Supplementary Information for " Enabling Edge Caching Through Full-duplex Non-Orthogonal Multiple Access "

Case I: The channel condition between S_0 and $UE_{d,m}$ is better than that between S_0 and $UE_{r,m}$, i.e., $|h_{0d,m}|^2>|h_{0r,m}|^2$. *Case II*: The channel condition between S_0 and $UE_{r,m}$ is better than that between S_0 and $UE_{d,m}$, i.e., $|h_{0r,m}|^2>|h_{0d,m}|^2$.

The successful transmission probability and successful SIC probability are derived as follow.

A. Successful Transmission Probability for Case I

The large scale fading with $r_{(\cdot)}^{-\alpha}$ and Rayleigh fading channel with $g_{(\cdot)}\sim$Exp(1) are assumed, where the channel power gain satisfies $|h_{(\cdot)}|^2=r_{(\cdot)}^{-\alpha}g_{(\cdot)}$. Especially, $|h_{SI}|^2=g_{SI}$, where $g_{SI}\sim$Exp$(\frac{1}{\sigma_{SI}^2})$ is predefined. In Case I, the successful transmission probability for $UE_{d,m}$, i.e., $q_{d,m}^1$, can be formulated as follows,

$$\begin{aligned} q_{d,m}^1 &= \mathbb{P}\left(\frac{|h_{0d,m}|^2 P_0^m \gamma_d^m}{N_0} > \delta_m^{th}\right), \\ &= \mathbb{P}\left(\frac{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m \gamma_d^m}{N_0} > \delta_m^{th}\right), \\ &= \exp\left(-\frac{\delta_m^{th} N_0}{r_{0d,m}^{-\alpha} P_0^m \gamma_d^m}\right), \end{aligned} \tag{1}$$

Similarly, the successful transmission probability for $UE_{r,m}$ via a relay link, i.e., $q_{r,m}^1$, is obtained as,

$$\begin{aligned} q_{r,m}^1 &= \mathbb{P}\left[\min\left(\xi_{r,m}^0, \xi_{r,m}\right) > \delta_{\mathrm{m}}^{\mathrm{th}}\right], \\ &\overset{(a)}{\approx} \mathbb{P}\left(\frac{g_{k0} r_{k0}^{-\alpha} P_k^m}{g_{SI} P_0} > \delta_{\mathrm{m}}^{\mathrm{th}}\right) \mathbb{P}\left(\frac{g_{0r,m} r_{0r,m}^{-\alpha} P_0^m \gamma_r^m + g_{kr,m} r_{kr,m}^{-\alpha} P_k^m}{g_{0r,m} r_{0r,m}^{-\alpha} P_0^m \gamma_d^m} > \delta_{\mathrm{m}}^{\mathrm{th}}\right), \\ &= \mathbb{P}\left(g_{k0} > \frac{g_{SI} P_0^m \delta_m^{th} r_{k0}^{\alpha}}{P_k^m}\right) \mathbb{P}\left(g_{kr,m} > \mathrm{A}\right), \\ &= \mathbb{E}_{g_{\mathrm{SI}}}\left[\exp\left(-\frac{g_{SI} P_0^m \delta_m^{th} r_{k0}^{\alpha}}{P_k^m}\right)\right] \begin{cases} \mathbb{E}_{g_{0r,m}}\left[\exp(-\mathrm{A})\right], & \frac{\gamma_r^m}{\gamma_d^m} < \delta_m^{th}, \\ 1, & \frac{\gamma_r^m}{\gamma_d^m} > \delta_m^{th}, \end{cases} \\ &= \begin{cases} \frac{P_k^m}{P_k^m + P_0^m \delta_m^{th} r_{k0}^{\alpha} \sigma_{SI}^2} \frac{r_{kr,m}^{-\alpha} P_k^m}{r_{0r,m}^{-\alpha} P_0^m (\delta_m^{th} \gamma_d^m - \gamma_r^m) + r_{kr,m}^{-\alpha} P_k^m}, & \frac{\gamma_r^m}{\gamma_d^m} < \delta_m^{th}, \\ \frac{P_k^m}{P_k^m + P_0^m \delta_m^{th} r_{k0}^{\alpha} \sigma_{SI}^2}, & \frac{\gamma_r^m}{\gamma_d^m} > \delta_m^{th}, \end{cases} \end{aligned} \tag{2}$$

where $A \triangleq \frac{g_{0r,m} r_{0r,m}^{-\alpha} P_0^m (\delta_m^{th} \gamma_d^m - \gamma_r^m)}{r_{kr,m}^{-\alpha} P_k^m}$. Step (a) accesses from the interference-limited consideration.

B. Successful SIC Probability for Case I

If the SINR at $UE_{d,m}$ for decoding the signal intended for $UE_{r,m}$ is greater than the threshold, the SIC is supposed to be successful. Therefore, $P_{SIC,m}^1$ can be formulated in closed-form as,

$$\begin{aligned} P_{SIC,m}^1 &= \mathbb{P}\left[\frac{|h_{0d,m}|^2 P_0^m \gamma_r^m + |h_{kd,m}|^2 P_k^m}{|h_{0d,m}|^2 P_0^m \gamma_d^m + N_0} > \delta_m^{th}\right], \\ &= \mathbb{P}\left[\frac{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m \gamma_r^m + g_{kd,m} r_{kd,m}^{-\alpha} P_k^m}{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m \gamma_d^m + N_0} > \delta_m^{th}\right], \\ &\approx \mathbb{P}\left[g_{kd,m} > \frac{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m (\delta_m^{th} \gamma_d^m - \gamma_r^m)}{r_{kd,m}^{-\alpha} P_k^m}\right], \\ &= \begin{cases} \mathbb{E}_{g_{0d,m}}\left[e^{-\frac{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m (\delta_m^{th} \gamma_d^m - \gamma_r^m)}{r_{kd,m}^{-\alpha} P_k^m}}\right], & \frac{\gamma_r^m}{\gamma_d^m} < \delta_m^{th}, \\ 1, & \frac{\gamma_r^m}{\gamma_d^m} > \delta_m^{th}, \end{cases} \\ &= \begin{cases} \frac{r_{kd,m}^{-\alpha} P_k^m}{r_{0d,m}^{-\alpha} P_0^m (\delta_m^{th} \gamma_d^m - \gamma_r^m) + r_{kd,m}^{-\alpha} P_k^m}, & \frac{\gamma_r^m}{\gamma_d^m} < \delta_m^{th}, \\ 1, & \frac{\gamma_r^m}{\gamma_d^m} > \delta_m^{th}. \end{cases} \end{aligned} \tag{3}$$

C. Successful Transmission Probability for Case II

In Case II where $|h_{0d,m}|^2<|h_{0r,m}|^2$, $UE_{r,m}$ will be involved with SIC. $UE_{d,m}$ needs to decode the desired signal $x_{i,m}$ while treating the signal $x_{j,m}$ which intended for $UE_{r,m}$ as noise. Therefore, at this situation, the successful transmission probability for $UE_{d,m}$, i.e., $q_{d,m}^2$, is derived as,

$$
\begin{aligned}
q_{d,m}^2 &= \mathbb{P}\left(\frac{|h_{0d,m}|^2 P_0^m \gamma_d^m}{|h_{0d,m}|^2 P_0^m \gamma_r^m + |h_{kd,m}|^2 P_k^m + N_0} > \delta_m^{th}\right), \\
&\approx \mathbb{P}\left(\frac{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m \gamma_d^m}{g_{0d,m} r_{0d,m}^{-\alpha} P_0^m \gamma_r^m + g_{kd,m} r_{kd,m}^{-\alpha} P_k^m} > \delta_m^{th}\right), \\
&= \begin{cases} \mathbb{P}\left[g_{0d,m} > \dfrac{g_{kd,m} r_{kd,m}^{-\alpha} P_k^m \delta_m^{th}}{r_{0d,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}\right], & \dfrac{\gamma_d^m}{\gamma_r^m} > \delta_m^{th}, \\ \mathbb{P}\left[g_{0d,m} < \dfrac{g_{kd,m} r_{kd,m}^{-\alpha} P_k^m \delta_m^{th}}{r_{0d,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}\right], & \dfrac{\gamma_d^m}{\gamma_r^m} < \delta_m^{th}, \end{cases} \\
&= \begin{cases} \mathbb{E}_{g_{kd,m}}\left[\exp\left(-\dfrac{g_{kd,m} r_{kd,m}^{-\alpha} P_k^m \delta_m^{th}}{r_{0d,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}\right)\right], & \dfrac{\gamma_d^m}{\gamma_r^m} > \delta_m^{th}, \\ 0, & \dfrac{\gamma_d^m}{\gamma_r^m} < \delta_m^{th}, \end{cases} \\
&= \begin{cases} \dfrac{r_{0d,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}{r_{kd,m}^{-\alpha} P_k^m \delta_m^{th} + r_{0d,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}, & \dfrac{\gamma_d^m}{\gamma_r^m} > \delta_m^{th}, \\ 0, & \dfrac{\gamma_d^m}{\gamma_r^m} < \delta_m^{th}. \end{cases}
\end{aligned} \tag{4}
$$

As for the $UE_{r,m}$ with $|h_{0d,m}|^2 < |h_{0r,m}|^2$, the successful transmission probability after successful SIC can be formulated as,

$$
\begin{aligned}
q_{r,m}^2 &= \mathbb{P}\left[\min\left(\xi_{r,m}^0, \xi_{r,m}\right) > \delta_{\mathrm{m}}^{\mathrm{th}}\right], \\
&\approx \mathbb{P}\left(\frac{g_{k0} r_{k0}^{-\alpha} P_k^m}{g_{SI} P_0} > \delta_{\mathrm{m}}^{\mathrm{th}}\right) \mathbb{P}\left(\frac{g_{0r,m} r_{0r,m}^{-\alpha} P_0^m \gamma_r^m + g_{kr,m} r_{kr,m}^{-\alpha} P_k^m}{N_0} > \delta_{\mathrm{m}}^{\mathrm{th}}\right), \\
&= \mathbb{P}\left(g_{k0} > \tfrac{g_{SI} P_0^m \delta_m^{th} r_{k0}^{\alpha}}{P_k^m}\right) \mathbb{P}\left(g_{0r,m} > \tfrac{\delta_m^{th} N_0 - g_{kr,m} r_{kr,m}^{-\alpha} P_k^m}{r_{0r,m}^{-\alpha} P_0^m \gamma_r^m}\right), \\
&= \mathbb{E}_{g_{\mathrm{SI}}}\left[\exp\left(-\frac{g_{SI} P_0^m \delta_m^{th} r_{k0}^{\alpha}}{P_k^m}\right)\right] \cdot \\
&\quad \left[\mathbb{P}\left(g_{0r,m} > \mathrm{B} | \mathrm{B} \geq 0\right) \mathbb{P}\left(B \geq 0\right) + \mathbb{P}\left(g_{0r,m} > \mathrm{B} | \mathrm{B} < 0\right) \mathbb{P}\left(B < 0\right)\right], \\
&= \frac{P_k^m}{P_k^m + P_0^m \delta_m^{th} r_{k0}^{\alpha} \sigma_{SI}^2} \cdot \\
&\quad \left[\int_0^{\frac{\delta_m^{th} N_0}{r_{kr,m}^{-\alpha} P_k^m}} e^{\left(-B - g_{kr,m}\right)} \mathrm{d}g_{kr,m} + \int_{\frac{\delta_m^{th} N_0}{r_{kr,m}^{-\alpha} P_k^m}}^{\infty} 1 \cdot e^{-g_{kr,m}} \mathrm{d}g_{kr,m}\right], \\
&= \frac{P_k^m}{P_k^m + P_0^m \delta_m^{th} r_{k0}^{\alpha} \sigma_{SI}^2} \cdot \\
&\quad \left[\frac{r_{0r,m}^{-\alpha} P_0^m \gamma_r^m}{r_{kr,m}^{-\alpha} P_k^m - r_{0r,m}^{-\alpha} P_0^m \gamma_r^m} \left(e^{\frac{-\delta_m^{th} N_0}{r_{kr,m}^{-\alpha} P_k^m}} - e^{\frac{-\delta_m^{th} N_0}{r_{0r,m}^{-\alpha} P_0^m \gamma_r^m}}\right) + e^{\frac{-\delta_m^{th} N_0}{r_{kr,m}^{-\alpha} P_k^m}}\right],
\end{aligned} \tag{5}
$$

where $B \triangleq \dfrac{\delta_m^{th} N_0 - g_{kr,m} r_{kr,m}^{-\alpha} P_k^m}{r_{0r,m}^{-\alpha} P_0^m \gamma_r^m}$ is defined.

D. Successful SIC Probability for Case II

The successful SIC probability in Case II, i.e., $P_{SIC,m}^2$ can be formulated in closed-form as,

$$
\begin{aligned}
P_{SIC,m}^2 &= \mathbb{P}\left[\frac{|h_{0r,m}|^2 P_0^m \gamma_d^m}{|h_{0r,m}|^2 P_0^m \gamma_r^m + |h_{kr,m}|^2 P_k^m + N_0} > \delta_m^{th}\right], \\
&\approx \mathbb{P}\left[\frac{g_{0r,m} r_{0r,m}^{-\alpha} P_0^m \gamma_d^m}{g_{0r,m} r_{0r,m}^{-\alpha} P_0^m \gamma_r^m + g_{kr,m} r_{kr,m}^{-\alpha} P_k^m} > \delta_m^{th}\right], \\
&= \begin{cases} \mathbb{P}\left(g_{0r,m} > \dfrac{\delta_m^{th} g_{kr,m} r_{kr,m}^{-\alpha} P_k^m}{r_{0r,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}\right), & \dfrac{\gamma_d^m}{\gamma_r^m} > \delta_m^{th}, \\ \mathbb{P}\left(g_{0r,m} < \dfrac{\delta_m^{th} g_{kr,m} r_{kr,m}^{-\alpha} P_k^m}{r_{0r,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}\right), & \dfrac{\gamma_d^m}{\gamma_r^m} < \delta_m^{th}, \end{cases} \\
&= \begin{cases} \dfrac{r_{0r,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}{\delta_m^{th} r_{kr,m}^{-\alpha} P_k^m + r_{0r,m}^{-\alpha} P_0^m (\gamma_d^m - \delta_m^{th} \gamma_r^m)}, & \dfrac{\gamma_d^m}{\gamma_r^m} > \delta_m^{th}, \\ 0, & \dfrac{\gamma_d^m}{\gamma_r^m} < \delta_m^{th}. \end{cases}
\end{aligned} \tag{6}
$$