Non-Orthogonal Multiple Access for mmWave Drone Communications

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Abstract

Non-orthogonal multiple access (NOMA) is a promising technology for the next generation communication systems due to its high spectral efficiency. In this work, we consider NOMA transmission for unmanned aerial vehicles (UAV) communications, where a flying base station is considered to serve densely packed user region, which might be a use case for stadiums, concert areas, etc. In particular, we investigate the optimal operation altitude of UAV to achieve the best user sum rates.

Problem Formulation

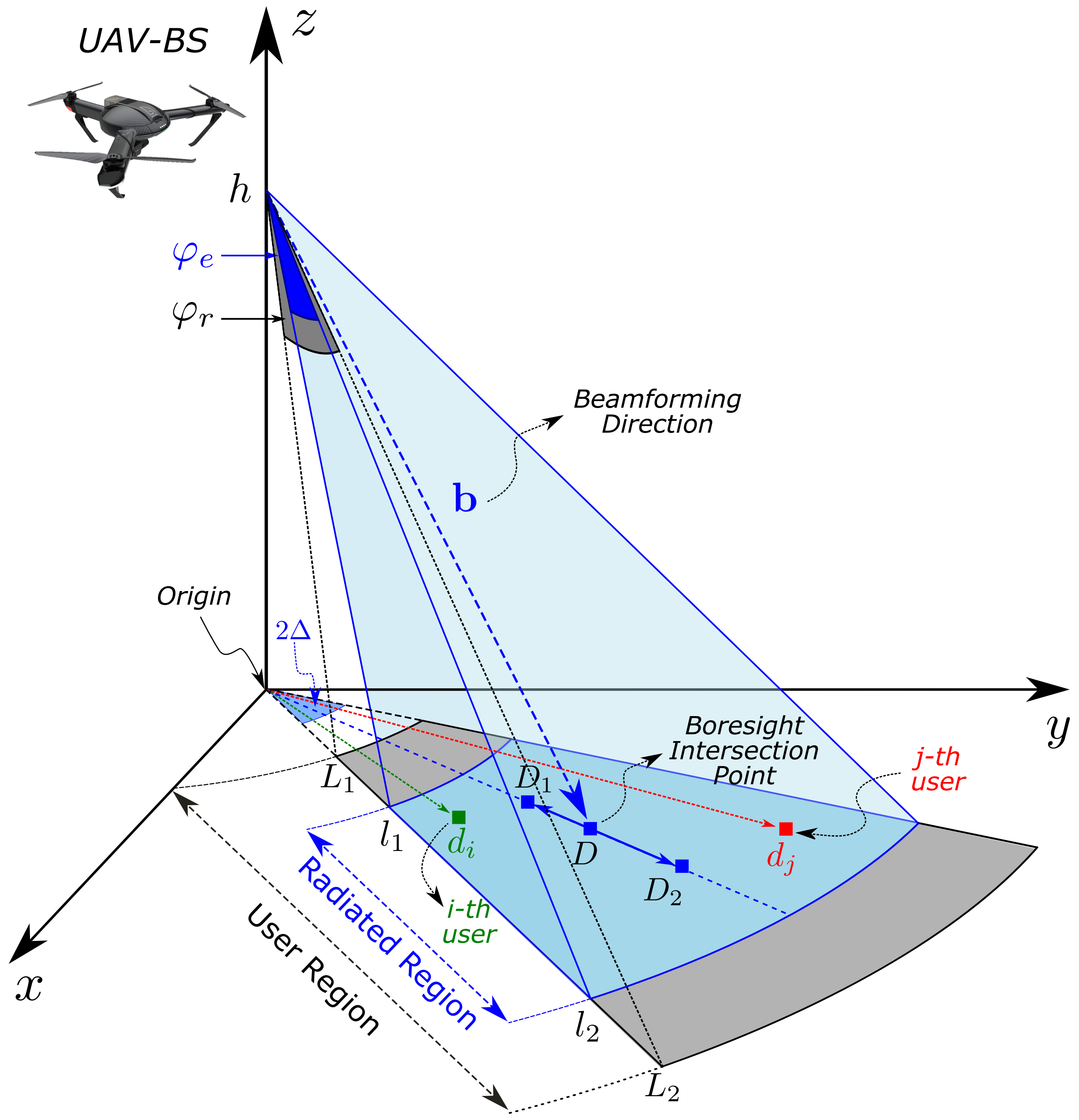

Figure 1: A multiuser DL scenario, where the entire *user region* is partially covered by the *radiated region*. NOMA transmission serves ith and jth users simultaneously within a single DL beam.

Depending on the coverage of user region, we identify 4 possibilities

- *Event* 1 (E_1): Both users are outside the radiated region,
- *Event* 2 (E_2): Only ith user is in the radiated region,
- *Event* 3 (E_3): Only jth user is in the radiated region,
- *Event* 4 (E_4): Both users are in the radiated region.

An example of coverage is given in Figure 2, where the upper and lower parts denote *insufficient* φ_e ($\varphi_e < \varphi_r$) and *sufficient* φ_e ($\varphi_e \geq \varphi_r$) regions, respectively, with respect to φ_r, where the user region is partially and fully covered, respectively.

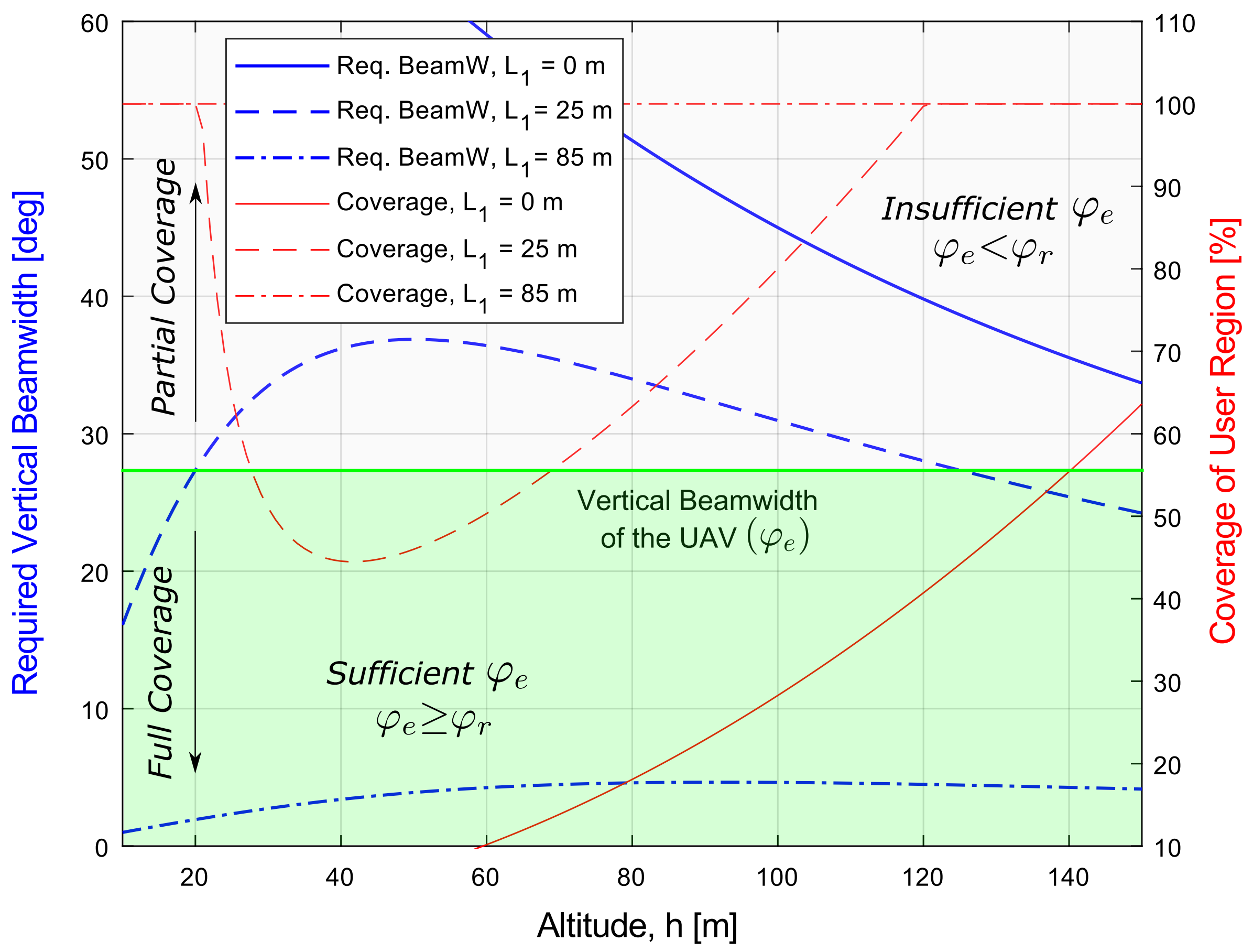

Figure 2: Required vertical beamwidth φ_r to cover the entire user region, and percentage of the user region covered by the UAV vertical beamwidth of $\varphi_e = 28°$ for various user deployment choices ($L_2 = 100$ m).

NOMA Transmission and SIC Receiver

Assuming that ith and jth users are the weak and strong users, respectively, with $i < j$, respective messages s_i and s_j are transmitted after superposition coding such that $s = \beta_i^2 s_i + \beta_j^2 s_j$. By successive interference cancellation (SIC), the resulting signal-to-interference-and-noise (SINR) for ith user is

$$\mathsf{SINR}_i = \frac{\left|\mathbf{h}_i^{\mathrm{H}}\mathbf{b}\right|^2 \beta_i^2}{\left|\mathbf{h}_i^{\mathrm{H}}\mathbf{b}\right|^2 \beta_j^2 + \gamma^{-1}},$$

and for jth user is

$$\mathsf{SINR}_{i\rightarrow j} = \frac{\left|\mathbf{h}_j^{\mathrm{H}}\mathbf{b}\right|^2 \beta_i^2}{\left|\mathbf{h}_j^{\mathrm{H}}\mathbf{b}\right|^2 \beta_j^2 + \gamma^{-1}}, \quad \text{and,} \quad \mathsf{SINR}_j = \left|\mathbf{h}_j^{\mathrm{H}}\mathbf{b}\right|^2 \beta_j^2 \gamma.$$

Assuming $R_i = \log_2\left(1 + \mathsf{SINR}_i\right)$ and $R_j = \log_2\left(1 + \mathsf{SINR}_j\right)$ are instantaneous rates, outage probabilities are

$$\mathsf{P}_j^{\mathrm{o}} = 1 - \Pr\left(R_{i\rightarrow j} > \overline{R}_i, R_j > \overline{R}_j\right),$$
$$\mathsf{P}_i^{\mathrm{o}} = 1 - \Pr\left(R_i > \overline{R}_i\right),$$

where $\overline{R}_k$ is the QoS based target rate of kth user. The respective sum rate is

$$R^{\mathrm{NOMA}} = \left(1 - \mathsf{P}_i^{\mathrm{o}}\right)\overline{R}_i + \left(1 - \mathsf{P}_j^{\mathrm{o}}\right)\overline{R}_j.$$

Numerical Results

We assume a geometry with $L_1 = 25$ m, $L_2 = 100$ m, and $\Delta = 0.2°$, ULA of vertical beamwidth $\varphi_e = 28°$ and size $M = 10$, noise power of $N_0 = -35$ dB, target rates of $\overline{R}_i = 0.5$ BPCU and $\overline{R}_j = 6$ BPCU with $\beta_i^2 = 0.75$ and $\beta_j^2 = 0.25$.

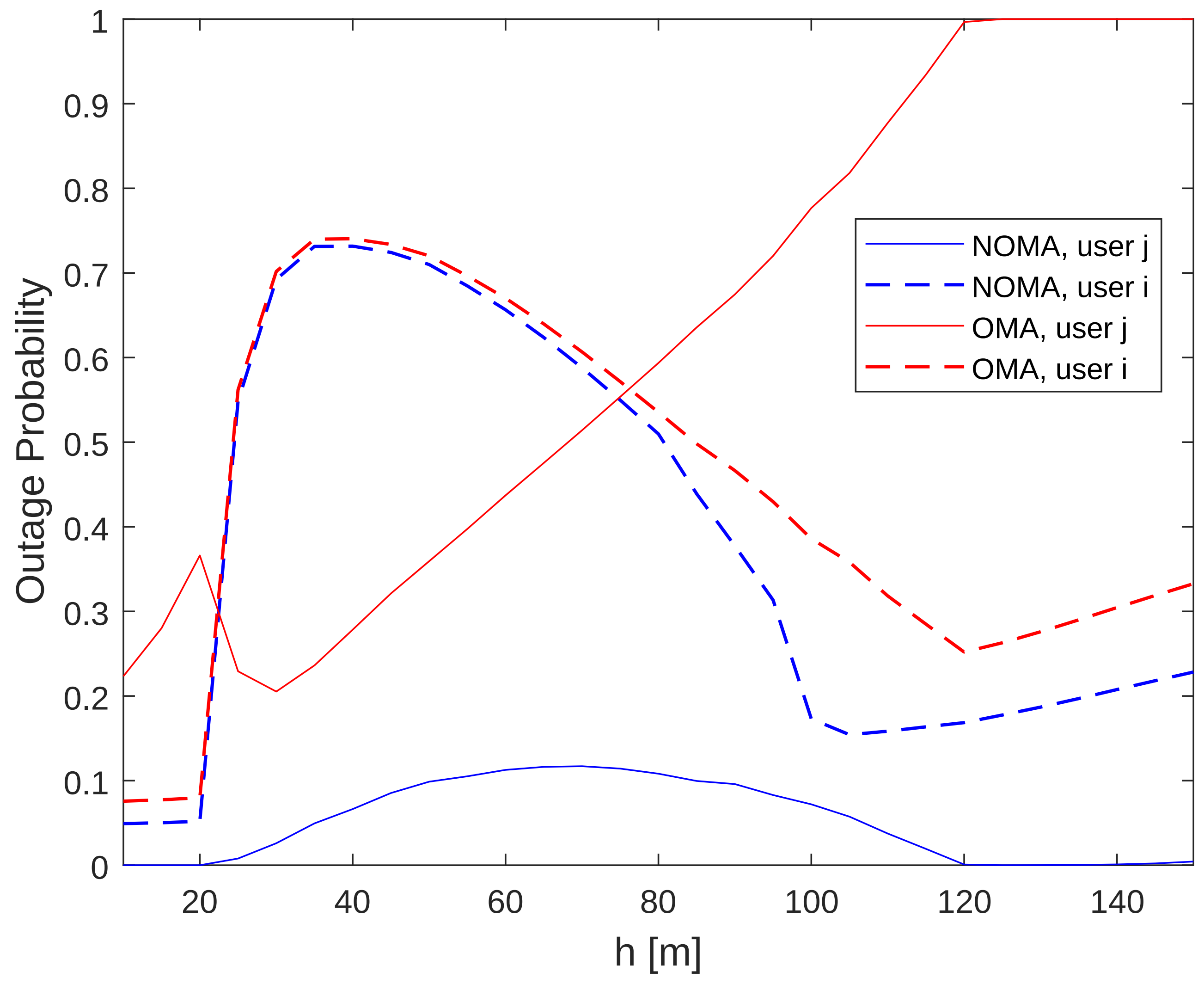

Figure 3: Outage probability for OMA and NOMA transmission strategies.

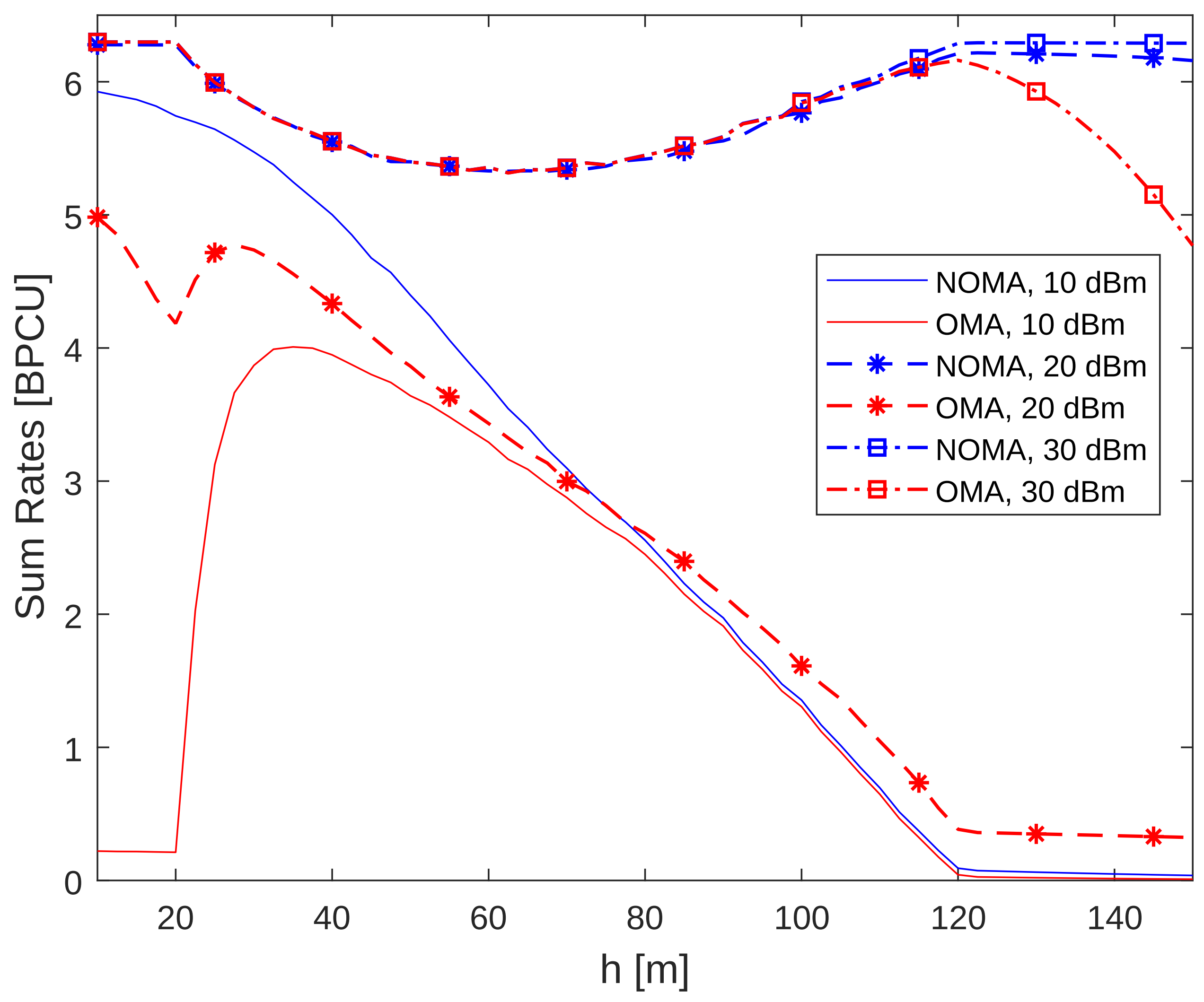

Figure 4: QoS based sum rates for OMA and NOMA transmission strategies.