

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 $Cox \Lambda$ 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 $Y = \{Y(s): s \in \mathbb{R}^2\}$ is a real valued Gaussian process.
- By changing the σ in *Y*, the LGCP generates a wide range of heterogeneities.



Realization of LGCP



Intensity map



Section 2 Model for User Spatial Heterogeneity

Realizations of LGCP with Different $\boldsymbol{\sigma}$



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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.
- Recompute the centroid of each cluster.

5: until Centroids do not change.

- 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

$$U_{i} = \frac{1}{n_{i}} \sum_{j=1}^{n_{i}} \log(\frac{d_{j}^{(m)}}{d_{j}^{(s)}})$$



Performance Evaluation

• Performance is improved significantly when picocells are deployed in the centers of user clusters.

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- 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:

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- 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!



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