Studying the Effects of LTE Interference on CQI

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Introduction

- Python program for visualizing an LTE network's performance
  - The program simulates a hexagonal grid of base stations (BSs) with user equipment (UEs) positioned randomly and uniformly within a square area
  - Each BS has three antennas with a maximum transmission power of 46 dBm
  - Path loss for each antenna is calculated using the 3rd Generation Partnership Project's (3GPP) macro cell propagation model
- Goal: Test how different parameters, such as a BS's transmission probability, affect the interference and key performance indicators of an LTE network.
  - **Our contribution:** An LTE simulator for visualizing the channel quality indicators (CQIs) of UEs; this program is highly configurable and could be modified for other purposes, such as testing scheduling algorithms

System Model

UE and BS Positions: UEs are positioned randomly in a square area with side length S. BSs are positioned equidistant from each other on a circle with radius R, such that a hexagonal grid is formed with 6 BSs. Only two dimensions are considered.

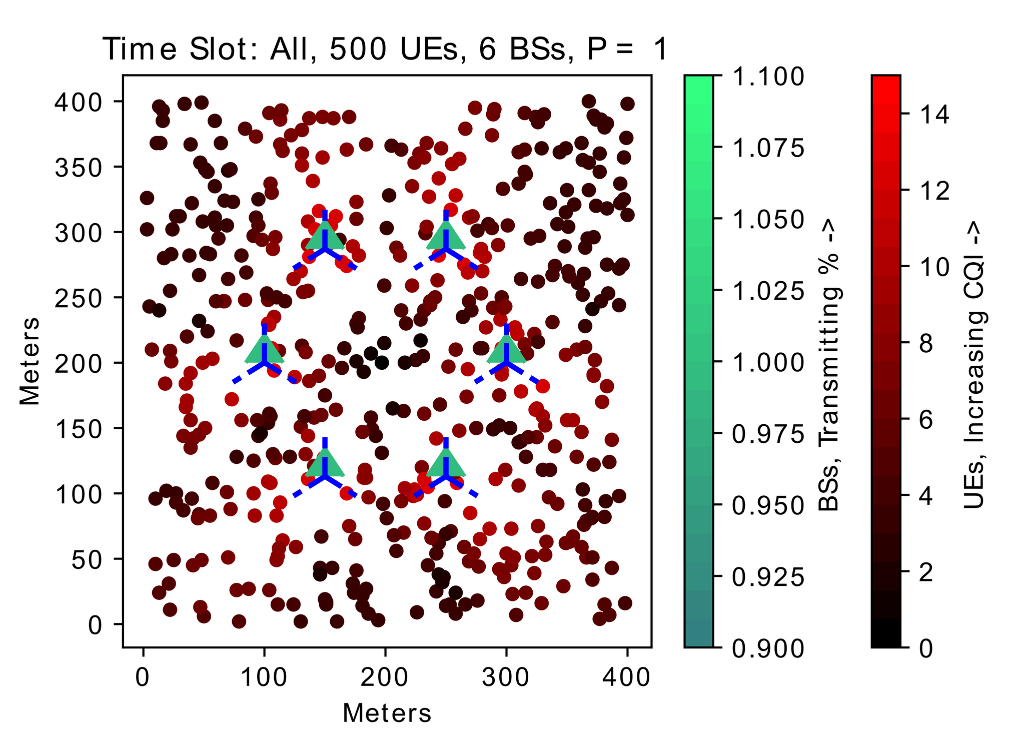

Figure: Six BSs (green triangles) with three antennas each (blue lines), and 500 UEs positioned randomly (red circles)

Each BS has three antennas with angles 90 degrees, 210 degrees, and 330 degrees, respectively. UEs with higher CQI values are plotted with brighter shades of red.

Path Loss Calculation: Each UE is associated with the antenna that gives it the highest signal power. First, the path loss L (dB) is calculated as a function of R, the distance from the UE to the antenna in km.

$$[1] \quad L_{dB}(R) = 128.1 + 37.6\log_{10} R_{km}$$

Antenna Gain Calculation: The angle A between the antenna and the UE is in the range [-180 degrees, 180 degrees]. The realized antenna gain, G, can be calculated using A, and M, the maximum antenna gain possible.

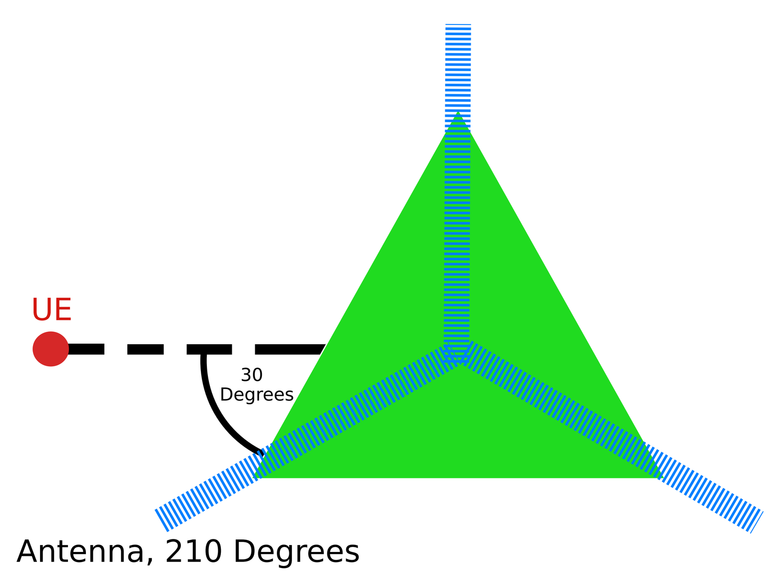

Figure: Determining the angle A between a UE and the 210 degree antenna it's associated with

$$[2] \quad G_{dB} = M_{dB} - min(12 * (A_{degrees}/70)^2, 20)$$

This equation is based on the "Simple Antenna Pattern" in 3GPP Release 15 [2].

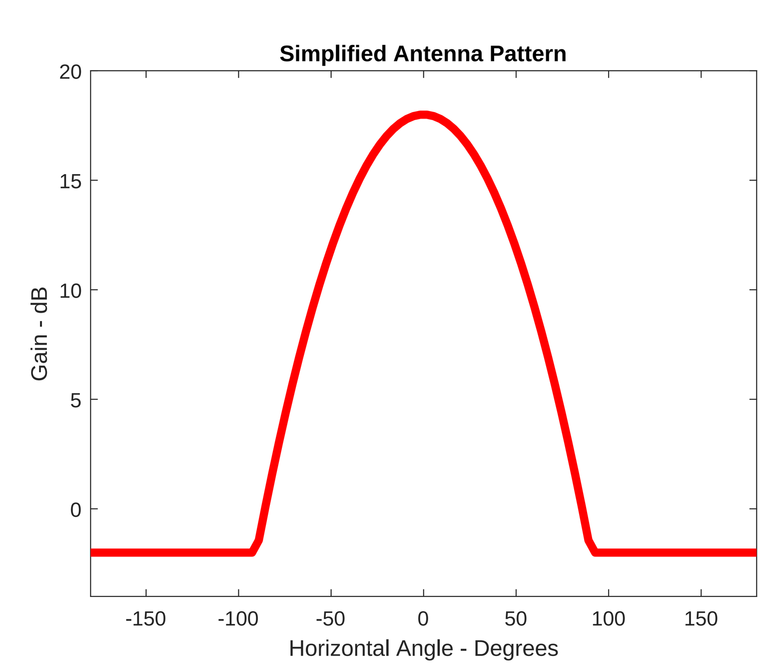

Figure: A plot of the implemented antenna pattern, with a maximum antenna gain G of 18 dB

UE Received Signal Power Calculation: After calculating the path loss, L, the received power P is determined. Antenna gain is not yet considered. Let T be the antenna transmission power, and N be a log-normal fading value, with a mean of 0 and a standard deviation of 6. All values are in dB.

$$P_{dB} = T_{dB} + G_{dB} - L_{dB} - N_{dB}$$

SINR and CQI A signal-to-interference-plus-noise ratio (SINR) is calculated for each UE using the power from the UE's associated antenna, P_0, the sum of all other antenna signal powers, P_1 - P_n, and N, a noise value in Watts.

$$SINR = \frac{P_0}{\sum_{n=1}^{k} P_k + N}$$

The SINR values are then mapped to CQIs using a table [3].

Plots

CQI Plots In each time step of the simulation, BSs are turned on with probability P. The following plot shows the average CQI values for different values of P. Each P value was simulated for 100 time steps.

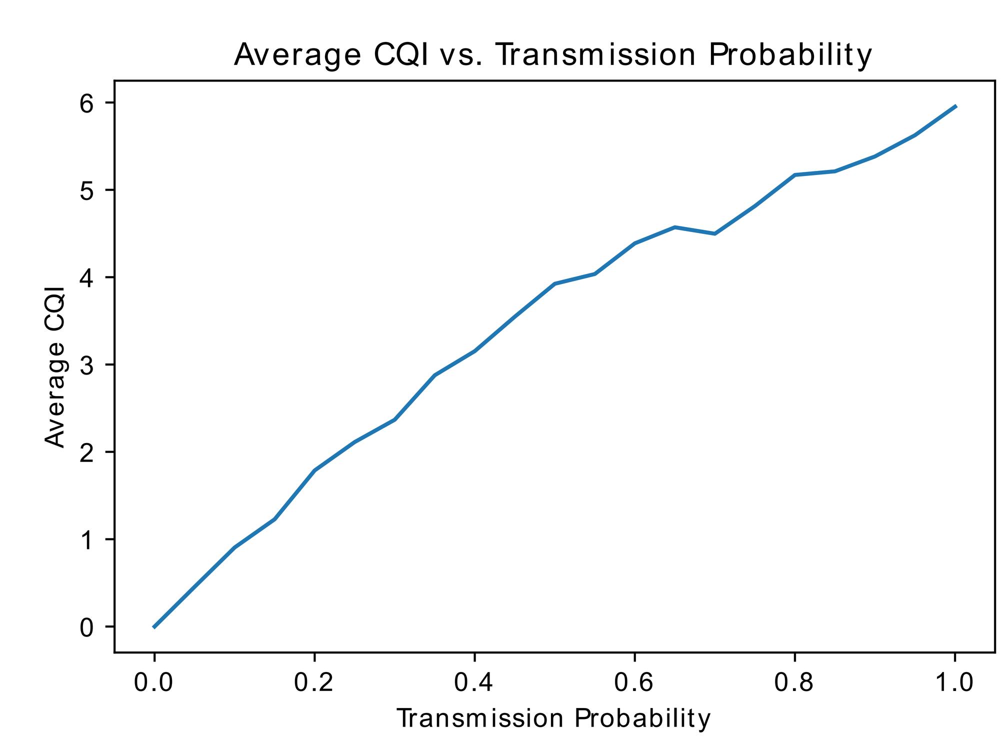

Figure: Plot of average CQI vs P with 20 data points

We see that the relationship between P and Average CQI is approximately linear:

Lastly, we plot a cumulative distribution function of all UE CQIs with P = 1.

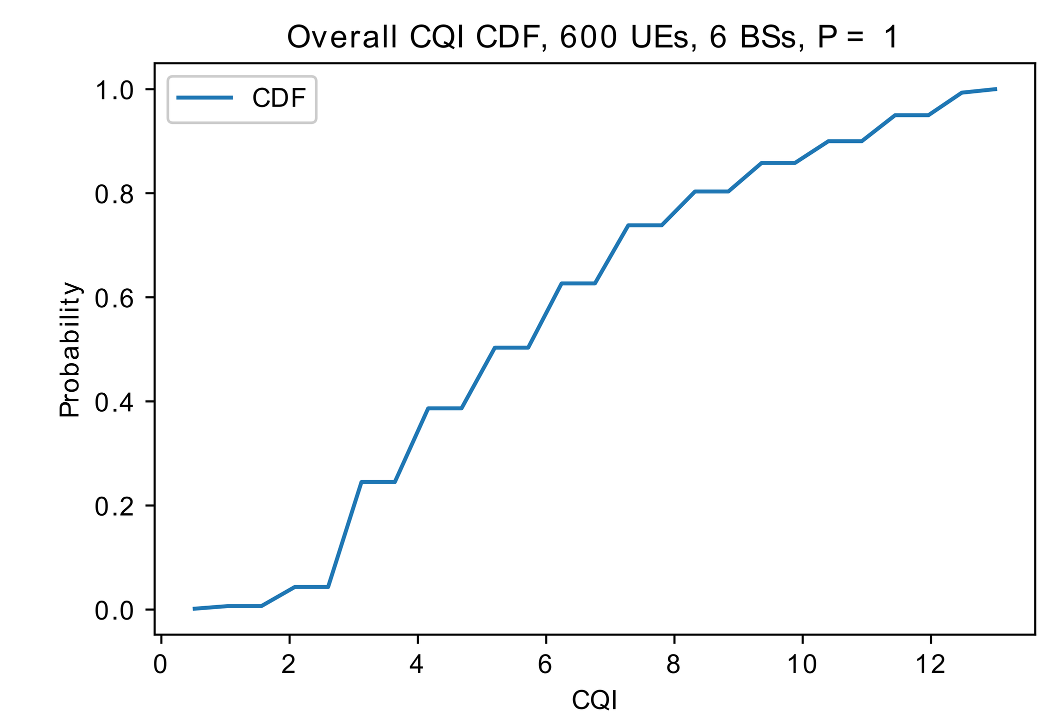

Figure: Cumulative distribution of CQIs, average CQI = 6

Conclusion

The relationship between P and average CQI in our system is approximately linear

- UEs in the center of the square experience the most interference
- UEs in corners of the square have low CQIs due to path loss

This program for visualizing network performance is highly configurable. Possible future modifications include adding scheduling algorithms, using more realistic UE positions, and measuring interference from BSs in space.

References

[1] ETSI 3rd Generation Partnership Project, "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) requirements for LTE Pico Node B," Release 9, p. 10, 2011.

[2] ETSI 3rd Generation Partnership Project, "5G; Study on channel model for frequencies from 0.5 to 100 GHz," Release 15, p. 22, 2018.

[3] J. C. Ikuno, M. Wrulich, and M. Rupp. "System Level Simulation of LTE Networks". In: 2010 IEEE 71st Vehicular Technology Conference.IEEE, 2010, p. 4.