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RF Propagation Models and Measurements for Small Cells

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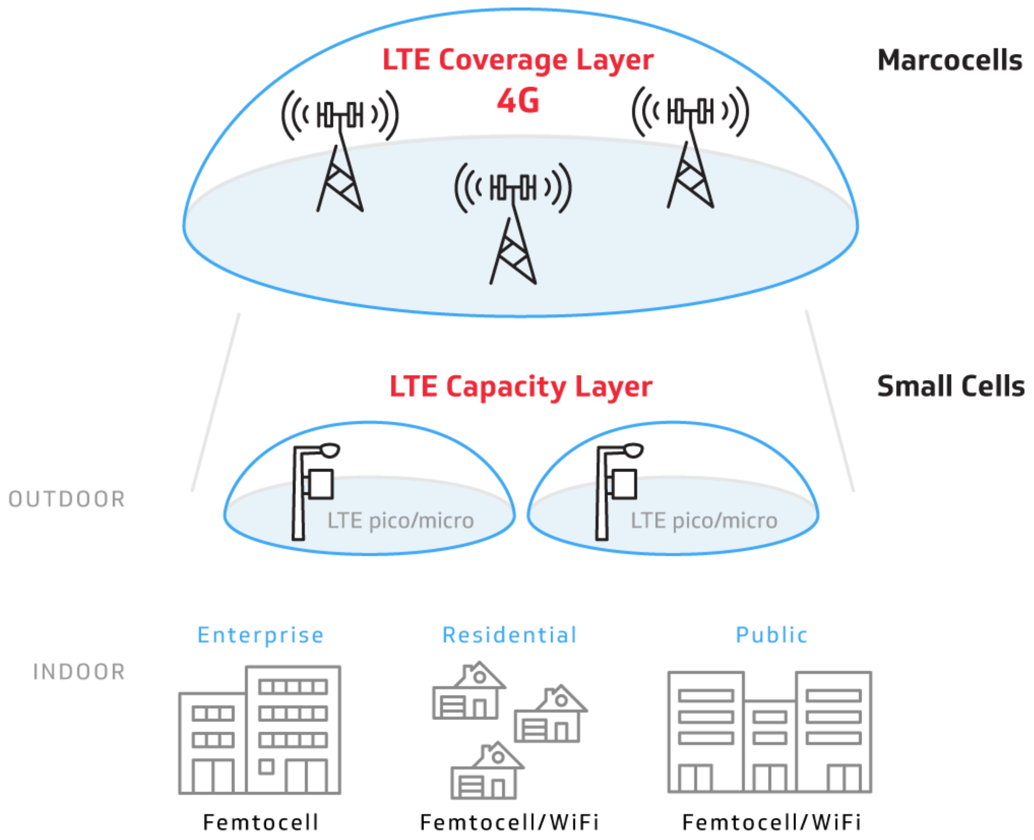
Agenda

- Industry challenges
- Propagation models
- Measurements
- Network Planning Tools
- Recommendations

Wireless Network Densification is Driving Small Cell Deployment

- Improves 4G LTE network performance, service delivery and user experience
- New spectrum allocations favor small cell deployments (i.e. CBRS, etc)
- Foundation for 5G networks
- Enables new business models



Industry RF Propagation Models

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MODEL	FREQUENCY RANGE	BASE STATION ANTENNA HEIGHT	T-R SEPARATION (Link) DISTANCE	MOBILE HEIGHT	DESCRIPTION
Okumura-Hata	150-1500 MHz	30-200 m	1-100 km	1-10m	Hata converted Okumura's empirical attenuation curves into a mathematical formula with correction factors per morphology, base station and mobile heights. Standard formula is based on urban areas with correction factors for other morphologies such as medium/small/large city, suburban. Valid for d> 1km
COST-231 Hata	1500-2000 MHz	30-200 m	1-20 km	1-10m	The European Co-operative for Scientific and Technical research (COST-231 working committee) extended Hata model to 2000 MHz.
COST-231 Walfisch-Ikegami	800 MHz to 2000 MHz	4-50 m	20 - 5000m	1-3m	An extension of the COST 231 Hata model, uses a LOS and NLOS components (with street diffraction and scatter loss) and has considerations for reflection and scattering above and between buildings in urban environments. Also uses street width, building height, and building separation.
Stanford University Interim (SUI)	Above 1900 MHz	not defined	not defined	not defined	Developed for 802.16 (WiMax) by Stanford University. Based on free space with correction factors for rural, suburban and urban environments (Terrain A, B, C)
ECC33 (ITU-R P.529)	700 MHz to 3500 MHz	not defined	not defined	not defined	ECC33 model for cellular and microwave communications

- Industry RF propagation models are based on sub 3-GHz empirical models for macro-cells
- Available 3.5 GHz models are typically for Fixed Wireless Access (FWA) or WiMax - not small cells
- Little industry research on small cell (low power) RF propagation models at/near clutter heights at 3.5 GHz
- Accurate RF propagations are critical for RF network planning, business case modeling

CableLabs 3.5 GHz Propagation Measurement Campaign

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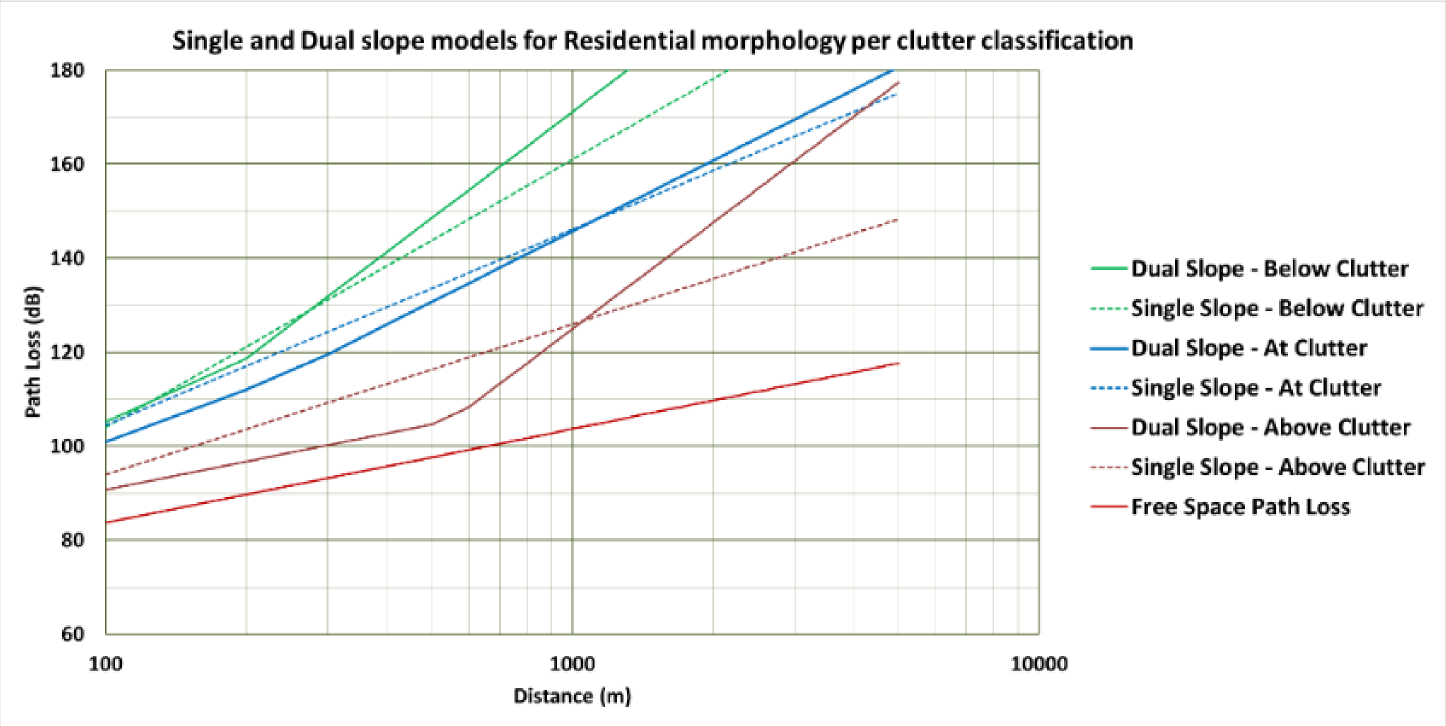
	ANTENNA CLASSIFICATION		
MORPHOLOGY CLASSIFICATION	Below Clutter	At Clutter	Above Clutter
Residential	x	x	x
Residential/Commercial mix	x	x	x
High Density Commercial	x	x	x

- Goal was to measure RF propagation at 3.5 GHz and create empirical models for use in RF network planning and business models
- Initial locations selected to represent common business case scenarios
  - Morphology: residential, residential/commercial mix, high density commercial
  - Clutter antenna heights: below, at and above clutter (~5m to 15m)
- Measurements taken at multiple markets in each morphology/clutter classification

Resulting Empirical 3.5 GHz Propagation Models



- Linear regression curve fitting of measured data was used to create single slope and dual slope Log-distance path loss models for residential morphology per clutter classifications
- Results show close correlation between the two models
- Dual slope model was shown to be more accurate due to more granularity with its two-slope structure

Propagation Model Summary

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- Single and dual slope 3.5 GHz propagation models were developed using linear regression least square curve fitting from measured data of initial propagation measurement campaign conducted in Denver and other markets
  - ***Close correlation was shown between these models and measured data and the dual slope model was shown to be more accurate due to more granularity with its two-slope structure***
- Using a typical 120 dB link budget as a path loss reference for a small cell LTE network with the resulting empirical 3.5 GHz models, initial small cell coverage distances were generated for 3 morphologies, 3 clutter heights
  - ***Predicted coverage can be used in initial business models for markets with similar morphologies***
  - ***Further propagation measurement and modeling is recommended for non-representative morphologies***
- “Untuned” industry empirical macro-cell models were shown to have underpredicting or overpredicting path loss by 10-30 dB resulting in shorter or larger coverage radius for small cells when compared to the 3.5 GHz empirical models
  - ***This variation creates large inaccuracies in cell count and service delivery for business models.***
  - ***However, the COST 231 Walfish-Ikegami model was shown to be the closest model to the 3.5 GHz empirical models, but mostly for residential morphology “at clutter” heights***

Propagation Model Predictions using Varying Data Resolutions

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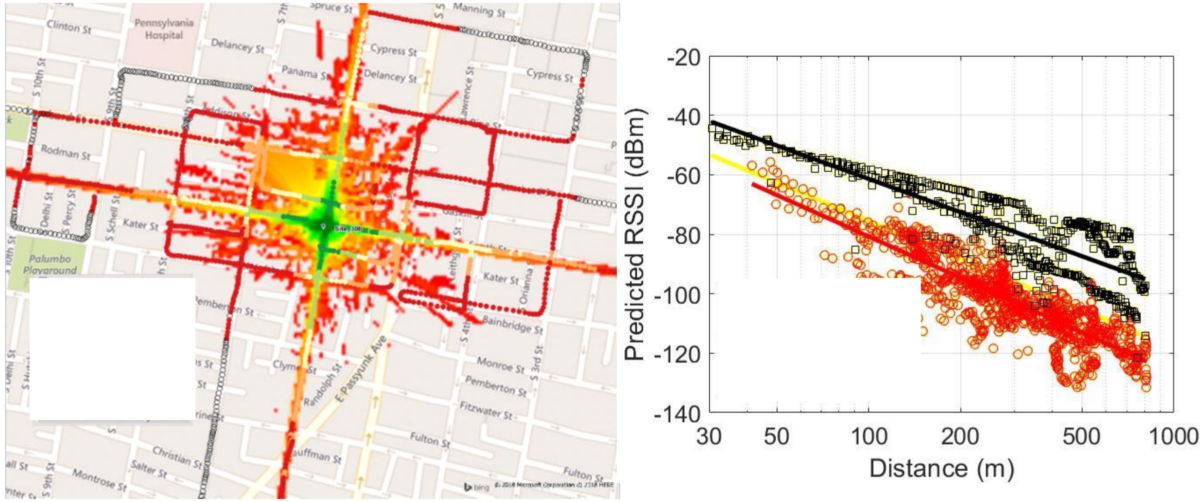
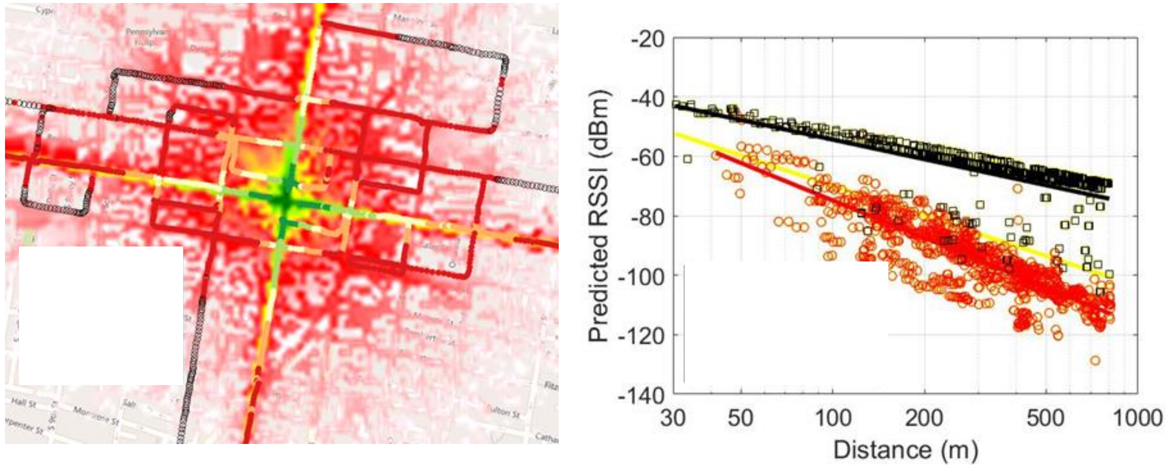


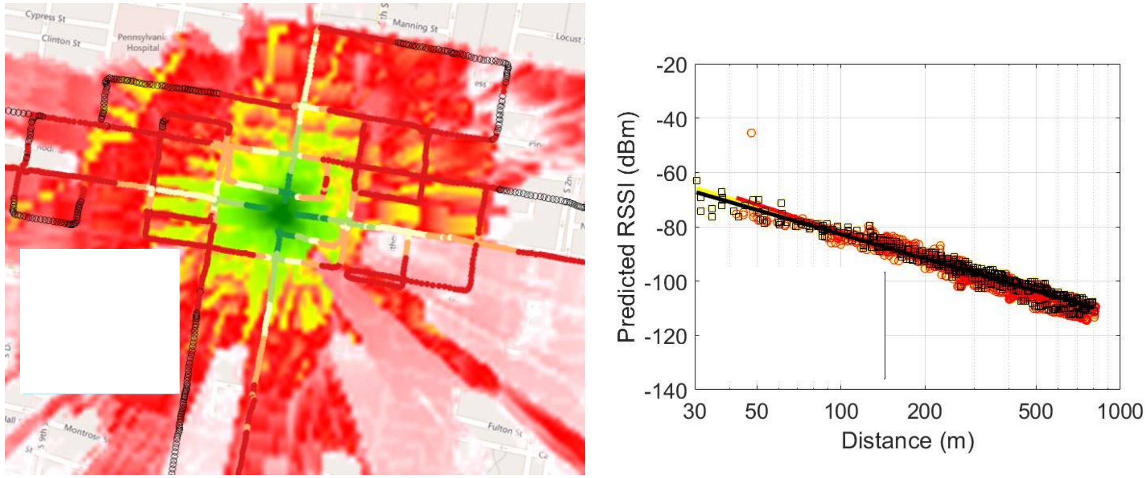
2-meter terrain/clutter data (single value per bin) with 2017 3D building polygons

- Propagation model prediction accuracies and tradeoffs were investigated using varying resolutions of terrain, clutter and 3D polygon data
- Analysis was conducted at the same site for ease of comparison and provides the ability to examine detailed distinctions in and around the site
- Tuned hybrid 3D ray-tracing propagation model was used for all comparisons
- A point-slope curve was generated for all, LOS and NLOS components
- Model predictions were also plotted against measured results (as colored dots) for comparison

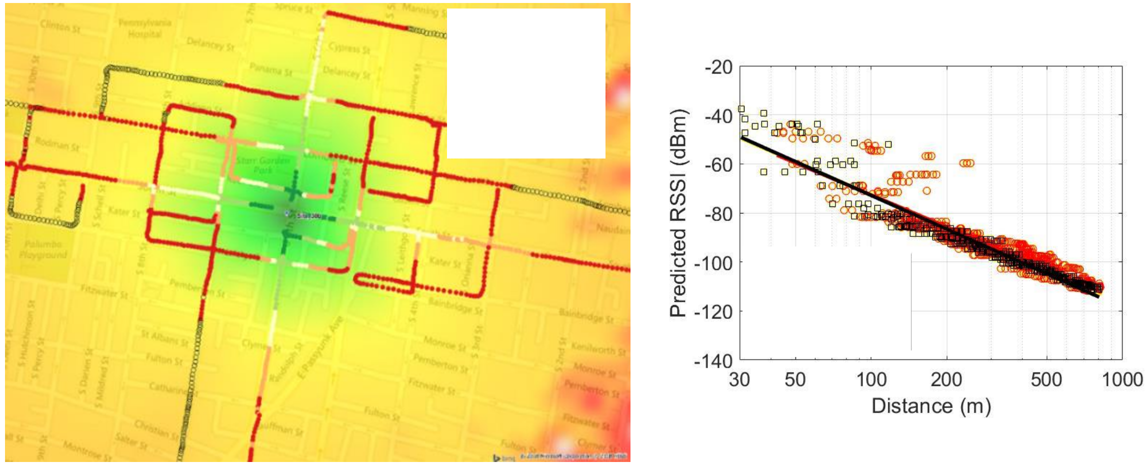
Propagation Model Predictions using Varying Data Resolutions



10-meter terrain/clutter data (single value per category) with 2013 3D building polygons



10-meter terrain/clutter data (single value per category) with no 3D building polygons



30-meter terrain/clutter data (single value per category) with no 3D building polygons

- Comparison of 10-m terrain/clutter with and without 3D building polygon data
- 30-m terrain/clutter with no 3D building polygon data

Recommendations

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- Industry has entered a new era of low-power small cell networks
- A common, industry based empirical RF propagation model for small cells at sub-6 GHz bands in needed
- A common, industry based set of high resolution data for terrain, clutter, buildings and vegetation (better than 5m) is needed
  - Must work in conjunction with RF propagation models in RF network planning tools
- Required for shared spectrum network management, network planning, business case modeling
- Challenge will be to determine a common framework for different use cases such as indoor, outdoor, indoor-out, outdoor-in, above/at/below clutter