

The Impact of User Spatial Heterogeneity in Heterogeneous Cellular Networks

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Problem Definition:

- The performance of wireless networks depends highly on their spatial configurations
- Stochastic geometry is increasingly popular in modeling nodes spatial distributions
- The research community mainly focus on locations of base stations; users are assumed to be uniformly (= homogeneously) distributed in the literature
- What is the impact of user spatial heterogeneity on wireless network performance, especially in the context of heterogeneous cellular networks (HCNs)?

Contributions:

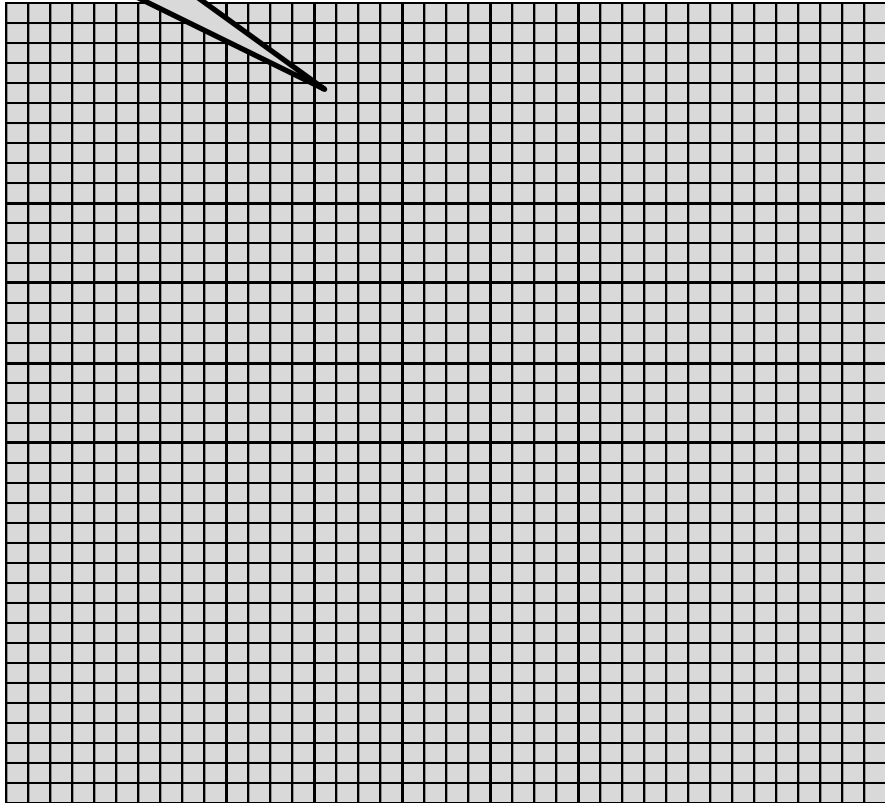
- Use log Gaussian Cox process to model heterogeneous user spatial distribution
- Get network performance with respect to user spatial heterogeneity
- Apply clustering analysis on user points to find locations for small cell

Log Gaussian Cox Process (LGCP)

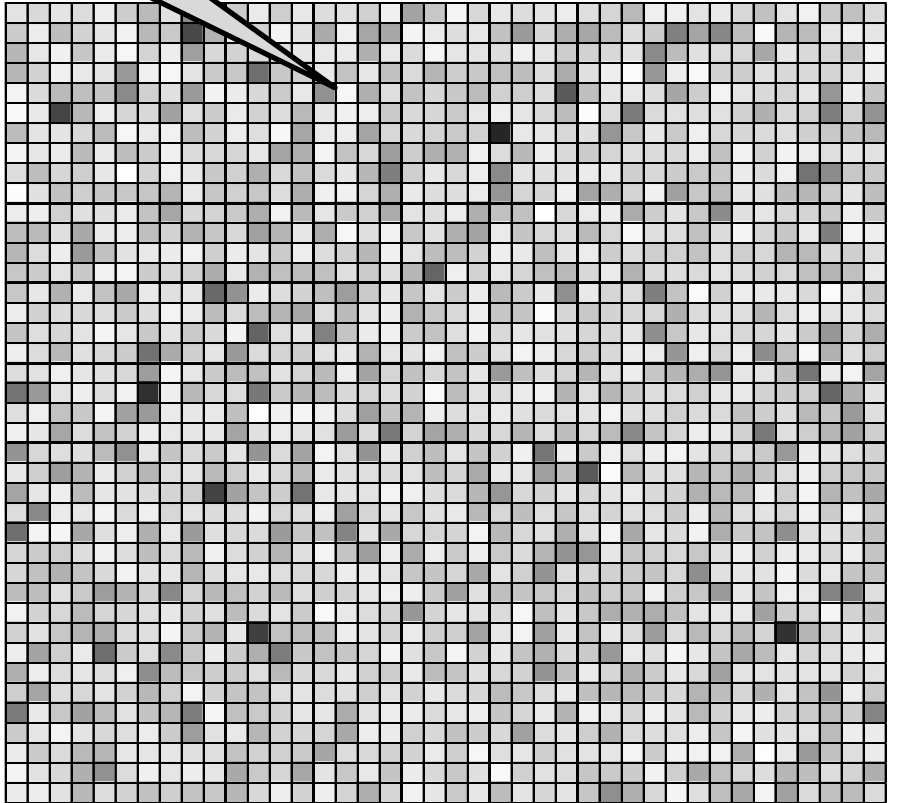
- Cox process is a generalization of the PPP, also known as Doubly Stochastic Poisson Process.
- The intensity in Cox Λ is itself a stochastic process.
- In a PPP, for any bounded area B , the number of points in B is a Poisson number with mean $\lambda \cdot A_B$
- In a Cox process, the number of points in B is a Poisson number with mean $\int_B \Lambda(s) ds$.
- A Cox process is a LGCP if $\Lambda(s) = \exp(Y(s))$, where $Y = \{Y(s): s \in R^2\}$ is a real valued Gaussian process.
- By changing the σ in Y , the LGCP generates a wide range of heterogeneities.

Realization of LGCP

λ is constant **PPP**

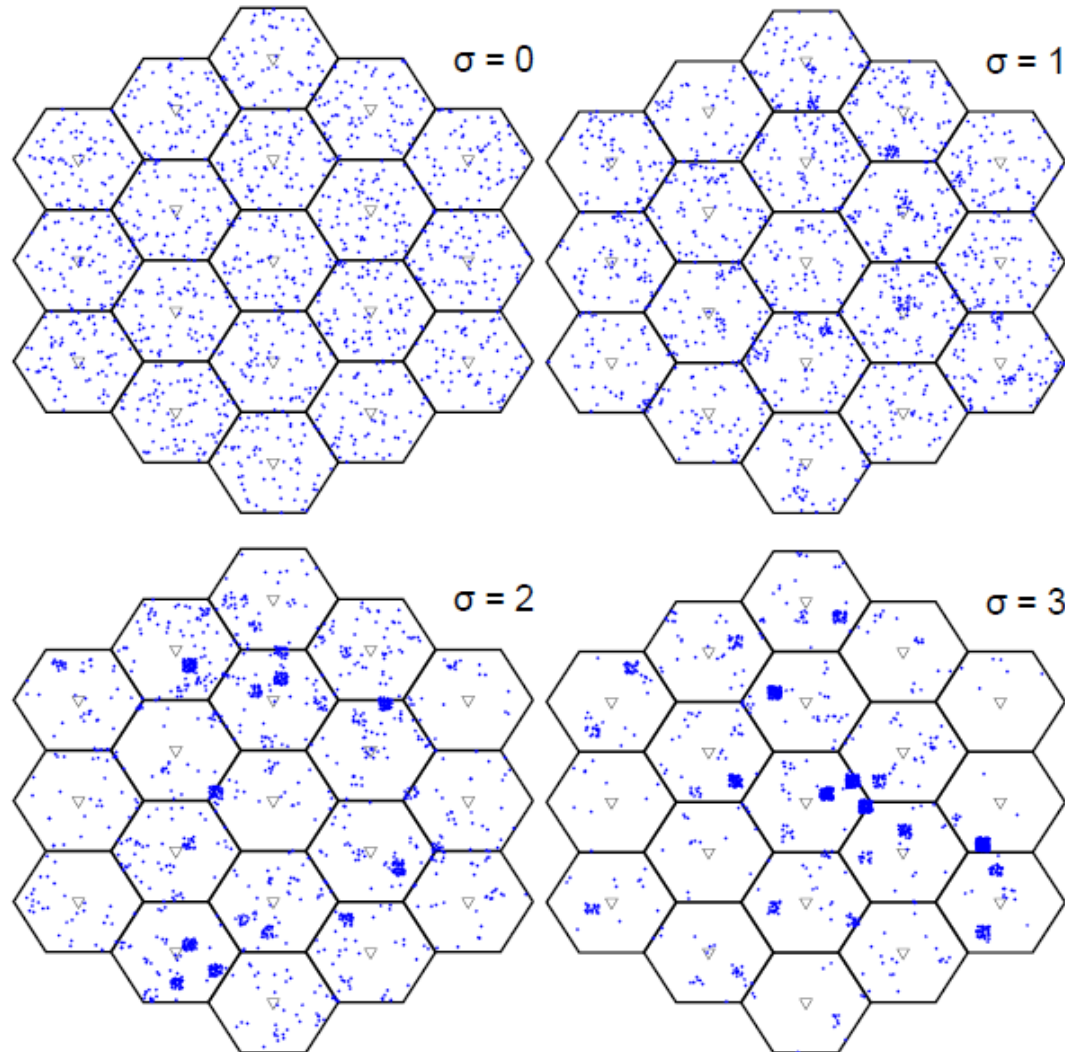


Λ is stochastic **LGCP**

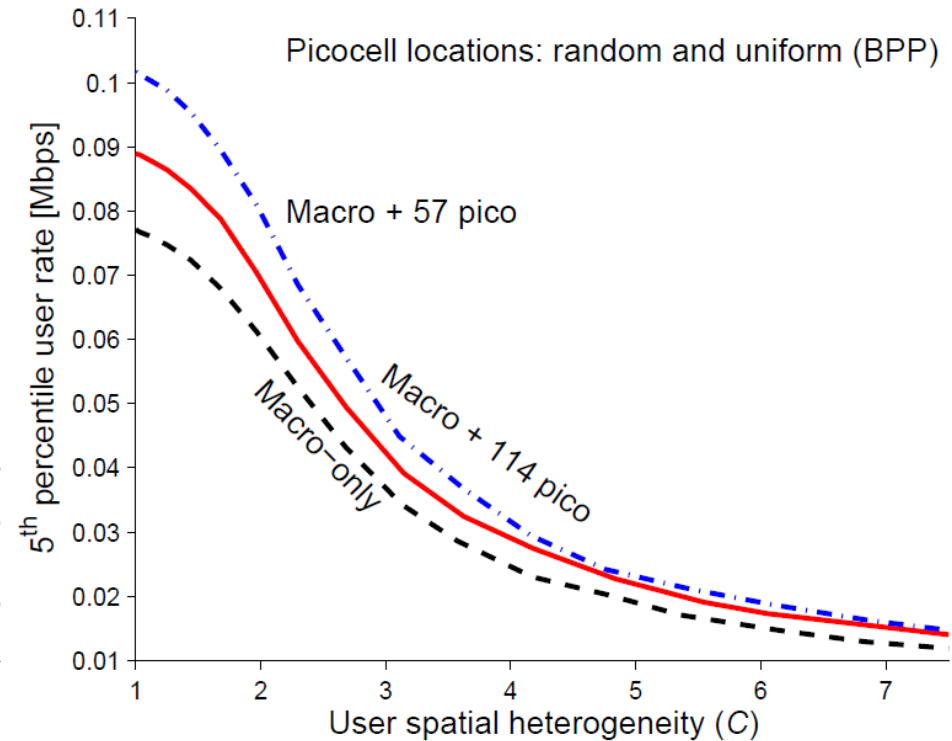
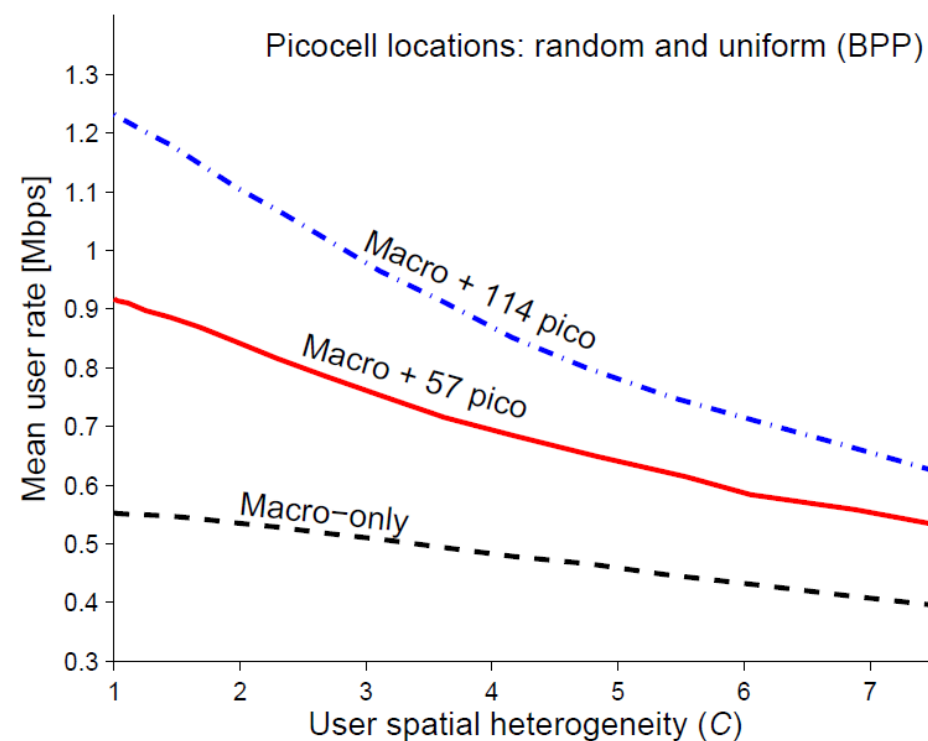


Intensity map

Realizations of LGCP with Different σ



The Impact of User Spatial Heterogeneity



- The locations of macrocell sites are fixed in the centers of hexagons
- Picocells are deployed randomly and uniformly.

- Users are modeled with LGCPs independently with the locations of BSs.
- The user spatial heterogeneity is measured by a positive real number C , which is equal to 1 for PPP, greater than 1 for super-Poisson processes.

Cluster Analysis - K-means Algorithm

K-means algorithm is one of the most popular clustering algorithms

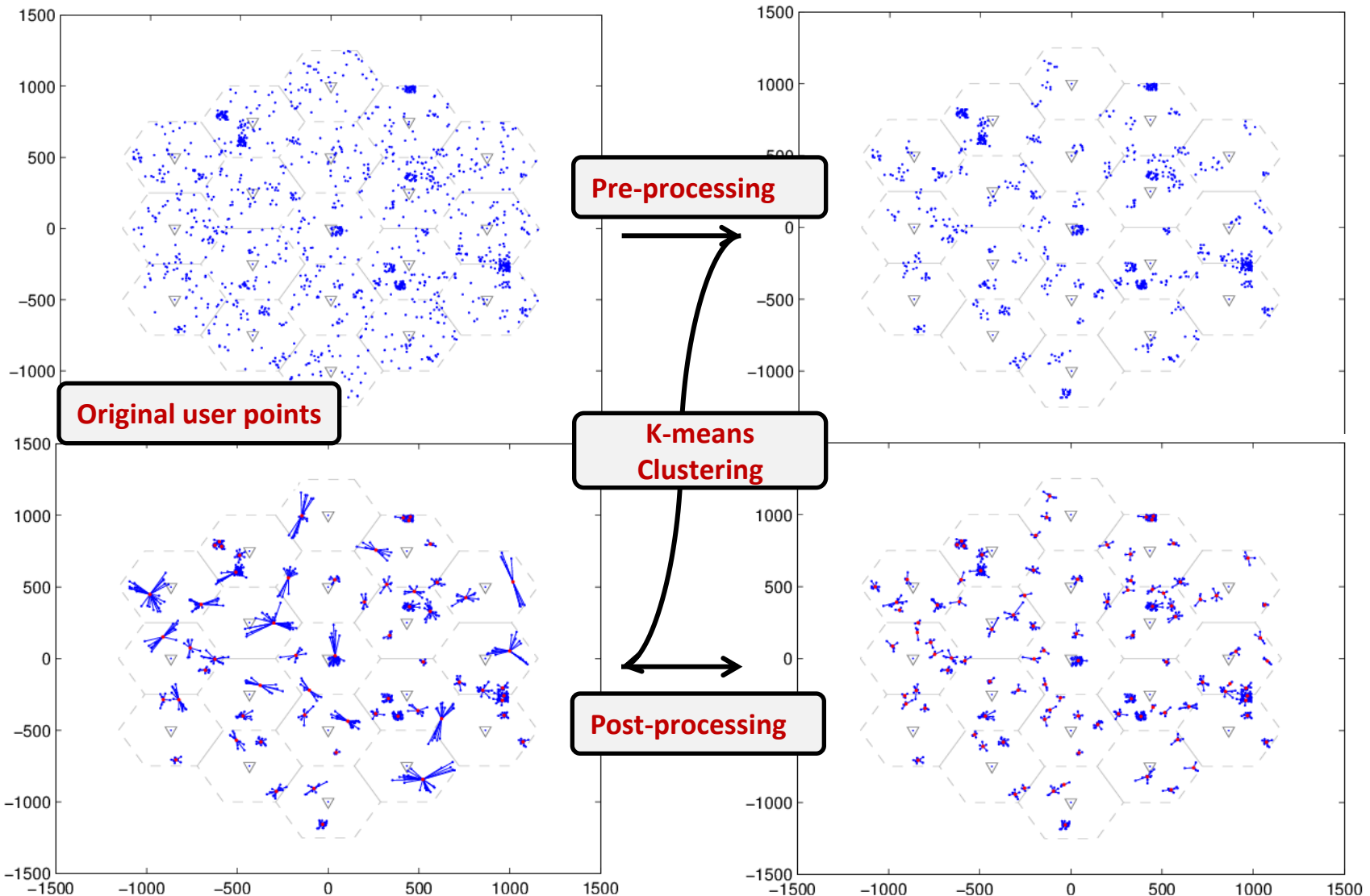
Algorithm Basic k -means Algorithm

- 1: Select k points as initial centroids.
 - 2: repeat
 - 3: Form k clusters by assigning each point to its closest centroid.
 - 4: Recompute the centroid of each cluster.
 - 5: until Centroids do not change.
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- **Cluster analysis groups data into clusters such that objects in the same cluster are more similar to each other than to those in a different cluster.**
- **It is a main task of data mining and has played an important role in a wide variety of fields.**



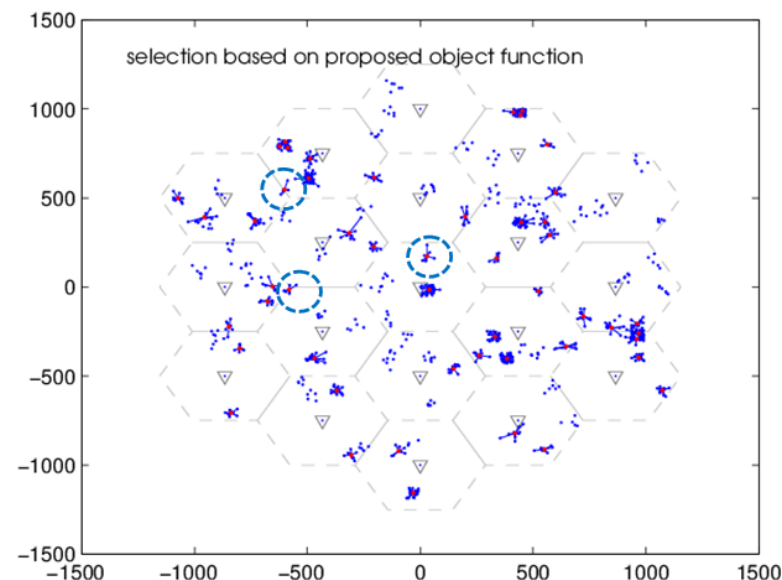
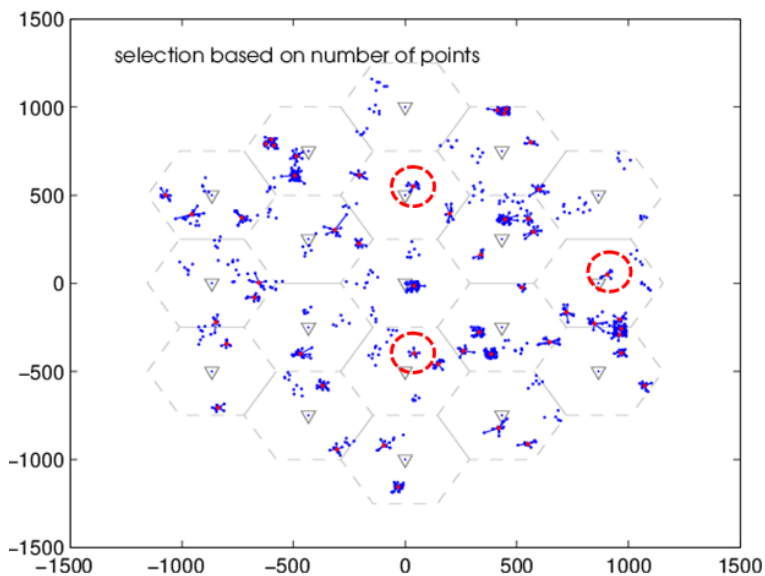
Pre-processing and Post-processing



Cluster Selection

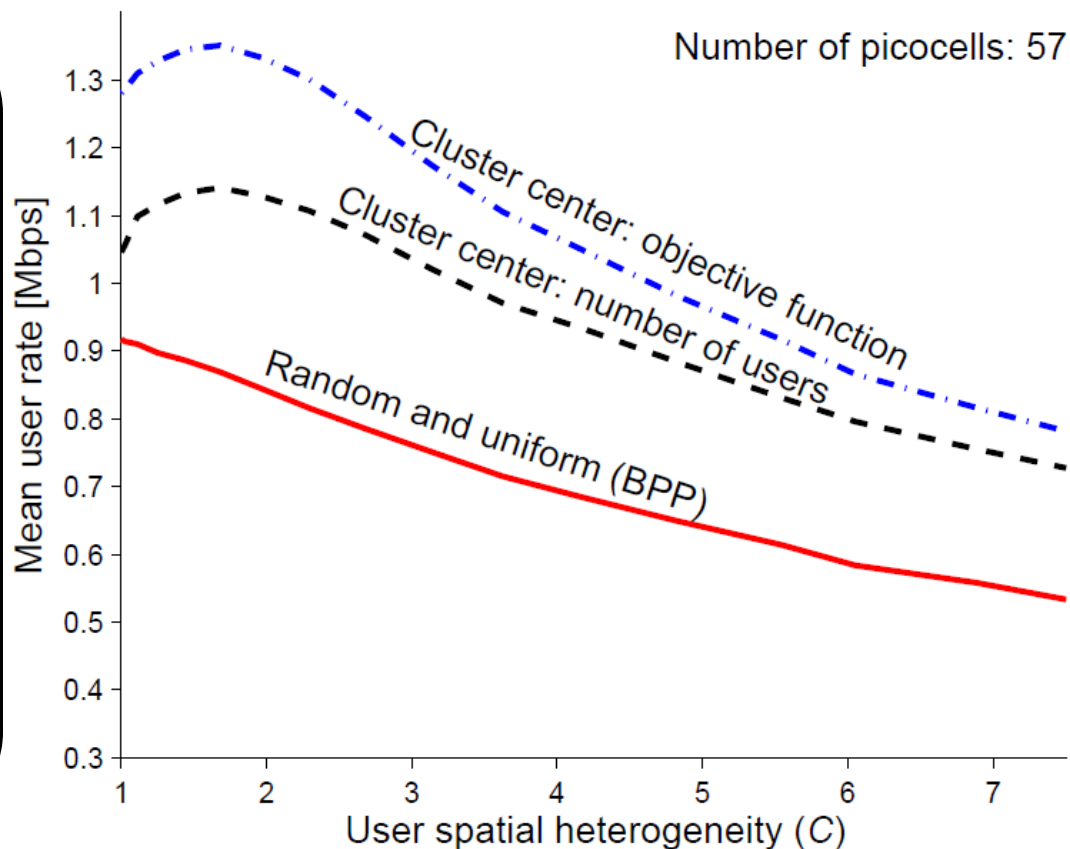
- Set K equals the number of planned small cells, after splitting (post-processing), we got more than K clusters. How to select K clusters out of them?
- The straight forward way is to select K clusters that have the most points inside. Yet a better way is to take the distance between users and macrocells into consideration. We propose the objective function as

$$U_i = \frac{1}{n_i} \sum_{j=1}^{n_i} \log\left(\frac{d_j^{(m)}}{d_j^{(s)}}\right)$$



Performance Evaluation

- Performance is improved significantly when picocells are deployed in the centers of user clusters.
- HetNet can benefit from user spatial heterogeneity in a certain degree.
- Cluster selection considering relative distance between users to macrocells and users to potential small-cells performs the best



Conclusion

□ Contributions:

- We generate heterogeneous user spatial heterogeneity by log Gaussian Cox process, and investigate the impact of user spatial heterogeneity on HCNs.
- The simulation results show that network performance deteriorates when users are more heterogeneously distributed.
- By deploying small cells in the center of users hot-zone found by clustering analysis, we provide insight that HCNs can benefit from a certain degree of user spatial heterogeneity if the locations of small cells are strongly correlated to the centre of user clusters.

□ Outlook:

- Use user-in-the-loop technique to reduce user spatial heterogeneity so as to improve network performance.
- Instead of same user rate demand, investigate different rate demand with different properties, e.g., real-time and non-real-time, and their influences on user-in-the-loop.

Thank you!