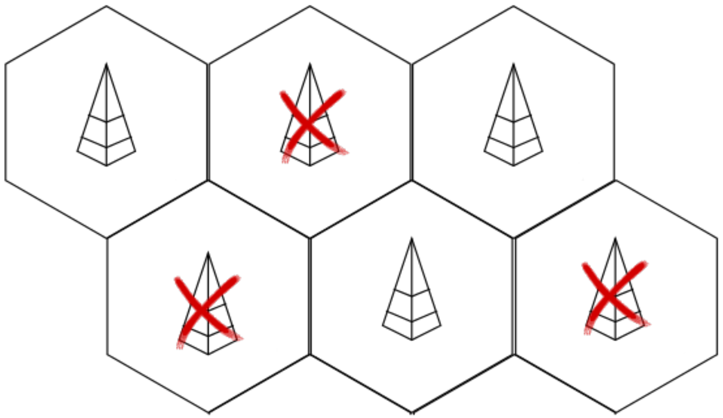
A Genetic Algorithm Based Cell Switch-off Scheme for Energy Saving in Dense Cell Deployments



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Introduction

- Energy consumption of wireless networks is rapidly growing
- Motivation to decrease energy consumption:
  - Reduced operating expenses
  - Reduced environmental impact
- Base stations are responsible for ~70% of cellular network energy consumption
  - Cell switch-off provides highest potential for energy saving (ES)

Problem Statement

- Switching off unutilized cells: Easy, but low potential for ES
- How to choose which cells to switch off? Each cell differs with respect to:
  - Energy which can be saved
  - Impact on outage when switched off
  - Interference caused to other cells

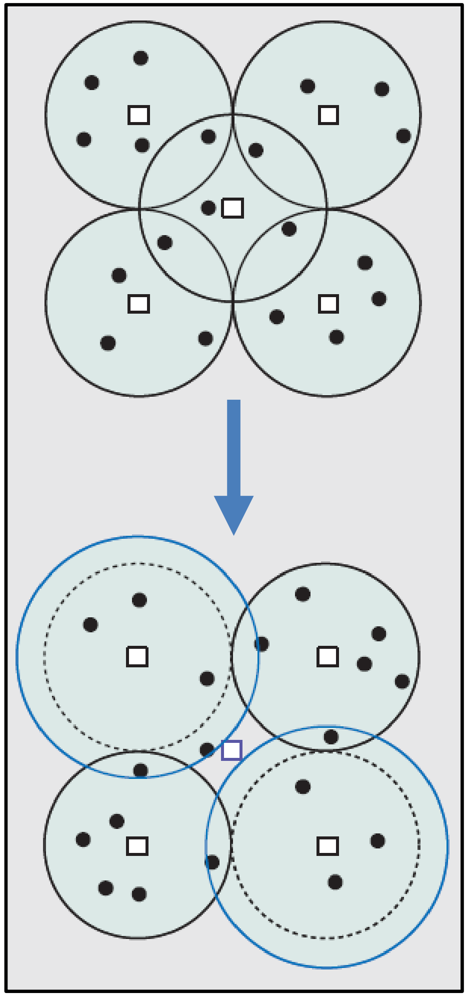

Figure adapted from Niu et al., 2010

Contributions

- Formulated cell switch-off problem with simple constant interference model and solved with binary integer linear programming (BILP)
- Improved existing heuristic from literature to bring it closer to BILP solution
- Re-constructed the problem with variable interference and developed heuristic solution
- Designed a genetic algorithm (GA) for the variable interference problem

- Variables & parameters defined as follows:
  - $x_{i,j}$: binary variable such that $x_{i,j} = 1$ if user i is connected to sector j
  - y_j: binary variable such that $y_j = 1$ if sector j is active
  - $\rho_{i,j}$: spectral efficiency for user i if it is associated to sector j
  - B_j: total bandwidth for sector j
  - R_i: minimum rate requirement for user i
  - I: number of users
  - J: number of sectors

Test Scenarios

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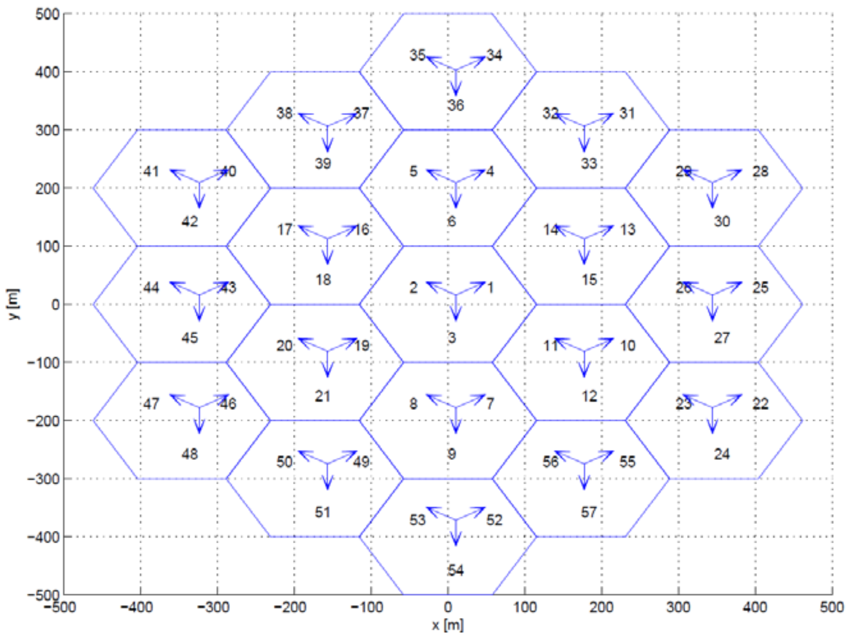
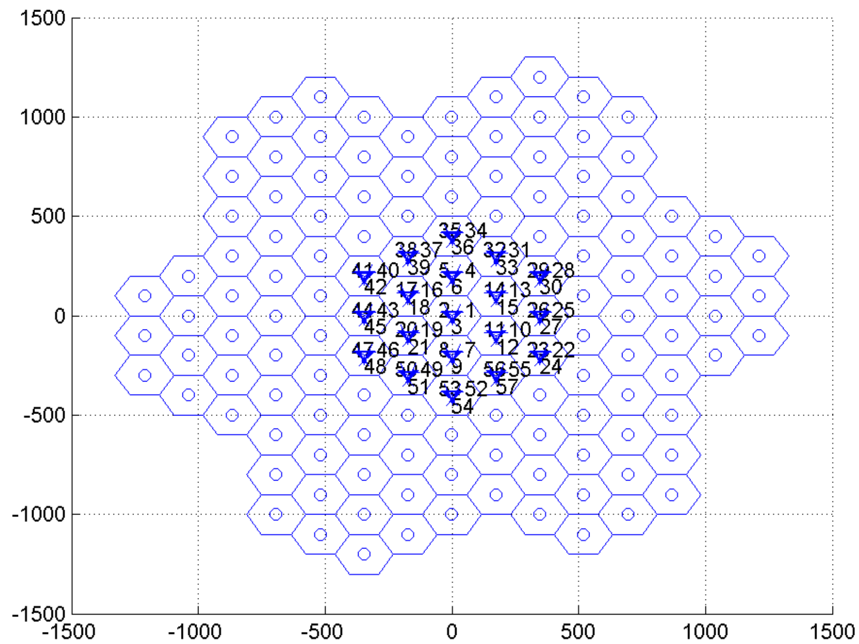
Cell layout



Wraparound

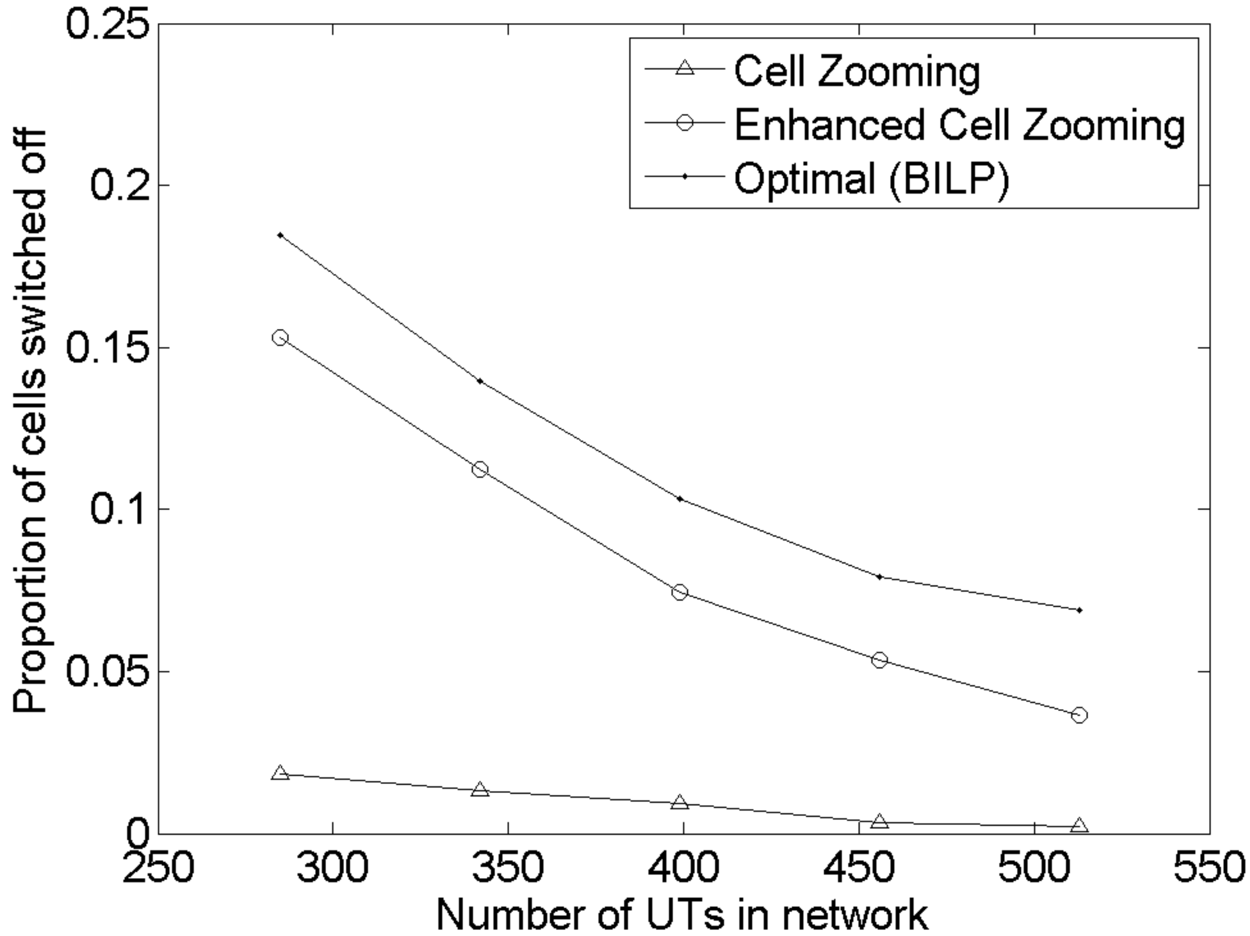


- Binary integer linear programming (BILP) formulation for constant interference problem:

$$\begin{aligned}
\underset{x_{i,j}, y_j, \forall i,j}{\text{minimize}} \quad & \sum_{j=1}^{J} y_j && \text{(1a)}\\
\text{subject to} \quad & \sum_{i=1}^{I} x_{i,j} \frac{R_i}{\rho_{i,j}} \leq B_j, \quad \forall j && \text{(1b)}\\
& x_{i,j} \leq y_j, \quad \forall i,j && \text{(1c)}\\
& \sum_{j=1}^{J} x_{i,j} = 1, \quad \forall i && \text{(1d)}\\
& x_{i,j}, y_j \in \{0,1\}, \quad \forall i,j && \text{(1e)}
\end{aligned}$$

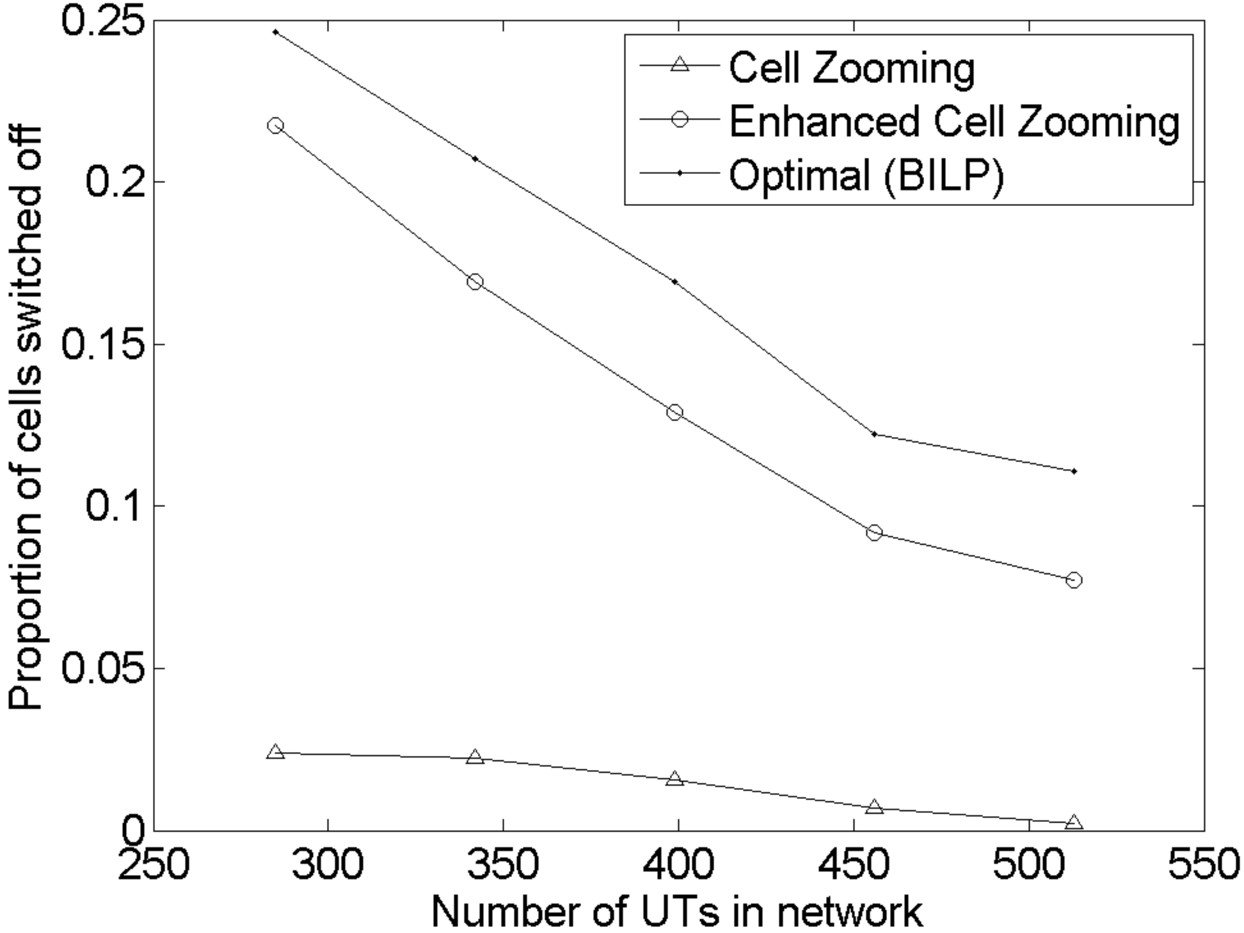
- We also improve heuristic by Nui et al. (2010) to bring it closer to optimality

Uniform UT distribution, regular hexagonal cell layout with 57 cells



CI Performance Evaluation (2)

Hotspot UT distribution, regular hexagonal cell layout with 57 cells



Variable Interference (VI)

- BILP formulation → already NP-hard
  - Variable interference → prohibitive complexity
- Built upon constant-interference heuristic to solve variable interference problem
  - No optimal solution to compare with
- Designed a genetic algorithm to apply to the variable interference problem

Genetic Algorithm

Initial Population

- Random solutions
- Fitness function: energy saving

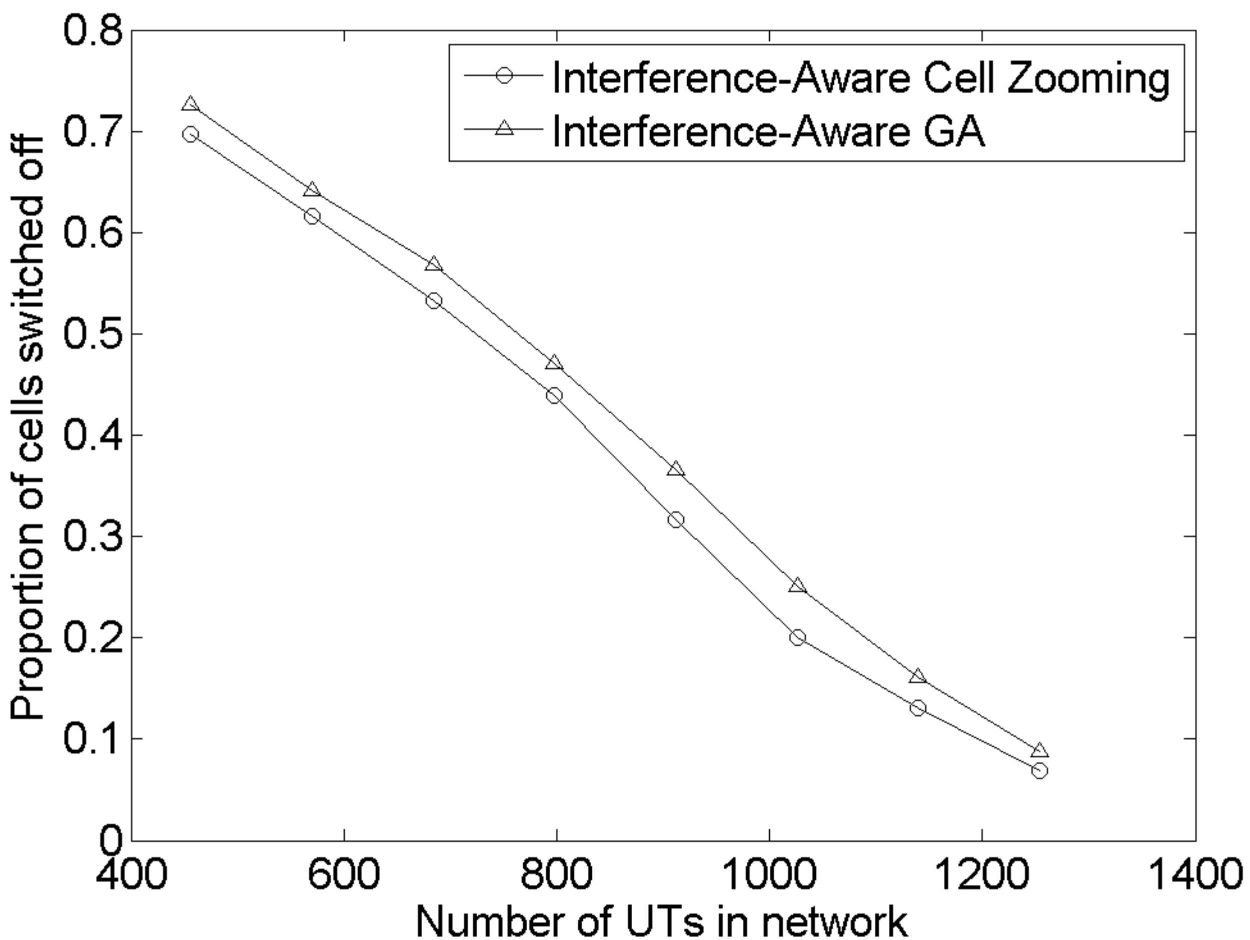
Crossover & Mutation

- Parent chromosomes chosen through tournament selection
- Partially matched crossover
- Child chromosomes inserted back into population

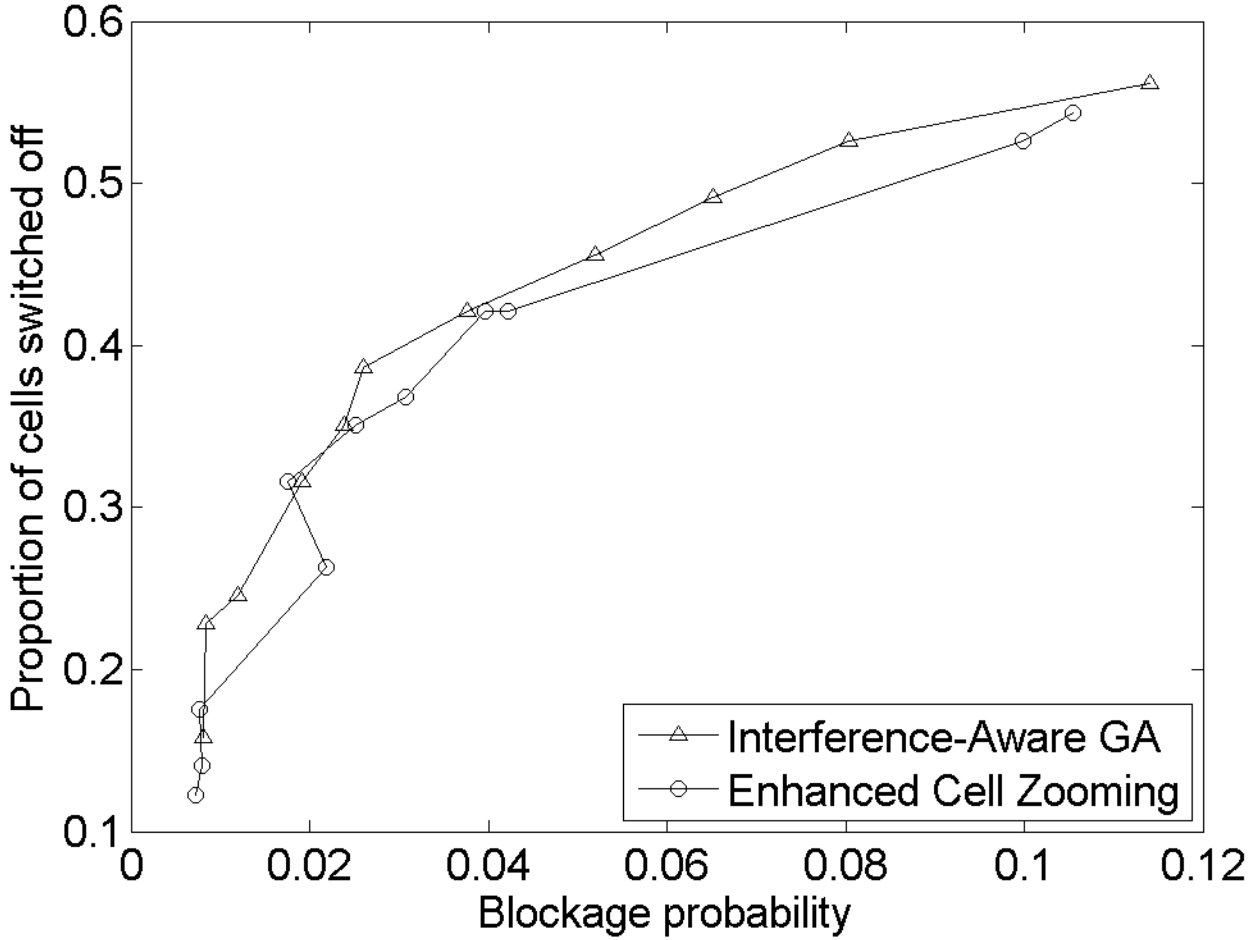
Termination

- When maximum number of crossovers have been performed

Hotspot UT distribution, regular hexagonal cell layout with 57 cells



Blocking probability with hotspot UT distribution (average 12 UTs per cell), regular hexagonal cell layout with 57 cells



Conclusions

- In simple scenarios, the cell switch-off problem can be formulated and solved as an optimization problem

- In more complex scenarios, heuristic approaches are needed

- GA is a good candidate for this problem

Future Work

- Cell parameter optimization
  - Hand-off thresholds, TX power, etc.
- ES in advanced radio access networks
  - Consider ICIC, CoMP, MIMO, etc.
- Traffic prediction & machine learning
- Parallel GAs
- Multiple power states, frequency bands
- Larger scale simulations
  - Consider mobility