Regular and Static Sector-Based Cell Switch-Off Patterns

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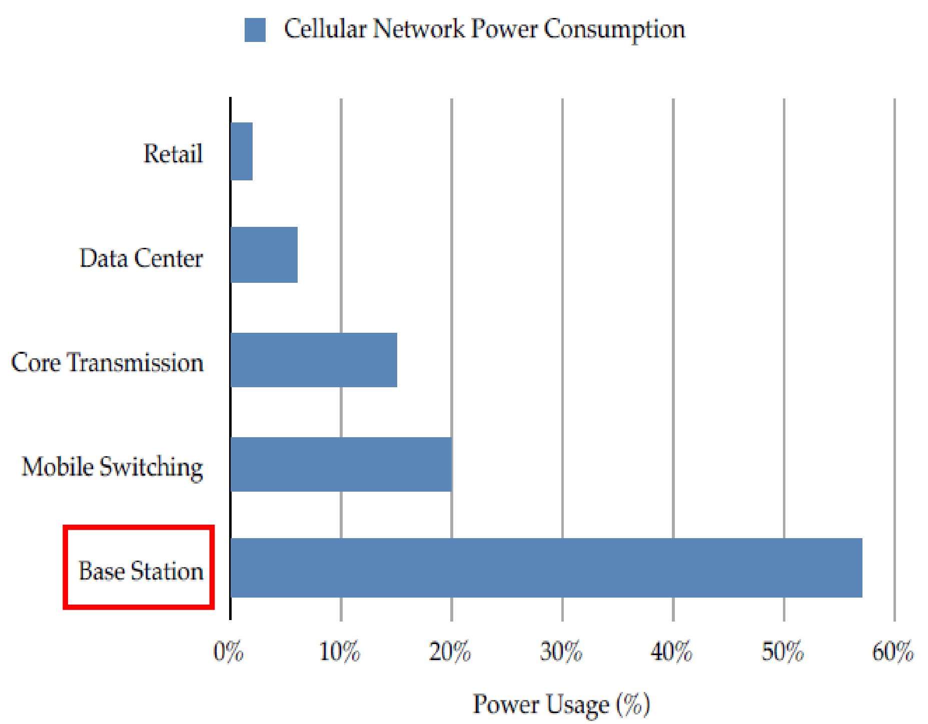
Motivation

- Cellular networks → Preferred for Internet access.
- Network densification → Provide high data rates.
- Light traffic periods → CSO for energy saving.



- Entirely switching off BSs → Significant energy saving.

Regular Static CSO (CSO Patterns)

- Predetermine the set of active cells such that their locations form a layout that is periodic in space.
- Are conceptually simple and resemble the intuitive well-known frequency reuse patterns.
- Model the interference properly.
- Minimize the coverage holes.
- Is more energy-efficient for users in the uplink, as there is always a nearby cell.
- The best SINR distribution can be achieved when the BSs are located on a regular grid ➔ reduce the interference

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CSO Classifications

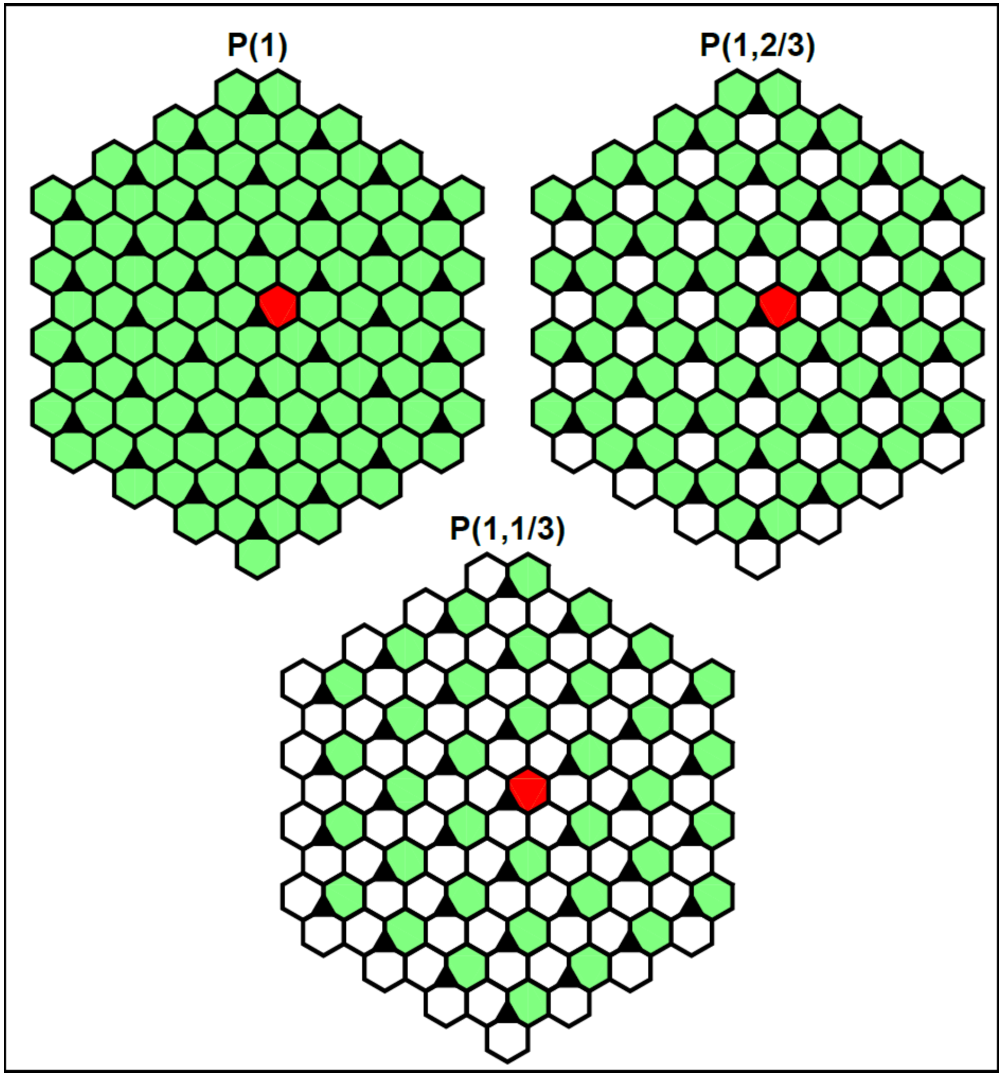
- Dynamic CSO
  - Executed in real time (online) to determine the set of active cells.
  - Requires global knowledge of channel state information, as well as the load levels of all cells in the network.
  - Sector-level CSO is the common practice.

- Static CSO
  - Predetermine the set of active (offline).
  - Designed for longer time scales.
  - Based on historical load distributions.
  - Sector-level CSO is not studied before.

Contribution

- Previous literature on regular CSO patterns only studies switching off entire BSs (*site-level*), however, additional gain may be obtained from switching off individual sectors within each BS (*sector-level*).
- To the best of our knowledge, this is the first paper to introduce sector-based CSO patterns and compare their performance in terms of number of supported UEs.
- We also analytically compare the site-level versus sector-level power saving.

Sector-based CSO Patterns



CSO patterns: Example 1

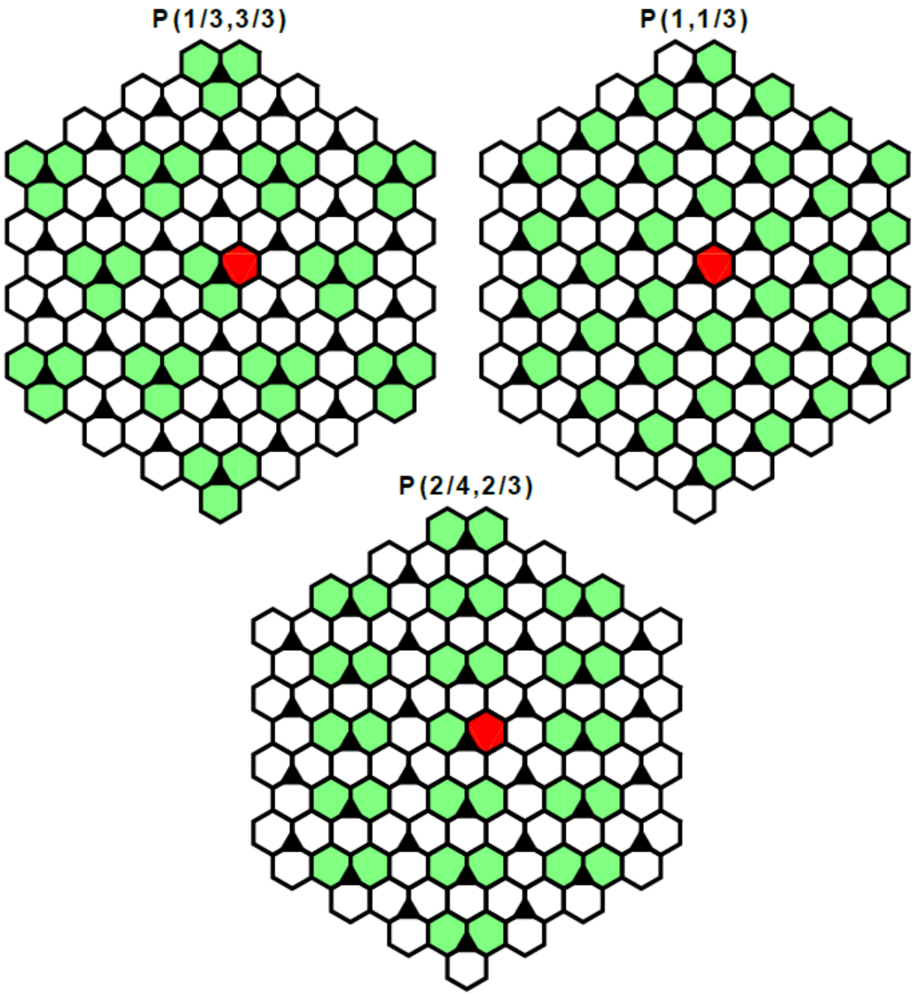


Figure 1. Different patterns with $\rho = 1/3$ active sectors.

Performance Metric

- Average number of supported users per sector

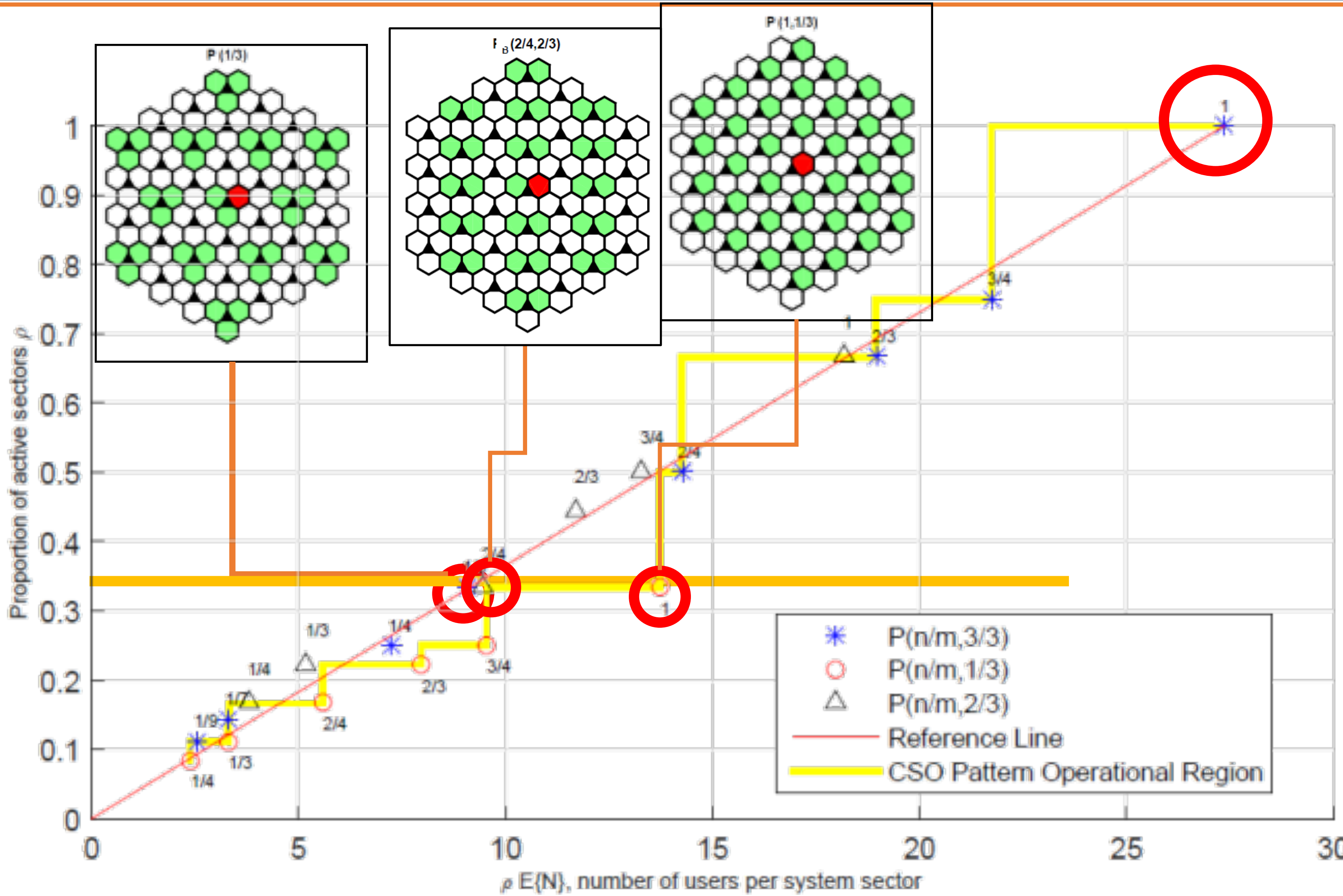
$$\eta_i = \log_2(1+\gamma_i) \text{ [bps/Hz]}. \tag{1}$$

$$b_i = \frac{R}{\eta_i}, \tag{2}$$

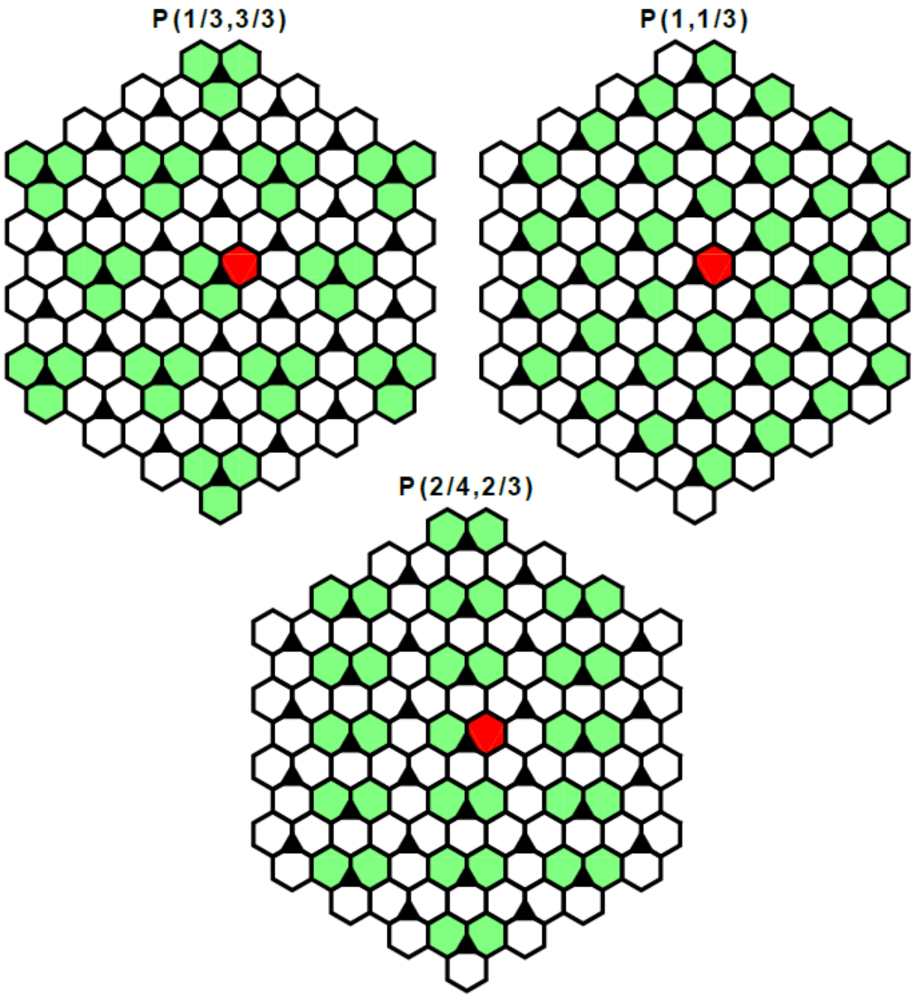
$$\sum_{i=1}^{N} b_i \leq W. \tag{3}$$

$$\mathbb{E}\{N\} \cong \frac{W}{R\,\mathbb{E}\left\{\frac{1}{\eta}\right\}}. \tag{4}$$

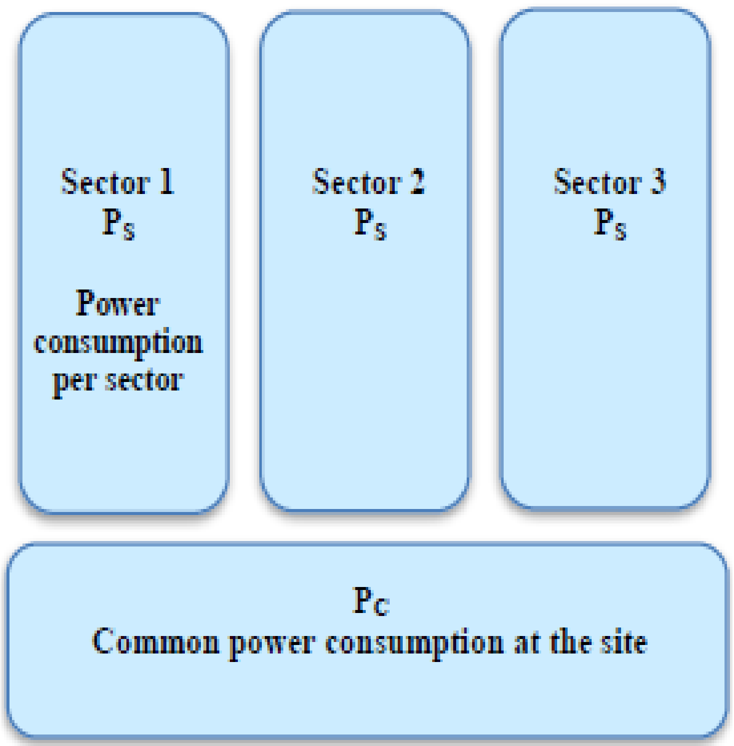
Performance Comparison



Case Study: CSO Patterns with 1/3



Power Saving in Sector Switch-Off



Power consumption at a site $P_{site} = P_C + 3P_S$, when all sectors are active.

$$\alpha = \frac{P_s}{P_c},$$

$$P(n/3m) : P(n/m, 1/3)$$

$$\frac{P_{pattern1}}{N_{users1}} = \frac{P_{pattern2}}{N_{users2}}$$

$$\frac{P_C + 3\ PS}{N_{users1}} = \frac{\frac{1}{3}(P_C +\ PS)}{N_{users2}}$$

$$\frac{1+\ \alpha}{\frac{1}{3}+\alpha} = \frac{1}{\delta} \quad , \alpha = \frac{P_s}{P_C}, \text{ and } \delta = \frac{N_{users}}{N_{user1}}$$

$$\alpha^* = \frac{\delta - \frac{1}{3}}{1-\delta} \qquad \begin{array}{c} \alpha^* = 0.95 \\ for\ P\left(\frac{1}{3}\right)\ vs\ P(1,\frac{1}{3}) \end{array}$$

- $\alpha < \alpha^*$ ➔ pattern$_1$ is more efficient.

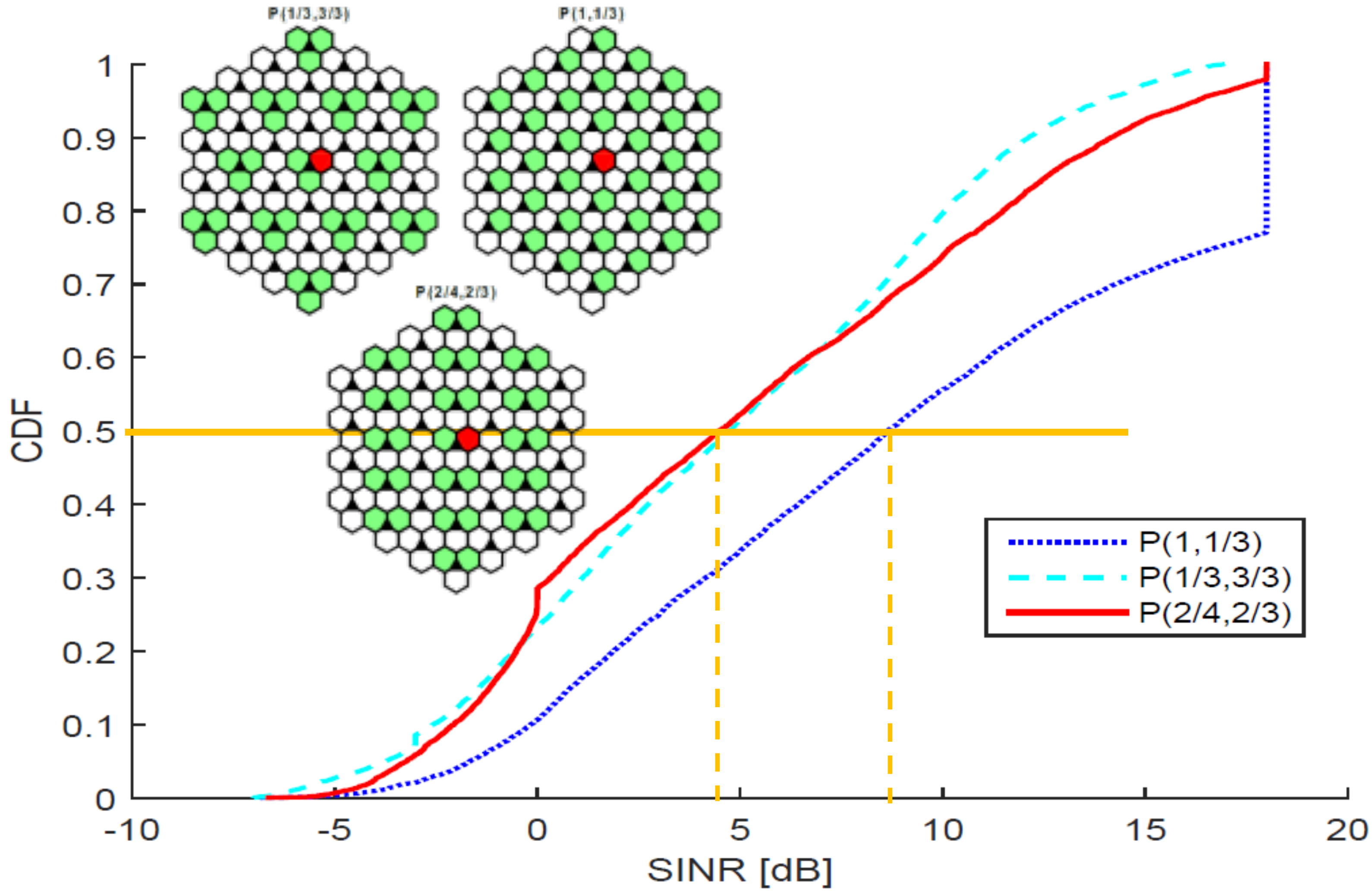
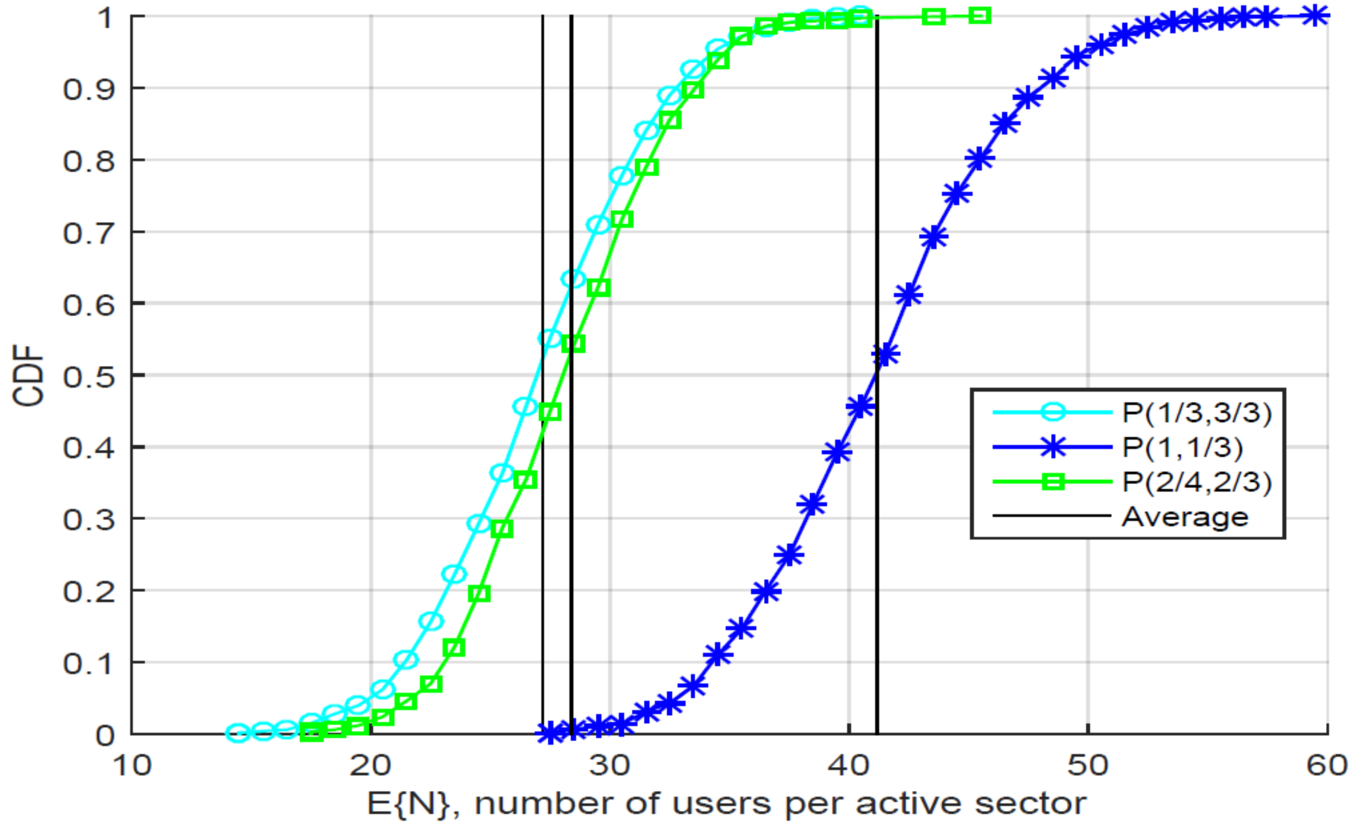


Figure 6. CDFs of SINR for patterns in Fig. 1 (with $\rho = 1/3$).

Case Study : *Number of Users per Active Sector*

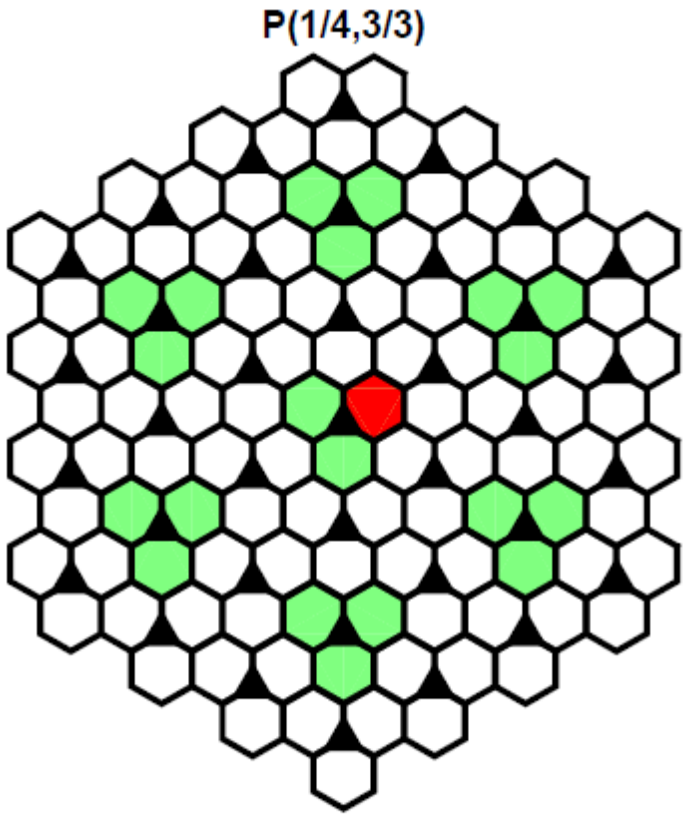


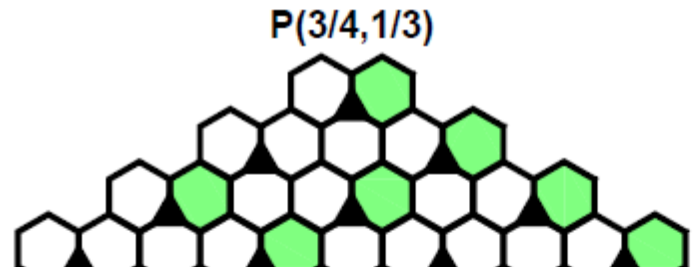
Conclusion:

- This paper is the first to investigate regular sector-based CSO patterns
- Performances are compared in terms of the number of users a pattern can support.
- Notably, patterns with <u>one active sector</u>, per active BS, perform best due to a <u>favourable interference</u> situation.
- P(1,1/3) ➔ only 1/3 active sectors,
  YET supports ½ the total users with

Thank You!

CSO patterns: Example 2





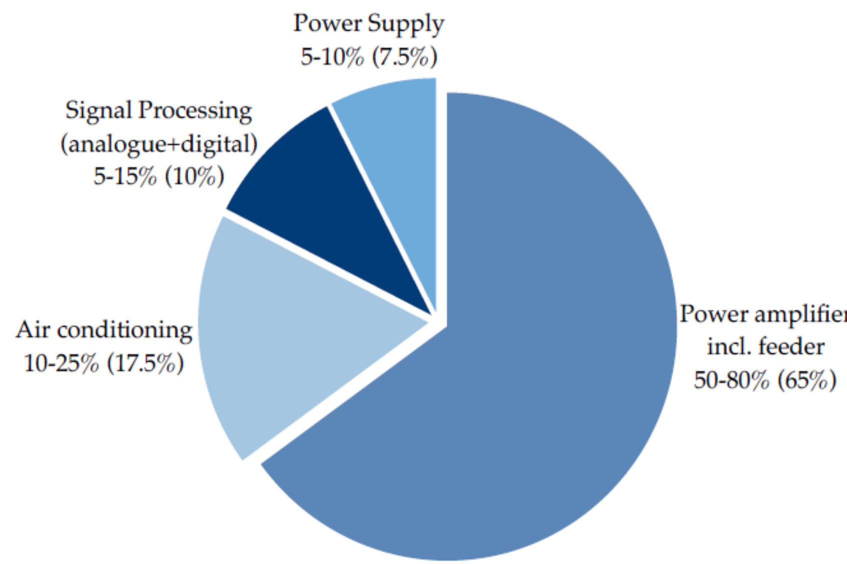


Figure 2. Two patterns with $\rho = 1/4$ active sectors.