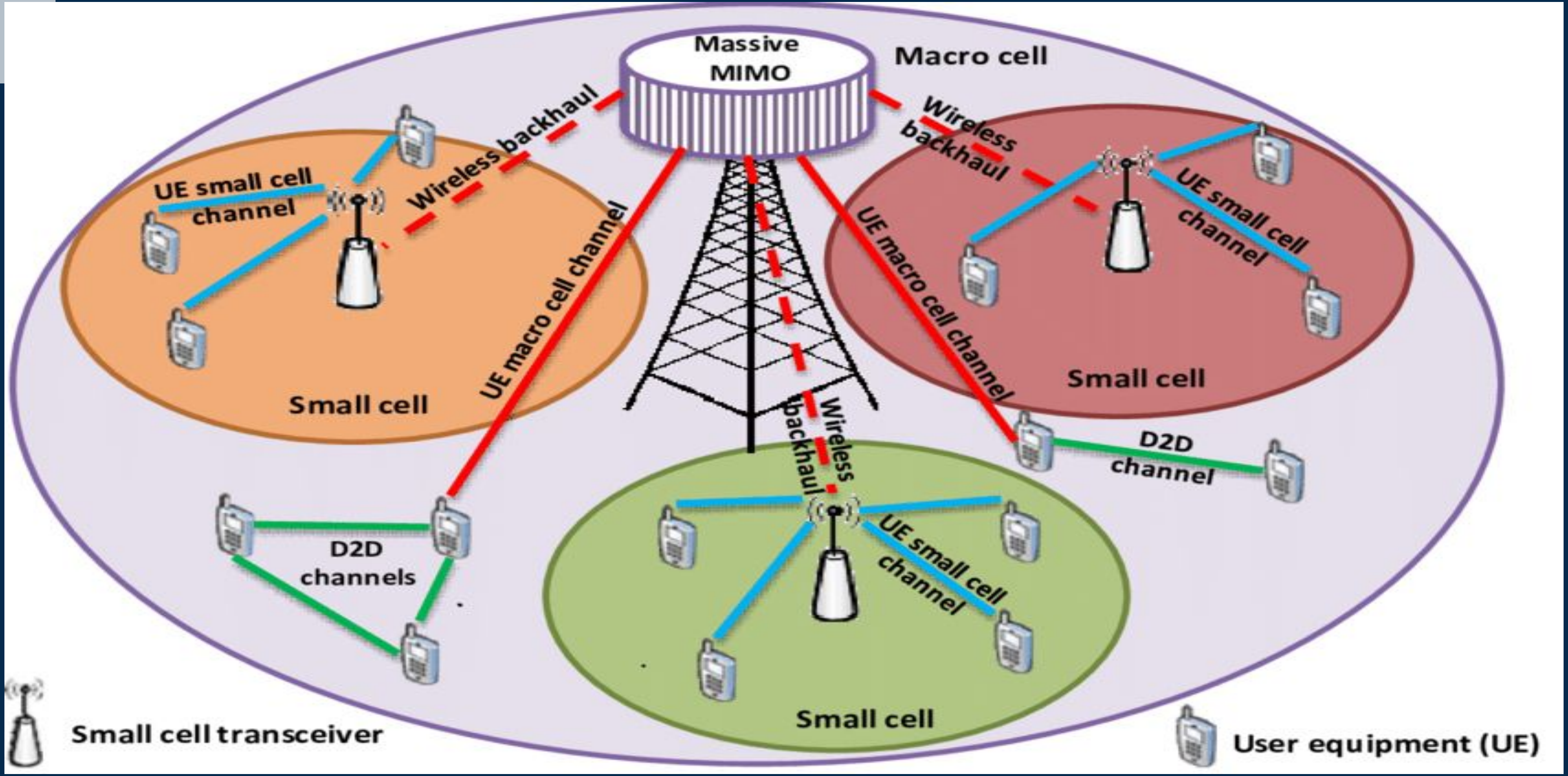
Simulating Massive MIMO and Small Cells

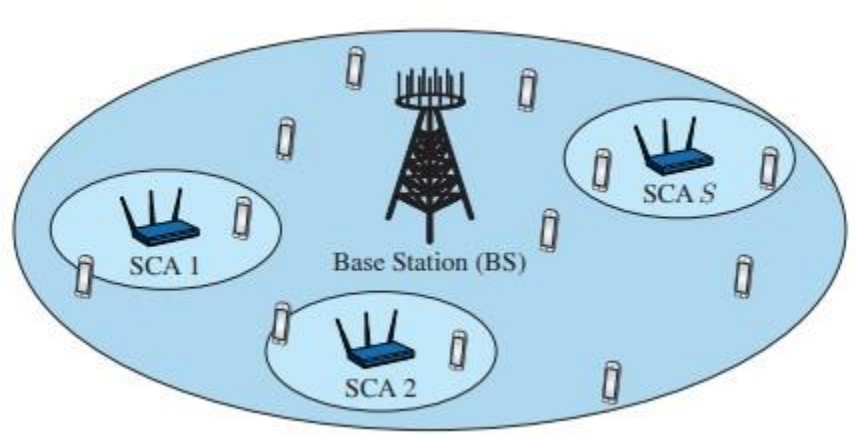


Objectives

- To improve the cellular energy efficiency, without sacrificing quality-of-service (QoS)
- Densify ‘Network Topology’ to enable higher spatial reuse.
    - MIMO base stations
    - Small-cell access points.
- Spatial soft-cell approach is taken where the multiple transmitters serve the users by joint non-coherent multiflow beamforming.
- Minimize the total power consumption satisfying QoS constraints.
- Hidden convexity that enables efficient solution algorithms.
- Exclusive assignment of users to transmitters.
- Total power consumption improved by combining massive MIMO and small cells; possible with both optimal and low-complexity beamforming.

Model [20]

Single-cell downlink scenario where a macro BS equipped with NBS antennas should deliver information to K single-antenna users.



$N_{BS} >> K$,Called Massive MIMO

Minimizing Power,

$$\begin{aligned} \underset{\mathbf{w}_{k,j}\ \forall k,j}{\text{minimize}} \quad & P_{\text{dynamic}} + P_{\text{static}} \\ \text{subject to} \quad & \log_2(1+\text{SINR}_k) \geq \gamma_k \quad \forall k, \\ & \sum_{k=1}^{K} \mathbf{w}_{k,j}^H \mathbf{Q}_{j,\ell} \mathbf{w}_{k,j} \leq q_{j,\ell} \quad \forall j,\ell. \end{aligned} \tag{7}$$

Algorithms

- Implementation of the Multiflow-RZF algorithm
    - General case with a macro base station and multiple small cells. Each transmitter applies regularized zero-forcing locally and joint power allocation.
- Minimize the total power consumption while satisfying the QoS,Power constraints
    - General case with a macro base station and multiple small cells. The power minimization under QoS requirements and power constraints.
    - Convex optimization problem.It is Complex(at least, handle 10 users, 100 antennas, and 100 power constraints)
- Minimize the total power consumption while satisfying the QoS,Power constraints
    - Special case of only a macro base station.

To minimize,

- Total transmit power subject to SINR_k >= SINRconstraints(k) for all users k.
- Power constraints.

Algorithms

Each transmitter j = 0, . . . , S computes

$$u_{k,j} = \frac{\left(\sum_{i=1}^{K} \frac{1}{\sigma_i^2} \mathbf{h}_{i,j}\mathbf{h}_{i,j}^H + \frac{K}{\bar{\gamma}_k q_j}\mathbf{I}\right)^{-1}\mathbf{h}_{k,j}}{\left\|\left(\sum_{i=1}^{K} \frac{1}{\sigma_i^2} \mathbf{h}_{i,j}\mathbf{h}_{i,j}^H + \frac{K}{\bar{\gamma}_k q_j}\mathbf{I}\right)^{-1}\mathbf{h}_{k,j}\right\|} \quad \forall k,$$

$$g_{i,k,j} = |\mathbf{h}_{i,j}^H \mathbf{u}_{k,j}|^2 \quad \forall i,k, \qquad Q_{j,\ell,k} = \mathbf{u}_{k,j}^H \mathbf{Q}_{j,\ell}\mathbf{u}_{k,j} \quad \forall \ell, k.$$

The jth SCA sends the scalars to the BS. The BS solves the convex optimization problem

$$\begin{aligned} \underset{p_{k,j}\geq 0 \ \forall k,j}{\text{minimize}} \quad & \sum_{j=0}^{S} \rho_j \sum_{k=1}^{K} p_{k,j} + P_{\text{static}} \qquad (9) \\ \text{subject to} \quad & \sum_{k=1}^{K} Q_{j,\ell,k} p_{k,j} \leq q_{j,\ell} \quad \forall j,\ell, \\ \sum_{j=0}^{S} p_{k,j} g_{k,k,j}\left(1+\frac{1}{\bar{\gamma}_k}\right) - & \sum_{i=1}^{K} p_{i,j} g_{k,i,j} \geq \sigma_k^2 \quad \forall k. \end{aligned}$$

The power allocation solving (9) sent to the jth SCA,

This algorithm applies the heuristic RZF beamforming

only a few parameters are exchanged per SCA while all other parameters are set to zero.

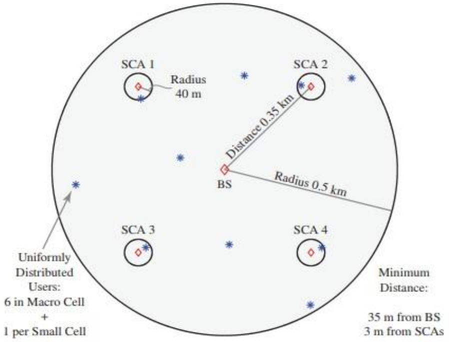


Fig. 2. The single-cell scenario analyzed in Section IV. The BS and SCAs are fixed, while the 10 users are randomly distributed as described above.

TABLE I
HARDWARE PARAMETERS IN THE NUMERICAL EVALUATION

Parameters	Values
Efficiency of power amplifiers	$\frac{1}{\rho_0} = 0.388$, $\frac{1}{\rho_j} = 0.052 \ \forall j$
Circuit power per antenna	$\eta_0 = 189$ mW, $\eta_j = 5.6$ mW $\forall j$
Per-antenna constraints	$q_{0,\ell} = 66$, $q_{j,\ell} = 0.08$ mW $\forall j,\ell$

Simulation/Numerical Evaluation

TABLE II
CHANNEL PARAMETERS IN THE NUMERICAL EVALUATION

Parameters	**Values**
Macro cell radius	0.5 km
Carrier frequency / Number of subcarriers	$F = 2$ GHz / $C = 600$
Total bandwidth / Subcarrier bandwidth	10 MHz / 15 kHz
Small-scale fading distribution	$\mathbf{h}_{k,j} \sim \mathcal{CN}(\mathbf{0}, \mathbf{R}_{k,j})$
Standard deviation of log-normal shadowing	7 dB
Path and penetration loss at distance d (km)	$148.1 + 37.6 \log_{10}(d)$ dB
Special case: Within 40 m from SCA	$127 + 30 \log_{10}(d)$ dB
Noise variance σ_k^2 (5 dB noise figure)	-127 dBm

MATLAB + Algorithmic toolbox SeDuMi [12], using the modeling language CVX[4][5]

Results

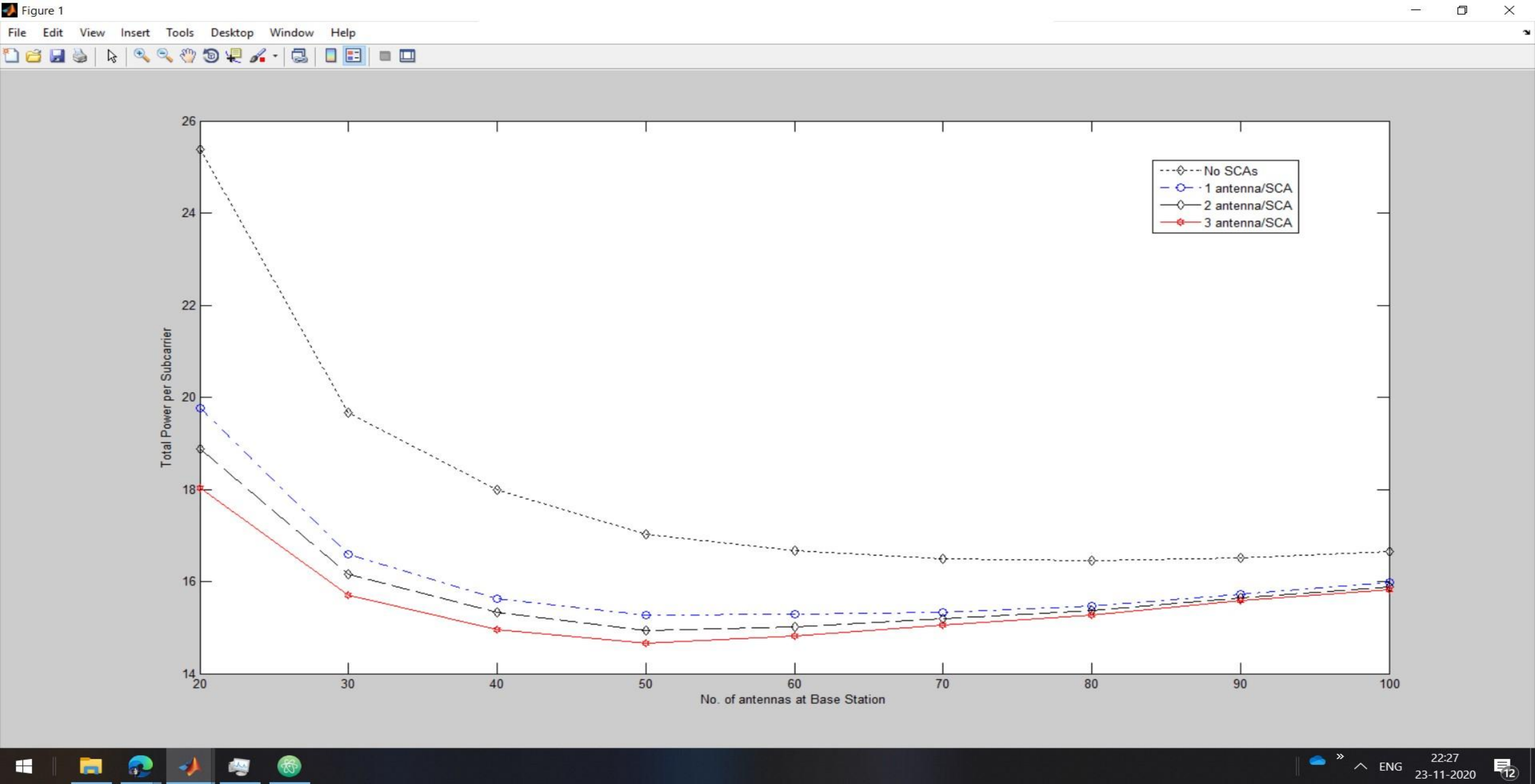


Figure 1
File Edit View Insert Tools Desktop Window Help
No SCAs
1 antenna/SCA
2 antenna/SCA
3 antenna/SCA
Total Power per Subcarrier
No. of antennas at Base Station
26
24
22
20
18
16
14
20
30
40
50
60
70
80
90
100
ENG
22:27
23-11-2020

Results

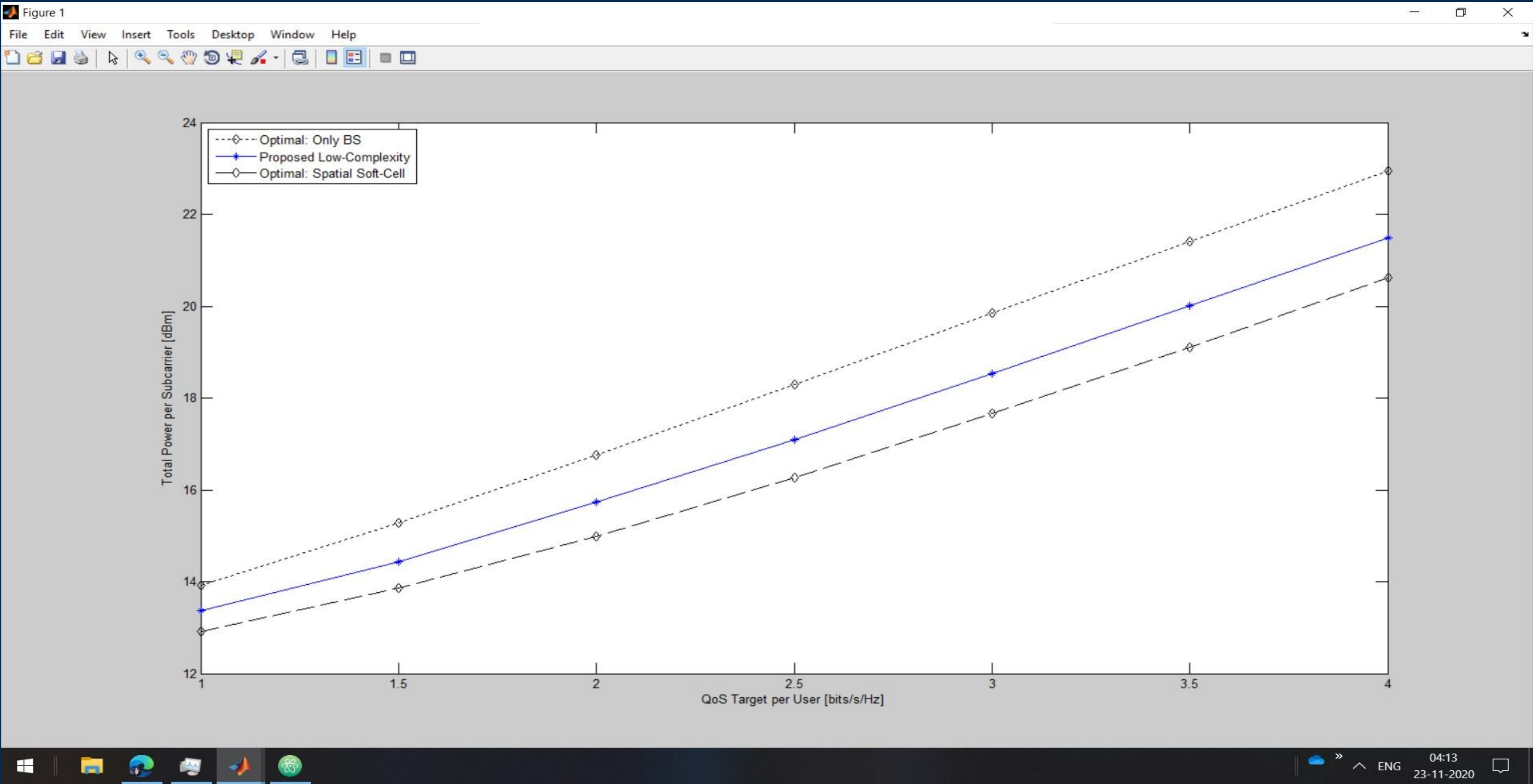


Figure 1
Optimal: Only BS
Proposed Low-Complexity
Optimal: Spatial Soft-Cell
Total Power per Subcarrier [dBm]
QoS Target per User [bits/s/Hz]
12
14
16
18
20
22
24
1
1.5
2
2.5
3
3.5
4

Conclusion

- Improved Energy Efficiency
- Soft-cell coordination with massive MIMO at the BSs and SCA overlaying.
- User is served by non-coherent beamforming from multiple transmitters.
- Power minimizing spatial multiflow transmission under QoS constraints by solving a convex optimization problem.
- Optimal solution dynamically assigns users to the optimal transmitters(BS or one of the SCAs)
- Total power consumption improved by combining massive MIMO and small cells(low-complexity beamforming,Multiflow-RZF beamforming)

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Thank You