Impacts of Propagation Models on CBRS GAA Coexistence and Deployment Density

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Purpose of This Presentation

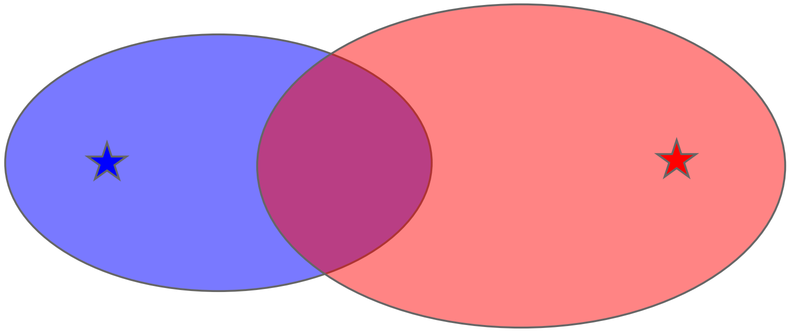
- Demonstrate the importance of accurate clutter-aware propagation model in planning networks
- Demonstrate improved protection where clutter is not present
- Demonstrate spectrum abundance created by using clutter data
- Approaches used to make the demonstration include
  - use of a WInnF GAA coexistence framework as the baseline process to evaluate impacts of propagation models
  - use of system simulation to analyze and quantify the benefit of clutter-aware propagation model

CBSD Coexistence Using GAA Spectrum

- Citizens Broadband Radio Service Device (CBSD) using the General Authorized Access (GAA) spectrum is the third tier of users and cannot expect interference protection, therefore the GAA coexistence issue
- Spectrum Access System (SAS) can facilitate frequency coordination between GAA users to minimize the potential interference among CBSDs using the GAA spectrum
- WInnF is working on a GAA coexistence framework to
  - Minimize interference
  - Increase spectrum reuse
  - Create spectrum abundance

Channel (Frequency) Orthogonalization or Not?

Mobile use case: amount of coverage overlap (area coordination)



Fixed wireless use case: amount interference at CBSD receiver (point coordination)

Information Used to Determine Frequency Orthogonalization

- CBSD antenna location
  - Latitude, longitude, height
- CBSD antenna pattern
  - Boresight, downtilt, beamwidth, peak gain, full 2D pattern
- CBSD transmission power
- Area or point coordination
- **Propagation models**
- Measurements
  - CBSD or EUD measurements reported to SAS

Types of Propagation Models

- **Irregular Terrain Model (ITM)** : developed in 1960s by Anita Longley and Phil Rice, the model predicts long-term median transmission loss over irregular terrain.
- **ITM-eHata hybrid model**: developed by NTIA and revised by WInnForum, the model adopts the path loss from ITM for long distance propagation and uses the larger path loss generated by either the ITM model or the extended Hata model for shorter distance transmission.
- **Clutter-aware propagation model**: a proprietary model that makes use of clutter data above ground, including buildings and vegetations, to estimate propagation loss.

Data Used By Propagation Models

	ITM	ITM-eHata Hybrid	Clutter-Aware
Tx/Rx locations	x	x	x
Terrain Data	x	x	x
Statistical Clutter Loss (urban, suburban, rural)		x	
Real Clutter Data			x

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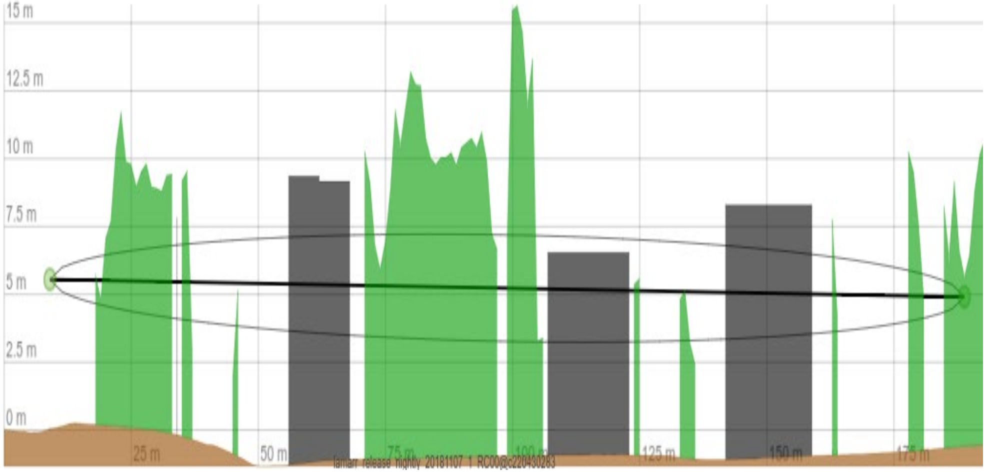
Clutter Data Used For Propagation Modeling



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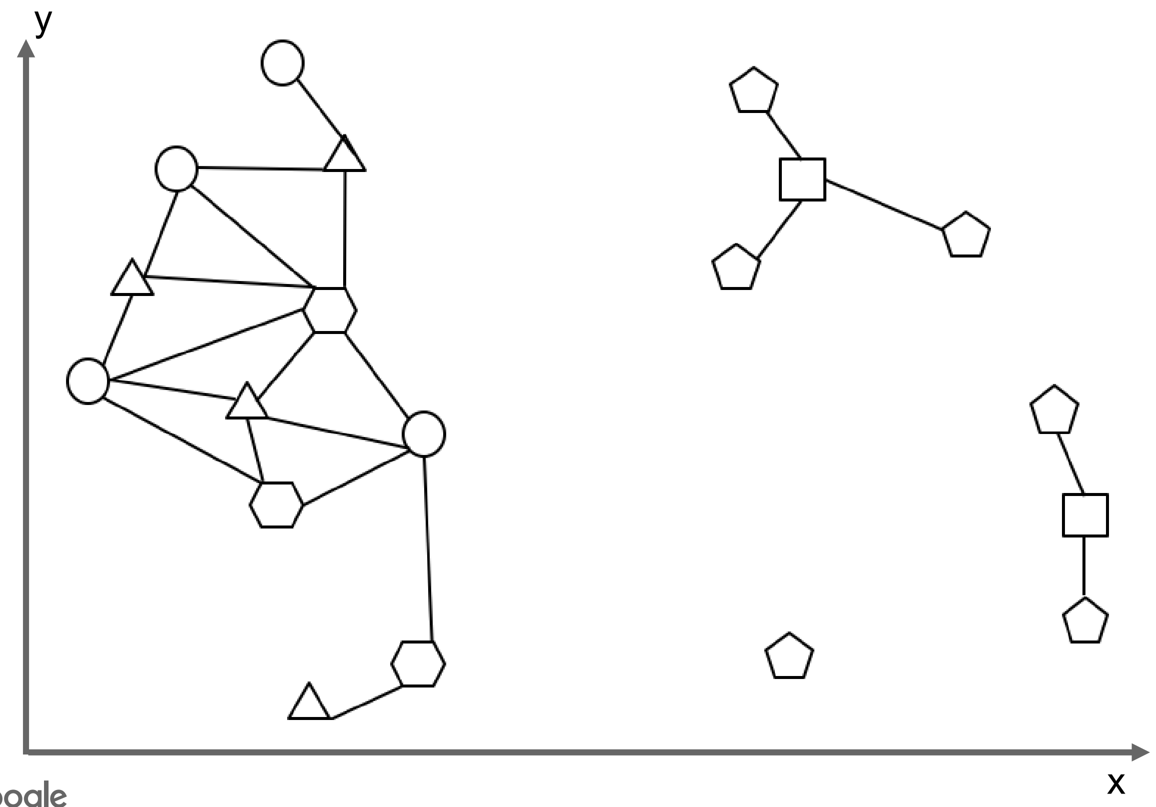
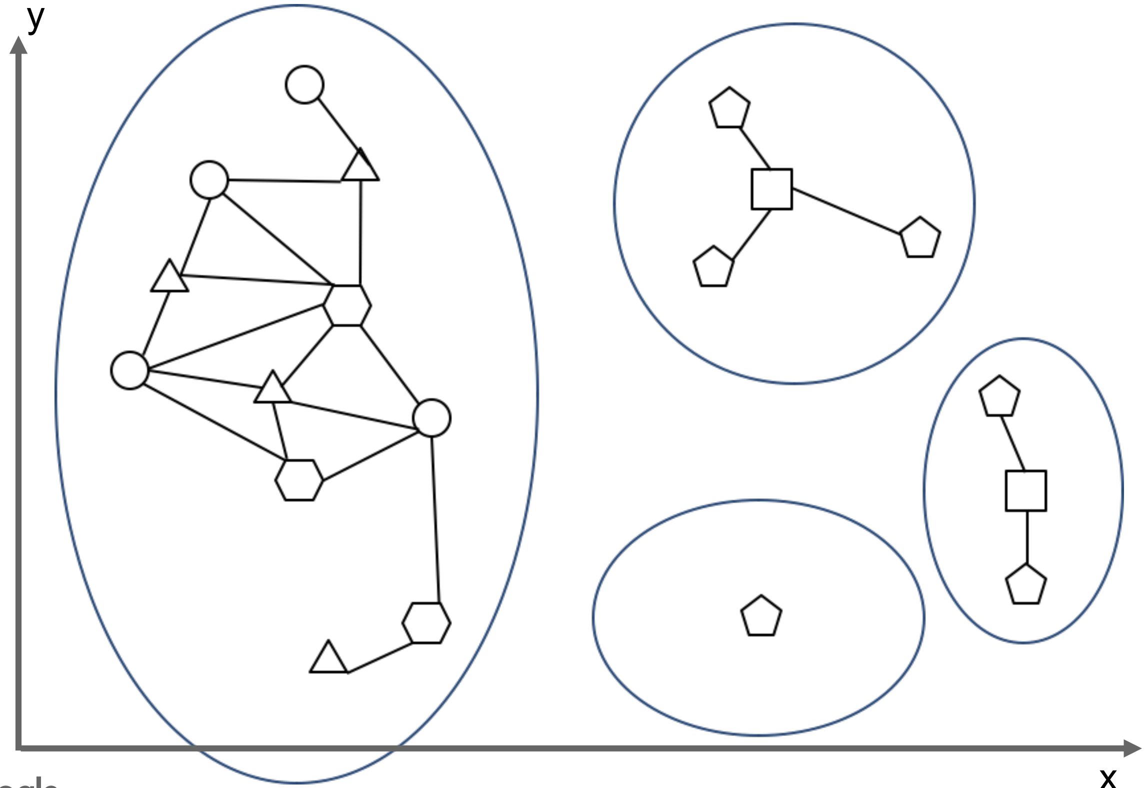
GAA Channel Assignment: Overlap Graph Creation



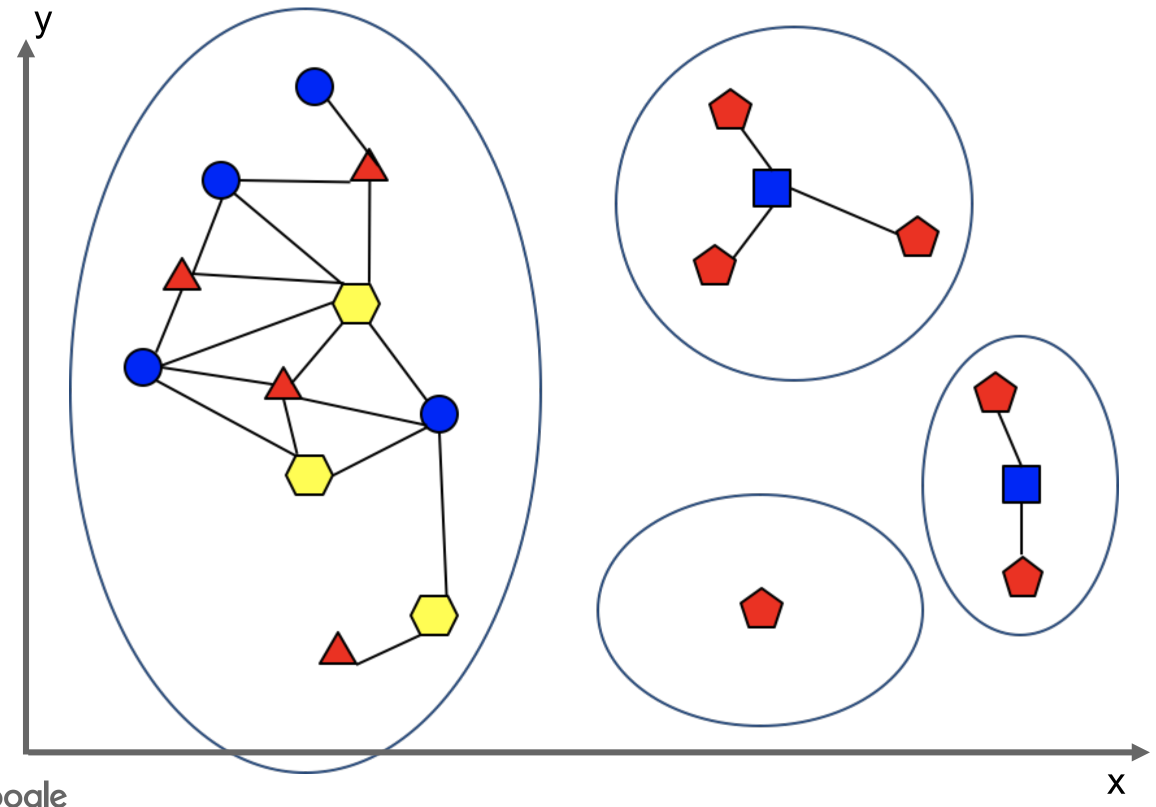
- A shape represents a CBSD. Different shapes represent different networks of CBSDs
- An “edge” (denoted by a line) is created between two CBSDs if they require different channels

GAA Channel Assignment: Connected Set Creation



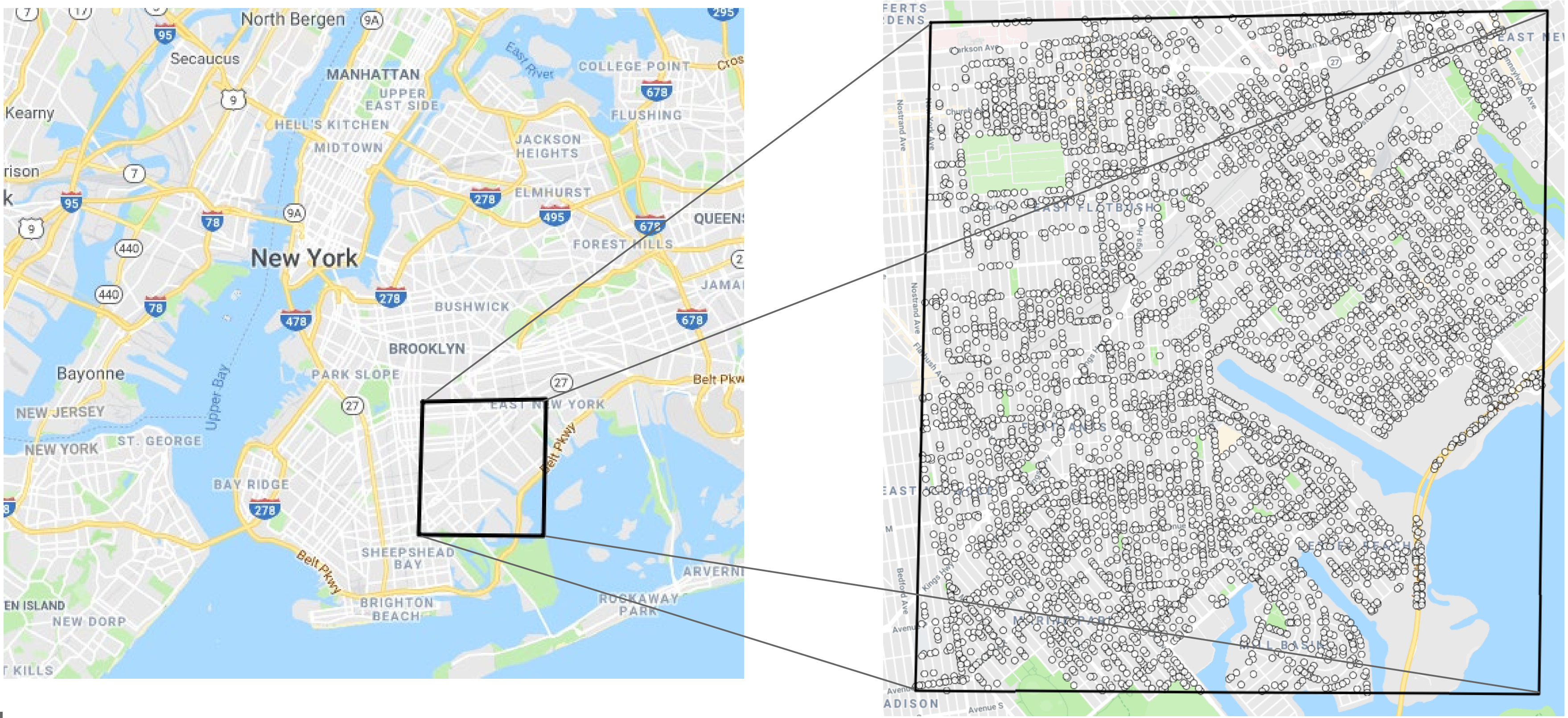
- CBSDs in a connected set have directly or indirectly interference relation with other CBSDs in the connected set.
- GAA channel assignment is performed independently in each connected set

GAA Channel Assignment: Graph Coloring



- Color CBSDs in a connected set with minimum number of colors s.t. two CBSDs connected with an edge get different colors
- For this presentation, each color is assigned with an equal portion of the GAA spectrum

Deployment Density Simulation: Brooklyn



Characteristics of the Simulated Area

- 30.71 km^2 area
- Urban residential area
  - Mostly two story houses
- Relative flat terrain
- Deployment assumption
  - Category A CBSDs supporting mobile users
  - 30 dBm/10 MHz EIRP
  - Omni-directional antenna
  - Outdoor installation at poles with 5.5 meter AGL
- Takeaway: very benign urban environment

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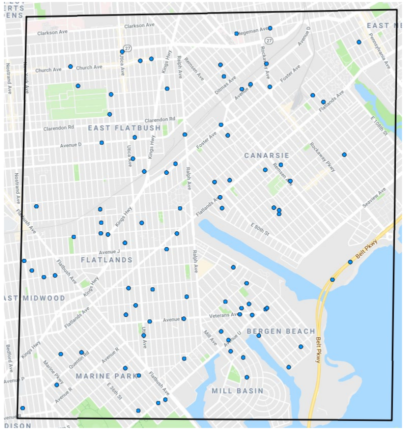
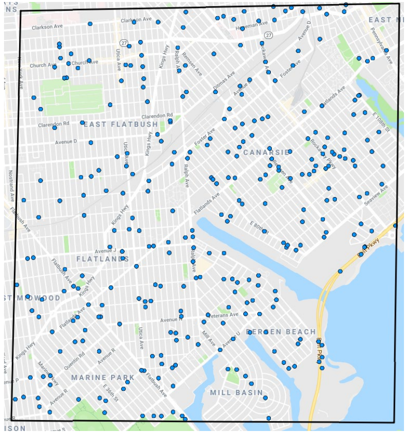
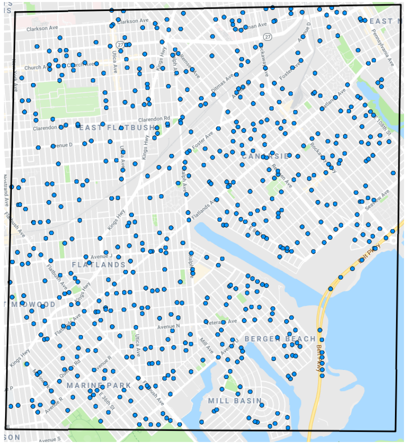
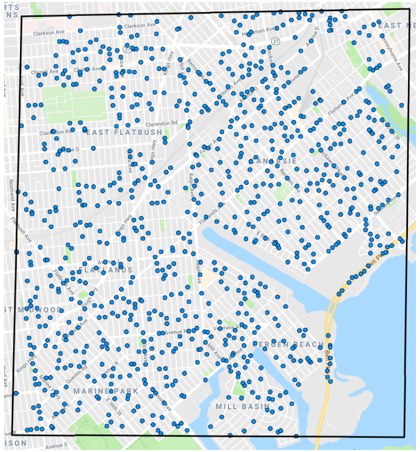
Deployment Densities

Scenario	# CBSDs in area	CBSD density (per km^2)
1	91	3
2	315	10
3	626	20
4	897	30
5	1406	47





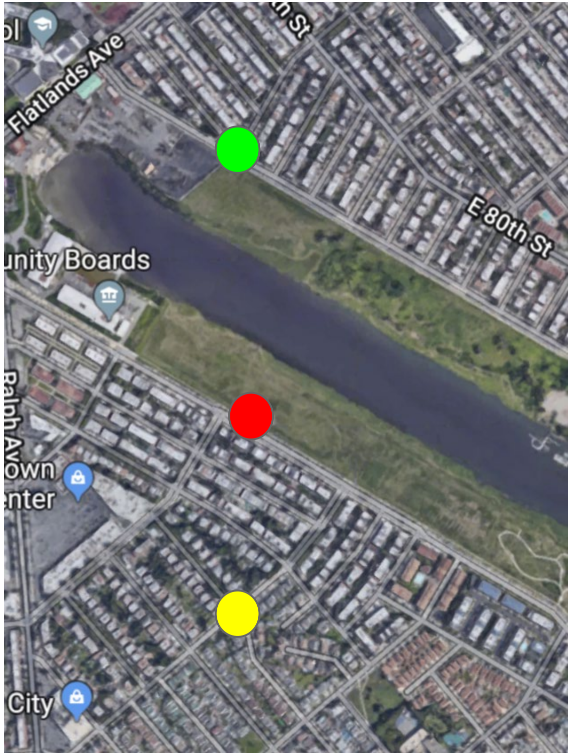




Simulation Parameters

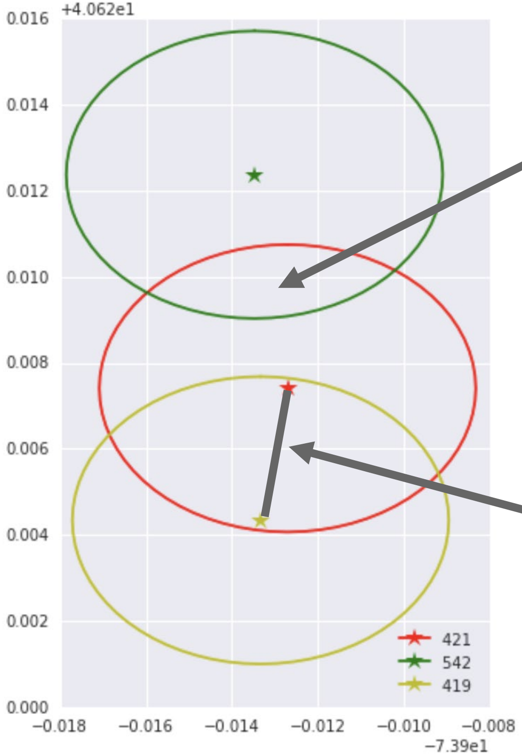
- CBSD locations: randomly chosen from a street pole database in the area
- CBSD antennas: omni-directional, 0 dBi
- CBSD EIRP: 30 dBm/10 MHz
- CBSD height: 5.5 meter above ground
- CBSD coverage area: -90 dBm/10 MHz received signal contour
- Edge creation between two CBSDs if their coverage overlap area is more than 20% of each individual coverage area

Coverage Difference Caused by Propagation Models (1)



- Example: three cells near the Paerdegat Basin
- No clutter between Green and Red CBSDs
- Building clutter between Red and Yellow CBSDs

Coverage Difference Caused by Propagation Models (2)



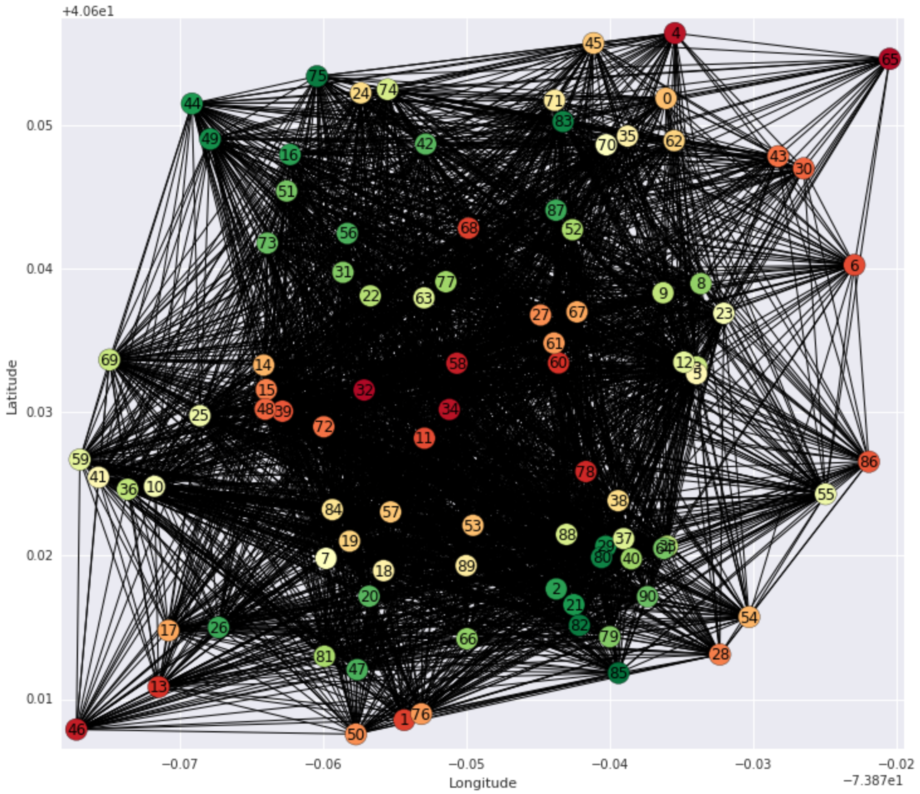
Under estimating interference

Over estimating interference

Coverage estimate using hybrid model

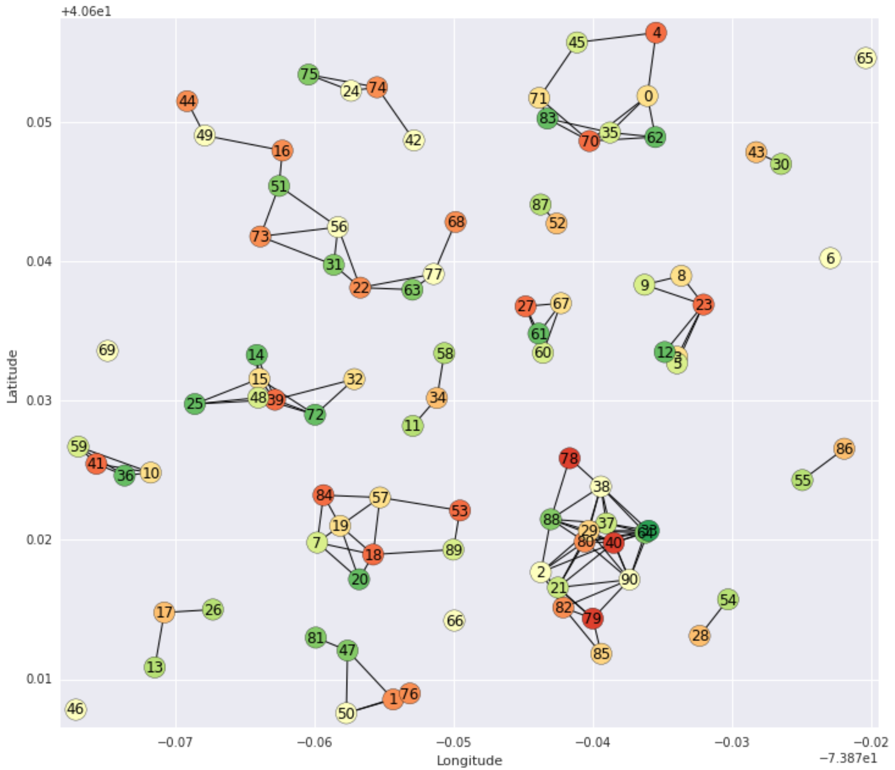
Coverage estimate using clutter-aware model

Overlap Graph using ITM, Density 3

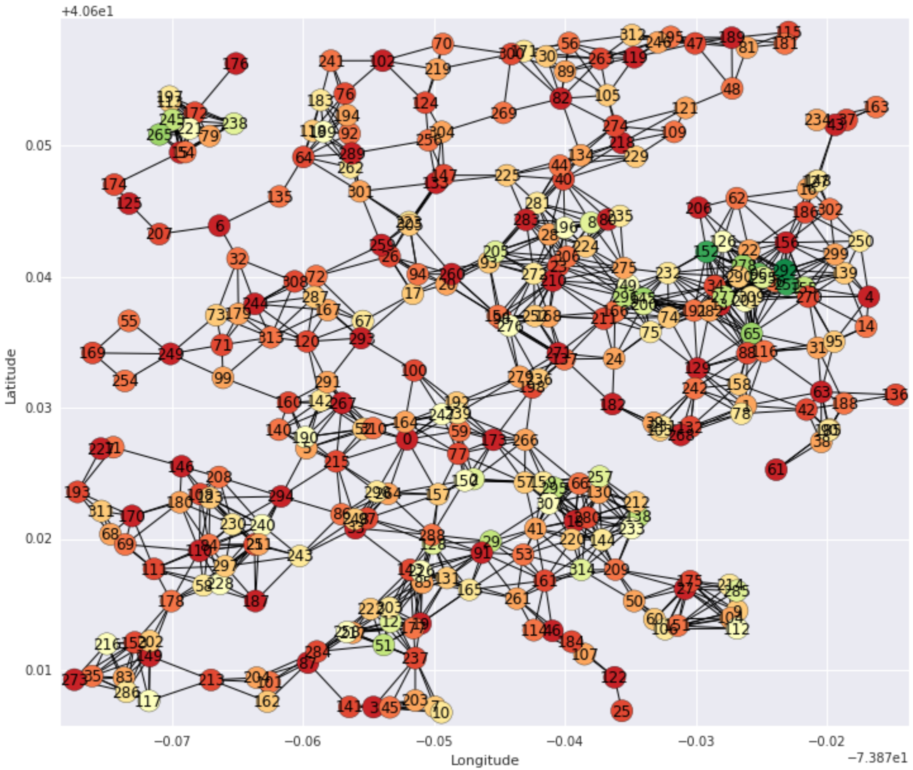


- 1 connected set, i.e., all CBSDs are directly or indirectly connected.
- 47 colors (channels) needed to color the graph
- Lots of edges mean lot of interference inter-dependency

Overlap Graphs Using Hybrid Model (1/3)



Density 3, 7 colors (channels), 21 connected set



Density 10, 13 colors (channels), 1 connected set

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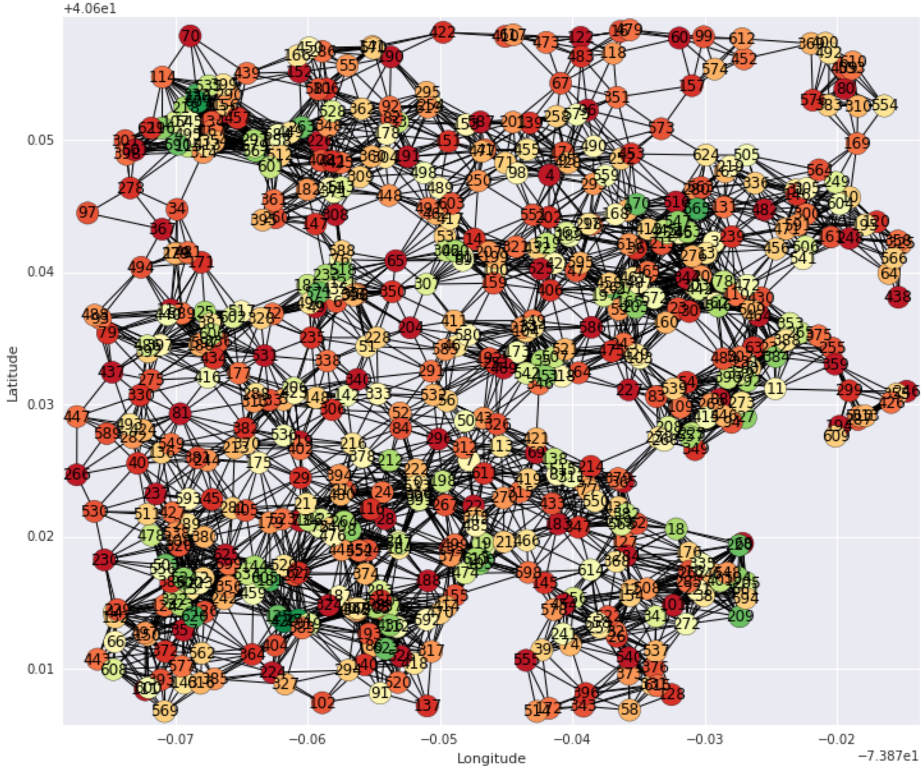
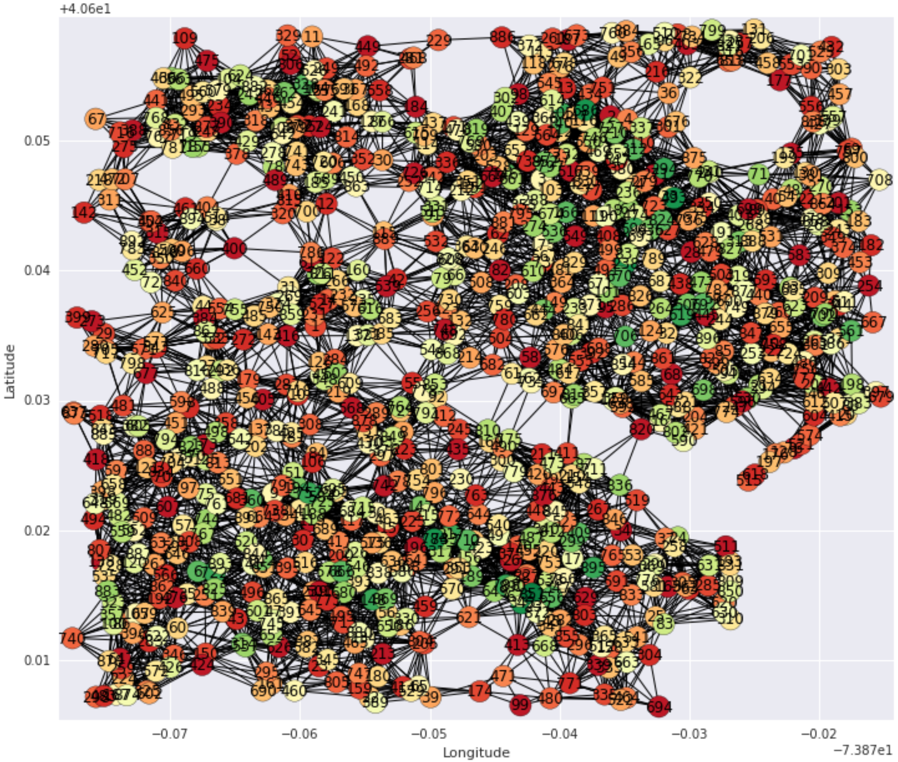
Overlap Graphs Using Hybrid Model (2/3)

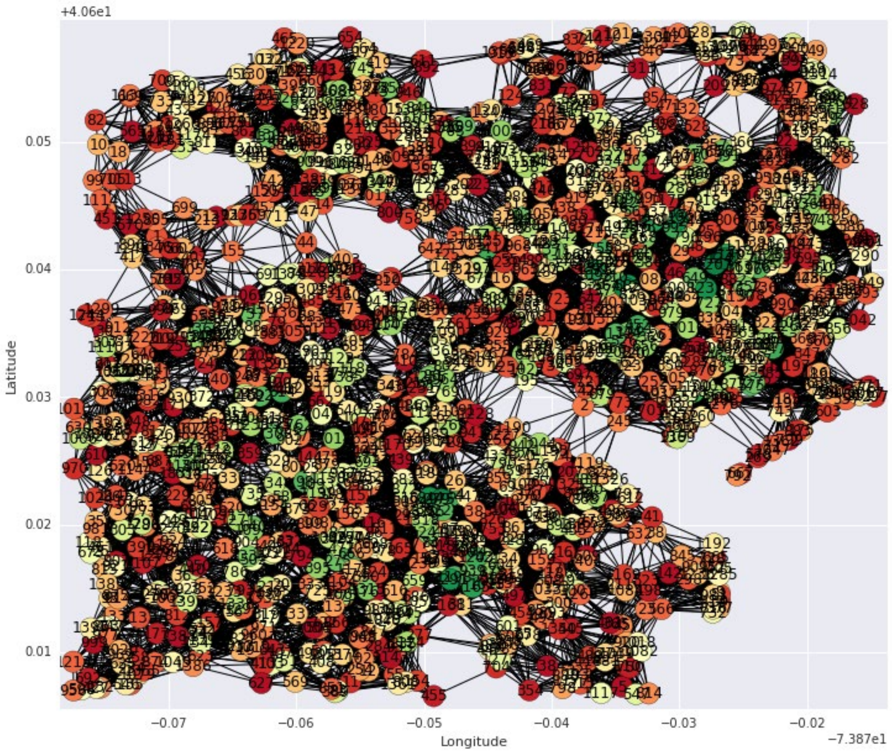


Density 20, 18 colors (channels), 1 connected set



Density 30, 20 colors (channels), 1 connected set

Overlap Graphs Using Hybrid Model (3/3)



Density 47, 31 colors (channels), 1 connected set

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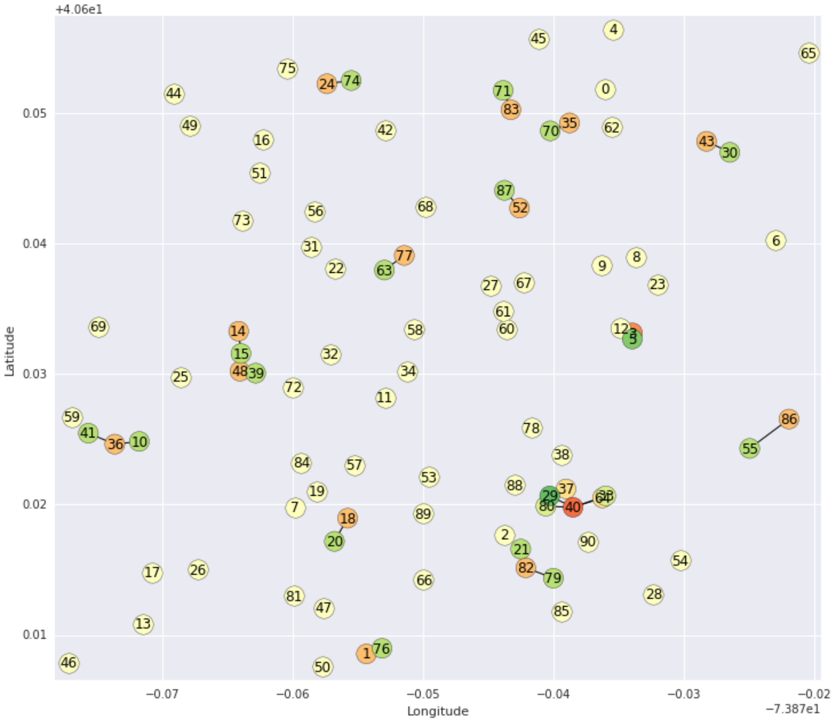
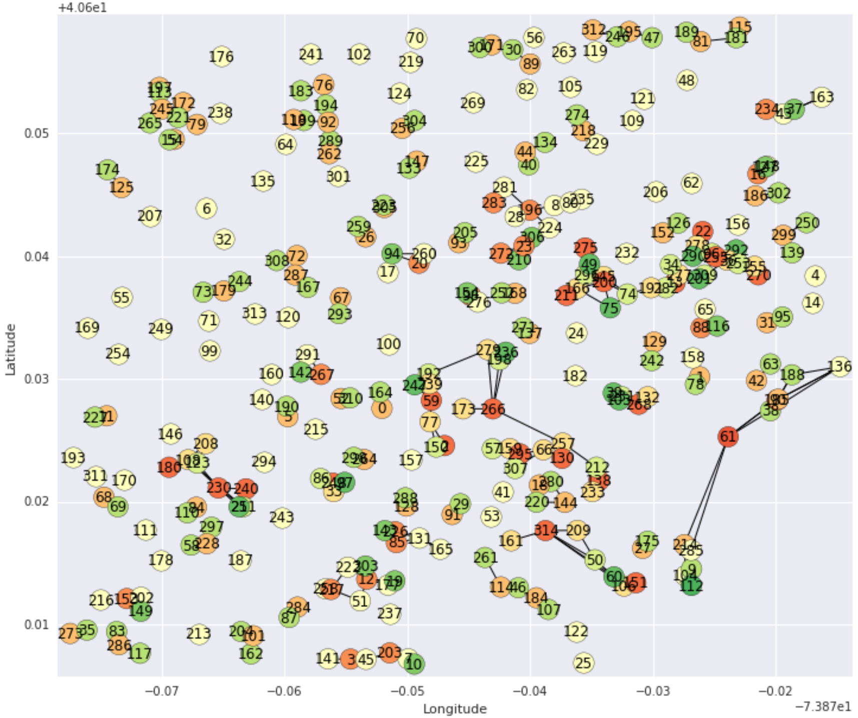
Overlap Graphs Using Clutter-Aware Model (1/3)



Density 3, 4 colors (channels), 68 connected set



Density 10, 5 colors (channels), 126 connected set

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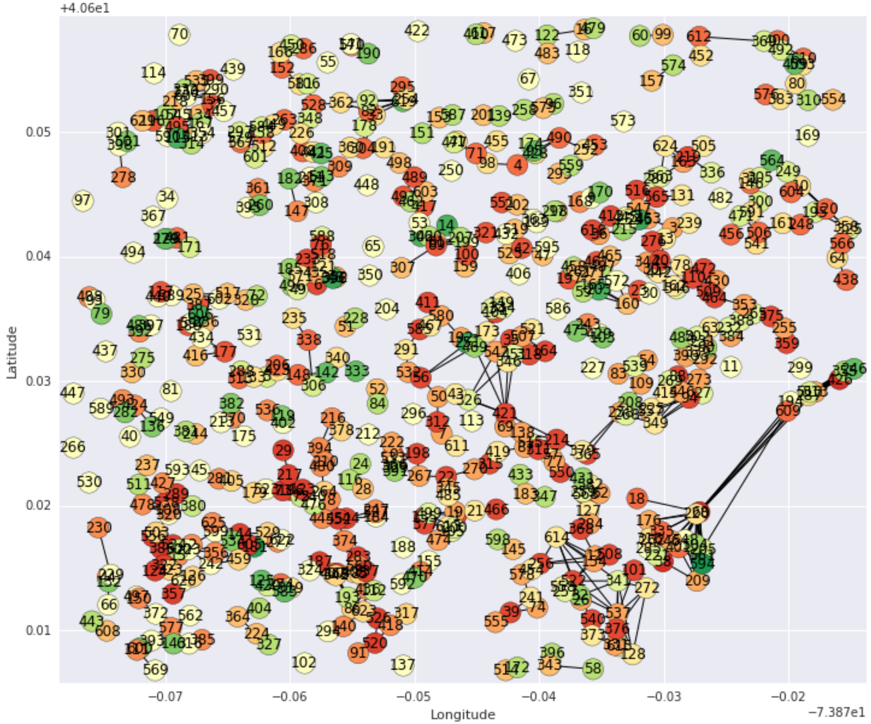
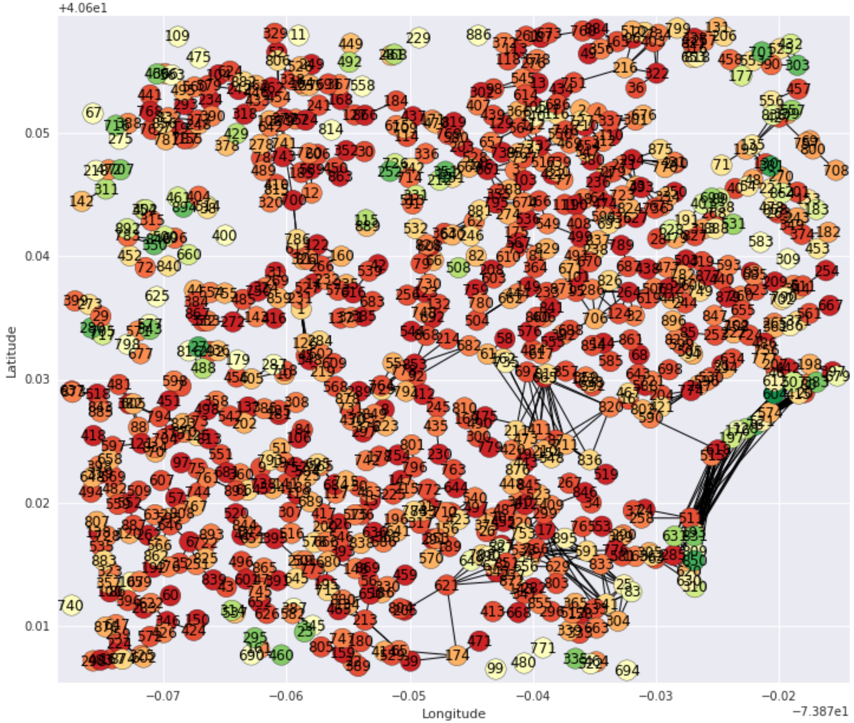
Overlap Graphs Using Clutter-Aware Model (2/3)



Density 20, 9 colors (channels), 90 connected set



Density 30, 12 colors (channels), 40 connected set

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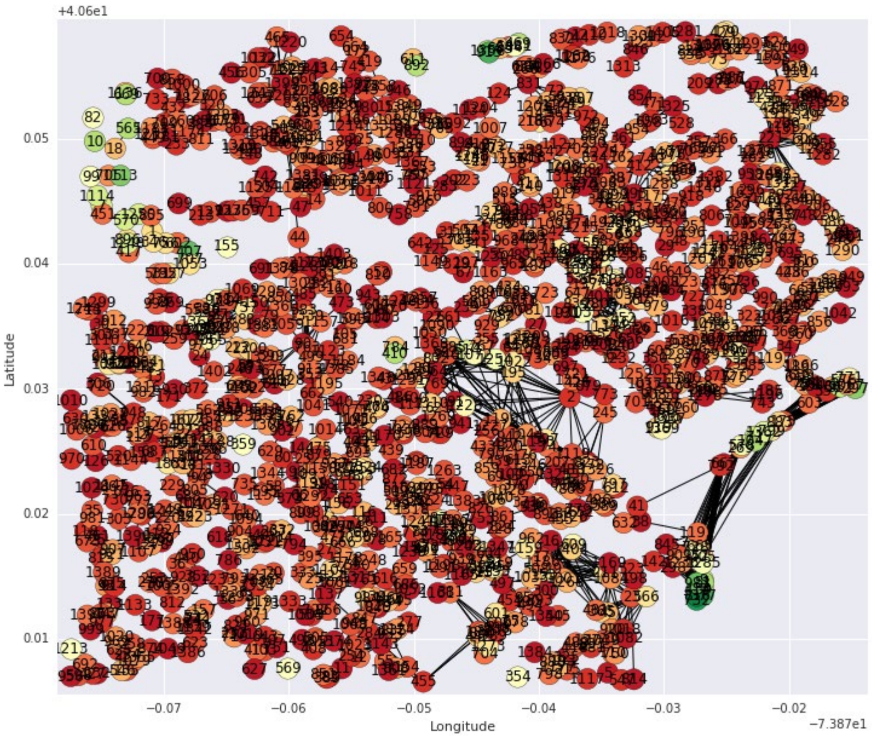
Overlap Graphs Using Clutter-Aware Model (3/3)

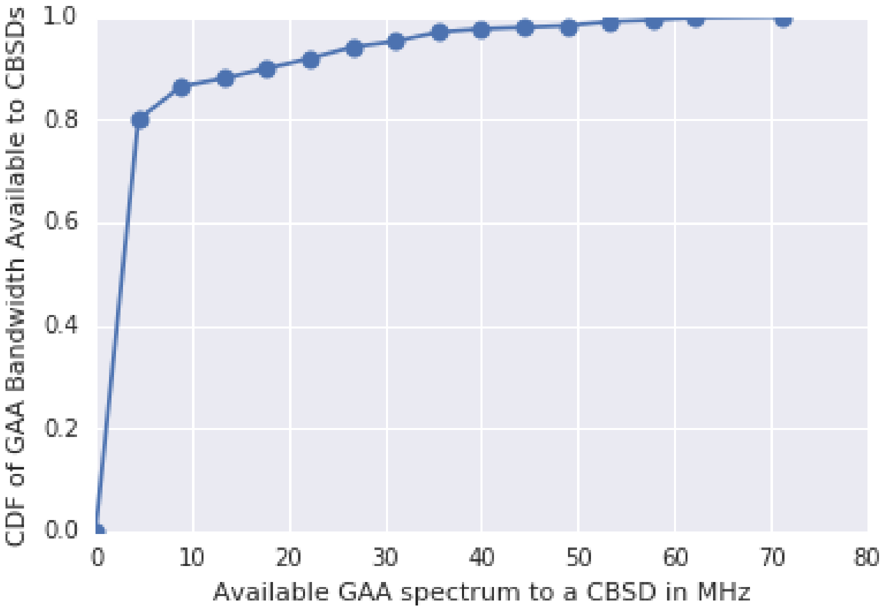


Density 47, 18 colors (channels), 14 connected set

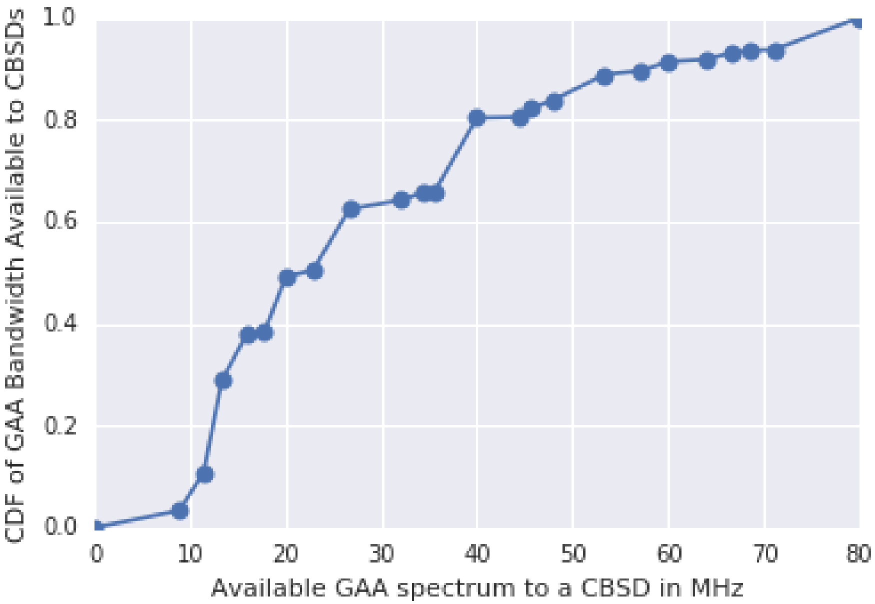
Available Bandwidth to CBSDs

- Each CBSD can use at least the amount of bandwidth associated with the assigned color
- In addition to the bandwidth associated with the assigned color, a CBSD can also utilize the bandwidth associated with other colors if other colors are not used by connected CBSDs
- By evaluating the available bandwidth of CBSDs, we gain more insights on the impact of using different propagation models for GAA coexistence.

CDF of Bandwidth Available to CBSDs (Density 20, 80 MHz of Total GAA Spectrum)



Hybrid Model



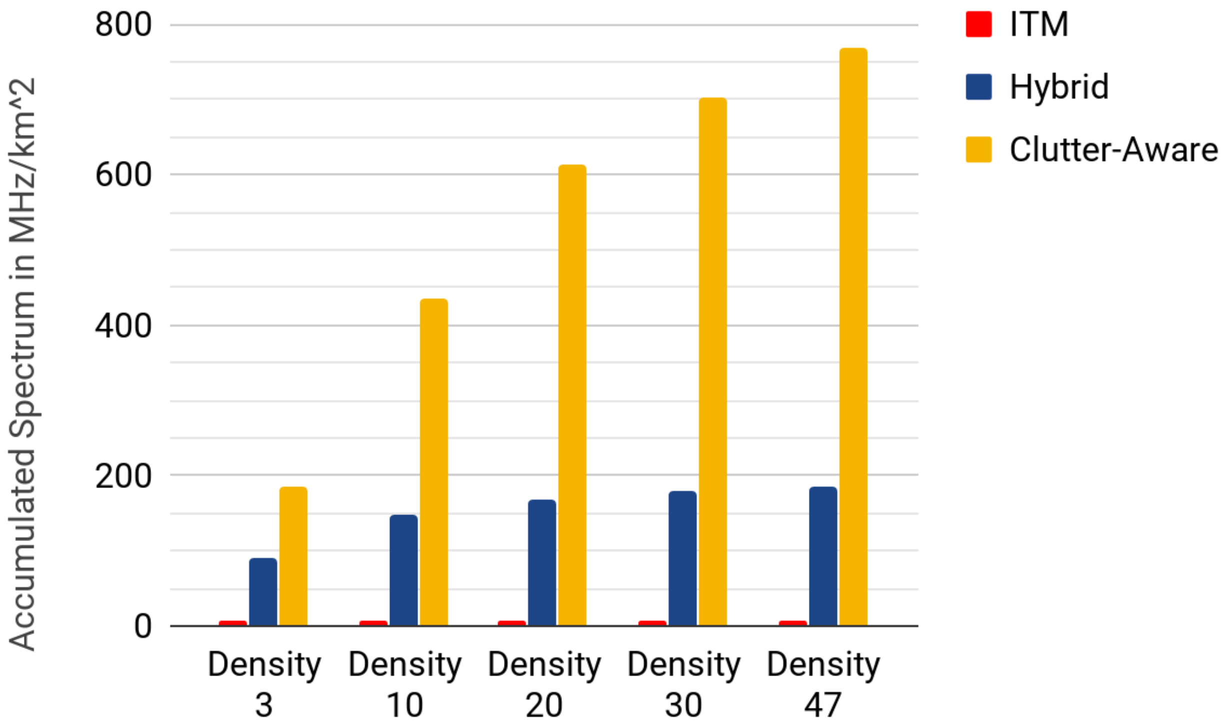
Clutter-Aware Model

Mean Percentage of Bandwidth Available to CBSDs

	ITM Model*	Hybrid Model*	Clutter-Aware Model*
Density 3	2.78% (2.2 MHz)	37.56% (30 MHz)	77.75% (62.2 MHz)
Density 10	0.86% (0.69 MHz)	18.19% (14.6 MHz)	53.15% (42.5 MHz)
Density 20	0.46% (0.37 MHz)	10.31% (8.2 MHz)	37.55% (30 MHz)
Density 30	0.32% (0.26 MHz)	7.73% (6.2 MHz)	30.05% (24 MHz)
Density 47	0.21% (0.17 MHz)	5.03% (4 MHz)	21.01% (16.8 MHz)

* Assuming 80 MHz of available GAA spectrum, scenarios marked in green means both the average and minimum available GAA bandwidth per CBSD is 5 MHz or more.

Spectral Abundance Created By Clutter-Aware Model



Summary

- Without considering clutter, GAA coexistence function can create channel assignments that unnecessarily limit GAA spectrum available to CBSDs
- Using clutter data can provide more realistic interference estimation to GAA coexistence functions
- Statistical clutter based on land cover category is inaccurate and can overestimate or underestimate interference
- We are in the big data era. Using REAL clutter data can significantly increase utilization and deployment density using the CBRS band
- **These results scale to general spectrum planning and deconfliction**

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