Beyond Voronoi: Plain Probabilistic Spatial Coverage Inference from Base Station Deployments

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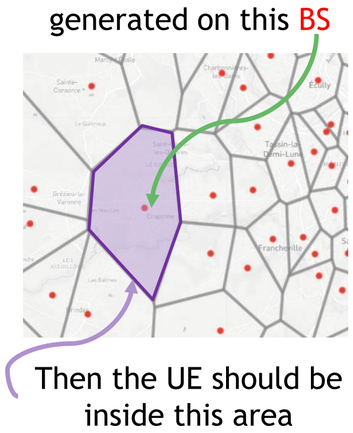
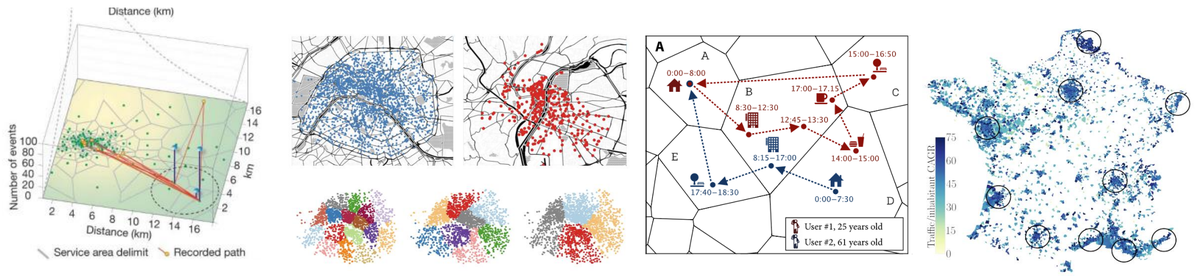
Introduction, Motivation & Goal

For remote sensing, Base Station (**BS**) coverage data can be useful. However, such data is rarely available due to privacy and commercial concerns.

Remote sensing community relies on **Voronoi tessellation** as an approximation to BS coverage.

Voronoi tessellation has been exploited in diverse fields of research, yet its validity is questionable.





Nature'08 [1] MobiCom'18 [2] Science'20 [3] WWW'22 [4]

Contributions

(1) Quantifying the quality of Voronoi approximation.

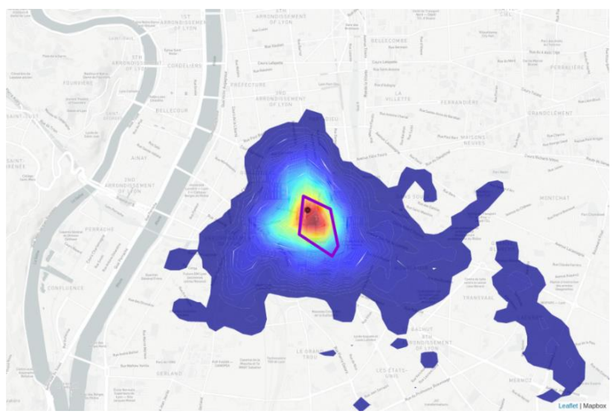
(2) Proposing **VoronoiBoost**, a data-driven model of BS coverage.

Problem & Concepts

Ground truth data

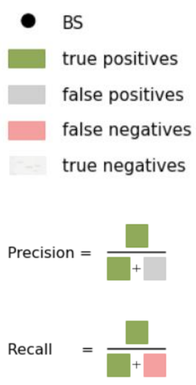
Ground truth coverage dataset provided by Orange.

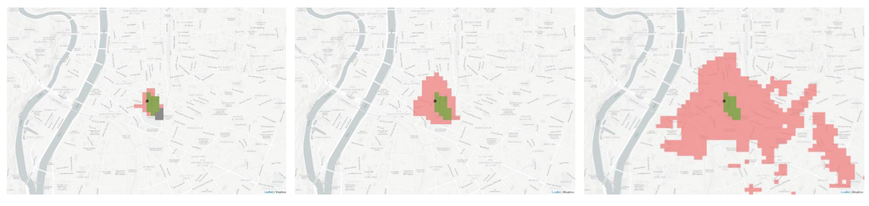
+240K antennas and we analyze 10 major France cities.



Understand Voronoi accuracy

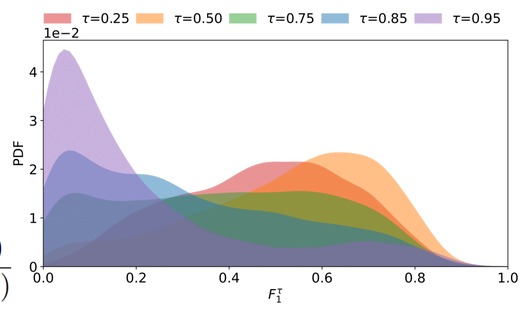
We define **τ-coverage** as the area that contains the top τ coverage probability.





F-Score metric

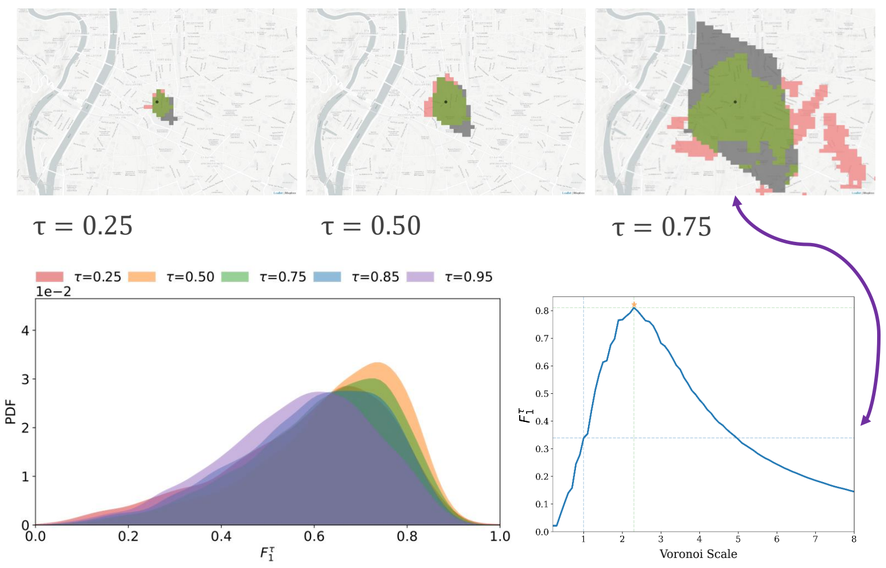
$$F_1^\tau(i) = 2 \cdot \frac{P^\tau(i) \cdot R^\tau(i)}{P^\tau(i) + R^\tau(i)}$$



Voronoi cells have substantial limitations in mimicking the actual coverage of BSs.

Scaling Voronois to improve coverage quality

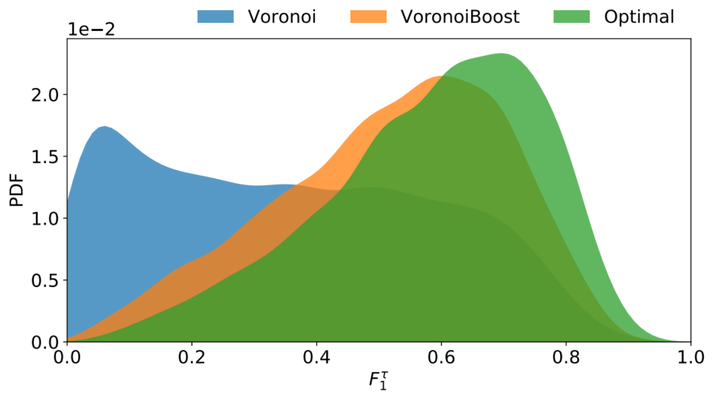
These limitations can be overcome by scaling the Voronoi cell up or down to the value that maximizes F_1^τ.



Results

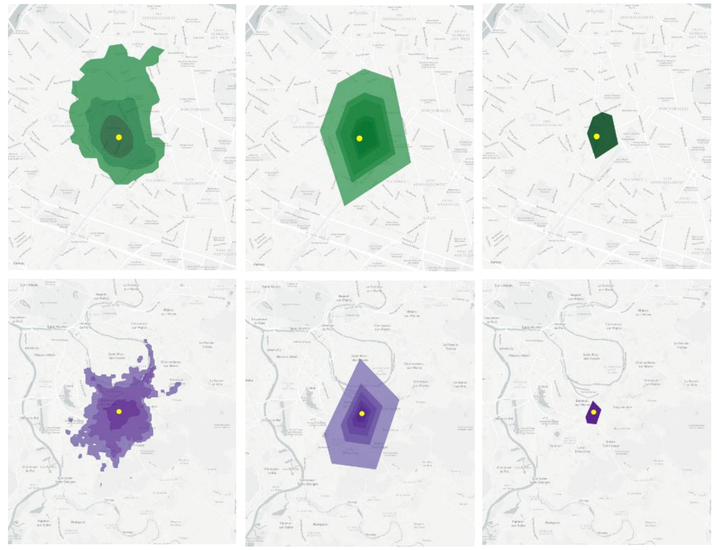
VoronoiBoost to predict coverage probability

VoronoiBoost is a Gradient Boost Regressor model that predicts with high accuracy ($R^2 = 0.84$) the optimal scaling of a Voronoi cell, using only location information.



VoronoiBoost can be used to predict the optimal scaling for several τ values, and by overlapping these predictions, one can obtain a more realistic coverage approximation.

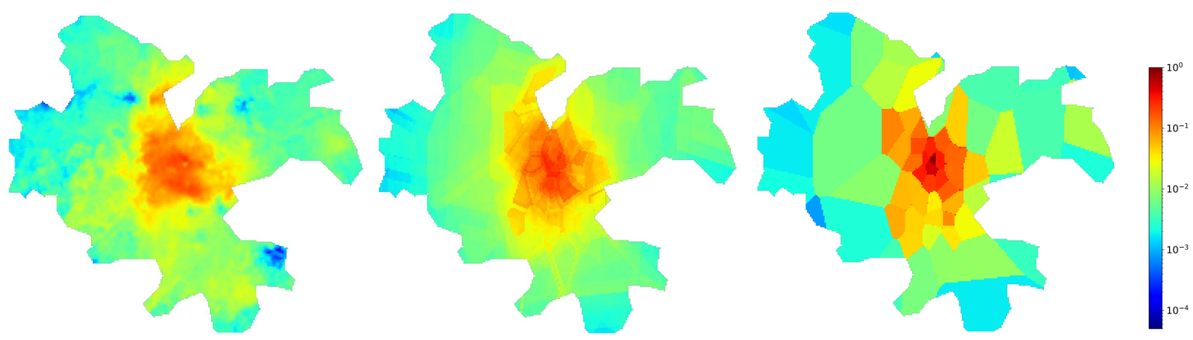
Provide the community with a tool that enables acquiring an improved version of Voronoi cell.



Ground Truth VoronoiBoost Voronoi

Practical application use cases

Application I: Traffic maps



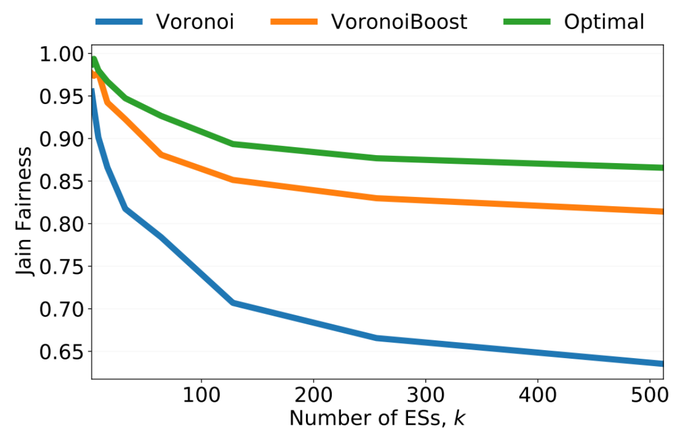
Ground Truth VoronoiBoost Voronoi

VoronoiBoost improves the **quality** of traffic mapping by **44%** on average over standard Voronoi cells.

Application II: Far Edge Site (ES) planning in virtualized RANs

The accuracy of traffic maps can affect the quality of the ES planning.

We use Jain Fairness Index metric to assess the planning quality.



VoronoiBoost induce up to **28%** more accurate ES deployment than the one obtained with Voronoi cells.

References

[1] Gonzalez, M. C., Hidalgo, C. A., & Barabasi, A. L. (2008). Understanding individual human mobility patterns. Nature.

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[3] Oliver, N., et al. (2020). Mobile phone data for informing public health actions across the COVID-19 pandemic life cycle. Science advances.

[4] Mishra, S., Smoreda, Z., & Fiore, M. (2022, April). Second-level Digital Divide: A Longitudinal Study of Mobile Traffic Consumption Imbalance in France. ACM Web Conference.