Dynamic Cell Clustering in Relay-Extended Cellular Networks
-
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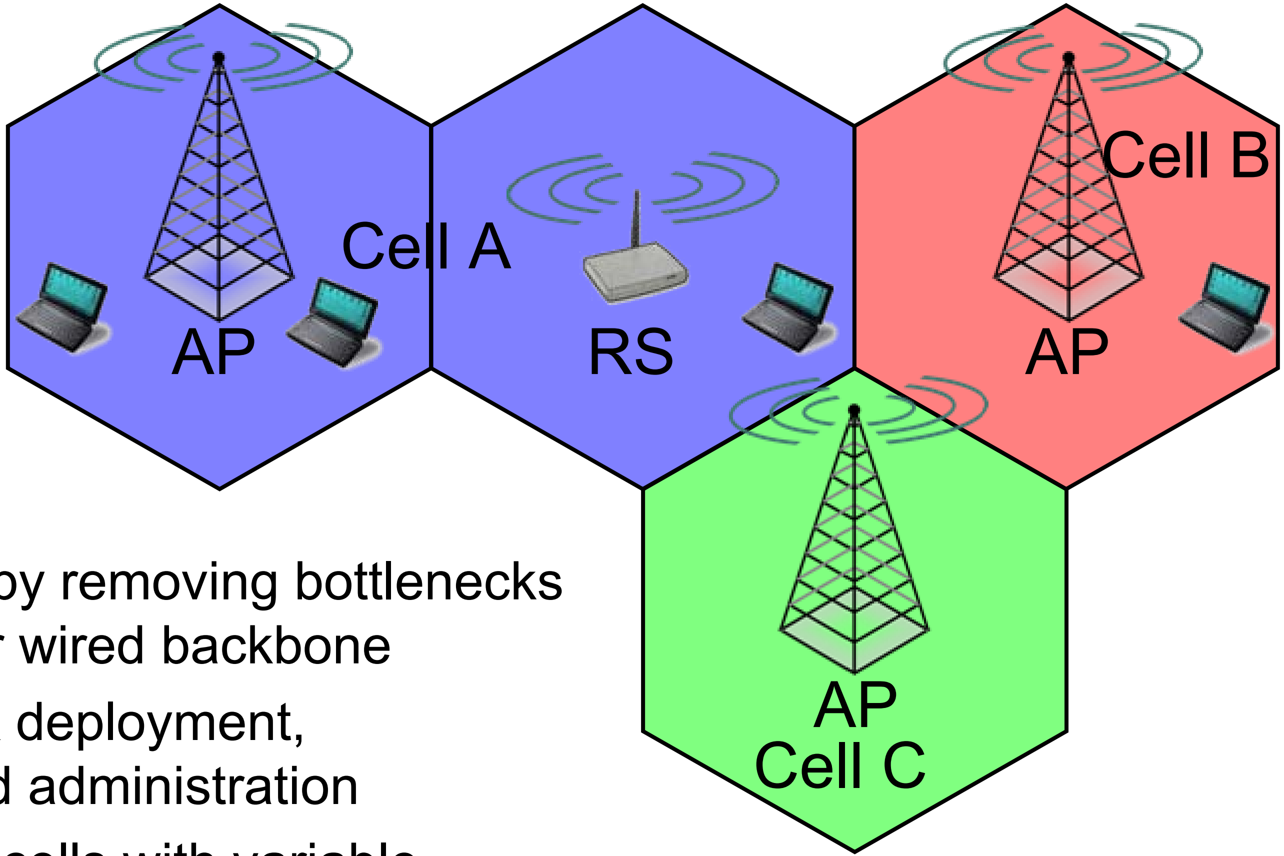
Dynamic Cell Clustering

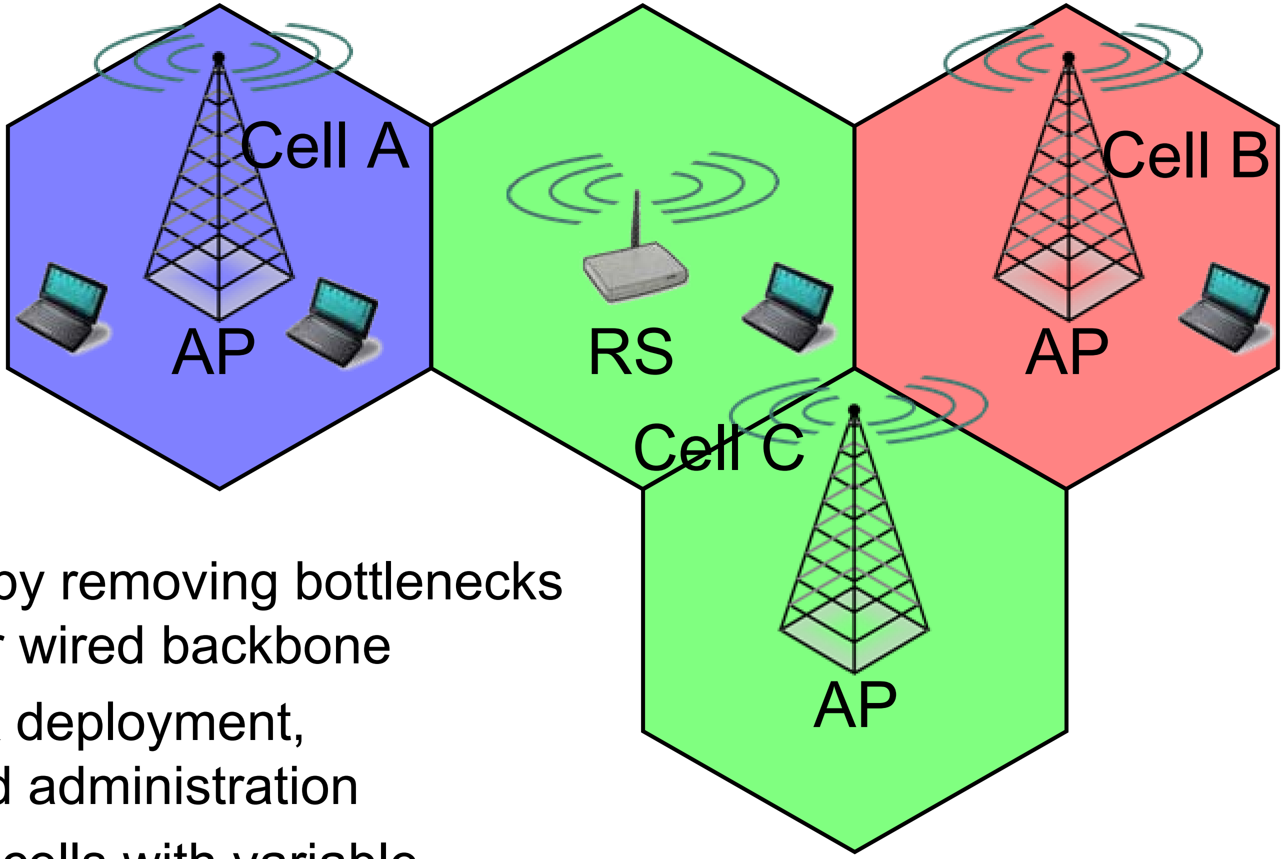


motivation:

- extend capacity by removing bottlenecks at air interface or wired backbone
- facilitate network deployment, maintenance and administration

⇒ create multi-hop cells with variable coverage and load by dynamically assigning relay stations to access points

Dynamic Cell Clustering



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Graph-Theoretical Network Model

assumptions:

- access point and set of relay stations form a single relay-extended cell
- no frequency reuse within cell feasible
- full spectrum reuse within neighboring cells

network model parameter set:

- node number N
- mesh degree γ
- access point density ρ
- aggr. traffic τ (uniformly distributed)
- confidence interval 95%

Fairness Measure: Balance Index

balance index:

- chosen from literature*
- keeps properties like boundedness, independence on metric and scale

$$\beta = \frac{\left(\sum_{\forall n} \lambda_n\right)^2}{N\left(\sum_{\forall n} \lambda_n^2\right)}$$

λ_n : traffic in cell n, $\lambda_n := \sum_{V \in \mathcal{V}_n} \tau(V)$

$n \in [1 \ldots N]$: cell number

* R. Jain, D. Chiu, and W. Hawe. A quantitative measure of fairness and discrimination for resource allocation in shared computer systems. In *DEC Research Report TR-301*, 1984.

Balancing Approaches

centralized

numerical optimization:

- central network management unit periodically receives measurement reports
- central unit calculates optimum network configuration and initiates switching process
- optimization objective: minimize sum of all differences between local cell load and average cell load

$$\Delta\lambda_n = |\lambda_n - \tilde{\lambda}|$$

$$\Omega_{load} := \sum_{n=1}^{N} \Delta\lambda_n \text{ and } \tilde{\lambda} := \frac{1}{N}\sum_{n=1}^{N} \lambda_n$$

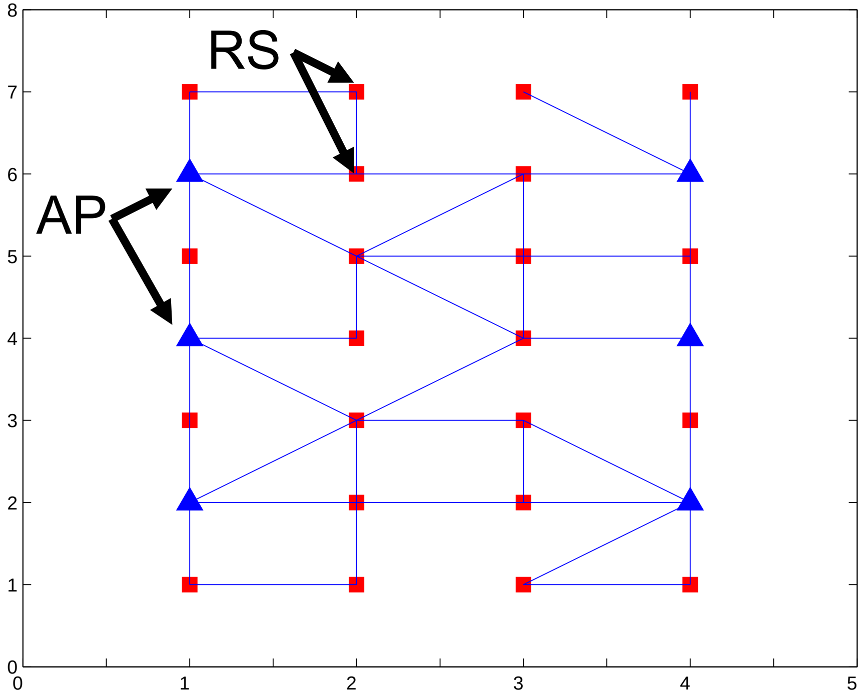
decentralized or hybrid

greedy algorithm:

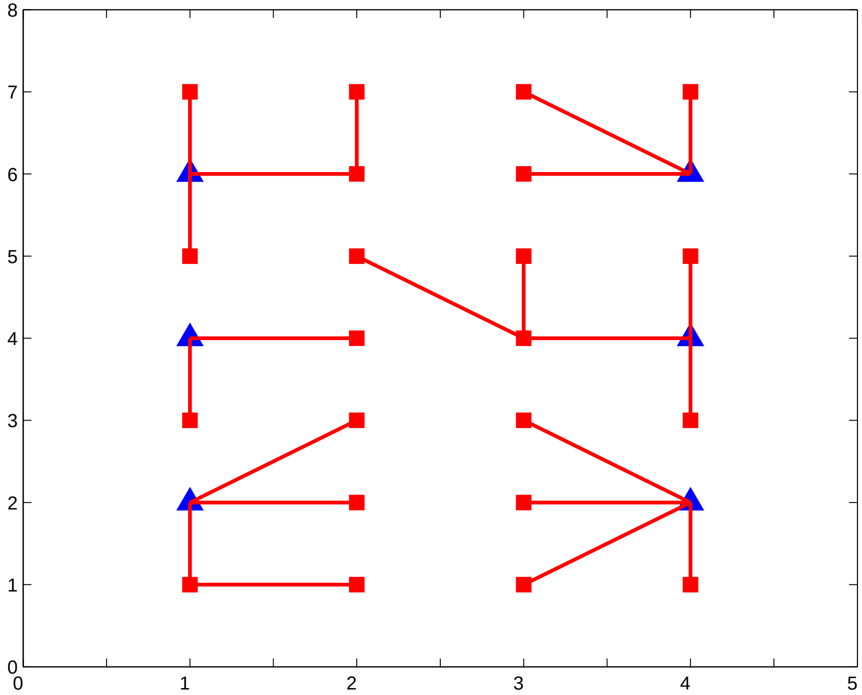
- local unit randomly checks local load situation
- in case of overload, a local reclustering process is initiated
- assign relay station to cell with maximum load difference

$$\Omega = \lambda_n - \lambda_i \Big|_{\mathcal{C}_i \in \mathcal{C}_l(C_n)}$$

Dynamic Cell Clustering in Example Network

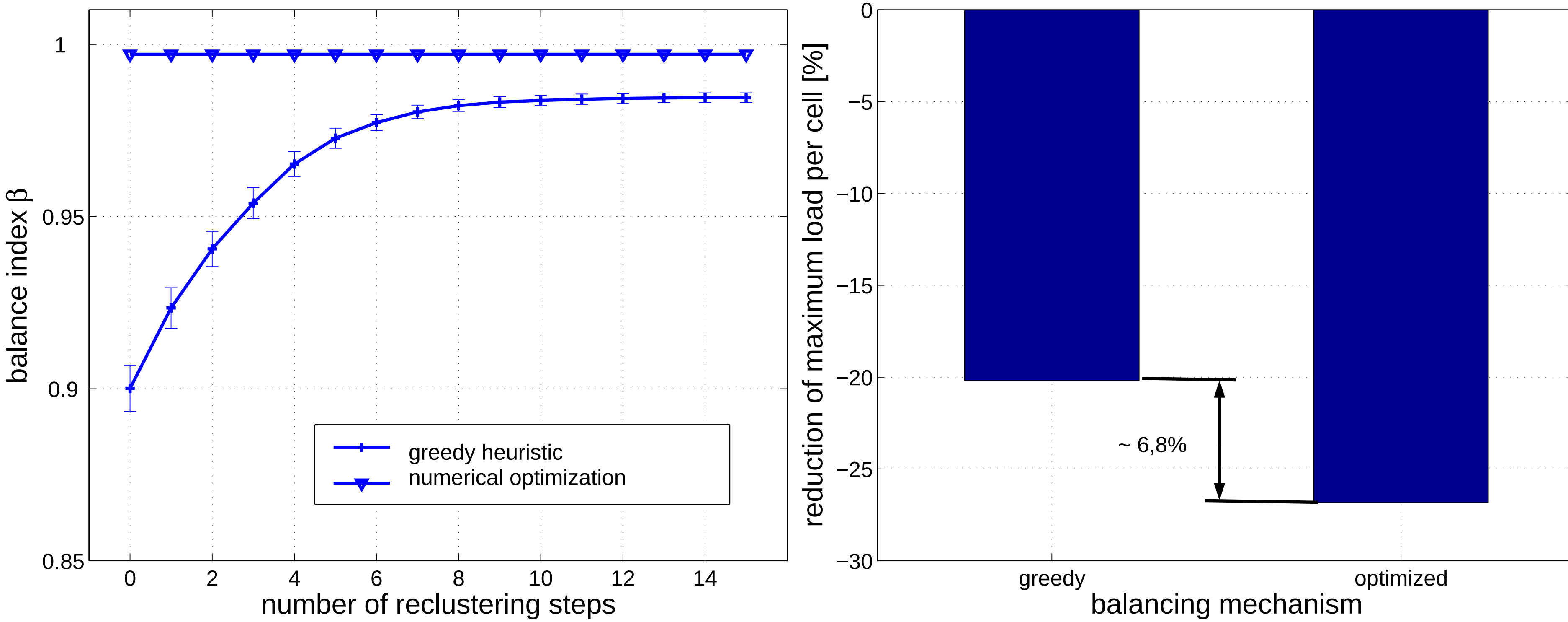


example network configuration
with access points and relay stations
(N=28, γ=3, ρ=0.21)



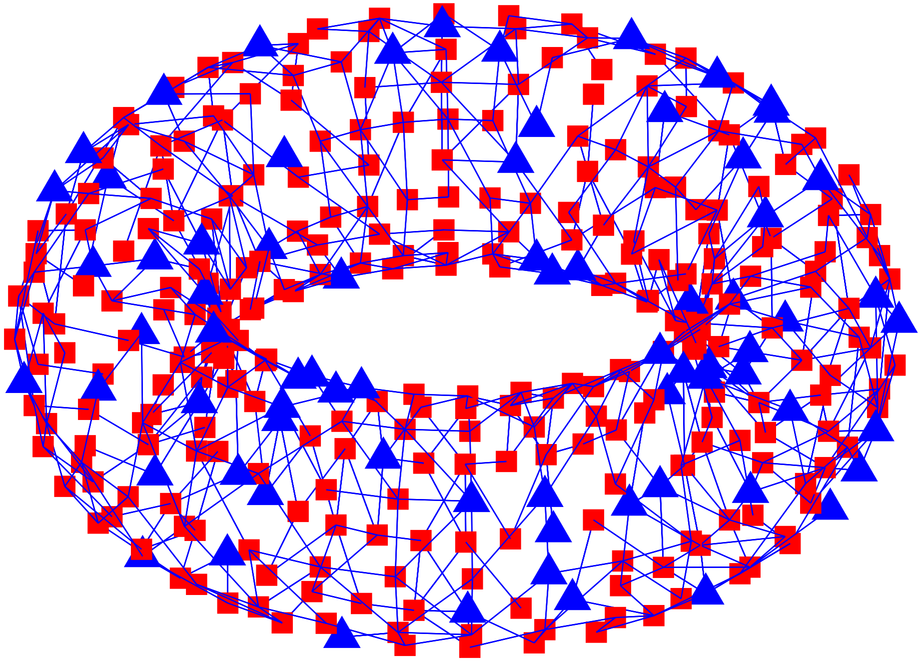
example configuration
after clustering process

Reduction of Maximum Cell Load By Dynamic Cell Clustering



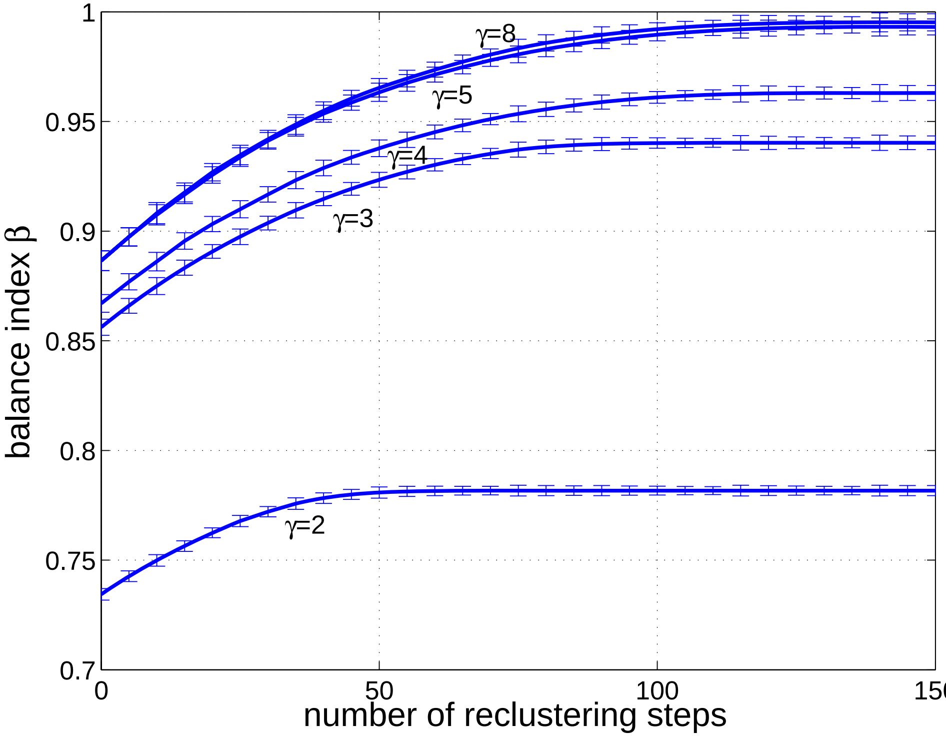
⇒ numerical optimization and greedy approach achieve good balancing results and reduce maximum cell load within network by 20% and 27% on average.
(N=28, ρ=0.21, γ =3, N_{sim}=200)

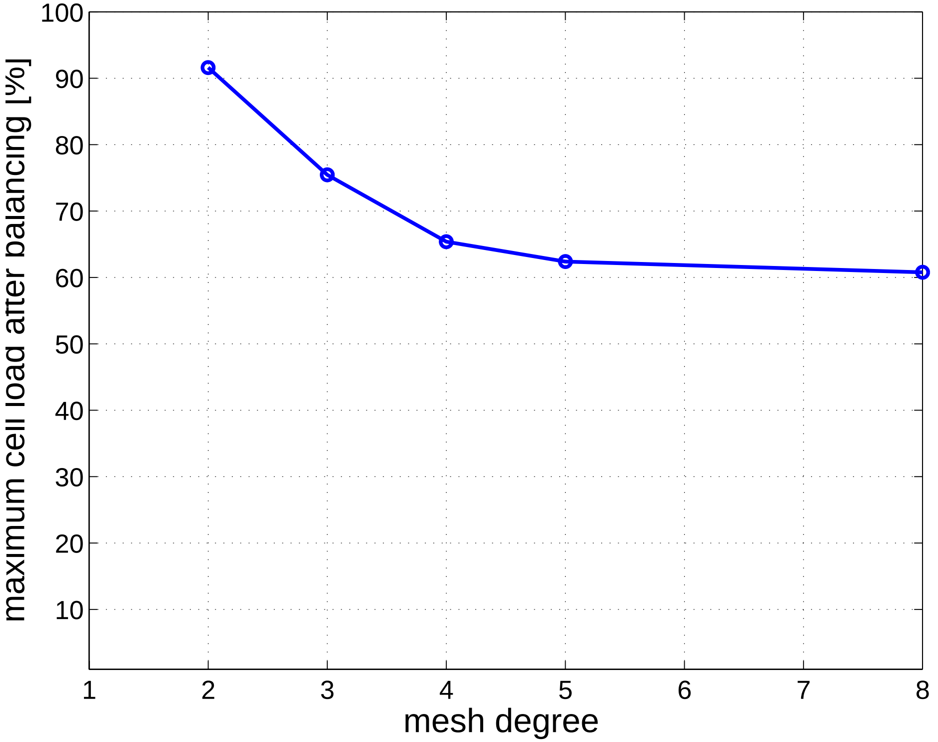
Generalized Network Model



parameter set:
-node number N=360
-mesh degree γ=4
-access point density ρ=0.2

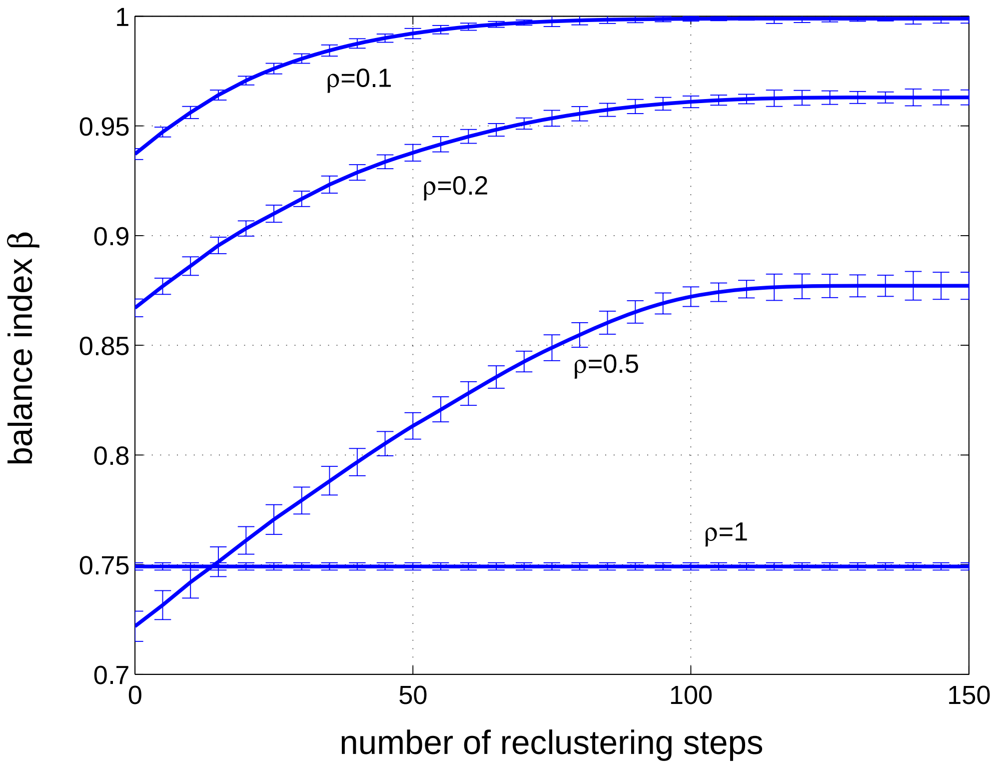
Dependence On Mesh Degree





⇒ balancing leads to significant performance gains for networks with mesh degree $\gamma \geq 4$, i.e. reduction of maximum by 40%. (N=360, ρ=0.2, N_{sim}=300)

Dependence on Access Point Density



⇒ access point density limits performance gains;
consider access point density as extrinsic design parameter
(N=360, γ =4, N_{sim}=300)

Conclusion

Dynamic Cell Clustering

- is an approach to combine gateway assignment and load-balancing in cellular multi-hop networks
- is feasible in a decentralized as well as centralized manner
- helps to decrease maximum cell load significantly by ~40% on average for suitable network topologies (ρ=0.2, γ=4)
- provides good and reliable results in terms of convergence even for networks with small/medium dynamics (not shown here)