Appendix I

The success probability of the first hop can be calculated by

$$\mathrm{P}_{SUC_{\mathrm{R_iU_i}}} \square \mathrm{P}\left(\frac{\rho_{\mathrm{R_i}} \Upsilon_{\mathrm{R_iU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2}{\mathrm{I}_{\mathrm{U_i}}} \geq \theta_{\mathrm{U_i}}\right) \tag{20}$$

$$\mathrm{P}_{SUC_{\mathrm{R_iU_i}}} \square \mathrm{P}\left(\left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2 \geq \theta_{\mathrm{U_i}} \rho_{\mathrm{R_i}}{}^{-1} \Upsilon_{\mathrm{R_iU_i}}{}^{\alpha} \mathrm{I}_{\mathrm{U_i}}\right) \tag{20-a}$$

where $\mathrm{I}_{\mathrm{U_i}}$ is defined in Eq. (3) as the overall interference received at $\mathrm{U_i}$ and written as

$$\mathrm{I}_{\mathrm{U_i}} \cong \sum_{\{i,j\}\in\phi} \left(\rho_{\mathrm{R_j}} \Upsilon_{\mathrm{R_jU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_jU_i}}\right|^2\right) + \left(\rho_{\mathrm{R_j}} \rho_{\mathrm{R_i}} \Upsilon_{\mathrm{R_jR_iU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_jR_iU_i}}\right|^2\right) \tag{20-b}$$

Let us define $f_{\mathrm{I}_{\mathrm{U_i}}}(t) = d\mathrm{P}\left(\mathrm{I}_{\mathrm{U_i}} \leq t\right)$ as the PDF of $\mathrm{I}_{\mathrm{U_i}}$. The integration of $f_{\mathrm{I}_{\mathrm{U_i}}}(t)$ using the CCDF $F^c_{\mathrm{I}_{\mathrm{U_i}}}(t)$, transforms it as

$$\nabla(s)_{\mathrm{U_i}} \square \int_0^\infty F^C_{RU}(st) \square f_{\mathrm{I}_{\mathrm{U_i}}}(t)dt \tag{20-c}$$

Note that the power of desired signal is distributed as $\left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2 \square X^2_{\mathrm{i}\,N_R}$, and the probability of success given is by

$$\mathrm{P}_{SUC_{\mathrm{R_iU_i}}} \square \mathrm{P}\left(SINR_{\mathrm{U_i}} \geq \theta_{\mathrm{U_i}}\right) \square \mathrm{P}\left(\left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2 \geq \theta_{\mathrm{U_i}} \rho_{\mathrm{R_i}}{}^{-1} \Upsilon_{\mathrm{R_iU_i}}{}^{\alpha} \mathrm{I}_{\mathrm{U_i}}\right) \tag{20-d}$$

$$\square \int_0^\infty F^C_{RU}(st) \square f_{\mathrm{I}_{\mathrm{U_i}}}(t)dt \tag{20-e}$$

$$= \nabla(s)\Big\|_{s=\theta_{\mathrm{U_i}} \rho_{\mathrm{R_i}}{}^{-1} \Upsilon_{\mathrm{R_iU_i}}{}^{\alpha}} \tag{20-f}$$

Finally, using the CCDF $F^C_{RU}(st) = e^{-t}$ and laplace transform, the success probability can be expressed using the transformation of $f_{\mathrm{I}_{\mathrm{U_i}}}(t)$ as

$$\nabla(s)_{\mathrm{U_i}} \square \int_0^\infty F^C_{RU}(st) \square f_{\mathrm{I}_{\mathrm{U_i}}}(t)dt \tag{21}$$

$$\lambda\left\{f_{I_{U_i}}(t)\right\}(s)=\lambda_{I_{U_i}} \tag{21-a}$$

Finally, using the CCDF $F_{RU}^{C}(t)=\prod_{n} e^{-nt}\prod_{i} e^{a_n t^i}$ the transformation of $f_{I_{U_i}}(t)$ is given by

$$\nabla(s)_{U_i} \square \int_0^{\infty} F_{RU}^{C}(st) \square f_{I_{U_i}}(t)dt \tag{21-b}$$

$$\nabla(s) \square \int_0^{\infty}\left(\prod_{n} e^{-nst}\prod_{i} e^{a_{n_i}(st)^i}\right)\cdot f_{I_{U_i}}(t)dt \tag{21-c}$$

$$\nabla(s) \square \prod_{n}\ \prod_{i}\ a_{n_i} st^i\left[\int_0^{\infty}\left(e^{-nt}t^i f_{I_{U_i}}(t)dt\right)\right] \tag{21-e}$$

$$\nabla(s) \square \prod_{n}\ \prod_{i}\ a_{n_i} s^i\left[\lambda\left(t^i f_{I_{U_i}}(t)\right)(ns)\right] \tag{21-f}$$

$$\nabla(s) \square \prod_{n}\ \prod_{i}\ \left[a_{n_i}(-s)^i \frac{d^i}{d(ns)^i}\lambda_{I_{U_i}}(ns)\right] \tag{21-g}$$

$$\nabla(s) \square \prod_{n}\ \prod_{i}\ \left[a_{n_i}\left(-\frac{s}{n}\right)^i \frac{d^i}{d(ns)^i}\lambda_{I_{U_i}}(ns)\right] \tag{22}$$

where Eq. (21-g) is obtained by using Laplace transform property $t^n f(t) \leftrightarrow (-1)^n \frac{d^n}{ds^n}\lambda\left[f(t)\right]s$. Using the moment-generating function of $X_{i\ N_R}^{j}$ and Gamma distributions, and applying it to [62] (Thr. 1)] we can get Eq. (10)

Appendix II

Building on [62] (Thr. 3)], we have $\upsilon(s)$ in Eq. (11) is bounded as $\upsilon(s)\in\left[\upsilon^{\max}(s),\upsilon^{\min}(s)\right]$, where $\upsilon^{\max}(s)$ and $\upsilon^{\min}(s)$ are defined in Eq. (15) and Eq. (16), respectively. Then, the lower and upper bounds on $\lambda_{I_{U_i}}(s)$ in Eq. (13) and Eq. (14) readily follow.

Appendix III

The success probability of the RU hop is calculated as

$$\mathrm{P}_{SUC_{\mathrm{R_iU_i}}} \square \mathrm{P}\left(SINR_{\mathrm{U_i}} \geq \theta_{\mathrm{U_i}}\right) \tag{23}$$

$$\mathrm{P}_{SUC_{\mathrm{R_iU_i}}} \square \mathrm{P}\left(\frac{\rho_{\mathrm{R_i}} \Upsilon_{\mathrm{R_iU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2}{\mathrm{I}_{\mathrm{U_i}}} \geq \theta_{\mathrm{U_i}}\right) \tag{23-a}$$

$$\mathrm{P}_{SUC_{\mathrm{R_iU_i}}} \square \mathrm{P}\left(\left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2 \geq \theta_{\mathrm{U_i}} \rho_{\mathrm{R_i}}{}^{-1} \Upsilon_{\mathrm{R_iU_i}}{}^{\alpha} \mathrm{I}_{\mathrm{U_i}}\right) \tag{23-b}$$

where $\mathrm{I}_{\mathrm{U_i}}$ is defined in Eq. (3) as,

$$\mathrm{I}_{\mathrm{U_i}} \cong \sum_{\{i,j\}\in\phi} \left(\rho_{\mathrm{R_j}} \Upsilon_{\mathrm{R_jU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_jU_i}}\right|^2\right) + \left(\rho_{\mathrm{R_j}} \rho_{\mathrm{R_i}} \Upsilon_{\mathrm{R_jR_iU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_jR_iU_i}}\right|^2\right) \tag{23-c}$$

The desired signal is distributed as $\left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2 \square X_{i\ N_R}^{j}$. On the other hand, the moment generating function of $X_{i\ N_R}^{j}$ distribution can provide the Laplace transform of $\mathrm{I}_{\mathrm{U_i}}$ [69] (P. 125) and can be computed as

$$\lambda_{\mathrm{I}_{\mathrm{U_i}}}(s) \square \xi\left(\prod_{\{i,j\}\in\phi} \xi\left\{\exp\left(-s\frac{\rho_{\mathrm{R_i}}}{N_R} \Upsilon_{\mathrm{R_iU_i}}{}^{-\alpha} \left|\mathrm{H}_{\mathrm{R_iU_i}}\right|^2\right)\right\}\right) \tag{23-d}$$

Appendix IV

Given the definition of $\vartheta(s,r)$

$$\psi\left(s, D_{RD}\right) \in \left[\frac{1}{1 + s\rho_{\mathrm{R_i}}\left(r + \Gamma_{RU}\right)^{-\gamma}}, \frac{1}{1 + s\rho_{\mathrm{R_i}}\left(r - \Gamma_{RU}\right)^{-\gamma}}\right] \tag{24}$$

where r is the origin point of relay and Γ_{RU} is the distance between RN and user. We can recall that distances between $\mathrm{R_i}$ to $\mathrm{U_i}$, then the maximum and minimum $\lambda_{\mathrm{I}_{\mathrm{U_i}}}$ can be formulated as stated in Eq. (13) and Eq. (14).