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Opportunistic Relaying Technique over Rayleigh Fading Channel to Improve Multicast Security

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Abstract

The performance of Rayleigh fading channels is substantially impacted by the impacts of relays, antennas, and the number of branches. Opportunistic relaying is a potent technique for enhancing the effects of the aforementioned factors while enhancing the performance of fading channels. Due to these issues, a secure wireless multicasting scenario using opportunistic relaying over Rayleigh fading channel in the presence of multiple wiretappers is taken into consideration in this study. So the investigation of a secure wireless multicasting scenario using opportunistic relaying over Rayleigh fading channel in the presence of multiple wiretappers is the focus of this paper. The primary goals of this study are to maximize security in wireless multicasting while minimizing security loss caused by the effects of relays, branches at destinations and wiretappers, as well as multicast users and wiretappers through opportunistic relaying. To comprehend the insight effects of prior parameters, the closed form analytical expressions are constructed for the probability of non-zero secrecy multicast capacity (PNSMC), ergodic secrecy multicast capacity (ESMC), and secure outage probability for multicasting (SOPM). The findings demonstrate that opportunistic relaying is a successful method for reducing the loss of security in multicasting.

Keywords

Ergodic Secrecy Multicast Capacity, Probability of Non-Zero Secrecy Multicast Capacity, Secure Wireless Multicasting, Secure Outage Probability for Multicasting

1. Introduction

Because of the diversification of application fields and users' mobility when using network components, wireless communication systems security is crucial. Furthermore, wireless communication is susceptible to fraud and wiretapping [1] [2] [3]. Video and voice conferencing and distance learning are examples of group-oriented applications where multicasting is a successful wireless data transmission technique [4]. Since wireless networks are open, they are susceptible to fraud and listening in. It is not possible to develop a secure foundation for multicasting using standard cryptology approaches. The physical layer security is essential for multicasting to obtain information-theoretic safety.

1.1. Related Works

Recently, in [5], authors consider a multicast network and investigate the secrecy performance using PRS with selection diversity over Rayleigh fading channels. In [6], authors focused only on one destination while analyzing the secrecy performance using PRS with selection diversity. In [7], authors only analyze the PNSMC using opportunistic relaying over Nakagami-m fading channels. In [8] and [9] respectively, an exclusive OR (XOR) operated point-to-point communication and a cognitive radio network were examined using PRS under security constraints. In [10], the diversity approach was applied under different fading environments. A multicasting cooperative network was also studied in [11] to investigate optimized secrecy performance. In [12], provides an investigation of the secrecy performance of the switch and stay partial relay selection. In [13], authors considered a multicast scenario that provides diversity to the destination users with opportunistic relaying in the absence of wiretapper. The multicast scenario with opportunistic relaying in the presence of combine effect of relays and branches at destinations and wiretappers, however, was not taken into consideration by the authors in the earlier publications. In order to minimize the loss of security caused by the impacts of relays, branches at destinations and wiretappers, as well as multicast users and wiretappers through opportunistic relaying, it is necessary to assure the security in wireless multicasting in this research.

1.2. Contributions

In this research, authors examined a secure wireless multicasting scenario over Rayleigh fading channels in the presence of multiple wiretappers. This study was inspired by the necessity of safety in multicasting and was based on the previously indicated condition that is documented in the literature. The authors created a mathematical model to forecast the safety in opportunistic relaying over Rayleigh fading channels. The following is a summary of this paper's main contributions.

- At first, authors deduced the analytical expression for cumulative distribution functions (CDFs) of signal-to-noise ratio (SNR) of best relay for source-to-destination link and source-to-wiretapper's link based on the probability density function (PDF) of Rayleigh fading channels.

- Secondly, authors generated the expression for PDFs of SNR of the best relay for source-to-destination link and source-to-wiretapper's link from these CDFs.
- Thirdly, using these PDFs of SNR of the best relay for source-to-destination link and source-to-wiretapper's link, authors deduced the expressions for the PDFs of minimum SNR of multicast channels and maximum SNR of wiretapper's channels.
- Fourthly, the authors developed the expressions for PNSMC, ESMC, and SOPM using the PDFs of minimum SNR of multicast channels and maximum SNR of wiretapper's channels. The PNSMC, ESMC, and SOPM will then be investigated based on the effect of relays, branches at destinations and wiretappers channels, multicast users and wiretappers, average SNR of the wiretappers channel.
- Finally, the provided analytical expressions are validated using Monte-Carlo simulation.

Following is how this document is structured for the remaining portions. System structure and Problem analysis are both treated in Sections II and III, respectively. The expressions for PNSMC, ESMC, and SOPM, respectively, are found in Sections IV, V, and VI. In Section VII, the numerical results are presented. Finally, the conclusions of this task are presented in Section VIII.

2. System Structure

In the presence of multiple wiretappers, Rayleigh fading channels are taken into consideration for the secure wireless multicasting communication circumstances depicted in Figure 1.

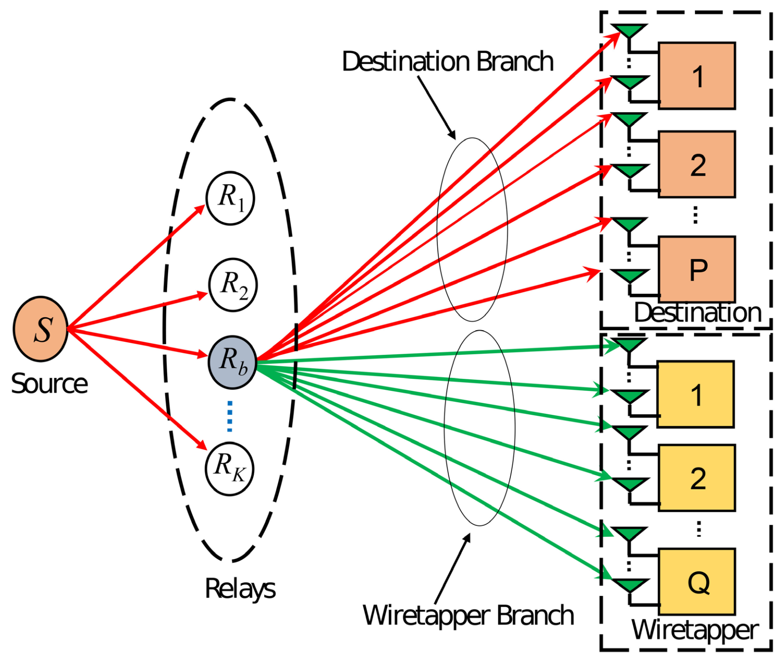

Figure 1. System structure.

The elements of this image are single source *S*, a collection of *K* relays, *P* destinations, *Q* wiretappers and the number of N_m and N_e branches at destinations and wiretappers respectively. Relays are used by the source to transmit a shared stream of privileged data to the *P* destinations. The wiretappers are attempting to decrypt the private data. By preventing this wiretapping, the goal of this thesis is to ensure secure communication between source and destinations. Multicast channels are those between the source and the destinations, whereas wiretappers channels are those between the source and the wiretappers.

3. Problem Analysis

The development of closed-form analytical equations for PDFs of multicast channels and wiretappers channels is the purpose of this section.

3.1. Rayleigh Fading Channels PDF

The symbol γ represents signal-to-noise ratio (SNR) of each sub-channel in a multicast channel. Then, for Rayleigh fading channels, PDF of γ represented by $f_\gamma(\gamma)$ is given by ([14], eq. (7.9))

$$f_\gamma(\gamma)=\frac{N}{\bar{\gamma}}\left(1-\mathrm{e}^{-\frac{\gamma}{\bar{\gamma}}}\right)^{N-1}\mathrm{e}^{-\frac{\gamma}{\bar{\gamma}}} \tag{1}$$

Putting the formula

$$(1-x)^n=\sum_{r=0}^{n}\binom{n}{r}(-1)^r x^r$$

in Equation (1), we get

$$f_\gamma(\gamma)=\frac{N}{\bar{\gamma}}\sum_{n=0}^{N-1}\binom{N-1}{n}(-1)^n\mathrm{e}^{-\left(\frac{1+n}{\bar{\gamma}}\right)\gamma}, \tag{2}$$

where *N* is the number of branch and $\bar{\gamma}$ is the average SNR for all branches.

3.2. PDF of SNR for Source-to-*k*th Relay

Let $\gamma_{s,k}$ represents SNR of source-to-*k*th relay. Then, PDF of $\gamma_{s,k}$ represented by $f_{\gamma_{s,k}}(\gamma_{s,k})$ for Rayleigh fading channels is shown by,

$$f_{\gamma_{s,k}}(\gamma_{s,k})=\frac{N_s}{\bar{\gamma}_s}\sum_{n=0}^{N_s-1}\binom{N_s-1}{n}(-1)^n\mathrm{e}^{-\left(\frac{1+n}{\bar{\gamma}_s}\right)\gamma_{s,k}}=s_1\mathrm{e}^{-s_2\gamma_{s,k}}, \tag{3}$$

where $s_1=\frac{N_s}{\bar{\gamma}_s}\sum_{n=0}^{N_s-1}\binom{N_s-1}{n}(-1)^n$, $s_2=\frac{1+n}{\bar{\gamma}_s}$.

3.3. PDF of SNR for *k*th Relay-to-*i*th Destination

Let $\gamma_{k,i}$ represents SNR of *k*th relay-to-*i*th destination. Then, PDF of SNR of $\gamma_{k,i}$ represented by $f_{\gamma_{k,i}}(\gamma_{k,i})$ for Rayleigh fading channel is shown by,

$$f_{\gamma_{k,i}}(\gamma_{k,i})=\frac{N_m}{\bar{\gamma}_m}\sum_{n=0}^{N_m-1}\binom{N_m-1}{n}(-1)^n\mathrm{e}^{-\left(\frac{1+n}{\bar{\gamma}_m}\right)\gamma_{k,i}}=d_1\mathrm{e}^{-d_2\gamma_{k,i}}, \tag{4}$$

where $d_1 = \frac{N_m}{\bar{\gamma}_m} \sum_{n=0}^{N_m-1} \binom{N_m-1}{n} (-1)^n$, $d_2 = \frac{1+n}{\bar{\gamma}_m}$.

3.4. PDF of SNR for *k*th Relay-to-*j*th Wiretapper

Let $\gamma_{k,j}$ represents SNR of *k*th relay-to-*j*th wiretapper. Then, PDF of SNR of $\gamma_{k,j}$ represented by $f_{\gamma_{k,j}}(\gamma_{k,j})$ for Rayleigh fading channels is given by,

$$f_{\gamma_{k,j}}(\gamma_{k,j}) = \frac{N_e}{\bar{\gamma}_e} \sum_{n=0}^{N_e-1} \binom{N_e-1}{n} (-1)^n \mathrm{e}^{-\left(\frac{1+n}{\bar{\gamma}_e}\right)\gamma_{k,j}} = e_1 \mathrm{e}^{-e_2 \gamma_{k,j}}, \tag{5}$$

where $e_1 = \frac{N_e}{\bar{\gamma}_e} \sum_{n=0}^{N_e-1} \binom{N_e-1}{n} (-1)^n$, $e_2 = \frac{1+n}{\bar{\gamma}_e}$.

3.5. CDF of SNR of Best Relay for Source-to-*i*th Destination

Let γ_i represents SNR of best relay for source-to-*i*th Destination. Then, CDF of γ_i represented by $F_{\gamma_{\Sigma_{d_i}}}(\gamma_i)$ for Rayleigh fading channels is shown by,

$$F_{\gamma_{\Sigma_{d_i}}}(\gamma_i) = \left\{F_{\gamma_{eqk}}(\gamma_i)\right\}^K = \left\{1 - Pr(\gamma_{s,k} > \gamma_i) Pr(\gamma_{k,i} > \gamma_i)\right\}^K, \tag{6}$$

where $Pr(\gamma_{s,k} > \gamma_i) \triangleq \int_{\gamma_i}^{\infty} f_{\gamma_{s,k}}(\gamma_{s,k}) \mathrm{d}\gamma_{s,k}$ and $Pr(\gamma_{k,i} > \gamma_i) \triangleq \int_{\gamma_i}^{\infty} f_{\gamma_{k,i}}(\gamma_{k,i}) \mathrm{d}\gamma_{k,i}$. Putting the value of $f_{\gamma_{s,k}}(\gamma_{s,k})$ and $f_{\gamma_{k,i}}(\gamma_{k,i})$, and using the following identity of

$$\int_x^{\infty} \mathrm{e}^{-bx} \mathrm{d}x = \frac{\mathrm{e}^{-bx}}{b}, \tag{7}$$

the value of $Pr(\gamma_{s,k} > \gamma_i)$ and $Pr(\gamma_{k,i} > \gamma_i)$ can be computed. Then, putting the value of $Pr(\gamma_{s,k} > \gamma_i)$ and $Pr(\gamma_{k,i} > \gamma_i)$ in Equation (6) and using the identity of

$$(1-x)^n = \sum_{r=0}^{n} \binom{n}{r} (-1)^r x^r \tag{8}$$

the expression for $F_{\gamma_{\Sigma_{d_i}}}(\gamma_i)$ can be derived as

$$F_{\gamma_{\Sigma_{d_i}}}(\gamma_i) = B_d \mathrm{e}^{-b_d \gamma_i}, \tag{9}$$

where $B_d = \sum_{k=0}^{K} \binom{K}{k} (-1)^k (A_d)^k$, $b_d = a_d k$.

3.6. CDF of SNR of Best Relay for Source-to-*j*th Wiretapper

Let γ_j represents SNR of best relay for source-to-*j*th Eavesdropper. Then, CDF of γ_j represented by $F_{\gamma_{\Sigma_{e_j}}}(\gamma_j)$, for Rayleigh fading channels is shown by,

$$F_{\gamma_{\Sigma_{e_j}}}(\gamma_j) = \left\{F_{\gamma_{qk}}(\gamma_j)\right\}^K = \left\{1 - Pr(\gamma_{s,k} > \gamma_j) Pr(\gamma_{k,j} > \gamma_j)\right\}^K, \tag{10}$$

where $Pr(\gamma_{s,k} > \gamma_j) \triangleq \int_{\gamma_j}^{\infty} f_{\gamma_{s,k}}(\gamma_{s,k}) \mathrm{d}\gamma_{s,k}$ and $Pr(\gamma_{k,j} > \gamma_j) \triangleq \int_{\gamma_j}^{\infty} f_{\gamma_{k,j}}(\gamma_{k,j}) \mathrm{d}\gamma_{k,j}$.

Putting the value of $f_{\gamma_{s,k}}(\gamma_{s,k})$ and $f_{\gamma_{k,j}}(\gamma_{k,j})$, and using the identities of Equations (7) and (8) the equation for the $F_{\gamma_{\Sigma_{e_j}}}(\gamma_j)$ can be deduced as

$$F_{\gamma_{\Sigma_{e_j}}}(\gamma_j) = B_e e^{-b_e \gamma_j}, \tag{11}$$

where $B_e = \sum_{k=0}^{K} \binom{K}{k} (-1)^k (A_e)^k$, $b_e = a_e k$.

3.7. PDF of SNR of Best Relay for Source-to-*i*th Destination

The PDF of γ_i denoted by $f_{\gamma_{\Sigma_{d_i}}}(\gamma_i)$ for Rayleigh fading channel is defined as

$$f_{\gamma_{\Sigma_{d_i}}}(\gamma_i) = K f_{\gamma_{eqk}}(\gamma_i) \left[F_{\gamma_{eqk}}(\gamma_i) \right]^{K-1}, \tag{12}$$

where the value of $f_{\gamma_{eqk}}(\gamma_i)$ can be derived from the expression which is stated as below

$$f_{\gamma_{eqk}}(\gamma_i) = \frac{\mathrm{d}}{\mathrm{d}\gamma_i} \left\{ F_{\gamma_{eqk}}(\gamma_i) \right\}. \tag{13}$$

Putting the value of $F_{\gamma_{eqk}}(\gamma_i)$ in Equation (13) and after differentiation, the expression of $f_{\gamma_{eqk}}(\gamma_i)$ is given by,

$$f_{\gamma_{eqk}}(\gamma_i) = A_d a_d e^{-a_d \gamma_i}, \tag{14}$$

where $A_d = \frac{s_1 d_1}{s_2 d_2}$ and $a_d = s_2 + d_2$. Finally, Putting the value of $f_{\gamma_{eqk}}(\gamma_i)$ and $F_{\gamma_{eqk}}(\gamma_i)$ in Equation (12) we get

$$f_{\gamma_{\Sigma_{d_i}}}(\gamma_i) = C_d e^{-c_d \gamma_i}, \tag{15}$$

where $C_d = K A_d a_d \sum_{k=0}^{K} \binom{K}{k} (-1)^k (A_d)^k$, $c_d = a_d (1+k)$.

3.8. PDF of SNR of Best Relay for Source-to-*j*th Wiretapper

The PDF of γ_j denoted by $f_{\gamma_{\Sigma_{e_j}}}(\gamma_j)$ for Rayleigh fading channel is defined as

$$f_{\gamma_{\Sigma_{e_j}}}(\gamma_j) = K f_{\gamma_{qk}}(\gamma_j) \left[F_{\gamma_{qk}}(\gamma_j) \right]^{K-1}. \tag{16}$$

The value of $f_{\gamma_{qk}}(\gamma_j)$ is determined as follows,

$$f_{\gamma_{qk}}(\gamma_j) = \frac{\mathrm{d}}{\mathrm{d}\gamma_j} \left\{ F_{\gamma_{qk}}(\gamma_j) \right\} = A_e a_e e^{-a_e \gamma_j} \tag{17}$$

where $A_e = \frac{s_1 e_1}{s_2 e_2}$ and $a_e = s_2 + e_2$. Putting the value of $f_{\gamma_{qk}}(\gamma_j)$ and $F_{\gamma_{qk}}(\gamma_j)$ in Equation (16), the expression for $f_{\gamma_{\Sigma_{e_j}}}(\gamma_j)$ can be deduced as,

$$f_{\gamma_{\Sigma_{e_j}}}(\gamma_j) = C_e e^{-c_e \gamma_j}, \tag{18}$$

where $C_e = KA_e a_e \sum_{k=0}^{K} \binom{K}{k} (-1)^k (A_e)^k$, $c_e = a_e(1+k)$.

3.9. PDF of $d_{\min}$

Let $d_{\min} = \min_{1\le i\le M} \gamma_i$ represents SNR of multicast channel. Then, PDF of $d_{\min}$ represented by $f_{d_{\min}}(\gamma_i)$, for Rayleigh fading channel is shown by [15],

$$f_{d_{\min}}(\gamma_i) = P f_{\gamma_{\Sigma d_i}}(\gamma_i)\left\{1 - F_{\gamma_{\Sigma d_i}}(\gamma_i)\right\}^{P-1} \tag{19}$$

Putting the value of $f_{\gamma_{\Sigma d_i}}(\gamma_i)$ and $F_{\gamma_{\Sigma d_i}}(\gamma_i)$ in Equation (19), the expression for the $f_{d_{\min}}(\gamma_i)$ can be deduced as

$$f_{d_{\min}}(\gamma_i) = D_d \mathrm{e}^{-d_d \gamma_i}, \tag{20}$$

where

$$D_d = PC_d \sum_{r=0}^{P-1} \binom{P-1}{r} (-1)^r (B_d)^r, d_d = c_d + b_d r$$

3.10. PDF of $d_{\max}$

Let $d_{\max} = \min_{1\le j\le N} \gamma_j$ represents maximum SNR of wiretapper's channel. Then, PDF of $d_{\max}$ represented by $f_{d_{\max}}(\gamma_j)$, for Rayleigh fading channel is shown by [15],

$$f_{d_{\max}}(\gamma_j) = Q f_{\gamma_{\Sigma e_j}}(\gamma_j)\left\{F_{\gamma_{\Sigma e_j}}(\gamma_j)\right\}^{Q-1} \tag{21}$$

Putting the value of $f_{\gamma_{\Sigma e_j}}(\gamma_j)$ and $F_{\gamma_{\Sigma e_j}}(\gamma_j)$ in Equation (21), the expression for $f_{d_{\max}}(\gamma_j)$ can be deduced as

$$f_{d_{\max}}(\gamma_j) = D_e \mathrm{e}^{-d_e \gamma_j}, \tag{22}$$

where $D_e = QC_e (B_e)^{Q-1}$, $d_e = c_e + b_e(Q-1)$

4. Probability of Non-Zero Secrecy Multicast Capacity

The PNSMC has the following mathematical definition: [5],

$$Pr\left(C_s^m > 0\right) = \int_0^\infty f_{d_{\min}}(\gamma_i) \int_0^{\gamma_i} f_{d_{\max}}(\gamma_j) \mathrm{d}\gamma_j \mathrm{d}\gamma_i \tag{23}$$

Putting the value of $f_{d_{\min}}(\gamma_i)$ and $f_{d_{\max}}(\gamma_j)$ in Equation (23) and using the identities of

$$\int_0^x \mathrm{e}^{-bx} \mathrm{d}x = \frac{1-\mathrm{e}^{-bx}}{b}, \tag{24}$$

and

$$\int_0^\infty \mathrm{e}^{-Bx} \mathrm{d}x = \frac{1}{B}, \tag{25}$$

the expression that was derived for the $Pr\left(C_s^m > 0\right)$ is given by

$$P_r\left(C_s^m>0\right)=\frac{PC_d\sum_{r=0}^{P-1}\binom{P-1}{r}(-1)^r}{a_d(1+k)+a_dkr}\frac{\left(\sum_{k=0}^{K}\binom{K}{k}(-1)^k\left(\frac{s_1d_1}{s_2d_2}\right)^k\right)^r}{a_d(1+k)+a_dkr+a_e(1+k)+a_ek(Q-1)}\times\frac{QC_e\left(\sum_{k=0}^{K}\binom{K}{k}(-1)^k\left(\frac{s_1e_1}{s_2e_2}\right)^k\right)^{Q-1}}{a_e(1+k)+a_ek(Q-1)}. \tag{26}$$

5. Ergodic Secrecy Multicast Capacity

The ESMC can be expressed as [5],

$$\left\langle C_s^m\right\rangle=\int_0^\infty\ln(1+\gamma_i)f_{d_{\min}}(\gamma_i)\mathrm{d}\gamma_i-\int_0^\infty\ln(1+\gamma_j)f_{d_{\max}}(\gamma_j)\mathrm{d}\gamma_j. \tag{27}$$

Putting the value of $f_{d_{\min}}(\gamma_i)$ and $f_{d_{\max}}(\gamma_j)$ in Equation (27) and after integration by using the identity of ([16], eq. (4.222.8))

$$\int_0^\infty\ln(1+ax)x^t\mathrm{e}^{-x}\mathrm{d}x=\sum_{s=0}^{t}\frac{t!}{(t-s)!}\times\left\{\frac{(-1)^{t-s-1}}{a^{t-s}\mathrm{e}^{-1/a}}E_i(-1/a)+\sum_{r=1}^{t-s}\frac{(r-1)!}{(-a)^{t-r-s}}\right\}, \tag{28}$$

the expression for ESMC is shown by

$$\left\langle C_s^m\right\rangle=QC_e\left(\sum_{k=0}^{K}\binom{K}{k}(-1)^k(A_e)^k\right)^{Q-1}\frac{\mathrm{e}^{c_e+b_e(Q-1)}}{c_e+b_e(Q-1)}E_i\left[-\left(c_e+b_e(Q-1)\right)\right]\times-PC_d\sum_{r=0}^{P-1}\binom{P-1}{r}(-1)^r\left(\sum_{k=0}^{K}\binom{K}{k}(-1)^k\left(\frac{s_1d_1}{s_2d_2}\right)^k\right)^r\frac{\mathrm{e}^{c_d+b_dr}}{c_d+b_dr}E_i\left[-(c_d+b_dr)\right] \tag{29}$$

6. Secure Outage Probability for Multicasting

For multicasting, the SOP is defined as [5],

$$P_{\text{out}}(R_s)=1-\int_0^\infty f_{d_{\max}}(\gamma_j)\int_{x_1}^\infty f_{d_{\min}}(\gamma_i)\mathrm{d}\gamma_i\mathrm{d}\gamma_j, \tag{30}$$

where $x=\mathrm{e}^{2R_s}(1+\gamma_j)-1$, $x=H+\mathrm{e}^{2R_s}\gamma_j$, $H=\mathrm{e}^{2R_s}-1$ and R_s represents target secrecy rate.

Putting the value of $f_{d_{\min}}(\gamma_i)$ and $f_{d_{\max}}(\gamma_j)$ in Equation (30) and using the identities of Equations (7) and (25), the deduced expression for the $P_{\text{out}}(R_s)$ is shown by

$$P_{\text{out}}(R_s)=1-PC_d\sum_{r=0}^{P-1}\binom{P-1}{r}(-1)^r\left(\sum_{k=0}^{K}\binom{K}{k}(-1)^k\left(\frac{s_1d_1}{s_2d_2}\right)^k\right)^r\times\frac{QC_e\left(\sum_{k=0}^{K}\binom{K}{k}(-1)^k\left(\frac{s_1e_1}{s_2e_2}\right)^k\right)^{Q-1}\mathrm{e}^{-d_d\left(2^{R_s}-1\right)}}{a_d(1+k)+a_dkr\left[a_d(1+k)+a_dkr+a_e(1+k)+a_ek(Q-1)\right]}. \tag{31}$$

7. Numerical Results

According to different values of relays and branches at destinations, the PNSMC is shown in Figure 2 as a function of multicast channel's average SNR. The figure indicates that PNSMC grows considerably as relays (K) and branches (N_m) at destinations increases. Additionally, this figure indicates that even while an increase in relays and branches at destinations separately causes the PNSMC to significantly improve, but their combined contribution results in a considerably better outcome than their individual results. This is due to the fact that secrecy multicast capacity rises as relays increase due to selection combining diversity offered by best relay.

According to different values of users and wiretappers, the PNSMC is shown in Figure 3 as a function of multicast channel's average SNR. With increases users (P) and wiretappers (Q), we observe that PNSMC declines considerably. This is because more multicast users consume less bandwidth overall, which in turn lowers the multicast users' capacity. Figure 4 displays the ESMC as a function of multicast channel's average SNR for different values of relays and branches at destinations. We can see that when relays (K) and branches (Nm) at destinations increases, ESMC rises dramatically. Moreover, this figure shows that even if an increase in relays and branches at destinations causes the ESMC to improve significantly on its own, but their combined contribution results in a far better outcome than either factor acting alone. This is due to an increase in relays, which enhances the diversity benefit they deliver. Figure 5 illustrates the ESMC in relation to average SNR of multicast channel for various relay values and the number of wiretapper branches. It has been found that ESMC rises with an increase in relays (K) and falls with an increase in branches (N_e) at the wiretappers. This is because, due to selection combining diversity secrecy multicast capacity

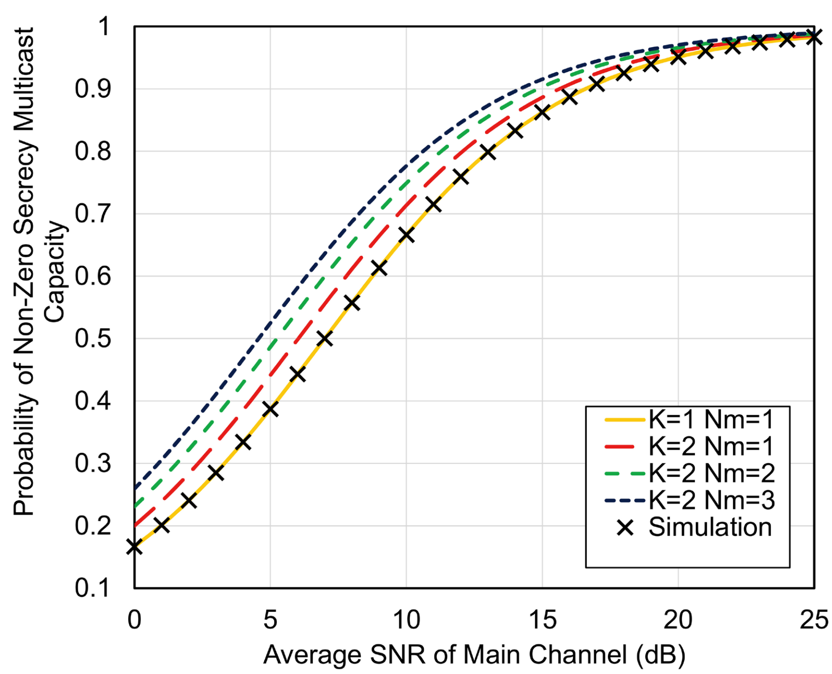

Figure 2. Simulation and analytical findings of PNSMC for different values of relays and branches at destinations.

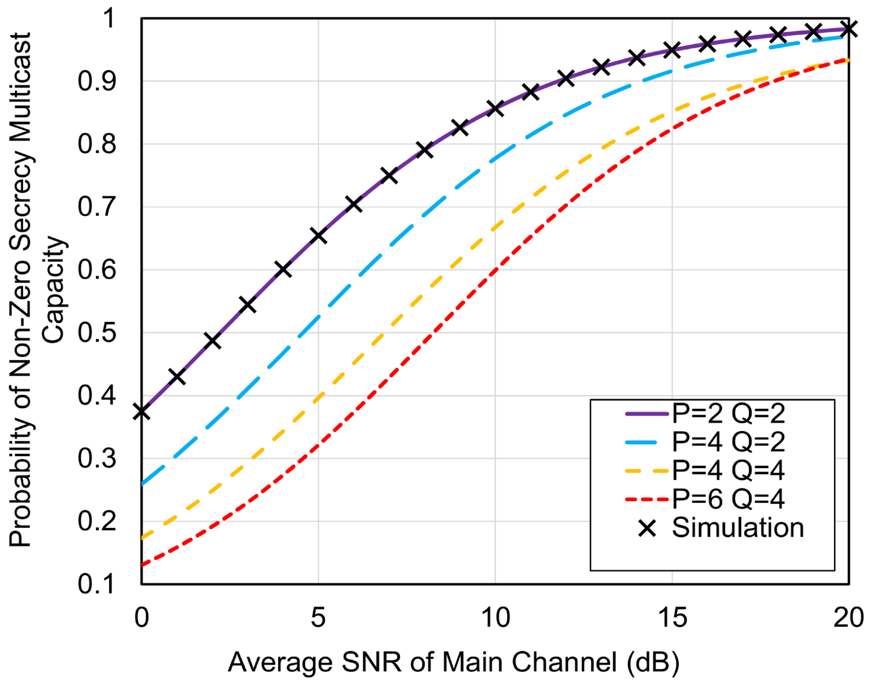

Figure 3. Simulation and analytical findings of PNSMC for various values of users and wiretappers.

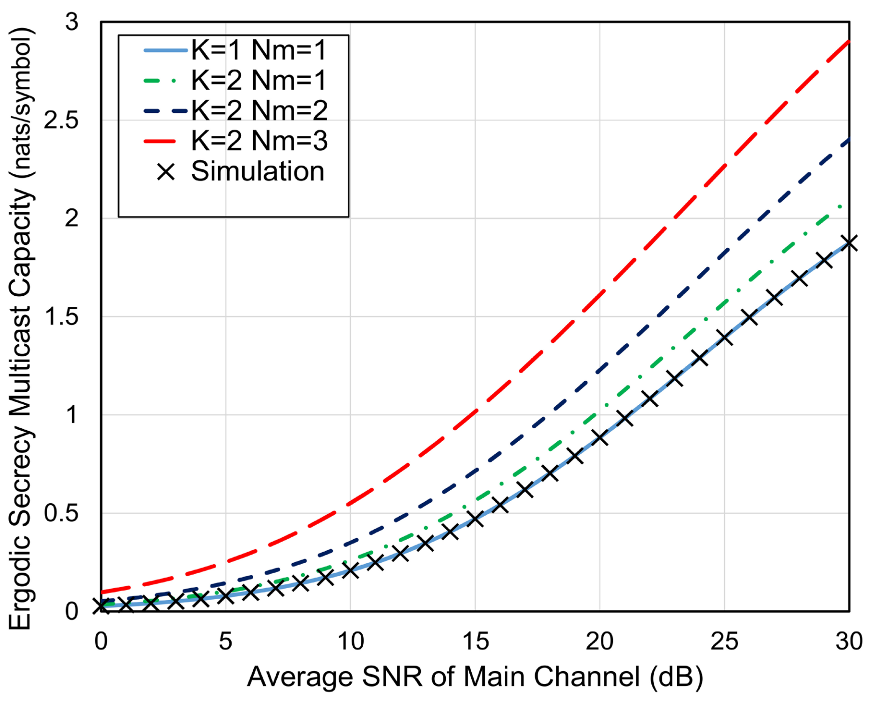

Figure 4. Simulation and analytical findings of ESMC for various values of relays and branches at destinations.

rises as relays increases and falls as wiretapper branches increases. **Figure 6** displays the ESMC, as a function of average SNR of multicast channel for different values of users and wiretappers. We see that ESMC decreases significantly

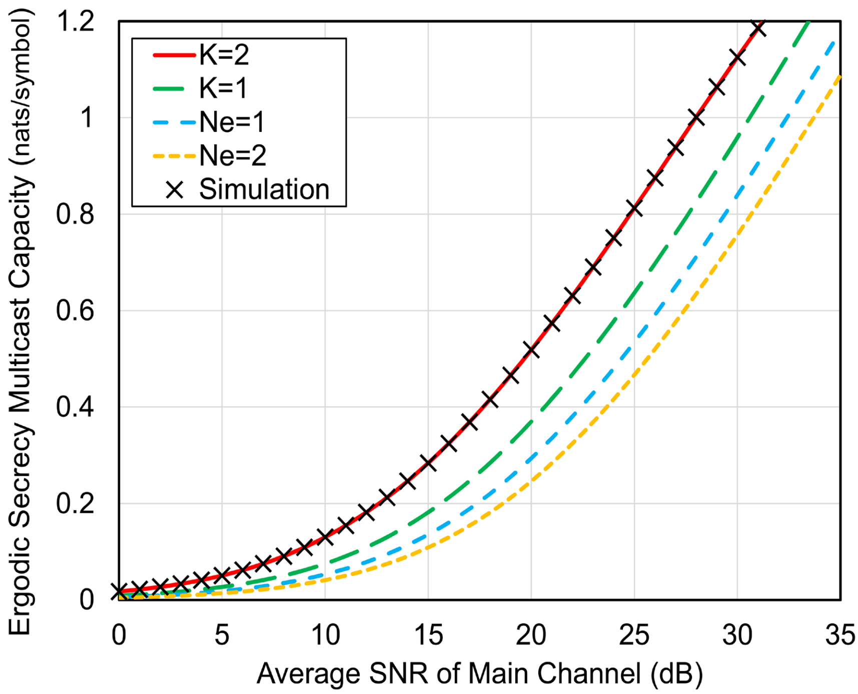

Figure 5. Simulation and analytical findings of ESMC for various values of relays and branches at wiretappers.

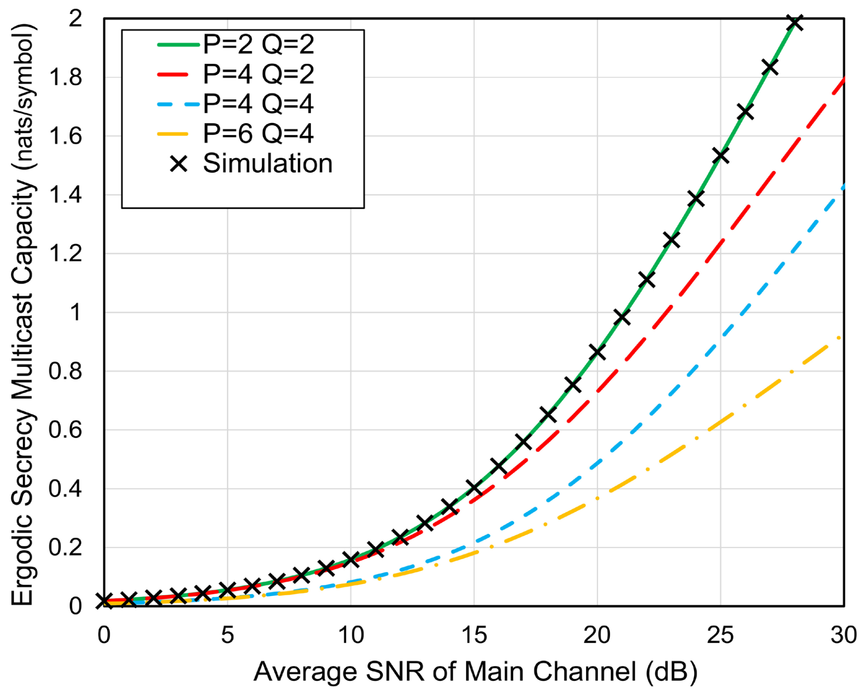

Figure 6. Simulation and analytical findings of ESMC for various values of users and wiretappers.

with the increase in users (P) as well as wiretappers (Q). This is because increasing in multicast users decreases the bandwidth of each user which in turn decrease the capacity of multicast user. Figure 7 shows the SOPM, as a function of average SNR of multicast channel for different values of branches at destinations and wiretappers. We see that SOPM grows with an increase in branches (N_e) at wiretappers while SOPM drastically drops with an increase in branches (N_m) at destinations. Figure 8 illustrates the SOPM, as a function of average SNR

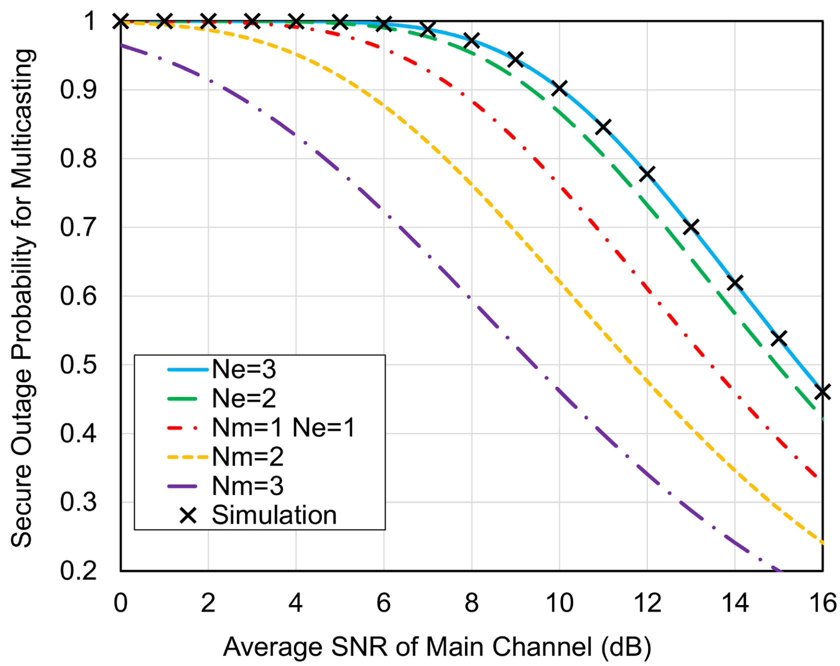

Figure 7. Simulation and analytical findings of SOPM for different values of branches at destinations and wiretappers.

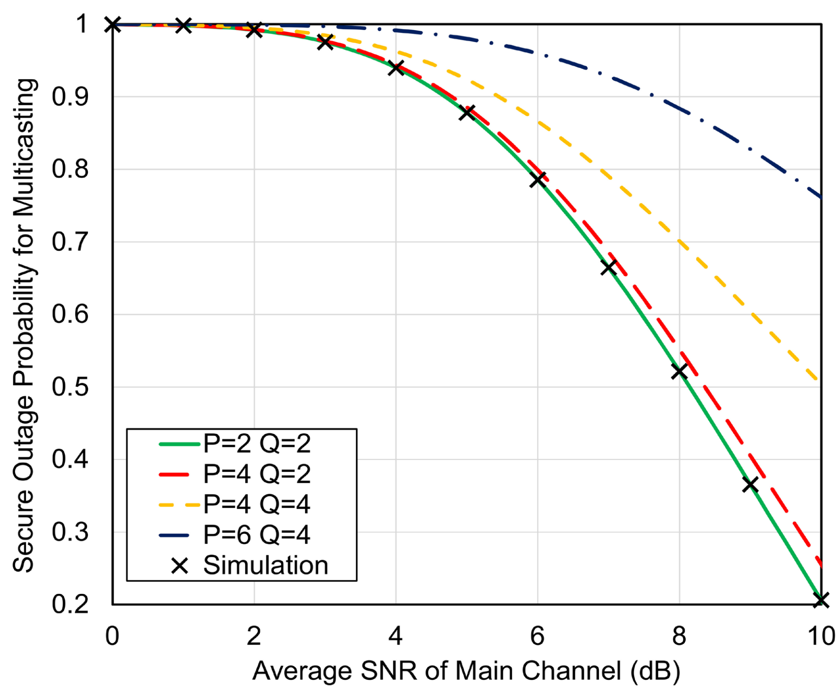

Figure 8. Simulation and analytical findings of SOPM for different values of users and wiretappers.

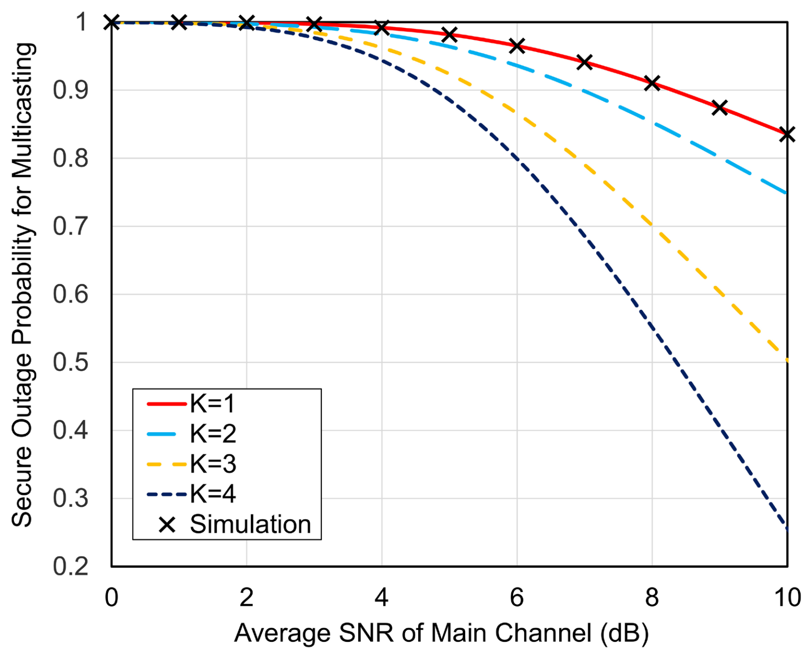

Figure 9. Simulation and analytical findings of SOPM for different values of relays.

of multicast channel for different values of users and wiretappers. As the rise of users (P) and wiretappers (Q), we can observe that SOPM also rises dramatically. This is due to the fact that an increasing in multicast users as well as wiretappers decreases the bandwidth. As a result, increase the outage probability for multicasting.

In relation to average SNR of multicast channel for different values of relays, Figure 9 illustrates the SOPM. Figure demonstrates that SOPM drastically decreases as relay (K) is increased. This happens when increases the diversity merit due to increase in relays.

Therefore, based on the observations of numerical data and analytical formulations for PNSMC, ESMC, and SOPM, the primary conclusions of this study can be summed up as follows: As N_e, P, and Q increase, the PNSMC and ESMC decline. As a result, a rise in N_e, P, and Q reduces system security. As opposed to this, if K and N_m rise, PNSMC and ESMC rise, and SOPM falls. Therefore, raising K and N_m improves system security.

8. Conclusion

This study focuses on creating a mathematical model for analytically to ensure the security in wireless multicasting using opportunistic relaying over Rayleigh fading channels. The closed-form analytical expressions for PNSMC, ESMC and SOPM are deduced in terms of parameters such as N_m, N_e, multicast users (P) and wiretappers (Q), and relays (K), which aid in gaining a clear understanding of the effects of anterior parameters. According to our findings, the security of wireless multicasting over Rayleigh fading channels declines as N_e, P, and Q grow. However, this loss of security can be reduced by simultaneously increasing relays (K) and branches (N_m) at destinations that compete using the opportunistic relaying technique to choose the best relay from a collection of relays. The effects of distributed switch and stay combining on the security in multicasting through Rayleigh fading channel are not considered in this paper. So the distributed switch and stay combining techniques can be used to enhance the security over Rayleigh fading channel. The accuracy of the analytical expression is finally verified using Monte Carlo simulation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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