x\frac{\lambda_{BE}\times\exp\left[-\frac{\lambda_{AE}(x-t)}{\Psi}\right]\times\exp\left(-\frac{\lambda_{AR}t(\beta y\Psi+1)}{\beta\Psi}\right)}{\lambda_{BE}+(x-t)\lambda_{AE}}dt \\
&= 1-\exp\left(-x\times r(y)\right)-\frac{\lambda_{BE}}{\lambda_{AE}}r(y)\exp\left(-\frac{\lambda_{AE}x}{\Psi}\right)P_3
\end{aligned} \tag{29}
$$

where $r(y) = \frac{\lambda_{AR}(\beta y\Psi+1)}{\beta\Psi}$ and

$$
\begin{aligned}
P_3 &= \int_0^x\frac{\exp\left(-t\left[r(y)-\frac{\lambda_{AE}}{\Psi}\right]\right)}{\frac{\lambda_{BE}}{\lambda_{AE}}+(x-t)}dt = \int_0^x\frac{\exp\left(-t\times\tilde{r}(y)\right)}{g(x)-t}dt \\
&= \exp\left(-\tilde{r}(y)g(x)\right)\times\mathrm{Ei}\left(\tilde{r}(y)g(x)-t\times\tilde{r}(y)\right)\Big|_x^0 \\
&= \exp\left(-\tilde{r}(y)g(x)\right)\times\left[\mathrm{Ei}\left(\tilde{r}(y)g(x)\right)-\mathrm{Ei}\left(\tilde{r}(y)g(x)-x\times\tilde{r}(y)\right)\right]
\end{aligned} \tag{30}
$$

where $\tilde{r}(y) = r(y) - \frac{\lambda_{AE}}{\Psi}$ and $g(x) = \frac{\lambda_{BE}}{\lambda_{AE}} + x$

Next, we find the CDF of $\tilde{\gamma}_A$ as follows

$$F_{\tilde{\gamma}_A}(x) = \Pr\left(\tilde{\gamma}_A < x\right) = \Pr\left(\frac{\kappa\beta\Psi|h_{RA}|^2 y}{\kappa|h_{RA}|^2 + \beta} < x\right)$$
$$= \begin{cases} \Pr\left(|h_{RA}|^2 < \frac{x\beta}{\kappa(\beta\Psi y - x)}\right), y > \frac{x}{\beta\Psi} \\ 1 \qquad , y \le \frac{x}{\beta\Psi} \end{cases}$$
$$= \begin{cases} 1 - \exp\left[-\frac{\lambda_{RA} x\beta}{\kappa(\beta\Psi y - x)}\right], x < \beta\Psi y \\ 1 \qquad , x \ge \beta\Psi y \end{cases} \tag{31}$$

where λ_{RA} are mean of RV $|h_{RA}|^2$

From (31), the PDF of $\tilde{\gamma}_A$ can be computed by

$$f_{\tilde{\gamma}_A}(x) = \frac{\partial F_{\tilde{\gamma}_A}(x)}{\partial x} = \begin{cases} \frac{\lambda_{RA}\beta^2\Psi y}{\kappa\left(\beta\Psi y - x\right)^2} \times \exp\left[-\frac{\lambda_{RA} x\beta}{\kappa\left(\beta\Psi y - x\right)}\right], x < \beta\Psi y \\ 0 \qquad , x \ge \beta\Psi y \end{cases} \tag{32}$$

Substituting (29) and (32) into (23), we obtain:

$$\Pr\left(\tilde{\gamma}_E^{MRC} < \tilde{\gamma}_A\right) = \int_0^{\beta\Psi y} F_{\tilde{\gamma}_E^{MRC}}(\tilde{\gamma}_A \mid \tilde{\gamma}_A = x) f_{\tilde{\gamma}_A}(x) dx$$
$$= \int_0^{\beta\Psi y} \left\{1 - \exp\left(-x \times r(y)\right) - \frac{\lambda_{BE}}{\lambda_{AE}} r(y) \exp\left(-\frac{\lambda_{AE} x}{\Psi}\right) P_3\right\}$$
$$\times \frac{\lambda_{RA}\beta^2\Psi y}{\kappa\left(\beta\Psi y - x\right)^2} \times \exp\left[-\frac{\lambda_{RA} x\beta}{\kappa\left(\beta\Psi y - x\right)}\right] dx \tag{33}$$

Substituting (33) into (22); finally we claim as:

$$NZSP = \int_0^{\infty} \int_0^{\beta\Psi y} \left\{1 - \exp\left(-x \times r(y)\right) - \frac{\lambda_{BE}}{\lambda_{AE}} r(y) \exp\left(-\frac{\lambda_{AE} x}{\Psi}\right) P_3\right\} \times \frac{\lambda_{BR}\lambda_{RA}\beta^2\Psi y}{\kappa\left(\beta\Psi y - x\right)^2} \times \exp\left[-\frac{\lambda_{RA} x\beta}{\kappa\left(\beta\Psi y - x\right)} - \lambda_{BR} y\right] dxdy \tag{34}$$

3.3. Lemma 2. Asymptotic analysis for NZSP

At high SNR regime, (24) can be reformulated by

$$F_{\tilde{\gamma}_{E\_\infty}^{MRC}}(x) = \Pr\left(\tilde{\gamma}_{E\_\infty}^{MRC} < x\right) = \Pr\left(\frac{|h_{AE}|^2}{|h_{BE}|^2} + \frac{|h_{AR}|^2}{y} < x\right)$$
$$= \Pr\left(\tilde{X} + \tilde{Y} < x\right) = \int_0^x F_{\tilde{X}}(x - \tilde{Y} \mid \tilde{Y} = t) f_{\tilde{Y}}(t) dt \tag{35}$$

where $\tilde{X} = \frac{|h_{AE}|^2}{|h_{BE}|^2}, \tilde{Y} = \frac{|h_{AR}|^2}{y}$

The CDF of $\tilde{X}$ can be obtained as

$$F_{\tilde{X}}(x) = 1 - \frac{\lambda_{BE}}{\lambda_{BE} + x\lambda_{AE}} \tag{36}$$

The CDF and PDF of $\tilde{Y}$ can be computed as followings, respectively

$$\begin{aligned} F_{\tilde{Y}}(t) &= \Pr\left(\tilde{Y} < t\right) = \Pr\left(|h_{AR}|^2 < yt\right) = 1 - \exp(-\lambda_{AR} yt), \\ f_{\tilde{Y}}(t) &= \lambda_{AR} y \exp(-\lambda_{AR} yt) \end{aligned} \tag{37}$$

Substituting (36), (37) into (35), we have:

$$\begin{aligned} F_{\tilde{\gamma}_{E\_\infty}^{MRC}}(x) &= \int_0^x \left\{1 - \frac{\lambda_{BE}}{\lambda_{BE} + (x-t)\lambda_{AE}}\right\} \lambda_{AR} y \exp(-\lambda_{AR} yt) dt \\ &= 1 - \exp(-\lambda_{AR} xy) - \frac{\lambda_{BE}\lambda_{AR} y \tilde{P}_3}{\lambda_{AE}} \end{aligned} \tag{38}$$

where

$$\begin{aligned} \tilde{P}_3 &= \int_0^x \frac{\exp(-\lambda_{AR} yt) dt}{g(x) - t} = \exp\left(-\lambda_{AR} y g(x)\right) \times \mathrm{Ei}\left(\lambda_{AR} y g(x) - \lambda_{AR} yt\right)\Big|_x^0 \\ &= \exp\left(-\lambda_{AR} y g(x)\right) \times \left[\mathrm{Ei}\left(\lambda_{AR} y g(x)\right) - \lambda_{AR} y \times \mathrm{Ei}\left(\frac{\lambda_{BE}}{\lambda_{AE}}\right)\right] \end{aligned}$$

Similar as exact case, we can obtain:

$$NZSP^{\infty} = \int_0^{\infty} \int_0^{\beta\Psi y} \left\{1 - \exp(-\lambda_{AR} xy) - \frac{\lambda_{BE}\lambda_{AR} y \tilde{P}_3}{\lambda_{AE}}\right\} \times \frac{\lambda_{BR}\lambda_{RA}\beta^2\Psi y}{\kappa\left(\beta\Psi y - x\right)^2} \times \exp\left[-\frac{\lambda_{RA} x\beta}{\kappa\left(\beta\Psi y - x\right)} - \lambda_{BR} y\right] dxdy \tag{29}$$

4. NUMERICAL RESULTS AND DISCUSSION

The influence of α on the system NZSP is illustrated in Figure 3. In this stage, we set the main system parameters as η=0.8, β=0.5 and ψ=5, 10 dB, respectively. From the simulation results, we can state that the NZSP of the model system has a massive increase with the rising of α from 0.05 to 0.45. Furthermore, the NZSP is considered as the function of β, as shown in Figure 4. Here we set α=0.3, ψ=5 dB, and η=0.5, 0.8, respectively. We vary β from 0 to 1 as shown in Figure 4. As shown in Figure 4, NZSP increases when β rises from 0 to 0.4, after the optimal value, the NZSP has a huge decrease when β varies from 0.4 to 1. The maximum value of the system NZSP obtained with β from 0.4 to 0.5. From Figure 4 and Figure 5, we can see that the analytical and the simulation curves are the same to verify the correctness of the system performance analysis section.

Finally, the system NZSP versus η and ψ are considered in Figure 5 and Figure 6, respectively. In Figure 5, we set α=0.3, β=0.5 and ψ=5, 10 dB, and in Figure 6, we set α=0.3, β=0.5, respectively. From Figure 5 and Figure 6, it can be observed that the system NZSP has a massive increase with rising η from 0 to 1 and ψ from 0 to 40 dB, respectively. In addition, the simulation and analytical values of the system NZSP agree with each other to convince the performance analysis section.

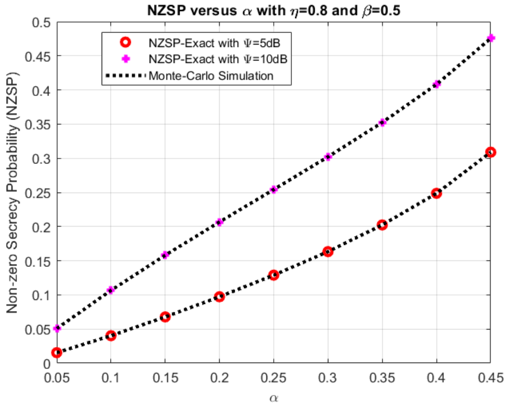

Figure 3. NZSP versus α

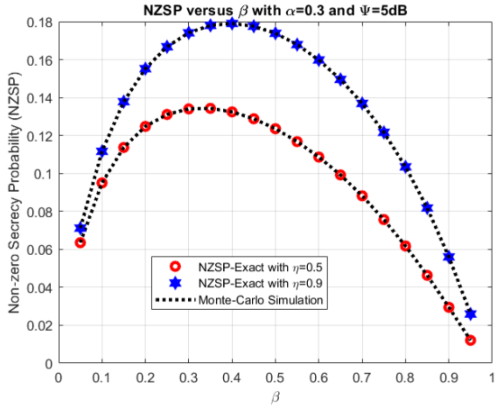

Figure 4. NZSP versus β

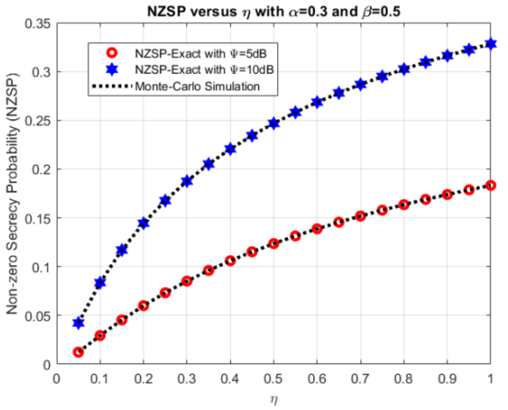

Figure 5. NZSP versus η

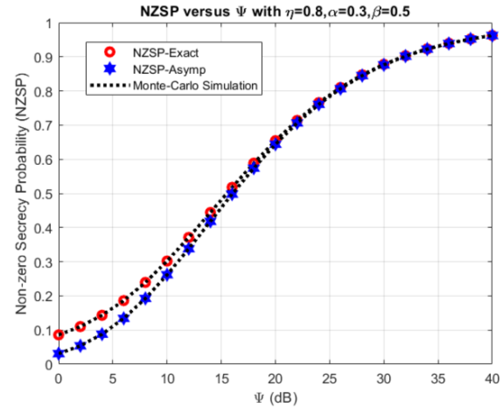

Figure 6. NZSP versus ψ

5. CONCLUSION

In this paper, we proposed and investigated the Hybrid TPSR Two-Way HD Relaying Communication Networks over Rayleigh Fading Channel in the presence of the Eavesdropper (E). For the system performance analysis, we analyzed and derived the exact and approximate integral-form of the system Non-zero secrecy probability (NSP) in the case that the E uses the MRC (maximal ratio combining) technique. In addition, the effect of the main system parameters on the system performance is investigated. Finally, all the research results are convinced by the Monte Carlo Simulation. This paper can provide a novel recommendation for relaying communication network manufacture.

REFERENCES

[1] S. Bi, et al., "Wireless powered communication: Opportunities and challenges," *IEEE Communications Magazine*, vol. 53, no. 4, pp. 117-125, 2015.

[2] D. Niyato, et al., "Wireless Powered Communication Networks: Research Directions and Technological Approaches," *IEEE Wireless Communications*, pp. 2-11, 2017.

[3] H. Yu, et al., "What is 5G? Emerging 5G Mobile Services and Network Requirements," *Sustainability*, vol. 9, no. 10, p. 1848, 2017.

[4] X. Zhou, et al., "Wireless Information and Power Transfer: Architecture Design and Rate-Energy Tradeoff," *IEEE Transaction on Communications*, vol. 61, no. 11, pp. 4754-4767, 2013.

[5] T. N. Nguyen, et al., "Multi-source in DF Cooperative Networks with the PSR Protocol Based Full-duplex Energy Harvesting over a Rayleigh Fading Channel: Performance Analysis," *Proceedings of the Estonian Academy of Sciences*, vol. 68, no. 3, pp. 264-275, 2019.

[6] Ngo Hoang An, Minh Tran, Tan N. Nguyen and Duy-Hung Ha,"Physical Layer Security in Hybrid TPSR Two-Way Half-Duplex Relaying Network over Rayleigh Fading Channel: Outage and Intercept Probability Analysis ", Electronics, Vol.9, No.3, Art.no.428,Mar.2020.

[7] T. N. Nguyen, et al., "Energy Harvesting over Rician Fading Channel: A Performance Analysis for Half-Duplex Bidirectional Sensor Networks under Hardware Impairments," Sensors, vol. 18, no. 6, p. 1781, 2018.
[8] T. N. Nguyen, et al., "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.
[9] D. Tin, et al., "Power Beacon Assisted Energy Harvesting Wireless Physical Layer Cooperative Relaying Networks: Performance Analysis," *Symmetry*, vol. 12, no. 1, p. 106, 2020.
[10] P. K. Gopala, et al., "On the Secrecy Capacity of Fading Channels," in *IEEE Transactions on Information Theory*, vol. 54, no. 10, pp. 4687-4698, Oct 2008.
[11] L. Sun and Q. Du, "A Review of Physical Layer Security Techniques for Internet of Things: Challenges and Solutions," *Entropy*, vol. 20, no. 10, p. 730, 2018.
[12] A. Kuhestani, et al., "Joint Relay Selection and Power Allocation in Large-Scale MIMO Systems with Untrusted Relays and Passive Eavesdroppers," *IEEE Transactions on Information Forensics and Security*, vol. 13, no. 2, pp. 341-355, 2017.
[13] L. Hu, et al., "Cooperative Jamming for Physical Layer Security Enhancement in Internet of Things," *IEEE Internet of Things Journal*, vol. 5, no. 1, pp. 219-228, 2018.
[14] P. T. Tin, et al., "Secrecy Performance Enhancement for Underlay Cognitive Radio Networks Employing Cooperative Multi-Hop Transmission with and without Presence of Hardware Impairments," *Entropy*, vol. 21, no. 2, p. 217, 2019.
[15] R. Zhao, et al., "Secrecy Performance Analysis of Cognitive Decode-and-Forward Relay Networks in Nakagami-m Fading Channels," *IEEE Transaction on Communications*, vol. 65, no. 2, pp. 549-563, 2017.
[16] P. T. Tin, et al., "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. 118-126, 2019.
[17] P. T. Tin, et al., "A new look at energy harvesting half-duplex DF power splitting protocol relay network over rician channel in case of maximizing capacity," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 13, no. 1, pp. 249-257, 2019.
[18] T. N. Nguyen, et al., "Performance Analysis of a User Selection Protocol in Cooperative Networks with Power Splitting Protocol-Based Energy Harvesting Over Nakagami-m/Rayleigh Channels," *Electronics*, vol. 8, no. 4, p. 448, 2019.
[19] T. N. Nguyen, et al., "Energy Harvesting over Rician Fading Channel: A Performance Analysis for Half-Duplex Bidirectional Sensor Networks under Hardware Impairments," *Sensors*, vol. 18, no. 6, p. 1781, 2018.
[20] P. T. Tin, et al., "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.
[21] H. Ju and R. Zhang, "Throughput Maximization in Wireless Powered Communication Networks," *IEEE Transaction Wireless on Communications*, vol. 13, no. 1, pp. 418-428, 2013.
[22] M. R. Bhatnagar, "On the Capacity of Decode-and-Forward Relaying over Rician Fading Channels," *IEEE Communications Letters*, vol. 17, no. 6, pp. 1100-1103, 2013.
[23] A. Jeffrey and D. Zwillinger, "Table of Integrals, Series, and Products," Springer, NY, USA, 2015.
[24] A. A. Nasir, et al., "Relaying Protocols for Wireless Energy Harvesting and Information Processing," *IEEE Transaction on Wireless Communications*, vol. 12, no. 7, pp. 3622-3636, 2013.
[25] T. N. Nguyen, et al., "Adaptive Energy Harvesting Relaying Protocol for Two-Way Half Duplex System Network over Rician Fading Channels," *Wireless Communications and Mobile Computing*, pp. 1-10, 2018.