Correction to: Base Station Sleep and Spectrum Allocation in Heterogeneous Ultra-Dense Networks

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There were typos in several equations in the original publication. The corrected equations are specified below. They do not alter the conclusions of the article.

Equations (9) and (10) are, respectively, modified to

$$\begin{aligned} p_s(\alpha, \lambda_s, \lambda_m) &= 2\pi p_a \lambda_s (1 - \eta) \int_0^\infty e^{-p_a \lambda_s \pi r^2 (1 + \rho(T, \alpha))} \cdot e^{-1/((1-\eta)P_s)Tr^x \sigma^2} r dr \\ &\quad + 2\pi p_a \lambda_s \eta \int_0^\infty e^{-[p_a \lambda_s \pi r^2 (1 + \rho(T, \alpha)) + \lambda_m \pi r^2 (TP_m / (cP_s))^{2/z} C(\alpha)]} \cdot e^{-1/(\eta P_s)Tr^x \sigma^2} r dr \\ p_m(\alpha, \lambda_s, \lambda_m) &= 2\pi \lambda_m \int_0^\infty e^{-[\lambda_m \pi r^2 (1 + \rho(T, \alpha)) + p_a \lambda_s \pi r^2 (cTP_s / P_m)^{2/z} C(\alpha)]} \cdot e^{-c/(\eta P_m)Tr^x \sigma^2} r dr \end{aligned}$$

Equation (12) is modified to

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$$p_m(\alpha, \lambda_s, \lambda_m) = \frac{1}{1 + \rho(T, \alpha) + \frac{p_a \lambda_s}{\lambda_m} (cTP_s/P_m)^{2/\alpha} C(\alpha)}$$

Equations (15) and (17) are modified to

$$p_a^* = \frac{\lambda_m}{2\lambda_s} \left(\frac{P_m}{cP_s} \right)^{2/\alpha} \left[\left(\left(\frac{(1-\eta)C(\alpha)T^{2/\alpha}}{1 + \rho(T, \alpha)} \right)^2 + 4\eta \right)^{1/2} - \frac{(1-\eta)C(\alpha)T^{2/\alpha}}{1 + \rho(T, \alpha)} \right]$$

Equation (18) is modified to

$$p_a^* = \frac{\lambda_m}{2\lambda_s} \left(\frac{P_m}{cP_s} \right)^{1/2} \left[\left(\left(\frac{(1-\eta)\pi T^{1/2}}{2(1 + \rho(T, 4))} \right)^2 + 4\eta \right)^{1/2} - \frac{(1-\eta)\pi T^{1/2}}{2(1 + \rho(T, 4))} \right]$$

In Appendix A, Eqs. (24) and (25) are, respectively, modified to

$$\begin{aligned} p_s^{\text{shared}}(T) &= \mathbb{E}_r[\mathbb{P}[\text{SINR}_s > T|r]] \\ &= \int_{r>0} \mathbb{P}[\text{SINR}_s > T] f_{r_s}(r) dr \\ &= \int_{r>0} \mathbb{P}\left[\frac{\eta P_s h r^{-\alpha}}{\sigma^2 + I_{s,s} + I_{s,m}} > T\right] f_{r_s}(r) dr \\ &= 2\pi p_a \lambda_s \int_{r>0} \mathbb{P}\left[h > \frac{Tr^\alpha}{\eta P_s} (\sigma^2 + I_{s,s} + I_{s,m})\right] \cdot e^{-\pi r^2 p_a \lambda_s} r dr \\ \mathbb{P}\left[h > \frac{Tr^\alpha}{\eta P_s} (\sigma^2 + I_{s,s} + I_{s,m})\right] &= \mathbb{E}_{I_{s,s}, I_{s,m}} \left[\mathbb{P}\left[h > \frac{Tr^\alpha}{\eta P_s} (\sigma^2 + I_{s,s} + I_{s,m}) \middle| I_{s,s}, I_{s,m} \right] \right] \\ &= \mathbb{E}_{I_{s,s}, I_{s,m}} \left[\exp\left(-\frac{1}{\eta P_s} Tr^\alpha (\sigma^2 + I_{s,s} + I_{s,m})\right) \right] \\ &= e^{-\frac{1}{\eta P_s} Tr^\alpha \sigma^2} \mathcal{L}_{I_{s,s}}\left(\frac{1}{\eta P_s} Tr^\alpha\right) \mathcal{L}_{I_{s,m}}\left(\frac{1}{\eta P_s} Tr^\alpha\right) \end{aligned}$$

Equations (26) and (27) are, respectively, modified to

$$\begin{aligned} \mathcal{L}_{I_{s,s}}(s) &= \mathbb{E}_{\Phi_s, \{g_{s,i}\}} \left[\prod_{i \in \Phi_s \setminus \{b_{so}\}} \mathbb{E}_{g_{s,i}} \left[\exp\left(-s\eta P_s g_{s,i} R_{s,i}^{-\alpha}\right) \right] \right] \\ &= \mathbb{E}_{\Phi_s} \left[\prod_{i \in \Phi_s \setminus \{b_{so}\}} \frac{1}{1 + s\eta P_s R_{s,i}^{-\alpha}} \right] \\ &= \exp\left(-2\pi p_a \lambda_s \int_r^\infty \left(1 - \frac{1}{1 + s\eta P_s v^{-\alpha}}\right) v dv\right) \\ \mathcal{L}_{I_{s,s}}(Tr^\alpha/(\eta P_s)) &= \exp(-\pi p_a \lambda_s r^2 \rho(T, \alpha)) \end{aligned}$$

Equations (28) and (29) are, respectively, modified to

$$\begin{aligned}
\mathcal{L}_{I_{s,m}}(s) &= \mathbb{E}_{\Phi_m, \{g_{m,i}\}} \left[\prod_{i \in \Phi_m} \mathbb{E}_{g_{m,i}} \left[\exp(-s\eta P_m g_{m,i} R_{m,i}^{-\alpha}) \right] \right] \\
&= \mathbb{E}_{\Phi_m} \left[\prod_{i \in \Phi_m} \frac{c}{c + s\eta P_m R_{m,i}^{-\alpha}} \right] \\
&= \exp \left(-2\pi\lambda_m \int_0^\infty \left(1 - \frac{c}{c + s\eta P_m v^{-\alpha}} \right) v dv \right) \\
\mathcal{L}_{I_{s,m}}(Tr^\alpha/(\eta P_s)) &= \exp \left(-2\pi\lambda_m \int_0^\infty \frac{\frac{P_m}{cP_s} T}{\frac{P_m}{cP_s} T + (v/r)^\alpha} v dv \right) \\
&= \exp \left(-\pi\lambda_m r^2 (TP_m/(cP_s))^{2/\alpha} \int_0^\infty \frac{1}{1+u^{2/2}} du \right)
\end{aligned}$$

Equations (30) and (31) are, respectively, modified to

$$\begin{aligned}
\mathcal{L}_{I_{s,m}}(Tr^\alpha/(\eta P_s)) &= \exp \left(-\pi\lambda_m r^2 (TP_m/(cP_s))^{2/\alpha} C(\alpha) \right) \\
p_s^{\text{unshared}}(T) &= \mathbb{E}_r [\mathbb{P}[\text{SINR}_s > T | r]] \\
&= 2\pi p_a \lambda_s \int_{r>0} \mathbb{P} \left[h > \frac{Tr^\alpha}{(1-\eta)P_s} (\sigma^2 + I_{s,s}) \right] \cdot e^{-\pi r^2 p_a \lambda_s} r dr \\
&= 2\pi p_a \lambda_s \int_{r>0} e^{-\pi r^2 p_a \lambda_s (1+\rho(T,\alpha))} e^{-Tr^\alpha \sigma^2 / ((1-\eta)P_s)} r dr
\end{aligned}$$

In Appendix B, the Eqs. (32), (33) and (34) are, respectively, modified to

$$\begin{aligned}
R_m &= \mathbb{E}[\ln(1 + \text{SIR}_m)] \\
&= \int_{r>0} \mathbb{E} \left(\ln \left(1 + \frac{\eta P_m h r^{-\alpha}}{I_{m,m} + I_{m,s}} \right) \right) f_m(r) dr \\
&= 2\pi\lambda_m \int_{r>0} \int_{t>0} \mathbb{P} \left[\ln \left(1 + \frac{\eta P_m h r^{-\alpha}}{I_{m,m} + I_{m,s}} \right) > t \right] \cdot e^{-\pi r^2 \lambda_m} dt dr \\
&= 2\pi\lambda_m \int_{r>0} \int_{t>0} \mathbb{P} \left[h > \frac{(e^t - 1)r^\alpha}{\eta P_m} (I_{m,m} + I_{m,s}) \right] \cdot e^{-\pi r^2 \lambda_m} dt dr \\
&= 2\pi\lambda_m \int_{r>0} \int_{t>0} \mathcal{L}_{I_{m,m}} \left(c \frac{r^\alpha}{\eta P_m} (e^t - 1) \right) \mathcal{L}_{I_{m,s}} \left(c \frac{r^\alpha}{\eta P_m} (e^t - 1) \right) \cdot e^{-\pi r^2 \lambda_m} dt dr \\
&\quad \mathcal{L}_{I_{m,m}}(c(e^t - 1)r^\alpha/(\eta P_m)) = \exp(-\pi\lambda_m r^2 \rho(e^t - 1, \alpha)) \\
&\quad \mathcal{L}_{I_{m,s}}(c(e^t - 1)r^\alpha/(\eta P_m)) = \exp(-\pi p_a \lambda_s r^2 (c(e^t - 1)P_s/P_m)^{2/\alpha} C(\alpha))
\end{aligned}$$

In Appendix A, $s = (Tr^{-\alpha})/P_s$ is modified to $s = Tr^\alpha/(\eta P_s)$.