Appendix A: The Proof of Theorem 2

Proof. Using (5), it can be easily shown that

$$\begin{aligned} P_{\text{out}}^{C} &= 1 - \Pr\left(\gamma_{S,C} \geqslant t_C, \gamma_{D,C} \geqslant t_C, \gamma_{C,C} \geqslant t_C\right) \\ &= 1 - I\,. \end{aligned} \tag{A-1}$$

Defining $Z = |g_3|^2$, from (6), (7), (8) and (A-1), one obtains

$$\left\{ \begin{array}{l} (a - b\,\tau_C)\,Y \leqslant b\,\tau_C\,X - \frac{1}{\gamma X} \\ (a - b\,\tau_C)\,X \leqslant b\,\tau_C\,Y - \frac{1}{\gamma Y} \\ \gamma Z\,(b\,\tau_C - a)\,(X + Y) \geqslant 1 \end{array} \right. . \tag{A-2}$$

If $\tau_C \leqslant a/b$, $\gamma_{C,C} \geqslant t_C$ will not hold, and therefore, $P_{\text{out}}^{C} = 1$. Otherwise, I can be obtained as follows

$$\begin{aligned} I &= \Pr\left(\gamma_{S,C} \geqslant t_C, \gamma_{D,C} \geqslant t_C, \gamma_{C,C} \geqslant t_C\right) \\ &= \underbrace{\int_0^{X_0}\int_{gx+\frac{1}{hx}}^{\infty}\int_{Z_0}^{\infty} f_X\left(x\right) f_Y\left(y\right) f_Z\left(z\right) \mathrm{d}z\mathrm{d}y\mathrm{d}x}_{I_1} \\ &+ \underbrace{\int_0^{X_0}\int_{gy+\frac{1}{hy}}^{\infty}\int_{Z_0}^{\infty} f_Y\left(y\right) f_X\left(x\right) f_Z\left(z\right) \mathrm{d}z\mathrm{d}x\mathrm{d}y}_{I_2} \\ &+ \underbrace{\int_{X_0}^{\infty}\int_{X_0}^{\infty}\int_{Z_0}^{\infty} f_X\left(x\right) f_Y\left(y\right) f_Z\left(z\right) \mathrm{d}z\mathrm{d}y\mathrm{d}x}_{I_3}, \end{aligned} \tag{A-3}$$

where $g = \frac{b\tau_c}{a - b\tau_c}, h = \gamma(b\tau_c - a),\ Z_0 = 1/[h(x+y)]$. Moreover, integral I_1

can be evaluated as

$$
\begin{aligned}
I_1 = & \sum_{k=0}^{m_3-1} \frac{\omega_3^k}{h^k k!} \\
& \times \int_0^{X_0} f_X(x) \int_{gx+\frac{1}{hx}}^{\infty} \exp\left(-\frac{\omega_3}{h(x+y)}\right) \frac{1}{(x+y)^k} f_X(x) f_Y(y) dy dx \\
& = \frac{\omega_2^{m_2}}{\Gamma(m_2)} \sum_{k=0}^{m_3-1} \frac{\omega_3^k}{h^k k!} \sum_{p=0}^{m_2-1} (-1)^{m_2-1-p} \binom{m_2-1}{p} \\
& \times \int_0^{X_0} x^{m_2-1-p} \exp\left(\omega_2 x\right) f_X(x) \int_{x+gx+\frac{1}{hx}}^{\infty} v^{p-k} \exp\left(-\frac{\omega_3}{hv} - \omega_2 v\right) dv \\
& \approx \frac{\omega_2^{m_2}}{\Gamma(m_2)} \sum_{k=0}^{m_3-1} \frac{\omega_3^k}{h^k k!} \sum_{p=0}^{m_2-1} (-1)^{m_2-1-p} \binom{m_2-1}{p} \\
& \times \int_0^{X_0} x^{m_2-1-p} \exp\left(\omega_2 x\right) f_X(x) \int_{x+gx+\frac{1}{hx}}^{\infty} v^{p-k} \exp\left(-\omega_2 v\right) dv \\
& = \frac{\omega_1^{m_1}}{\Gamma(m_1)} \frac{\omega_2^{m_2}}{\Gamma(m_2)} \sum_{k=0}^{m_3-1} \sum_{p=0}^{m_2-1} \frac{\omega_3^k}{h^k k!} (-1)^{m_2-1-p} \omega_2^{-(p-k+1)} \binom{m_2-1}{p} \\
& \times \int_0^{X_0} x^{m_1+m_2-2-p} e^{(-\omega_1 x + \omega_2 x)} \Gamma\left(p-k+1, \omega_2\left(x+gx+\frac{1}{hx}\right)\right) dx.
\end{aligned}
\tag{A-4}
$$

Similarly, I_2 and I_3 can also be deduced, yielding (12), which concludes the proof. □

References

[1] Gradshteyn I S, Ryzhik I M. Table of Integrals, Series, and Products. 7th ed. Academic Press, 2007