Uplink Fractional Power Control in LTE Networks

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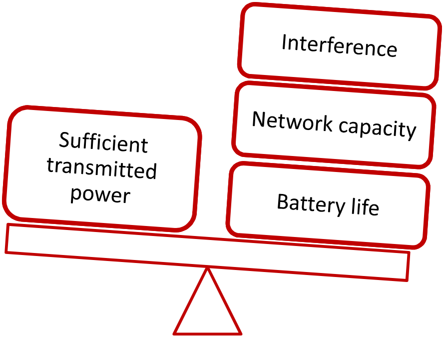
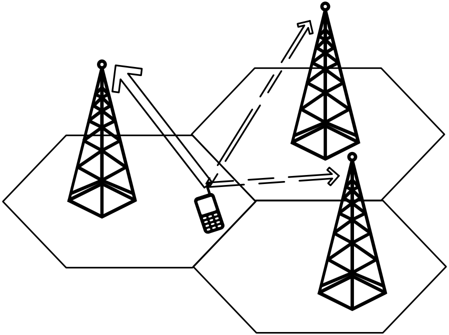
Background. Aims of Uplink Power Control (PC)

Minimize transmit power of user equipment (UE), while maintaining the required signal quality

Decrease interference, increase capacity and battery life of UEs

UL PC balances





Background. Uplink Fractional Power Control (FPC)

- FPC is a slow open loop PC scheme
- FPC allows full or partial compensation of path loss $L_{i\sigma_i}$
- FPC can increase the overall capacity compared to traditional PC
- FPC controlled by two discrete cell specific parameters P_0 and α.

Power transmitted by UE i served by cell $\sigma_i = c$:

$$P_i = \min\left\{P_{max}, P_{0\sigma_i} + \alpha_{\sigma_i} L_{i\sigma_i} + 10\log_{10} M_i\right\} \text{ [dBm]},$$
$$P_{0\sigma_i} \in \left\{P_0^{min}, P_0^{min} + 1, \ldots, P_0^{max}\right\} \text{ [dBm]},$$
$$\alpha_{\sigma_i} \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}.$$

Two approach of choosing P_0 and α

1. Same for all cells
   - \+ Simple and the most abundant approach
   - \- It might be not suitable in actual situation with
     - irregularly shaped cells
     - inhomogeneous traffic distribution
     - heterogeneous network (macro+pico/femto)
2. Individually for each cell
   - \- Existing method is very slow
     It randomly tries different values of FPC parameters for each cell
     There are $(mk)^C$ possible configurations ($\sim 10^{349}$ for $C = 109$ cells)

Research goals

develop more efficient methods related to the second approach

Problem statement

- Given path loss and traffic distribution
- Improve Key Performance Indicators (KPI) under consideration Φ by finding suitable discrete FPC parameters P_{0c} and α_c for each cell c individually

Optimization problem statement

$$
\begin{array}{lll}
\text{maximize} & \Phi(\mathbf{P}),\ \mathbf{P} = (P_1, \dots, P_N)\,, & \\
 & P_i = \min\{P_{max}, P_{0c} + \alpha_c L_{ic} + 10\log_{10} M_i\}\,, & i = 1, \dots, N, \\
\text{subject to} & P_{0c} \in \{P_0^{min}, P_0^{min} + 1, \dots, P_0^{max}\}\,, & c = 1, \dots, C, \\
 & \alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}\,, & c = 1, \dots, C, \\
\text{variables:} & P_{0c},\ \alpha_c\,, & c = 1, \dots, C.
\end{array}
$$

C – number of cells, N – number of UEs/pixels. The problem is nonconvex and nonsmooth with discrete optimization variables

Key Performance Indicators (KPI)

We consider two types of KPI

1. cell load-dependent: sum of cell loads, call drop and block rates (CDBR), etc
2. SINR(Signal to Interference plus Noise Ratio)-dependent: weighed sum rate, lowest weighted rate, etc

Examples of cell load-dependent KPIs

$$\Phi = \sum_{c} w_c \lambda_c, \; c = 1, \ldots, C,$$

$$\Phi = \sum_{c} w_c (1 - \lambda_c), \; \Phi = \sum_{c} \delta_c, \; c = 1, \ldots, C \text{ (should be minimized)},$$

where call drop and block rates (CDBR) $(1 - \lambda_c)$, call acceptance probability λ_c and cell load δ_c can be calculated using
Nonlinear load coupling system:

$$I_c = n_c + \sum_{d \neq c} \lambda_d U_{c,d} f(V_{c,d} I_d),$$
$$\delta_c = G_c f(H_c I_c),$$
$$\lambda_c = \min \left\{1, \delta_c^{max} / \delta_c \right\},$$

$f(x) = 1/\log_2(1 + 1/x)$ and U, V, G, H – functions of $\mathbf{P_0}, \alpha$, path loss and traffic distribution. I_c – interference, n_c – thermal noise.

Examples of SINR-dependent KPIs

$$\Phi = \sum_i w_i \log(1 + \mathrm{SINR}_i),\ i = 1, \ldots N,$$

$$\Phi = \min_i w_i \log(1 + \mathrm{SINR}_i),\ i = 1, \ldots N.$$

$$\Phi = \sum_i w_i \log \mathrm{SINR}_i,\ i = 1, \ldots N,$$

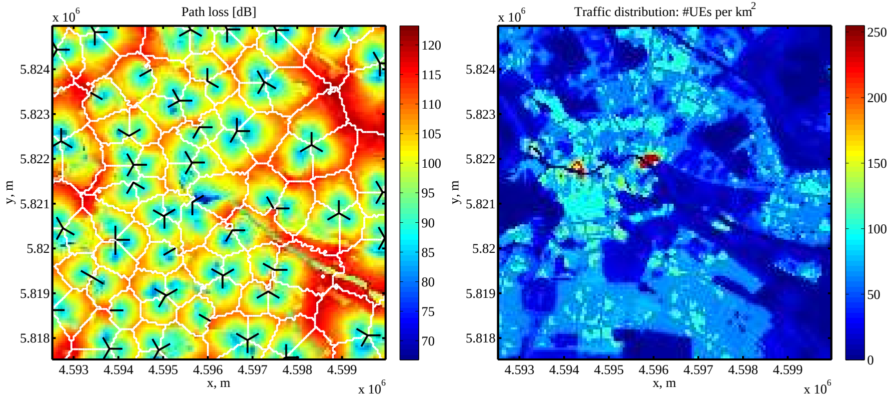
$$\Phi = \min_i w_i \mathrm{SINR}_i,\ i = 1, \ldots N.$$

where SINR_i – Signal to Interference plus Noise Ratio (SINR):

$$\mathrm{SINR}_i = \frac{p_i g_{i\sigma_i}}{\sum_{j:\sigma_j \neq \sigma_i} p_j g_{j\sigma_j} + n_i},\ p_i = 10^{P_i/10},\ g_{i\sigma_i} = 10^{-L_{ic}/10}.$$

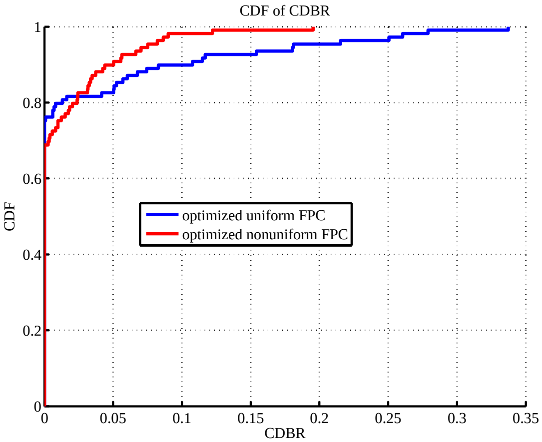
Numerical Examples: Berlin network scenario

Path loss and traffic distribution



109 cells, 2500 UEs, 55.5 km^2, 22500 pixels of size 50 by 50 m

CDF of CDBR for optimized uniform and nonuniform FPC

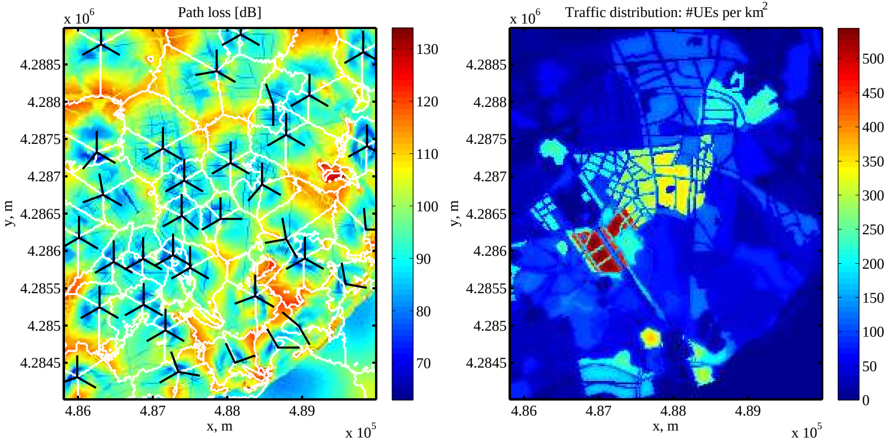


CDBR for best uniform(same for all cells) FPC parameters: 0.040
CDBR for FPC parameters obtained by applying developed method: 0.017

Relative improvement: 57.7%

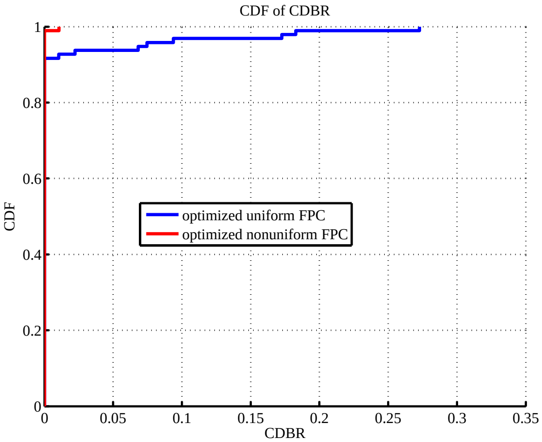
Numerical Examples: Lisbon network scenario

Path loss and traffic distribution



96 cells, 1508 UEs, 20.8 km^2, 52500 pixels pixels of size 20 by 20 m

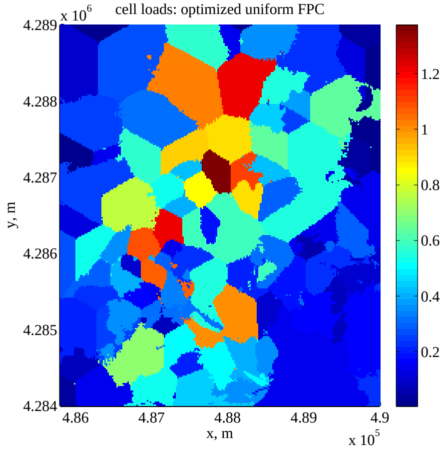
CDF of CDBR for optimized uniform and nonuniform FPC

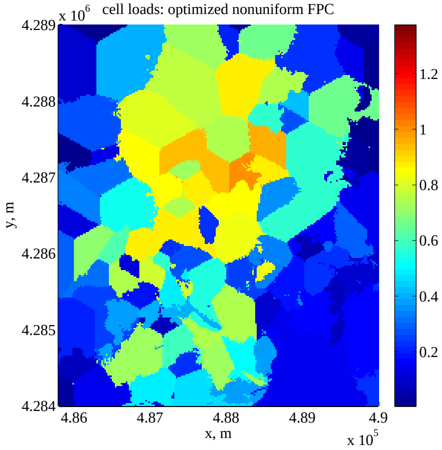


CDBR for best uniform(same for all cells) FPC parameters: 0.023
CDBR for FPC parameters obtained by applying developed method: 1.9e-4

Relative improvement: 99.2%

Cell loads calculated for uniform and nonuniform FPC parameters optimized for CDBR





Conclusions

Developed methods for improving various KPIs by finding suitable discrete FPC parameters for each cell individually

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Thank you!