www.tetcos.com

NetSim 5G NR

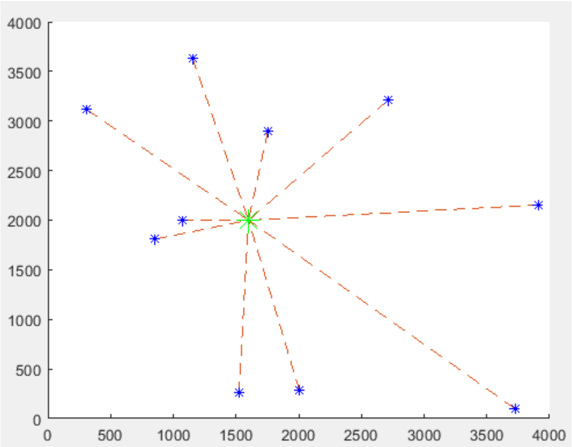
Optimal base-station placement for downlink throughput maximization

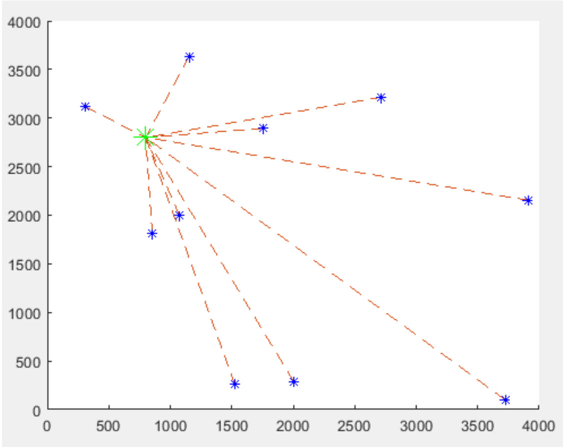
The problem

We have several (say N) stationary cellular users (UEs) at different locations.

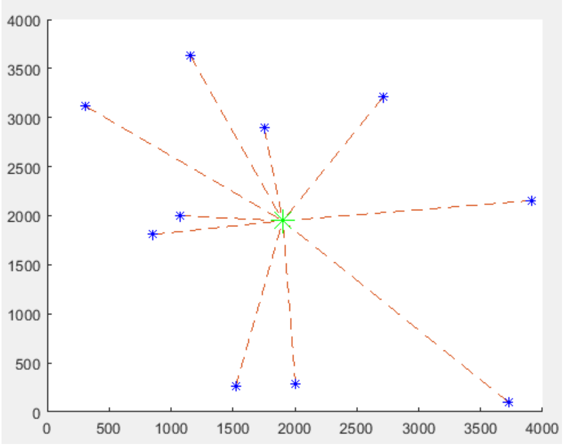
Let's denote these locations per the X-Y co-ordinate system as $(x_1, y_1), (x_2, y_2), \ldots, (x_N, Y_N)$.

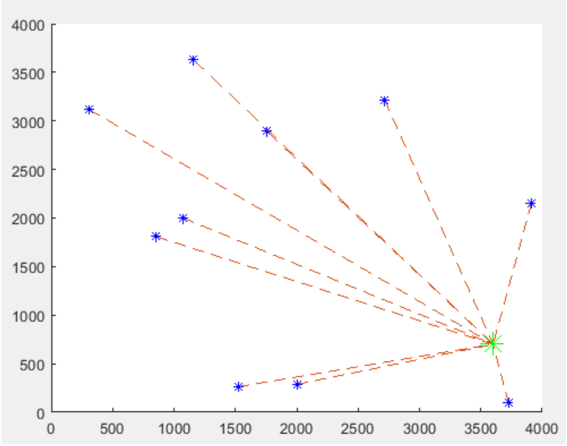
Where should one base station (gNB) station be placed to maximize aggregate downlink throughput i.e., sum of throughputs of individual UEs?





Which is the best gNB location?





Intuitive guesses

Least sum squared distance

- Compute the square of distance from gNB to each UE. Sum the (squared) distances. Find the point which minimizes this (sum squared) distance
- Result is center of mass. Place the base station at $\left(X^* = \frac{(x_1+x_2+ \ldots +x_n)}{N}, Y^* = \frac{(y_1+y_2+ \ldots +y_n)}{N}\right)$

Least sum distance

- Compute the distance from gNB to each UE. Sum the distances. Find the point which minimizes this (sum) distance. Place the base station at this point.
- Known as the geometric median problem and can be solved numerically using the Weiszfeld's algorithm

However (as shown later) these points do not give the best aggregate throughput

The exact solution and its algorithm

Theoretically, we know that signal to noise ratio, $SNR = \frac{C}{d_i^2}$,

where d_i is distance of i^{th} UE from the gNB, and that

$r_i = \log(1 + SNR) = \log\left(1 + \frac{C}{d_i^2}\right)$ where r_i is the rate

(throughput) seen by the i^{th} UE. Then (X*, Y*) the optimal

base station placement point is given by

$$(X^*, Y^*) = \arg\max_{X,Y} \sum_{i=0}^{n} \log\left(1 + \frac{C}{(X - x_i)^2 + (Y - y_i)^2}\right)$$

This is a difficult non-convex optimisation problem

Assumptions

(a) equal resource allocation to all UEs (round robin scheduler)

(b) log distance pathloss with exponent equal to 2

(c) no fading or shadowing

(d) SINR cutoff (γ_{high}) for Max rate (Highest MCS)

(e) SINR cut off (γ_{low}) for Min rate(Zero)

Algorithm: Generate a convex hull of the points and then grid that area. Evaluate the sum rate by placing the base station at each of the points. Pick the best point.

Applying the algorithm to a simple example

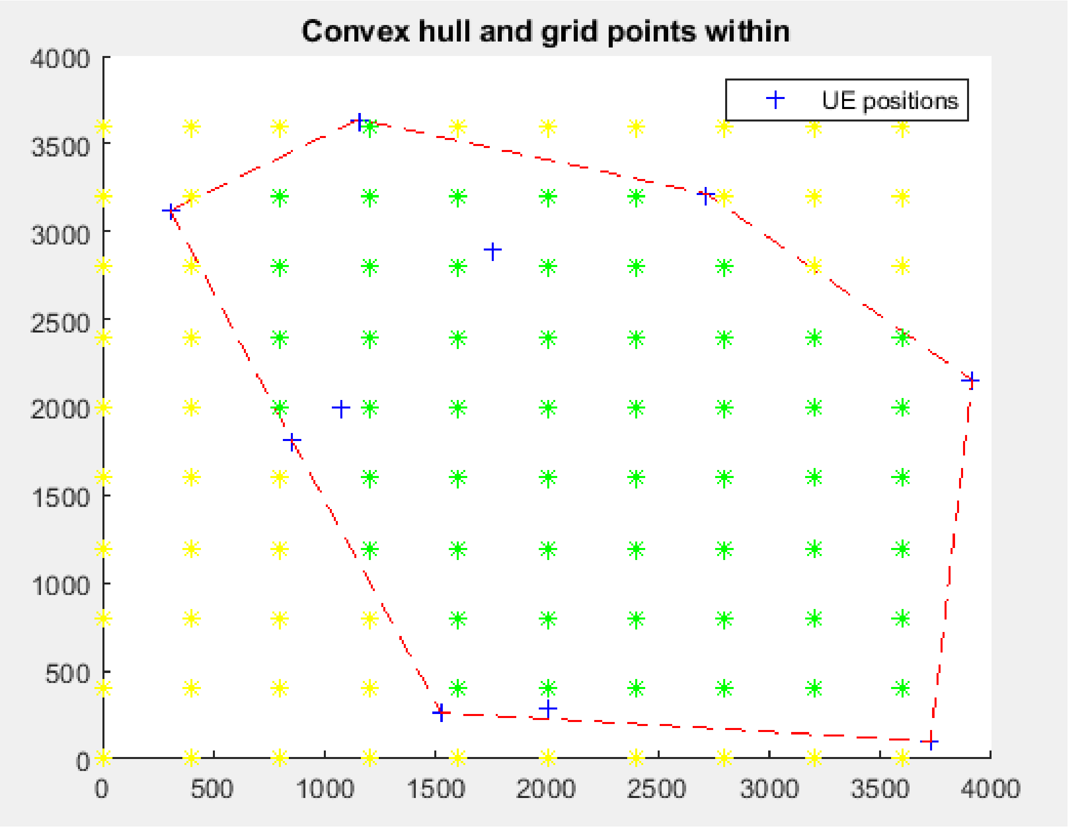
- We couple MATLAB with NetSim for optimization
- Consider a 4km * 4km area. Grid the area using D (=10) divisions in each X and Y
- Generate N (=10) random (X, Y) points within this area from MATLAB
  - Place N (=10) mobiles (UEs) at these (X, Y) points in NetSim
- Construct a planar 2D convex hull
  - MATLAB function convhull ( ) generates a 2D Hull
  - MATLAB function inpolygon ( ) finds grid points that are within the polygon (hull)
- Run NetSim simulations by placing the gNB at the grid points
  - Automate simulation execution using the multi-parameter sweeper utility
  - Record aggregate throughput at each point
- The point with max aggregate throughput is the optimal gNB position

MATLAB

NETSIM

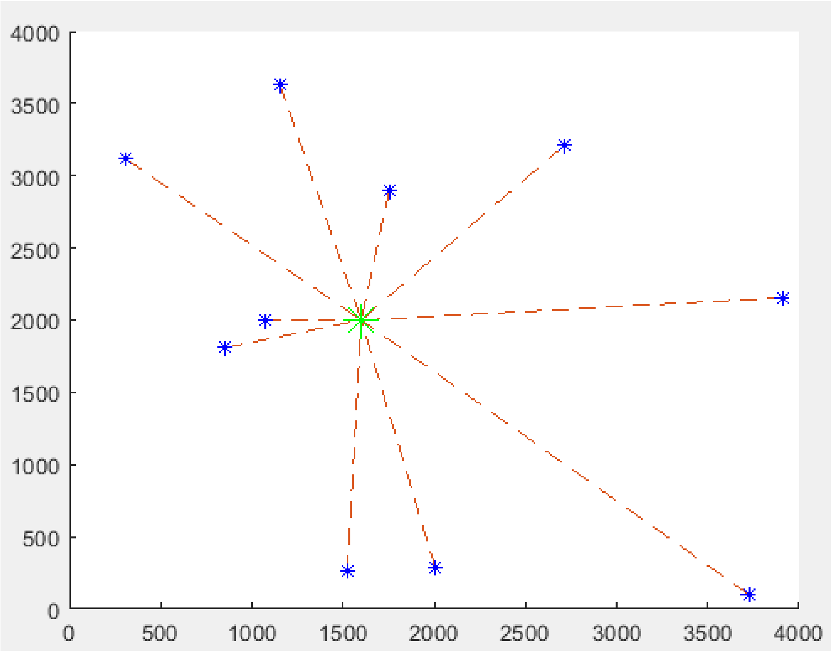
Simulation scenario and parameters

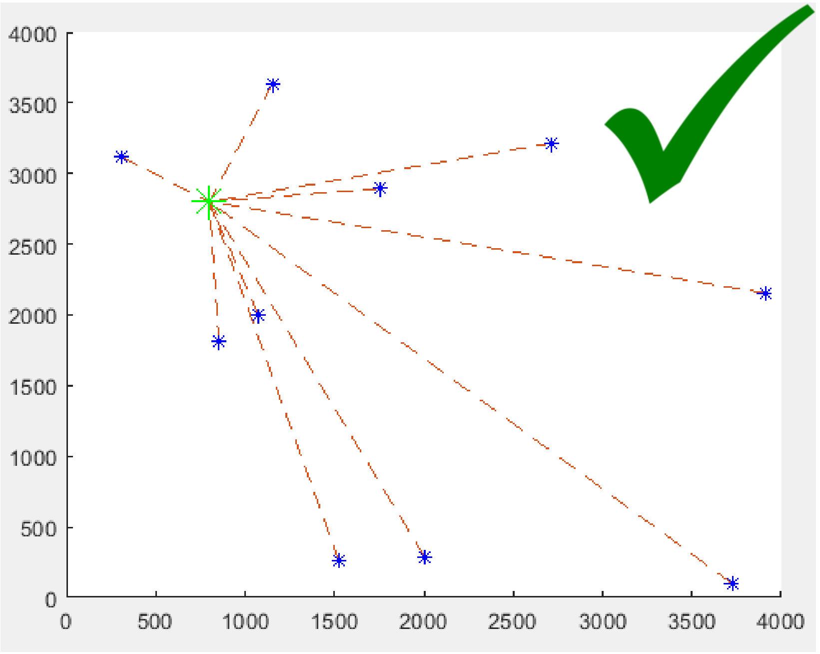
Simulation Parameters	Values
Environment Size	4 km x 4 km
Grid Points	Every 500m in X and in Y
Path loss Model	3GPP, no fading
LOS Probability	1
Base station Tx Power	40 dBm
Traffic Model	Full Buffer

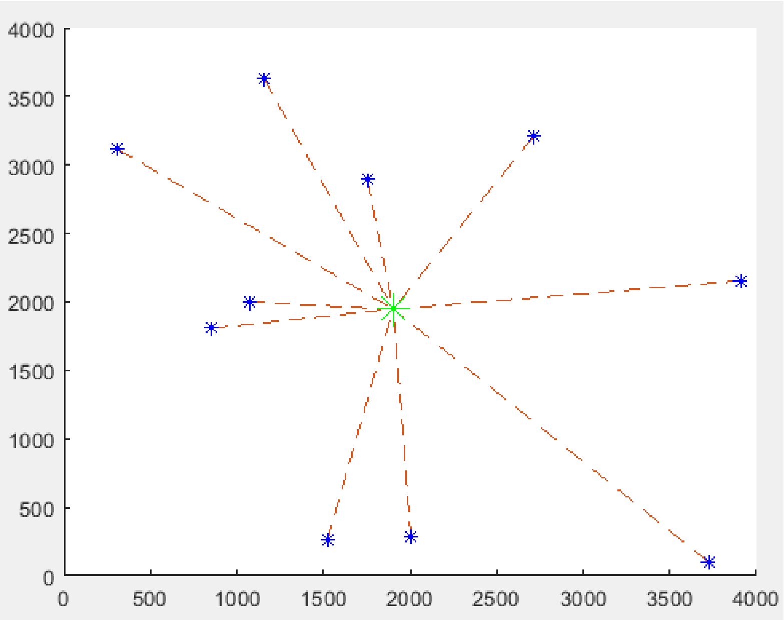


The green markers are the points where the base station can be placed. At each point the sum throughput is computed. We then pick the point with maximum aggregate throughput

Results and observations







Distance in meters and throughput in Mbps

Min Sum Distance
Sum Throughput = 251.65
Sum Distance = 15928

Max Sum Throughput
Sum Throughput = 310.64
Sum Distance = 18839

Min Sum Square Distance (Centre of mass)
Sum Throughput = 258.08
Sum Distance = 16186

Base station placement at min sum distance or at center of mass does not lead to max throughput
Optimal point (per algorithms) is different; gives more than 20% higher throughput

Similar questions that can be answered

- Where should K base stations be placed to maximize aggregate throughput of N users?
  - Subject to each user being guaranteed some minimum throughput
  - Variations: Urban/Rural environments, Line-of-sight/non line-of-sight
- What is the minimum number of base stations required?
  - To meet some coverage target
  - To meet average uplink/downlink throughput requirements for N users
- What is the optimal inter site distance (between base stations) for a highway?
- How many base stations should be added for doubling the average throughput?
- …. and so on

Requires a deep understanding of NetSim and a working knowledge of MATLAB
We can provide professional services for algorithms