Performance of multi-hop cognitive MIMO relaying networks with joint constraint of intercept probability and limited interference

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ABSTRACT

In this paper, we propose a multi-hop multiple input multiple output (MIMO) decode-and-forward relaying protocol in cognitive radio networks. In this protocol, a multi-antenna secondary source attempts to send its data to a multi-antenna secondary destination with assistance of multiple intermediate multi-antenna nodes, in presence of a multi-antenna secondary eavesdropper. A primary network includes a primary transmitter and a primary receiver which are equipped with multiple antennas, and use transmit antenna selection (TAS) and selection combining (SC) to communicate with each other. Operating on the underlay spectrum sharing method, the secondary source and relay nodes have to adjust their transmit power so that the outage performance of the primary network is not harmful and satisfy the quality of service (QoS). Moreover, these secondary nodes also reduce their transmit power so that the intercept probability (IP) at the eavesdropper at each hop is below a desired value. To improve the outage performance of the secondary network under the joint constraint of IP and limited interference, the TAS/SC method is employed to relay the source data hop-by-hop to the destination. We derived exact closed-form expressions of the end-to-end (e2e) outage probability (OP) and IP of the proposed protocol over Rayleigh fading channels. Monte Carlo simulations are then performed to verify the theoretical derivations.

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1. INTRODUCTION

Due to noises, co-channel interference, path loss and multi-path fading, quality of service (QoS) of wireless networks can be degraded. One of approaches for performance enhancement is MIMO (multiple input multiple output) [1-4], where transmitters can use transmit diversity methods (e.g., transmit antenna selection (TAS)), and receivers can use the receive diversity methods (e.g., SC (selection combining), MRC (maximal ratio combining)). In practical cases such as sensor nodes, the wireless devices cannot be equipped with multiple antennas due to constraint of size. Therefore, the MIMO-based diversity techniques cannot be applied for such single devices. To obtain diversity gain, diversity relaying techniques [5-10] can be used. J. N. Laneman *et al.* [5] proposed dual-hop cooperative communication protocols with MRC at the destination. T. T. Duy *et al.* [6] considered dual-hop decode-and-forward (DF) protocols with various relay selection strategies. The authors of [7] considered a multi-hop relaying protocol using amplify-and-forward (AF) method at all the relays. In [8], a multi-hop DF relaying protocol with various path-selection approaches was proposed. In [9, 10], a cooperative multi-hop relaying protocol was studied, where all the relays can exploit cooperative communication to enhance the end-to-end performances.

Recently, physical-layer security (PLS) [11-15] has gained much attention of researchers because PLS is not only simple but also effective. In this method, only characteristics of radio communication channels such as distance, channel quality, interference (or jamming noises) can be used to achieve security. From [2, 13, 14] evaluated the secrecy performance via the metric intercept probability (IP) at the eavesdropper. To reduce the IP and outage probability (OP) values, the transmitters can reduce their transmit power, and then the MIMO methods can be employed to enhance quality of the data link. Besides, cooperative jamming methods [16-19] can also be used o reduce the channel capacity of the eavesdropping links. However, implementation of the cooperative jamming techniques is too difficult because it requires a perfect interference cancelation at the receivers and high synchronization between the nodes.

This paper proposes the PLS-based multi-hop MIMO DF relaying protocol in cognitive radio networks. In the primary network, the primary transmitter uses TAS to send its data to the primary receiver equipped with the SC combiner. In the secondary network, the source and relay nodes have to adapt their transmit power so that QoS of the primary network is guaranteed, and IP at the eavesdropper is below a pre-determined value. In addition, the TAS/SC method is employed at each hop to enhance the channel capacity for the data links. To avoid the eavesdropper from combining the signals overheard over multiple hops, the secondary transmitters randomly generate code-book [20, 21]. Different with published work [22], all of the nodes in our proposed scheme are equipped with multiple antennas. Unlike [23], we propose an efficient method to determine the transmit power of the secondary transmitters under joint constraint of intercept probability and limited interference. For performance evaluation, an exact closed-form expression of the e2e outage probability (OP) of the secondary network over Rayleigh fading channels is derived, and verified the correction via Monte Carlo simulations. The rest of this paper is organized as follows. The system model of the proposed protocol is presented in section 2. Section 3 analyzes the OP and IP performances. Both simulation and theoretical results are shown in section 4, and section 5 concludes this paper.

2. SYSTEM MODEL AND OPERATION PRINCIPLE

In Figure 1, in the primary network, the N_{PT}-antenna primary transmitter (PT) sends its data to the N_{PR}-antenna primary receiver (PR), employing the TAS/SC method. In the secondary network, the source T_0 attempts to send its data to the destination T_M, using the multi-hop DF relaying approach with the help of $(M-1)$ secondary relays denoted by T_u, $u = 1,2, ...,$ $M-1$. Assume that $T_m(m = 1, ..., M)$ has K_T transmitting antennas and K_R receiving antennas. Next, there are *M* orthogonal time slots used, and the TAS/SC method is employed at each time slot to enhance the channel quality. Also, in the secondary network, the eavesdropper E with K_E antennas attempts to illegally obtain the source data at all the time slots. We denote $\varphi_{X^a,\mathrm{Y}^b}$ as channel gain between $a-$th antenna of a transmitter X and $b-$th antenna of a receiver Y. Because the channels are Rayleigh fading; $\varphi_{X^a,\mathrm{Y}^b}$ has an exponential distribution [24] whose cumulative distribution function (CDF) and probability density function (PDF) are given as;

$$F_{\varphi_{X^a,\mathrm{Y}^b}}(x) = 1 - exp\left(-\Omega_{\mathrm{X,Y}}x\right), f_{\varphi_{X^a,\mathrm{Y}^b}}(x) = \Omega_{\mathrm{X,Y}}\, exp\left(-\Omega_{\mathrm{X,Y}}x\right), \tag{1}$$

where $\Omega_{\mathrm{X,Y}} = d_{\mathrm{X,Y}}^{\mu}$ [25],μ is path-loss exponent, and $d_{\mathrm{X,Y}}$is distance between X and Y.

Let us consider the $T_{m-1} \rightarrow T_m$ and PT → PR data transmission at the $m-$th time slot, where $m = 1,2, \dots, M$. In this time slot, the TAS/SC methods are set up at the primary network and the secondary network, respectively as follows:

$$\varphi_{T_{m-1}^a,\mathrm{T}_m^b} = \max_{u=1,2,\dots,K_T}\left(\max_{v=1,2,\dots,K_R}\left(\varphi_{T_{m-1}^u,\mathrm{T}_m^v}\right)\right), \tag{2}$$

$$\varphi_{\mathrm{PT}^c,\mathrm{PR}^d} = \max_{u=1,2,\dots,N_{\mathrm{PT}}}\left(\max_{v=1,2,\dots,N_{\mathrm{PR}}}\left(\varphi_{\mathrm{PT}^u,\mathrm{PR}^v}\right)\right), \tag{3}$$

where *a* and *b* denote the antennas selected by T_{m-1} and T_m when performing the TAS/SC method, and *c* and *d* denote the antennas selected by PT and PR when performing the TAS/SC method, with $a \in \{1,2, \dots, K_T\}$,

$b \in \{1,2,\ldots,K_R\}, c \in \{1,2,\ldots,N_{\mathrm{PT}}\}$, $d \in \{1,2,\ldots,N_{\mathrm{PR}}\}$. Considering the eavesdropper E; since this node also uses the SC technique, the best receive antenna of E can be selected by using the following algorithm:

$$\varphi_{T_{m-1}^{a},\mathrm{E}^{e}} = \max_{r=1,2,\ldots,K_E}\left(\varphi_{T_{m-1}^{a},\mathrm{E}^{r}}\right), \tag{4}$$

where $e = 1,2,\ldots,N_E$. Next, the signal-to-interference-plus-noise ratio (SINR) obtained at PR, T_m and E can be given, respectively as

$$\psi_{\mathrm{PT}^{c},\mathrm{PR}^{d}} = \frac{P_{\mathrm{PT}}\max_{u=1,2,\ldots,N_{\mathrm{PT}}}\left(\max_{v=1,2,\ldots,N_{\mathrm{PR}}}\left(\varphi_{\mathrm{PT}^{u},\mathrm{PR}^{v}}\right)\right)}{P_{T_{m-1}}\varphi_{T_{m-1}^{a},\mathrm{PR}^{d}}+N_0}, \tag{5}$$

$$\psi_{T_{m-1}^{a},\mathrm{T}_{m}^{b}} = \frac{P_{T_{m-1}}\max_{u=1,2,\ldots,K_T}\left(\max_{v=1,2,\ldots,K_R}\left(\varphi_{T_{m-1}^{u},\mathrm{T}_{m}^{v}}\right)\right)}{P_{\mathrm{PT}}\varphi_{\mathrm{PT}^{c},\mathrm{T}_{m}^{b}}+N_0}, \tag{6}$$

$$\psi_{T_{m-1}^{a},\mathrm{E}^{e}} = \frac{P_{T_{m-1}}\max_{r=1,2,\ldots,K_E}\left(\varphi_{T_{m-1}^{a},\mathrm{E}^{r}}\right)}{P_{\mathrm{PT}}\gamma_{\mathrm{PT}^{c},\mathrm{E}^{e}}+N_0}. \tag{7}$$

In (5-7), P_{PT} is transmit power of PT, $P_{T_{m-1}}$ is transmit power of T_{m-1}that is derived later, and N_0 is variance of additive white Gaussian noise (AWGN) at all of the receivers. Then, we can formulate the instantaneous SINR of the primary link, the secondary data link, the secondary eavesdropping link at the $m -$ th time slot as follows:

$$C_{X^{x},\mathrm{Y}^{y}} = \frac{1}{M}log_2\left(1+\psi_{X^{x},\mathrm{Y}^{y}}\right), \tag{8}$$

where $(X^{x},\mathrm{Y}^{y}) \in \{(T_{m-1}^{a},\mathrm{T}_{m}^{b}), (\mathrm{PT}^{c},\mathrm{PR}^{d}), (T_{m-1}^{a},\mathrm{E}^{e})\}$.

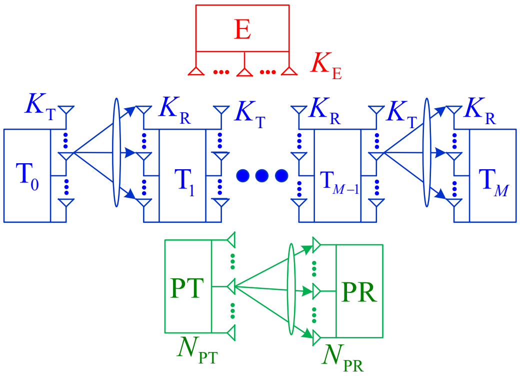

Figure 1. System model of the TAS/SC based multi-hop relaying protocol

3. RESEARCH METHOD

In this section, OP of the primary and secondary networks are evaluated. Besides, we also consider IP of eavesdropper at secondary networks. Then, we propose algorithms to allocate the transmit power for the secondary transmitters. Finaly, end to end OP will be derived exact closed-form expressions.

3.1. OP of the primary network at the $m -$ th time slot

Firstly, OP of the PT − PR link in the $m -$ th time slot can be defined as

$$\mathrm{OP}_{\mathrm{P},m} = Pr\left(C_{\mathrm{PT}^{c},\mathrm{PR}^{d}} < C_P\right) = Pr\left(\psi_{\mathrm{PT}^{c},\mathrm{PR}^{d}} < \theta_P\right), \tag{9}$$

where C_P is the target rate of the primary network, and $\theta_P = 2^{MC_P} - 1$. Combining (3) and (5) into (9), which yields;

$$\mathrm{OP}_{\mathrm{P},m} = \int_0^{+\infty} F_{\varphi_{\mathrm{PT}^c,\mathrm{PR}^d}}(\tau_P x + \omega_P)\, f_{\varphi_{T^a_{m-1},\mathrm{PR}^d}}(x)dx, \tag{10}$$

where $\tau_P = \theta_P P_{T_{m-1}}/P_{\mathrm{PT}}, \omega_P = \theta_P N_0/P_{\mathrm{PT}}$. Next, similar to [23, eq. (39)], we can write.

$$F_{\varphi_{\mathrm{PT}^c,\mathrm{PR}^d}}(\tau_P x + \omega_P) = 1 + \sum_{v=1}^{N_{\mathrm{PT}}N_{\mathrm{PR}}}(-1)^v C_{N_{\mathrm{PT}}N_{\mathrm{PR}}}^v\, exp\left(-v\Omega_{\mathrm{PT,PR}}\tau_P x\right) exp\left(-v\Omega_{\mathrm{PT,PR}}\omega_P\right). \tag{11}$$

From (1), (10) and (11), we can obtain (12) as follows:

$$\mathrm{OP}_{\mathrm{P},m} = 1 + \sum_{v=1}^{N_{\mathrm{PT}}N_{\mathrm{PR}}}(-1)^v C_{N_{\mathrm{PT}}N_{\mathrm{PR}}}^v \frac{\Omega_{T_{m-1},\mathrm{PR}}}{\Omega_{T_{m-1},\mathrm{PR}} + v\Omega_{\mathrm{PT,PR}}\tau_P} exp\left(-v\Omega_{\mathrm{PT,PR}}\omega_P\right). \tag{12}$$

3.2. IP of the eavesdropper at the $m -$ th time slot

Firstly, IP at E in the $m -$ th time slot can be defined as;

$$\mathrm{IP}_m = Pr\left(C_{T^a_{m-1},\mathrm{E}^e} \geq C_S\right) = Pr\left(\psi_{T^a_{m-1},\mathrm{E}^e} \geq \theta_S\right), \tag{13}$$

where C_S is target rate of the secondary network, and $\theta_S = 2^{MC_S} - 1$. Next, combining (4), (7) and (14); similar to the derivation method of $\mathrm{OP}_{\mathrm{P},m}$, we have

$$\mathrm{IP}_m = \int_0^{+\infty} \left[1 - F_{\varphi_{T^a_{m-1},\mathrm{E}^e}}(\tau_S x + \omega_S)\right] f_{\gamma_{\mathrm{PT}^c,\mathrm{E}^e}}(x)dx =$$

$$\sum_{v=1}^{K_E}(-1)^{v+1} C_{K_E}^v \frac{\Omega_{\mathrm{PT,E}}}{\Omega_{\mathrm{PT,E}} + v\Omega_{T_{m-1},\mathrm{E}}\tau_S} exp\left(-v\Omega_{T_{m-1},\mathrm{E}}\omega_S\right), \tag{14}$$

where $\tau_S = \theta_S P_T/P_{T_{m-1}}, \omega_S = \sigma_0^2\theta_S/P_{T_{m-1}}$.

3.3. Transmit power of the secondary transmitters

Firstly, T_{m-1} must adjust it transmit power to guarantee QoS of the primary network, i.e., $\mathrm{OP}_{\mathrm{P},m} \leq \varepsilon_P$ [15], where ε_P is a predefined threshold. By using the algorithm presented in Table 1, we can first find the solution $P_{T_{m-1}}^{(1)}$ of the equation $\mathrm{OP}_{\mathrm{P},m} = \varepsilon_P$. The algorithm in Table 1 can be explained briefly as follows. We first consider $\mathrm{OP}_{\mathrm{P},m}$ as a function of $P_{T_{m-1}}^{(1)}$, i.e., $\mathrm{OP}_{\mathrm{P},m}\left(P_{T_{m-1}}^{(1)}\right)$. It is obvious that if $\mathrm{OP}_{\mathrm{P},m}(0) \geq \varepsilon_P$, T_{m-1} cannot use the licensed band because QoS of the primary network is not guaranteed. If $\mathrm{OP}_{\mathrm{P},m}(0) < \varepsilon_P$, there exists a solution $P_{T_{m-1}}^{(1)}$ so that $\mathrm{OP}_{\mathrm{P},m} \leq \varepsilon_P$. Also, in Table 1, $P_{\mathrm{T,max}}$ and α are pre-designed parameter.

Next, the transmitter T_{m-1} attempts to reduce its transmit power so that IP_m obtained at E in this time slot must be below a desired value denoted by ρ_{IP}. Indeed, after determining $P_{T_{m-1}}^{(1)}$ as in the above algorithm; we can use the algorithm in Table 2 to obtain the value of $P_{T_{m-1}}$. This algorithm can be explained briefly as follows. We first consider IP_m as a function of $P_{T_{m-1}}$, i.e., $\mathrm{IP}_m\left(P_{T_{m-1}}\right)$. It is obvious that if $\mathrm{IP}_m\left(P_{T_{m-1}}^{(1)}\right) \leq \rho_{\mathrm{IP}}$, then $P_{T_{m-1}} = P_{T_{m-1}}^{(1)}$ is a solution. In the case where $\mathrm{IP}_m\left(P_{T_{m-1}}^{(1)}\right) > \rho_{\mathrm{IP}}$, the solution of $P_{T_{m-1}}P_{T_{m-1}}$ belongs to the interval $\left(0, P_{T_{m-1}}^{(1)}\right)$. Using the similar approach as in Table 1, we can find $P_{T_{m-1}}$.

Table 1. Algorithm for finding the solution $P_{T_{m-1}}^{(1)}$ of the equation $\mathrm{OP}_{\mathrm{P},m} = \varepsilon_P$

Steps	Procedures
1	Calculating $\mathrm{OP}_{\mathrm{P},m}(0)$; if $\mathrm{OP}_{\mathrm{P},m}\left(0\right) \geq \varepsilon_{\mathrm{P}}$, $P_{T_{m-1}}^{(1)} = 0$, else go to Step 2.

2	Setting P_{min}, PT,max$_{max}$, flag = 0;
	while flag = 0
	$P_{T_{m-1}}^{(1)} = (Pmax_{min}/2;)$ calculating $\mathrm{OP}_{\mathrm{P},m}\left(P_{T_{m-1}}^{(1)}\right)$;
	if $0 \leq \varepsilon_P - \mathrm{OP}_{\mathrm{P},m}\left(P_{T_{m-1}}^{(1)}\right) \leq \alpha$, flag = 1
	else if $\mathrm{OP}_{\mathrm{P},m}\left(P_{T_{m-1}}^{(1)}\right) < \varepsilon_P$, $P(Pmax_{min}/2)_{min}$
	else if $\mathrm{OP}_{\mathrm{P},m}\left(P_{T_{m-1}}^{(1)}\right) \geq \varepsilon_P$, $P(Pmax_{min}/2)_{max}$
	end

Table 2. Algorithm for finding $P_{T_{m-1}}$ to satisfy $\mathrm{IP}_m \leq \rho_{\mathrm{IP}}$

Steps	Procedures
1	Calculating $\mathrm{IP}_m\left(P_{T_{m-1}}^{(1)}\right)$; if $\mathrm{IP}_m\left(P_{\mathrm{T}_{m-1}}^{(1)}\right) \leq \rho_{\mathrm{IP}}$, $P_{T_{m-1}} = P_{T_{m-1}}^{(1)}$, else go to Step 2.

2	Setting Q_{min}, $Q\ {}^{(1)}_{T_{m-1},max}{}_{max}$, flag = 0;
	while flag = 0
	$P_{T_{m-1}} = (Qmax_{min}/2;)$ calculating $\mathrm{IP}_m\left(P_{T_{m-1}}\right)$;
	if $0 \leq \rho_{\mathrm{IP}} - \mathrm{IP}_m\left(P_{T_{m-1}}\right) \leq \alpha$, flag = 1
	else if $\mathrm{IP}_m\left(P_{T_{m-1}}\right) > \rho_{\mathrm{IP}}$, $Q(Qmax_{min}/2)_{max}$
	else if $\mathrm{IP}_m\left(P_{T_{m-1}}\right) \leq \rho_{\mathrm{IP}}$, $Q(Qmax_{min}/2)_{min}$
	end

3.4. End-to-end OP of the secondary network

Firstly, the end-to-end channel capacity of the data link can be formulated as;

$$C_D = \min_{m=1,2,\ldots,M}\left(C_{T_{m-1}^a,\mathrm{T}_m^b}\right) = \frac{1}{M}log_2\left(1 + \min_{m=1,2,\ldots,M}\left(\psi_{T_{m-1}^a,\mathrm{T}_m^b}\right)\right) \tag{15}$$

Therefore, the end-to-end OP of the data link can be defined as;

$$\mathrm{OP}_S = Pr(C_D < C_S) = 1 - \prod_{m=1}^{M}\left(1 - Pr\left(\psi_{T_{m-1}^a,\mathrm{T}_m^b} < \theta_S\right)\right), \tag{16}$$

Then, combining (2), (5) and (16), we have;

$$Pr\left(\psi_{T_{m-1}^a,\mathrm{T}_m^b} < \theta_S\right) = \int_0^{+\infty} F_{\varphi_{T_{m-1}^a,\mathrm{T}_m^b}}(\tau_S x + \omega_S) f_{\varphi_{\mathrm{PT}^c,\mathrm{T}_m^b}}(x)dx. \tag{17}$$

Similar to [23, in eq. (39)], CDF $F_{\varphi_{T_{m-1}^a,\mathrm{T}_m^b}}(\tau_S x + \omega_S)$ can be expressed as;

$$F_{\varphi_{T_{m-1}^a,\mathrm{T}_m^b}}(\tau_S x + \omega_S) = 1 + \sum_{v=1}^{K_T K_R}(-1)^v C_{K_T K_R}^v\, exp\left(-v\Omega_{T_{m-1},\mathrm{T}_m}\omega_S\right) exp\left(-v\Omega_{T_{m-1},\mathrm{T}_m}\tau_S x\right) \tag{18}$$

Combining (1), (17) and (18), after some manipulations, we obtain;

$$Pr\left(\psi_{T_{m-1}^a,\mathrm{T}_m^b} < \theta_S\right) = 1 - \sum_{v=1}^{K_T K_R}(-1)^{v+1}\frac{C_{K_T K_R}^v \Omega_{\mathrm{PT},\mathrm{T}_m}}{\Omega_{\mathrm{PT},\mathrm{T}_m} + v\Omega_{T_{m-1},\mathrm{T}_m}\tau_S} exp\left(-v\Omega_{T_{m-1},\mathrm{T}_m}\omega_S\right) \tag{19}$$

Substituting (19) into (16), we can obtain an exact closed-form expression of OP_S.

4. RESULTS AND DISCUSSION

In section 4, we present computer simulations using Monte Carlo method to validate the formulas derived in section 3 by Matlab. For simulation environment, we fix the position of the primary nodes as follows: PT (0.4,0.7) and PR (0.4,0.4), and the secondary nodes are located at $T_m(m/M, 0)$, $m = 0,1,\ldots,M$. More clearly, the source T_0 is at (0,0), the distance between T_0 and T_M is fixed by 1, and the d_{T_{m-1},T_m} is fixed by 1. For the E node, it is placed at (0.5,0.4). Next, the path-loss exponent (μ) is set to 3, the variance of the additive noises (N_0) is fixed 1, the number of antennas at PT and PR are $N_{\mathrm{PT}} = 3$, $N_{\mathrm{PR}} = 2$, the value of α and $P_{T,max}$ in Tables 1 and 2 is 0.00001 and 35 dB, respectively, the target rates are assigned by $C_P = 1$, $C_S = 0.75$, the OP threshold of the primary network is $\varepsilon_P = 0.05$, and the IP threshold at E is $\rho_{\mathrm{IP}} = 0.1$.

Figure 2 presents the transmit power of the source (T_0) and the relay (T_1) as a function of P_{PT} in dB when $M = 2$ (M). It is worth noting that the transmit power of T_0 and T_1 are obtained from algorithms presented in Tables 1 and 2 to satisfy two conditions: $\mathrm{OP}_{P,m} \leq \varepsilon_P$ and $\mathrm{IP}_m \leq \rho_{\mathrm{IP}}$ for all m. As seen in Figure 2, the transmit power of both the nodes linearly increases with the increasing of P_{PT}, and the transmit power of T_0 is higher than that of T_1. In Figure 3, the end-to-end OP of the secondary network is presented as a function of P_{PT} in dB when $M = 2$ and $K_R = 2$. As seen, the OP performance is better when increasing the number of the transmitting antennas equipped at the secondary nodes. Figure 3 shows that the OP values are very high when $K_T = 1$. Therefore, the performance of the secondary networks can be improved via increasing the number of antennas. We also see that the simulation results match very well with the theoretical ones, which confirms the correction of the derived equations in section 3.

In Figure 4, we assume that $K_T + K_R = 6$, and present the end-to-end OP of the secondary network follows P_{PT} in dB when $M = 2$. It is worth noting that the values of OP do not change when $K_T = n, K_R = 6 - n$ and $K_T = 6 - n, K_R = n$, where $n = 1,2,3$. Therefore, Figure 4 only presents the OP performance in three cases as follows: $K_T = 1, K_R = 5$; $K_T = 2, K_R = 4$ and $K_T = 3, K_R = 3$. As we can see, the OP performance is best when $K_T = 3, K_R = 3$.

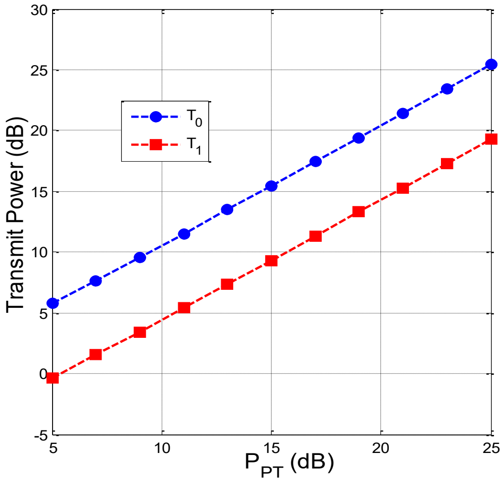

Figure 2. Transmit power of the secondary transmitters as a function of P_{PT} (dB) when $M = 2$

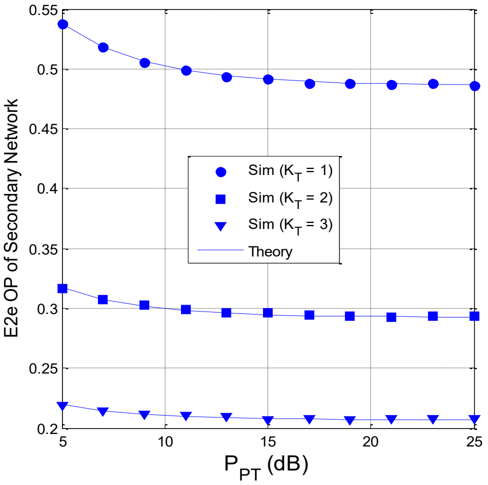

Figure 3. End-to-end outage probability of the secondary network as a function of P_{PT} (dB) when $M = 2$ and $K_R = 2$

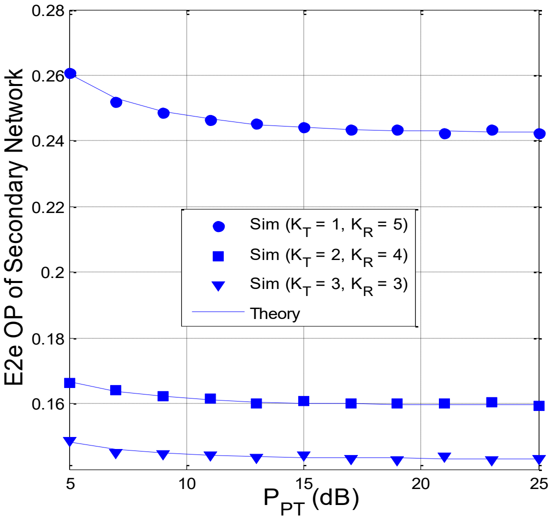

Figure 4. End-to-end outage probability of the secondary network as a function of P_{PT} (dB) when $M = 2$ and $K_T + K_R = 6$

5. CONCLUSION

This paper proposed and evaluated the e2e OP performance for multi-hop cognitive MIMO relaying protocols employing the TAS/SC technique in both the networks, in presence of the eavesdropper. We also proposed a simple algorithm to calculate the transmit power of the secondary transmitters to quarantee both the primary QoS and the secure transmission for the secondary network. The results in this paper showed that there were a trade-off between the secrecy performance and the data transmission reliability. For increasing the reliability or reducing the OP value can be done by increasing the transmit power for the secondary networks. However, the disadvantage of this method is that the intercept probability also increases accordingly. To reduce OP, the number of antennas at the primary and secondary users should be appropriately designed.

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