Impact of Elevated Base Stations on the Ultra-Dense Networks

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Keywords

- Elevated BSs
- LoS(Line of Sight)/NLoS
- Stochastic geometry
- Coverage probability

UDN Characteristics

-The distance between BS and UE is small

- The height of BSs cannot be ignored
- The possibilities of having LoS propagation increases.

Former studies models

- Assumption: the probability of LoS propagations decreases as the antenna height of BSs increases -unlikely to be valid in practice

- BSs with a higher height are more likely to establish the LoS path towards the UEs.

- Assumption: equal height for all BSs-not realistic.

→heights of buildings should be different and random

System Model

- Single-antenna BSs and single-antenna Ues are randomly distributed.
- Modeled as PPPs(Poisson point processes) respectively(Φ_{BS} and Φ_{UE})
- each BS has at least one UE associated in its coverage for simplicity

System Model-Network Description

- All BSs have their antennas at the height l
- All UEs are on the ground
- Each BS supports one UE using time and frequency with the same transmission power.
- each BS has a LoS/NLoS path to associated UE with probability

$$\mathcal{P}_{\mathrm{L}}\left(r_i\right) = \frac{1}{1 + a\exp\left(-b\left(\theta\left(r_i\right) - a\right)\right)}$$

$$\mathcal{P}_{\mathrm{NL}}(r_i) = 1 - \mathcal{P}_{\mathrm{L}}\left(r_i\right)$$

System Model-Network Description

- Consider both fading and path loss
- LoS/NLoS propagation experiences Nakagami-m fading
    - *LoS: Rician fading
    - *NLoS: Rayleigh fading
- Path loss exponent $2 < \alpha_L \leq \alpha_{NL} \leq 4$

BS Association Rule

- the path loss exponents are different for LoS and NLoS propagations

→the signal strength of the nearest BS is not always the strongest one

- cf) conventional model : the signal strength of the nearest BS is the strongest one

- Consider BS with average strongest received power.

BS Association Rule

- Conventional PDF of the distance between UE and BS canoot be applied to the system.

- Should be consider LoS/NLoS propagation respectively.

BS Association Rule

- The approximated PDFs of r_0
- LOS

$$\tilde{f}^{\mathrm{L}}_{r_0}(r) = 2\pi\lambda_{\mathrm{BS}} r \left(1 - \exp\left(-p_\ell r^2\right)\right) \exp\left(-\pi\lambda_{\mathrm{BS}} r^{\frac{2\alpha_{\mathrm{L}}}{\alpha_{\mathrm{NL}}}}\right) \times \exp\left[\frac{\pi\lambda_{\mathrm{BS}}}{p_\ell}\left(\exp\left(-p_\ell r^2\right) - \exp\left(-p_\ell r^{\frac{2\alpha_{\mathrm{L}}}{\alpha_{\mathrm{NL}}}}\right)\right)\right]$$

- NLOS

$$\tilde{f}^{\mathrm{NL}}_{r_0}(r) = 2\pi\lambda_{\mathrm{BS}} r \exp\left(-p_\ell r^2\right) \exp\left(-\pi\lambda_{\mathrm{BS}} r^2\right) \times \exp\left[-\frac{\pi\lambda_{\mathrm{BS}}}{p_\ell}\left(\exp\left(-p_\ell r^2\right) - \exp\left(-p_\ell r^{\frac{2\alpha_{\mathrm{NL}}}{\alpha_{\mathrm{L}}}}\right)\right)\right]$$

p_l : tunable value determined by the BS height l

Signal-to-Interference Radio

- SIR at the typical UE located at the origin

$$\mathrm{SIR}_o = \frac{h_o\left({r_o}^2 + \ell^2\right)^{-\frac{\alpha_0}{2}}}{I_{\mathrm{L}} + I_{\mathrm{NL}}},$$

- h: channel fading(LoS: $h_0 = h_L$, NLoS: $h_0 = h_{NL}$
- r: horizontal distance between UE and BS
- α: pathloss exponent
- I_L, I_{NL}: total interference power received from BSs in $\Phi_L, \Phi_{\mathrm{NL}}$

Coverage Probability analysis

- The coverage probability of the system is

$$
\begin{aligned}
\mathrm{SIR}_o =& \mathbb{P}\left[\mathrm{SIR}_o > \zeta\right] \\
=& \int_0^\infty \mathbb{E}\left[\mathbb{P}\left[h_{\mathrm{L}} > \frac{\zeta I}{(r^2+\ell^2)^{-\frac{\alpha_{\mathrm{L}}}{2}}} \middle| r, I\right]\right] f_{r0}^{\mathrm{L}}(r)\,\mathrm{d}r \\
&+ \int_0^\infty \mathbb{E}\left[\mathbb{P}\left[h_{\mathrm{NL}} > \frac{\zeta I}{(r^2+\ell^2)^{-\frac{\alpha_{\mathrm{NL}}}{2}}} \middle| r, I\right]\right] f_{r0}^{\mathrm{NL}}(r)\,\mathrm{d}r,
\end{aligned}
$$

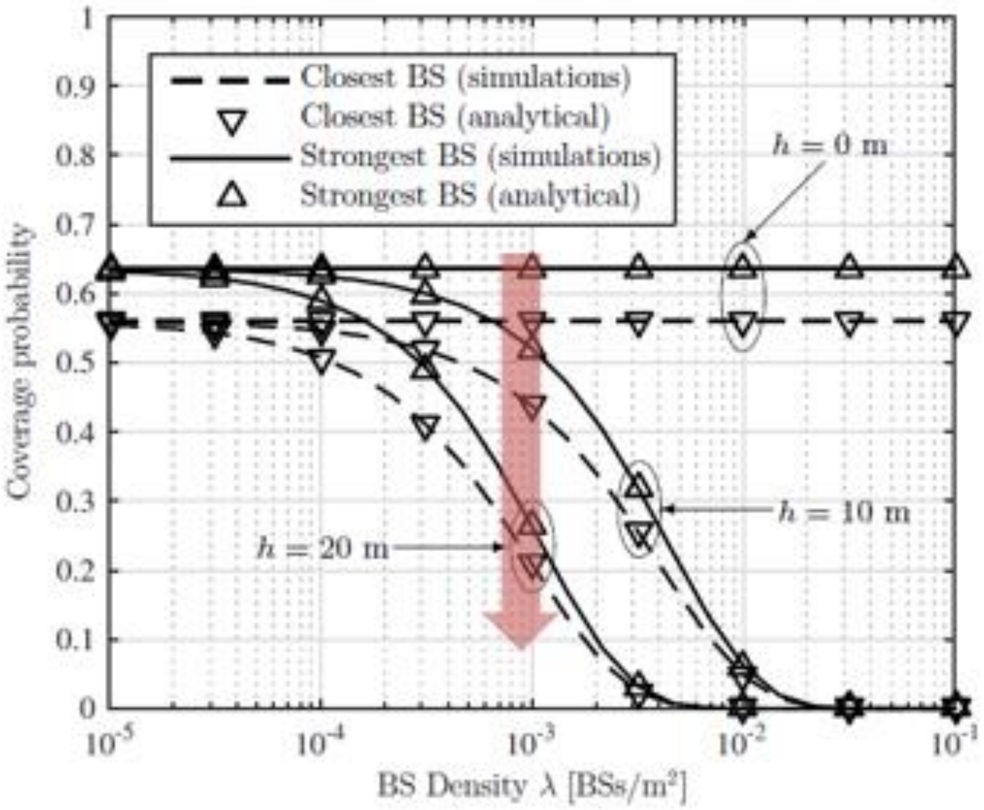
Coverage Probability Analysis

- **Coverage Probability**
  - **The coverage probability** when **the main link transmitter** is in ***j*-tier** under **channel *c*** is selected with **distance *d***

$$\boxed{p_j^{(c)}(d) = \mathbb{P}\left[\mathrm{SINR}_j^{(c)}(d) > \beta\right]}$$

- β : SINR threshold
- $\mathrm{SINR}_j^{(c)}(d) = P_j^{(c)}(d)/\mathcal{I}$ is SINR when the main link transmitter is in the *j*-tier under channel *c* with distance *d*

Numerical Results



$$P_{\mathrm{cov}}(\theta, \lambda) = P(\mathrm{SIR} > \theta)$$

Numerical Results

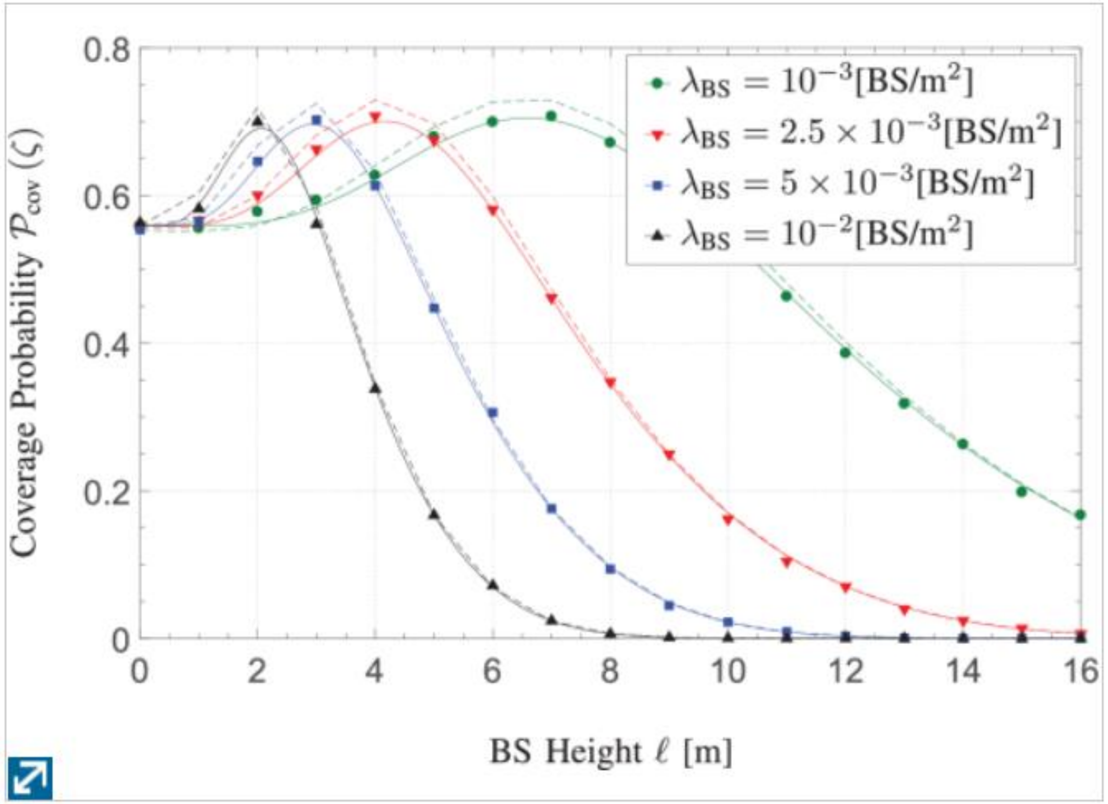


Fig. 2.
$\mathcal{P}_{\text{cov}}(\zeta)$ versus ℓ for difference values of λ_{BS} with $\zeta = 1$.

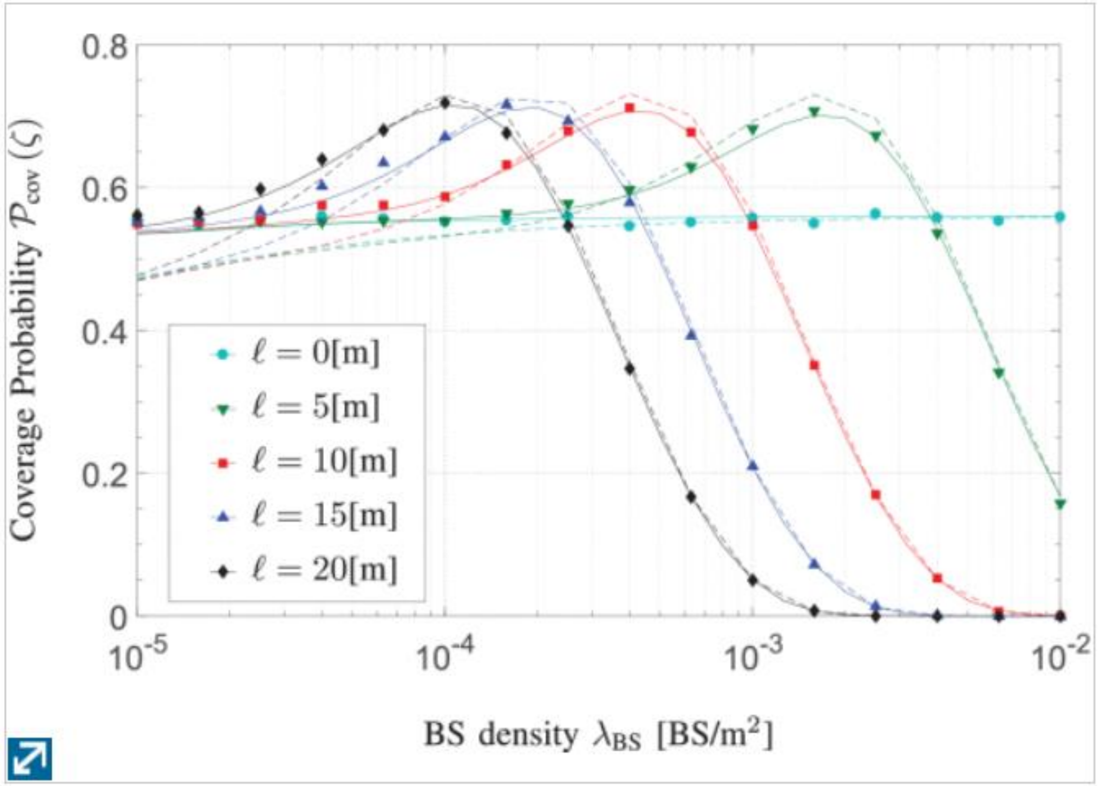


Fig. 3.
$\mathcal{P}_{\text{cov}}(\zeta)$ versus λ_{BS} for difference values of ℓ with $\zeta = 1$.

Questions?

Thank you