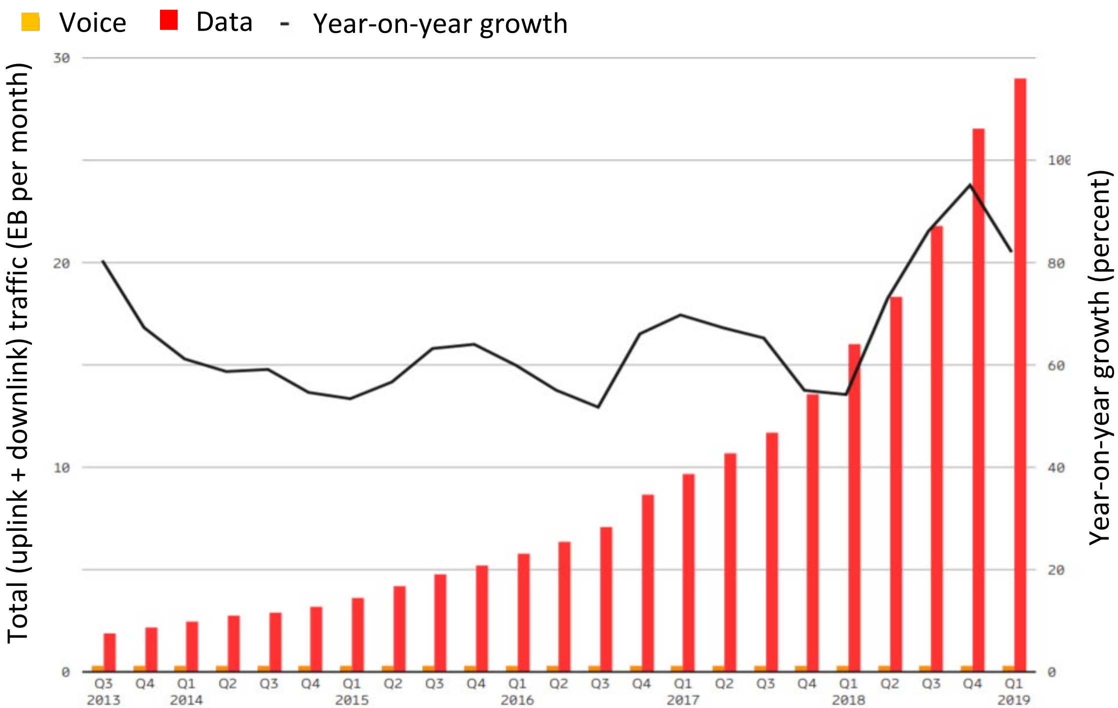
Interference-aware power coordination algorithm for 5G Ultra-Dense Networks (UDN)

Presented by

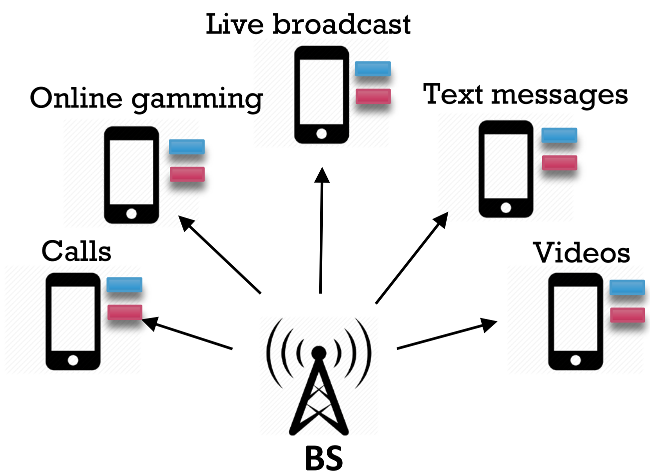
Alexis Anzaldo

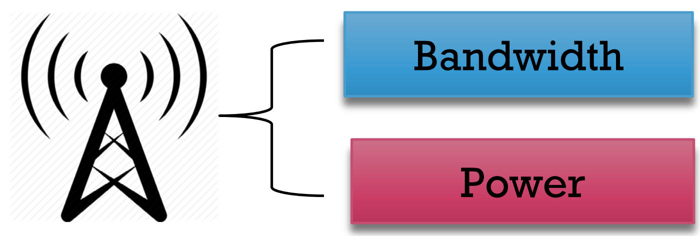
Problem Context



[1] Ericsson Mobility Report, June 2019.

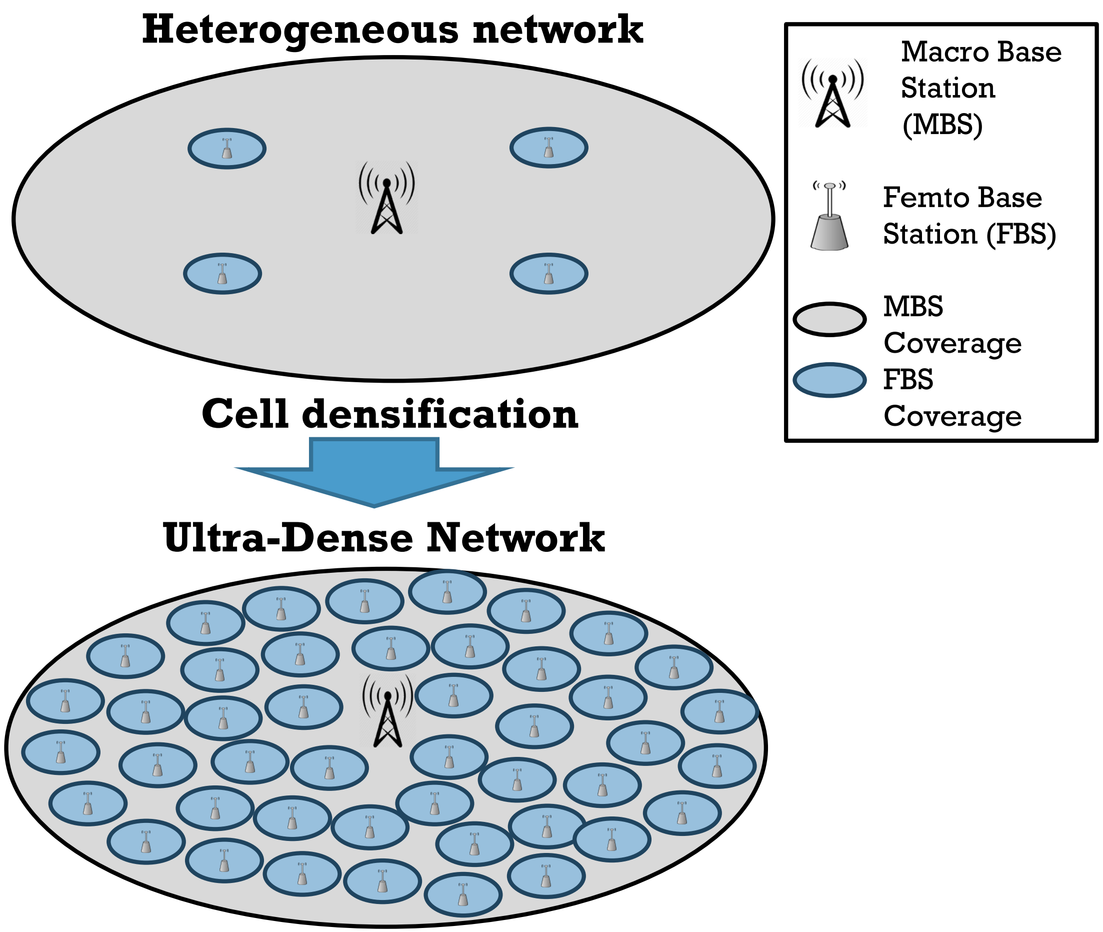
- Increment of data demands
- Increment of mobile users





BS allocate the resources to meet the users demands

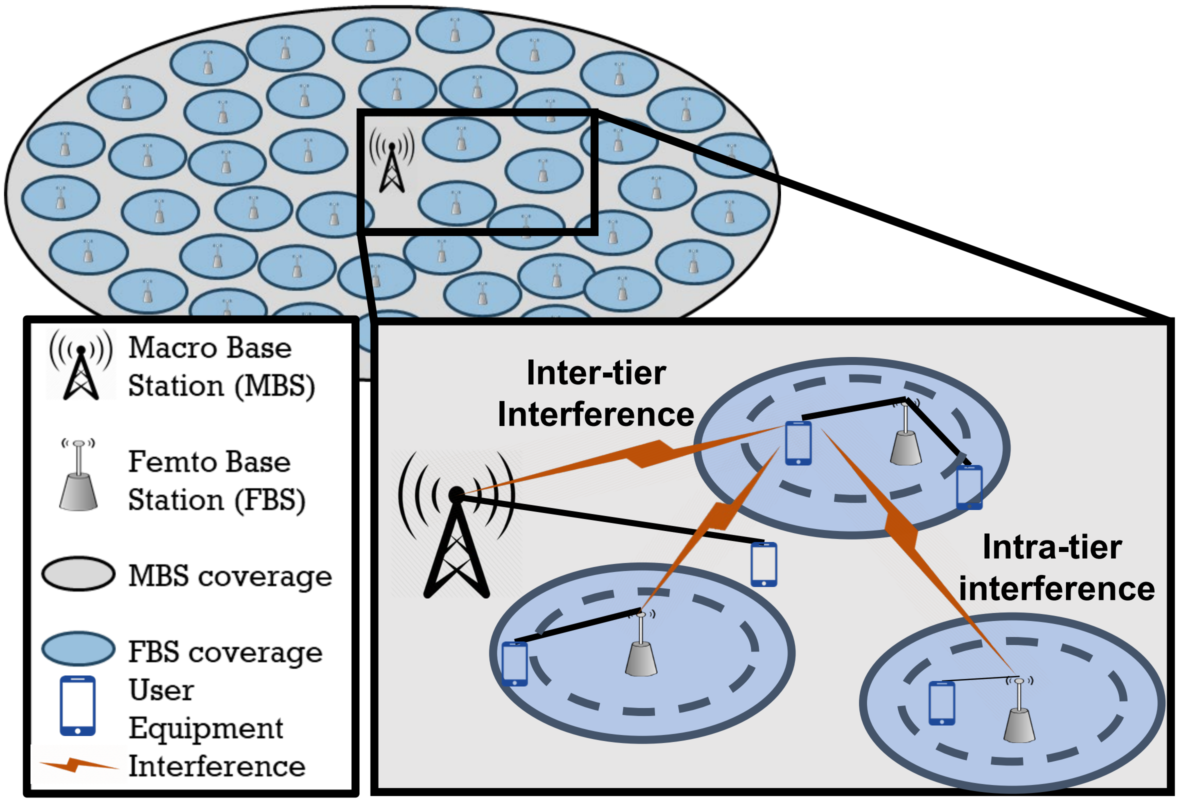
Ultra-Dense Network



UDN characteristics

- Enhance the user connections
- Offload the Macro Base Station traffic
- Increase the spectral reuse

Resource allocation problem



Shannon's capacity

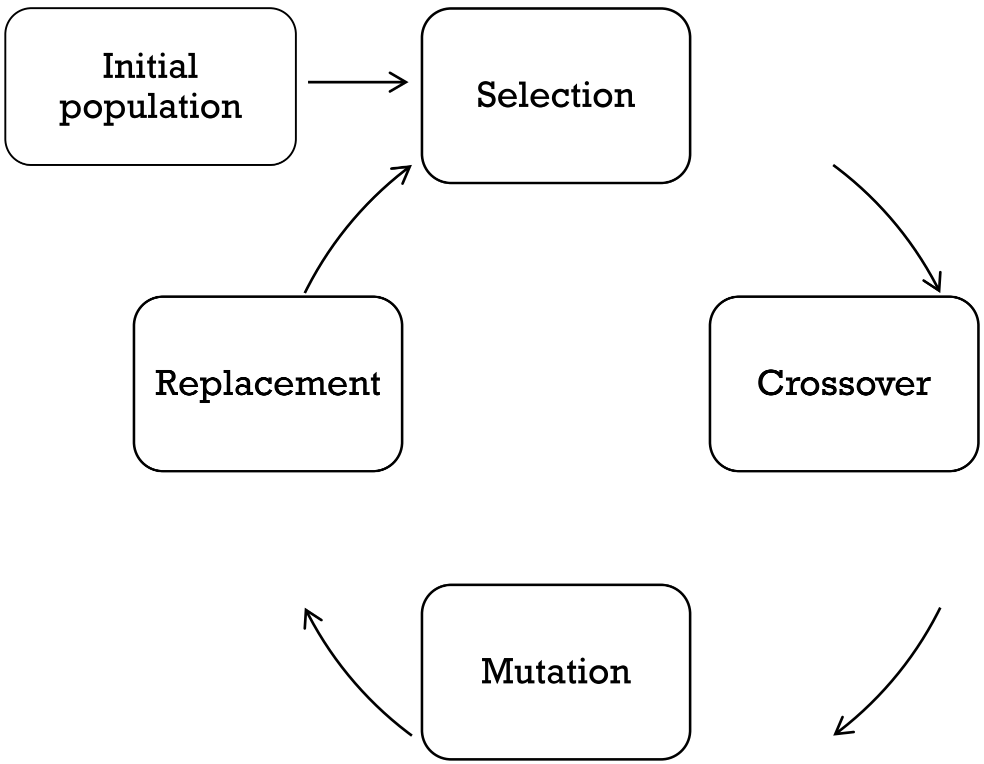
$$C = B\log_2(1 + SINR)$$

$$SINR = \frac{PL\alpha}{N+I}$$

B	Bandwidth	(Hz)
I	Interference	(Watts)
L	Pathloss	-
α	Multipath loss	-
P	Power	(Watts)
N	Noise power	(Watts)
SINR	Signal-to-noise-plus-interference ratio	**-**

Optimization Problem

Genetic Algorithm (GA) processs



$$max \sum_{i=1}^{I} \sum_{u \in \{i\}} \sum_{q \in \{u\}} B_{u,q} log_2(1 + SINR_{u,q})$$

$$SINR_{u,q} = \frac{P_{u,q} L_{i,u} \alpha_{u,q}}{N + \sum_{j \neq i}^{I} \sum_{w \neq u}^{U} P_{w,q} L_{j,u}}$$

s. t.

(1) $\sum_{u \in \{i\}} \sum_{q \in \{u\}} P_{u,q} \leq P_{max}^{i}, \forall i$

(2) $\sum_{u \in \{i\}} \sum_{q \in \{u\}} B_{u,q} \leq B_{max}^{i}, \forall i$

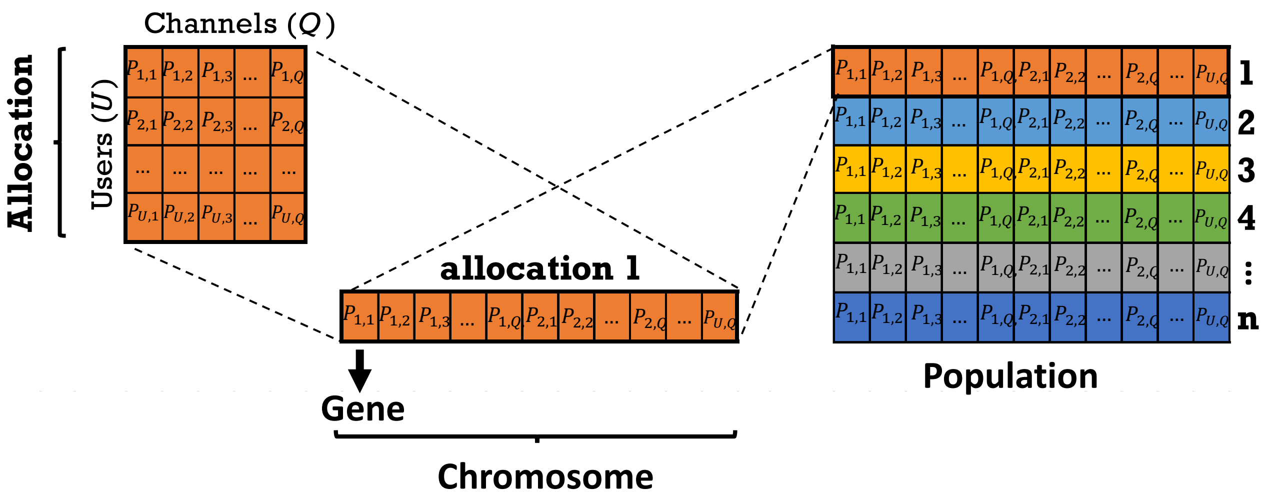
(3) $SINR_{u,q} \geq SINR_{th}$

$$\mathrm{F} = \frac{C}{1 + \alpha P_1 + \beta P_2}$$

C: *Network Throughput*
P_1: *Power Penalty*
P_2: *Unserver Users Penalty*
α, β: *weigth constant*
$\alpha \gg \beta$

Genetic Algorithm process (1/3)

Population structure



Gene: Represents the power in a channel

Chromosome : Represent the power allocation on all channels

Population: Represent the whole set of chromosomes

Initial population generation

Equal power transmission

$$P_{prom}^{Rb} = \frac{P_{max}^{i}}{Q^{i}}, \forall i$$

Q^{i}: Number of channels of BS i.

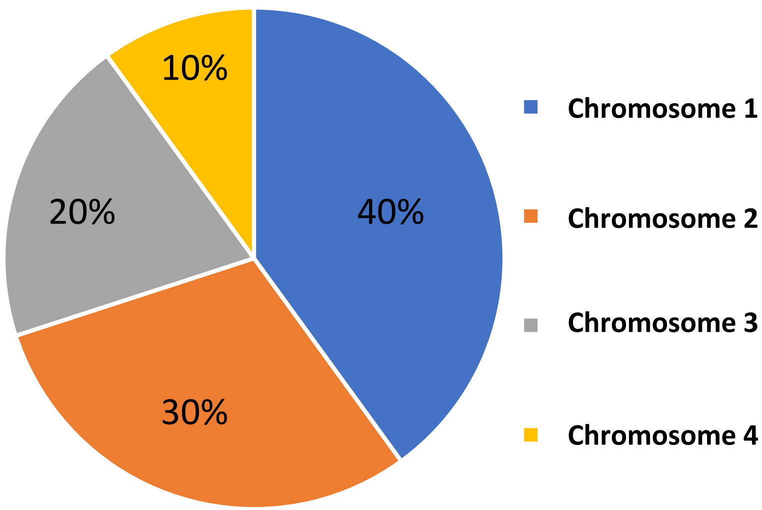
P_{max}^{i}: Maximum power of BS i.

Gene power range

$$[(P_{prom}^{Rb})/2, (P_{prom}^{Rb}) * 2]$$

Genetic Algorithm process (2/3)

Selection

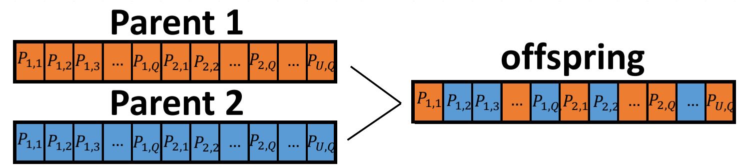


$$X_i = \frac{2R_i}{K(K+1)}$$

K is the population size

R_i is the position of chromosome *i* respect to the throughput in descent order

Crossover



Crossover by BLX-α operator [2]

$$\begin{cases} ub_i = \max(x_i^{(1)}, x_i^{(2)}) \\ lb_i = \min(x_i^{(1)}, x_i^{(2)}) \\ I = ub_i - lb_i \end{cases}$$

Random power values between these limits

$$[lb_i - I\alpha, ub_i + I\alpha]$$

ub_i: Upper bound of gene i of the parents

lb_i : Lower bound of gene i of the parents

I: Maximum range of gen i

α: Random uniform value between [0,1]

Genetic Algorithm process (3/3)

Mutation and replacement

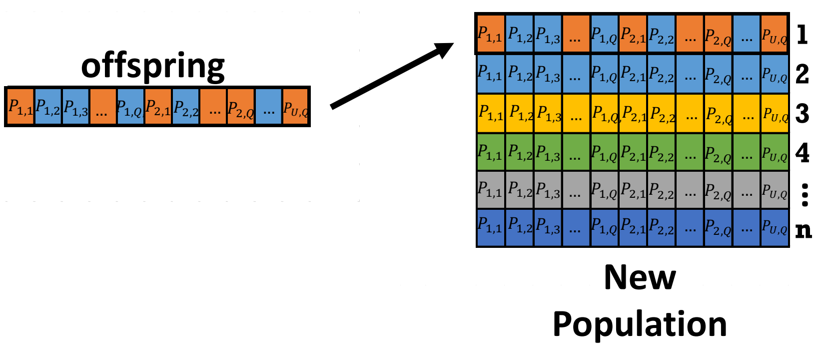
$$[(P_{prom}^{Rb})/2, (P_{prom}^{Rb}) * 2]$$

Mutation probability: 1%

0.28	0.31	0.43	0.24	0.15	0.12	0.21	0.07	**0.11**	0.27	0.38	0.41	0.09

0.28	0.31	0.43	0.24	0.15	0.12	0.21	0.07	**0.32**	0.27	0.38	0.41	0.09

Replacement: CD/RW [3]



Detention criteria

Iterations	100	1000	2000	3000	4000	5000
Throughput (Gbps)	1.99	2.81	3.01	3.11	3.17	3.25
Gain	-	40.97	7.23	3.28	2.09	1.48

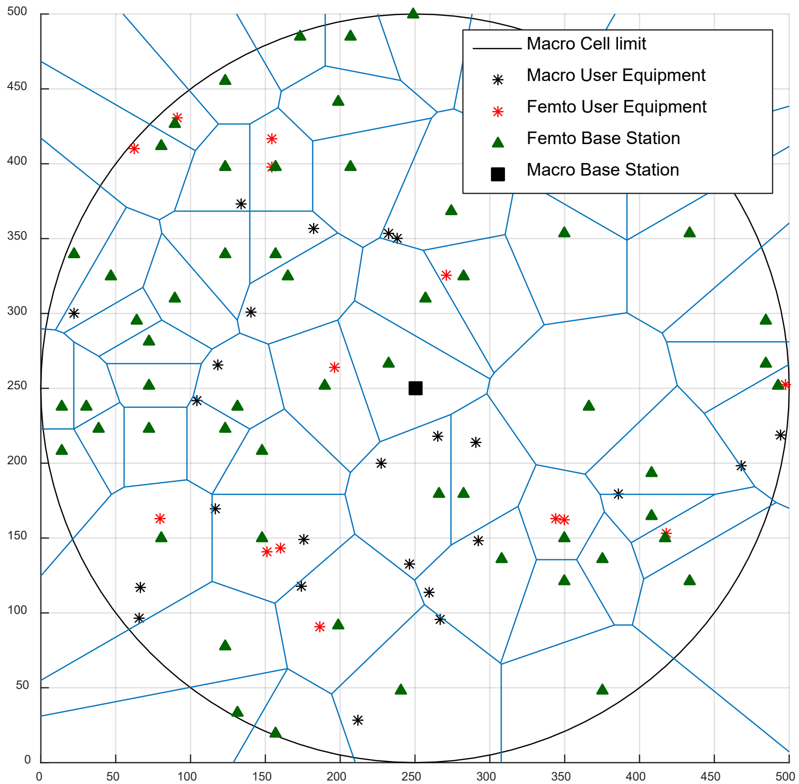
Genetic algorithm parameters

Crossover	BLX-α [2]
Detention criteria	3000 iterations
Initial population	Random Generation
Mutation probability	1%
Population size	30 chromosomes
Replacement strategy	CD/RW [3]
Selection method	Ranking Selection [4]

[2] Sorsa, A., Leiviskä, K. Real-coded genetic algorithms and nonlinear parameter identification. IS 2008 - IEEE International Conference on Intelligent Systems, Varna, Bulgaria, September 6-8, 2008.
[3] Lozano, Manuel & Herrera, Francisco & Cano, José. (1970). Replacement Strategies to Maintain Useful Diversity in Steady-State Genetic Algorithms. 10.1007/3-540-32400-3_7.
[4] N. Sivanandam, S & Deepa, S N. (2008). Introduction to Genetic Algorithms.

Results

Simulation Scenario



[5] M. Ding, D. Lopez-Perez, H. Claussen, M. A. Kaafar, " On the Fundamental Characteristics of Ultra Dense Small Cell Networks", *IEEE Network,* vol. 32, no. 3, pp 92-100, May/June 2018.

Simulation Parameters

Parameter	Value
Channel bandwidth	180 KHz
Fading Rayleigh parameter	1
FBS power	24 dBm
FBS radius	10, 25 m
GA Iterations	3000
Initial population	30
MBS power	46 dBm
MBS radius	250 m
Noise power density	-174 dBm/Hz
Density of Users (UED)	300, 600 UE/km^2
SINR-threshold	22.4 dB
Total channels	60

Downlink pathloss model

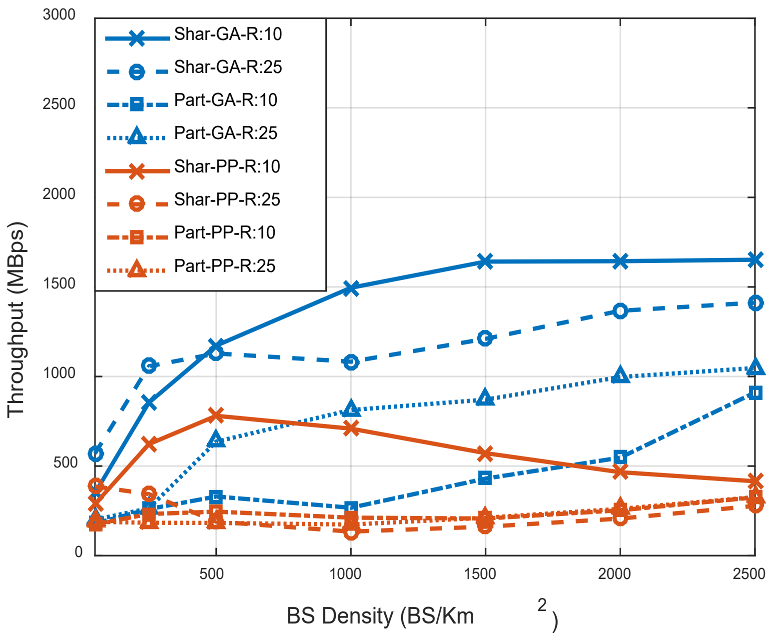
LOS Pathloss	$103.8 + 20.9 log_{10} d\ [dB], \quad (d \text{ in } km)$
NLOS Pathloss	$145.4 + 37.5 log_{10} d\ [dB], \quad (d \text{ in } km)$
LOS Probability	$\begin{cases} 1 - 5exp\left(\frac{-0.156}{d}\right), & 0 < d \leq 0.0667\ km \\ 5\exp\left(\frac{-d}{0.03}\right), & d > 0.0667\ km \end{cases}$

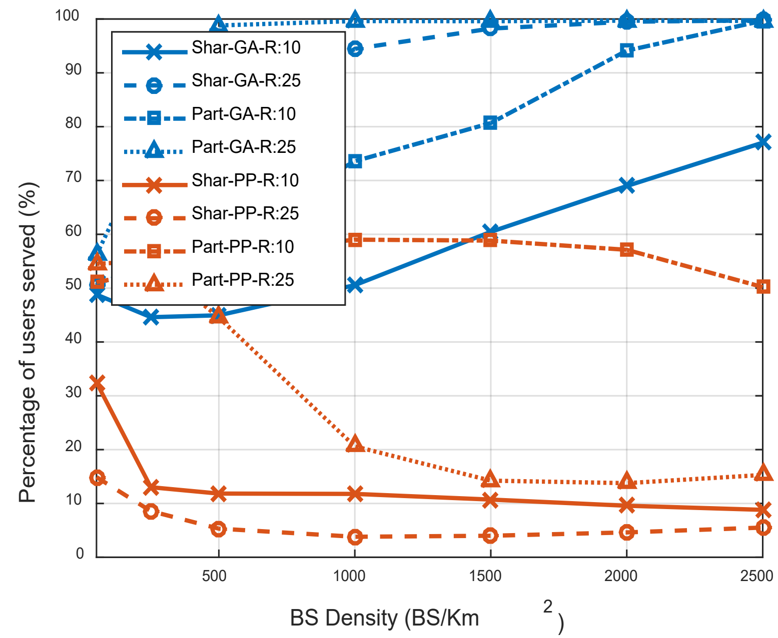
[6] 3GPP, "TR 36.828: Further Enhancements to LTE Time Division Duplex for Downlink-Uplink Interference Management and Traffic Adaptation," June 2012

Results

Base station increment

User Density: 600 UE/Km^2, SINR$_{th}$: 22.4 dB

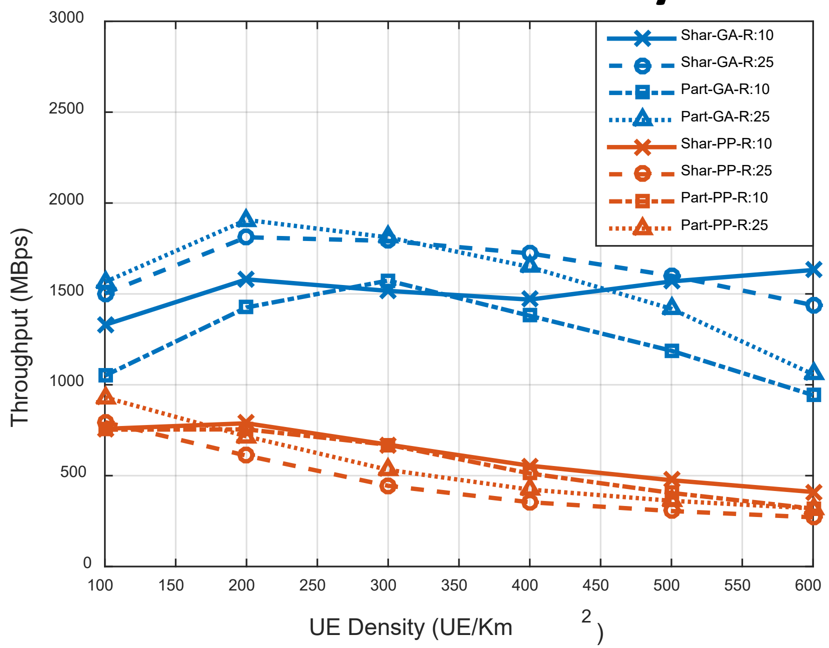


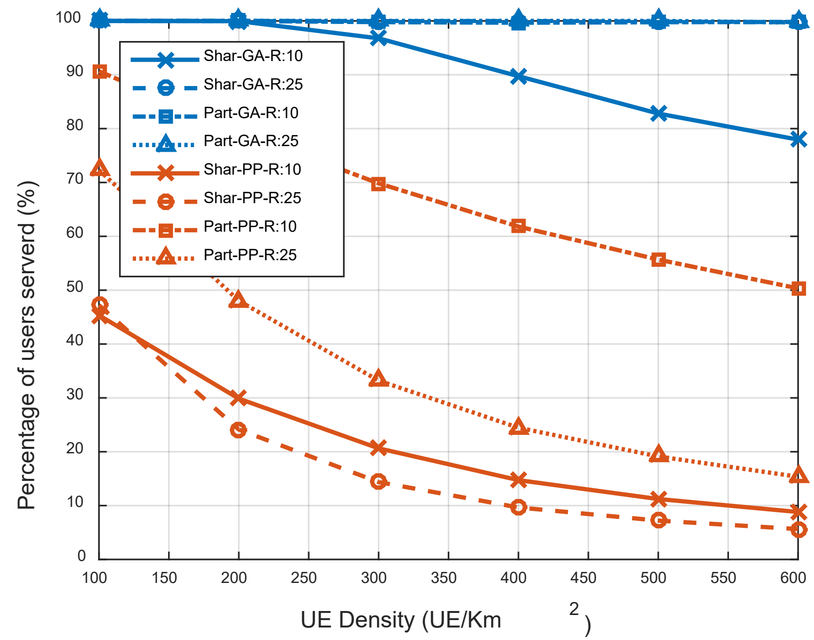


Results

User increment

BS Density: 2500 BS/Km^2, SINR$_{th}$: 22.4 dB





Conclusion

- Network densification is one promising strategy to accomplish 5G Mobile Systems capacity goals.
- The benefits of densification are limited because of interference and spectrum sharing among small-cells.
- Resource Allocation (RA) strategies can efficiently manage or avoid interference between small-cells.
- With a proper power allocation strategy is possible to maximize the network capacity and the percentage of users attended simultaneously.
- The robustness of our energy allocation algorithm must be improved to ensure that under all conditions, the total number of users in the UDN is served.

Thanks!