

# Deployment Characteristics of "The Edge" in Mobile Edge Computing

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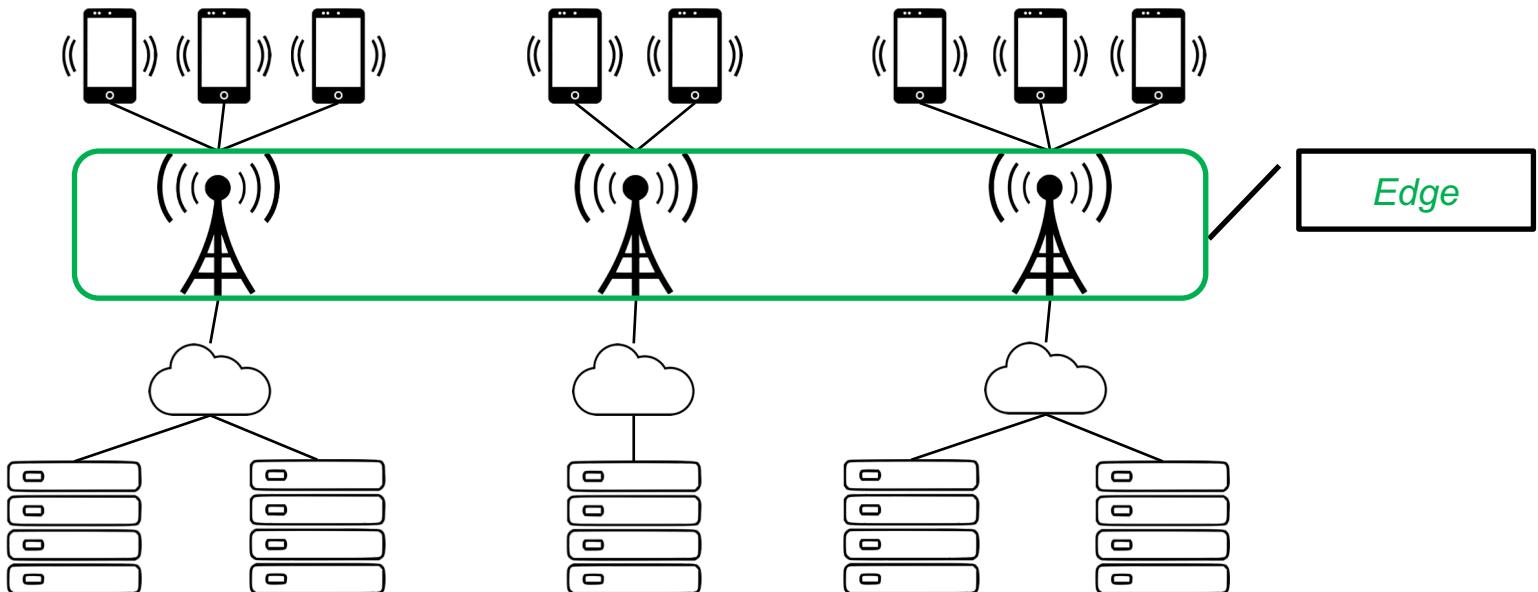


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# Where is “The Edge”?



Source: [www.onlinewebfonts.com/icon](http://www.onlinewebfonts.com/icon)

*Our definition: Locations of cellular towers – primary service infrastructure for mobile devices*

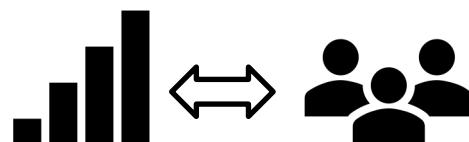


# Computation at “The Edge”

- Push computation *closer* to users
- Reduce edge-to-core latencies for mobile devices
- Deploying compute at each edge location is impractical!

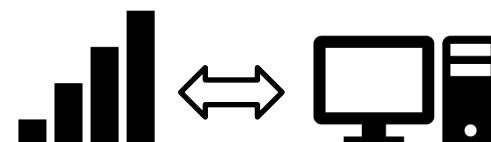
*Research question: How to identify the best “Edge” locations for deploying “Mobile Edge Computing (MEC)” micro data centers?*

Cell tower proximity  
to population



**Proximity Analysis**

Cell tower proximity  
to compute



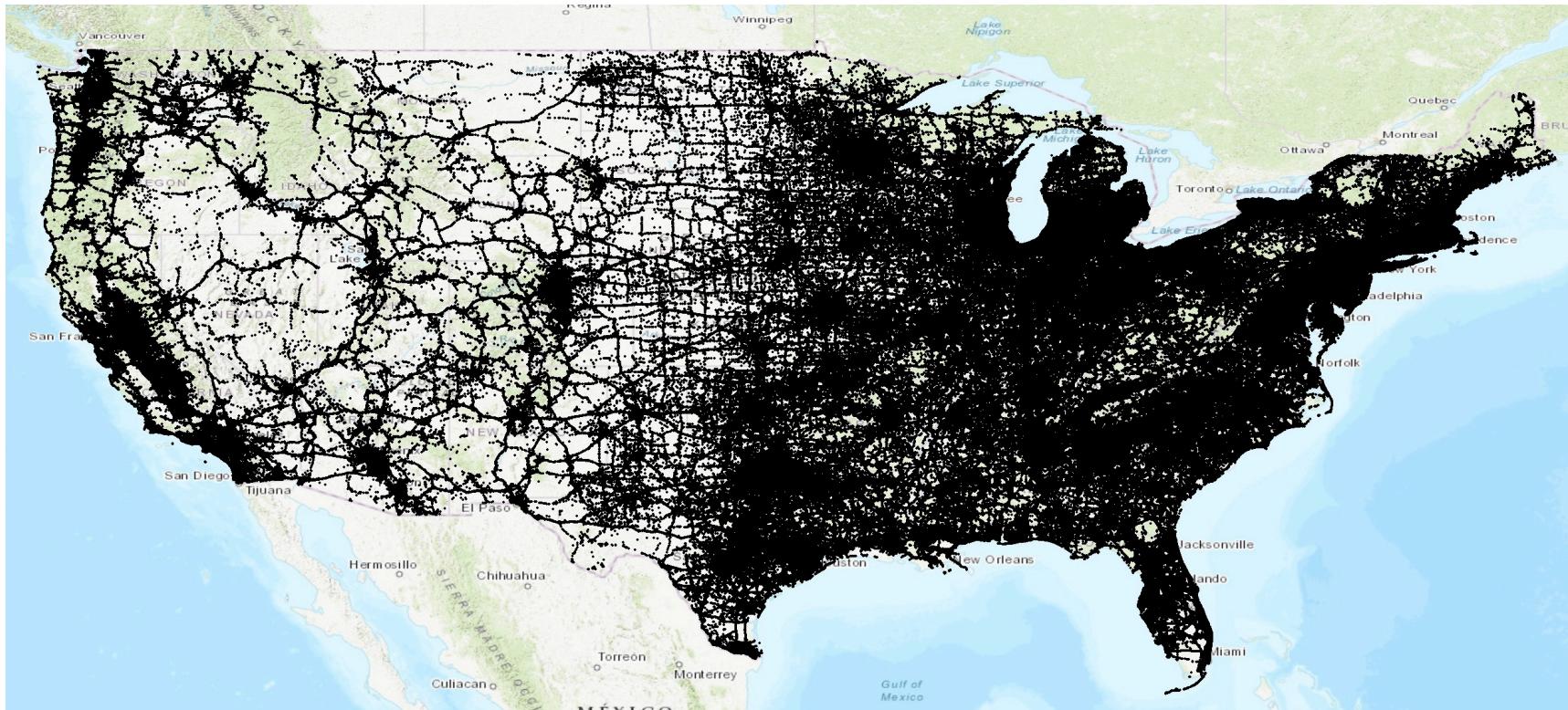
**MEC Deployment Analysis**



# Datasets

- OpenCellID (<https://opencellid.org/>)
  - Crowd-sourced dataset of ~5 million cell tower geolocations in US
  - Filtering:
    - US boundary filtering
    - National Hydrography Dataset (NHD) filtering
- Census (<https://www.census.gov/>)
  - Shapefiles: US outline, Metropolitan Statistical Area (MSA) boundaries and block-level population estimates
  - Tables of population estimates
- Internet Atlas (<http://internetatlas.org/>)
  - Repository of Internet infrastructure dataset gathered from public sources via web search
- Average Annual Daily Traffic (<https://wisconsindot.gov/>)
  - Count of vehicles per day using a section of highway

# US cell tower geo footprint



ESRI ArcMap visualization of cell towers locations from OpenCellID

ms@cs.wisc.edu



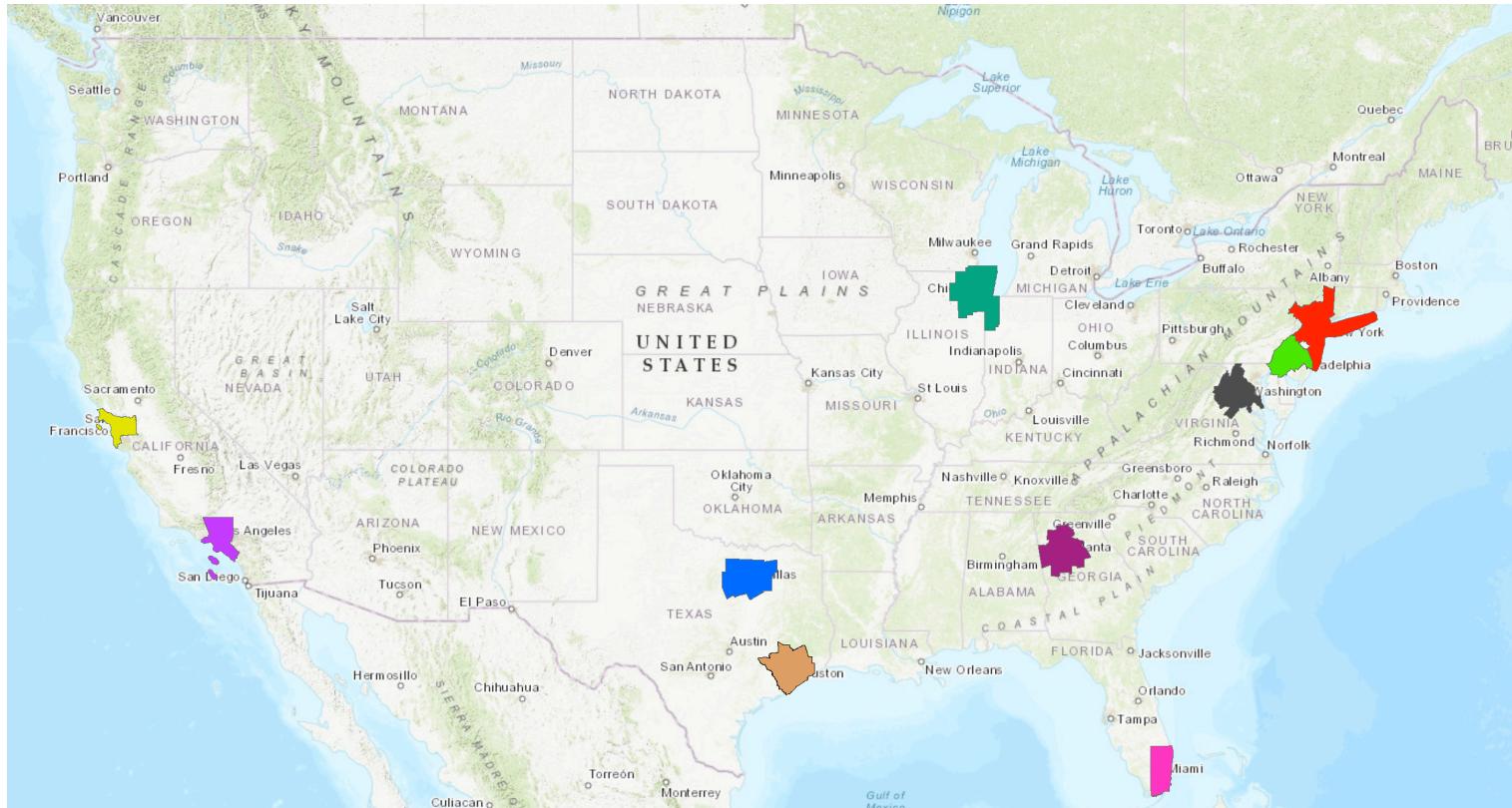
# Metropolitan Statistical Areas (MSA)

- Most populated geographical regions in the US
- Top 3 MSAs

MSA	#Cell towers	Population
New York	310,916	20,153,634
Los Angeles	248,227	13,310,447
Chicago	174,348	9,512,999

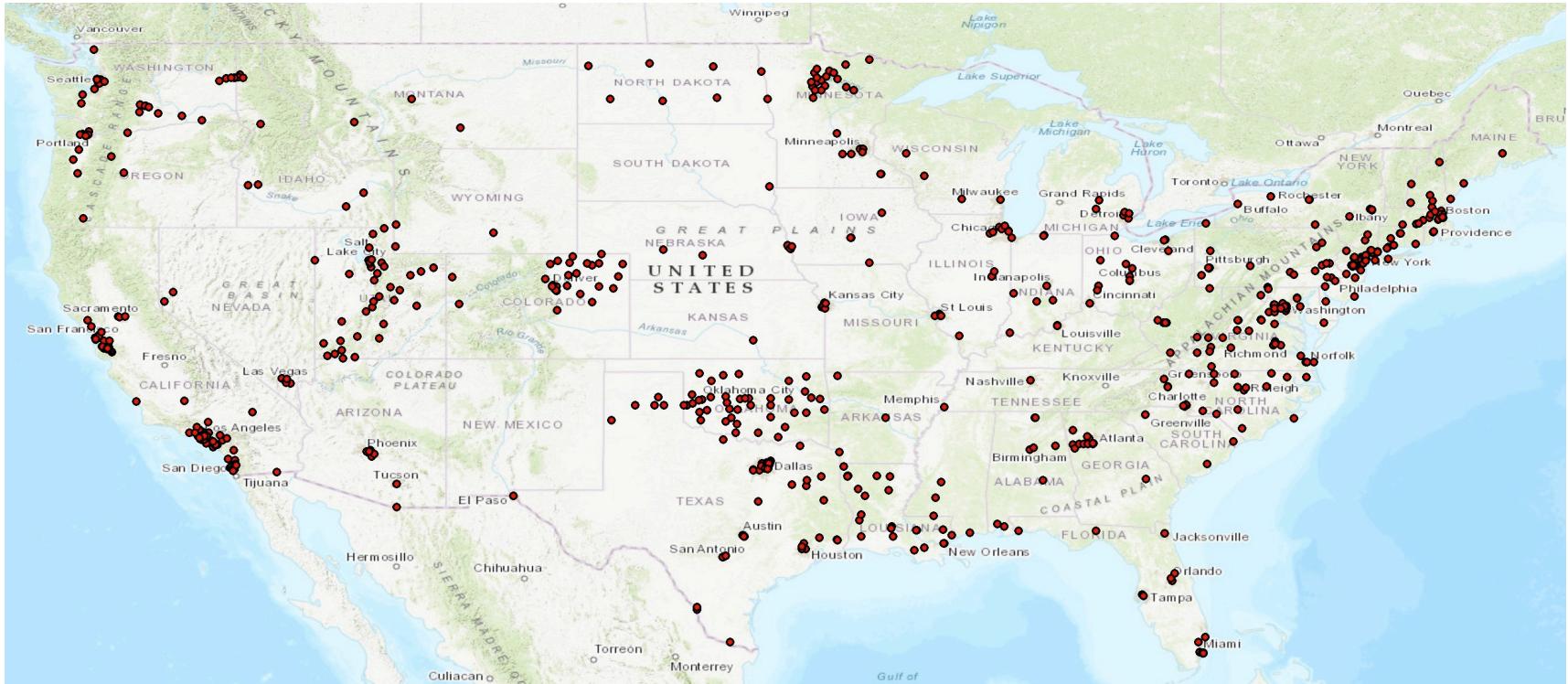


# Top 10 MSAs





# US data center geo footprint



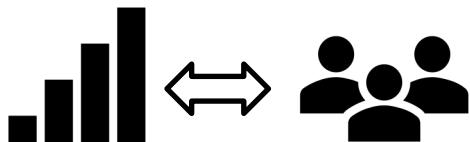
ESRI ArcMap visualization of data centers from Internet Atlas

ms@cs.wisc.edu



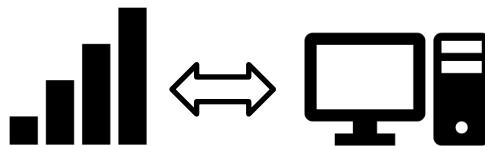
# Talk outline

Cell tower proximity  
to population



**Proximity Analysis**

Cell tower proximity  
to compute



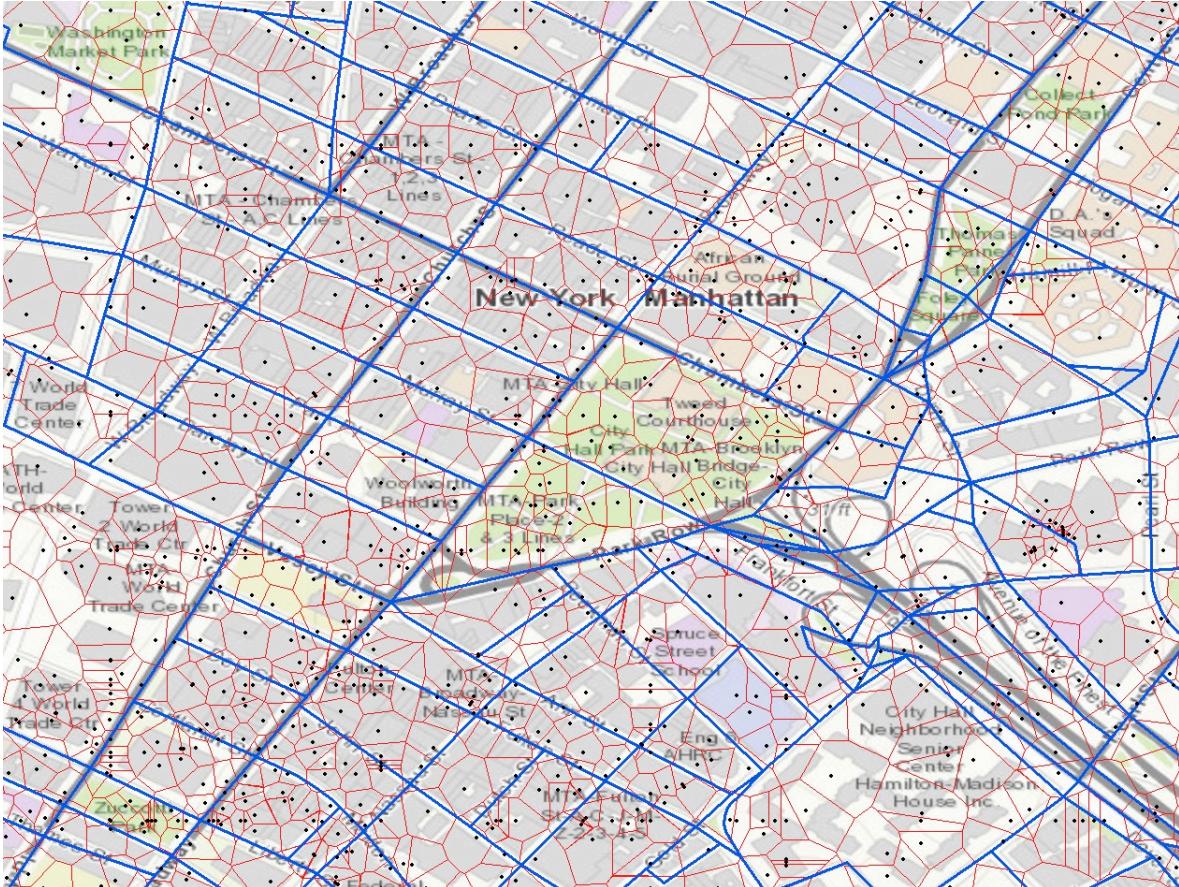
**MEC Deployment Analysis**

# Proximity analysis

1. Compute coverage area of each cell tower using Voronoi tessellation  
[Candia *et al.* Journal of Physics 2008, Taylor *et al.* GLOBECOMa 2012]
2. Compute area of each Voronoi cell
3. Compute total area of Voronoi cells contained within a Census Block
4. Estimate population served per Voronoi cell by assigning proportioned value as per area covered
5. Categorize the cell towers into 5 classes based on served population

Further details in the paper!

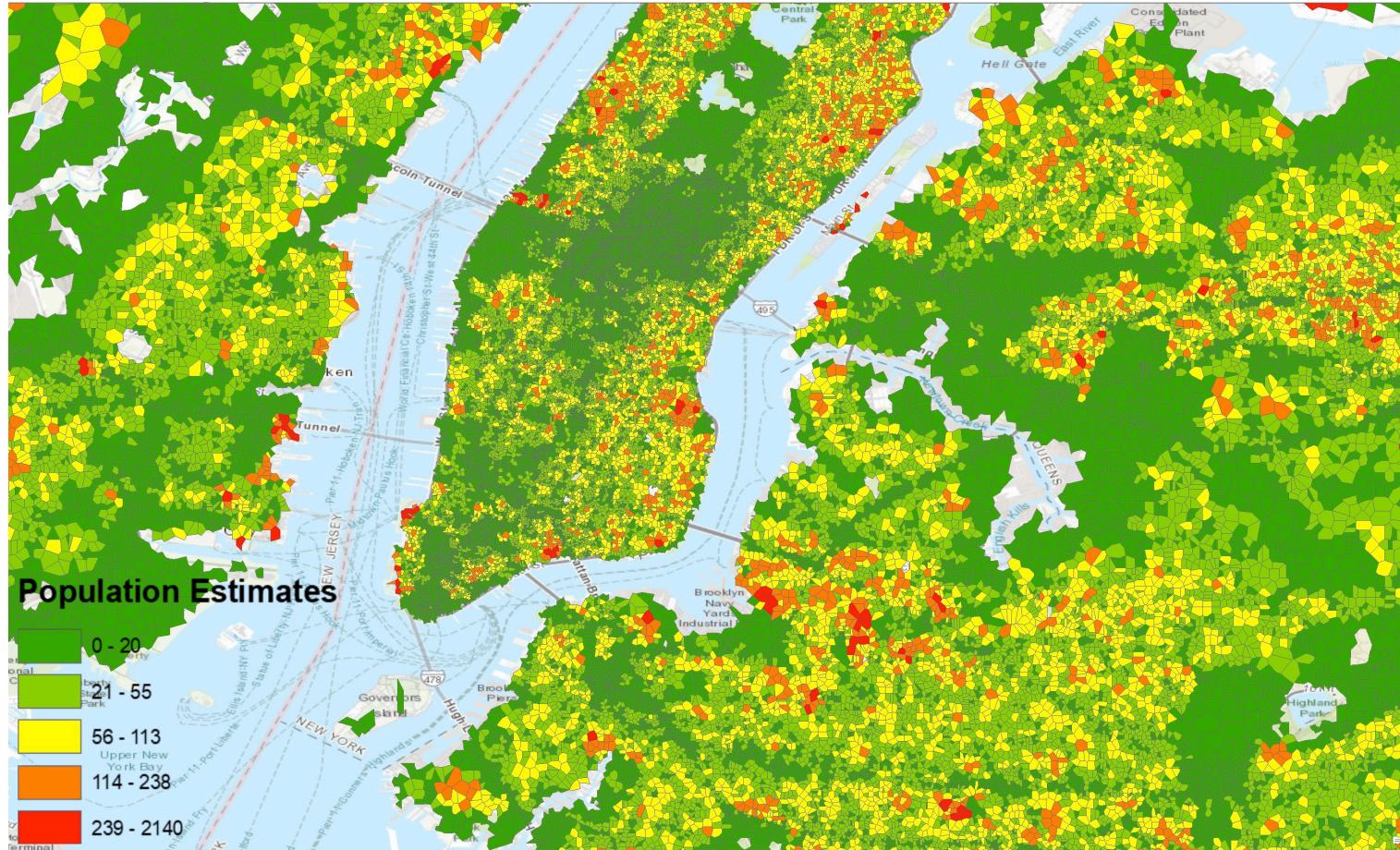
# Voronoi tessellation



Cell towers (black), Voronoi cells (red) and Census Blocks (blue) in the Manhattan area of NYC

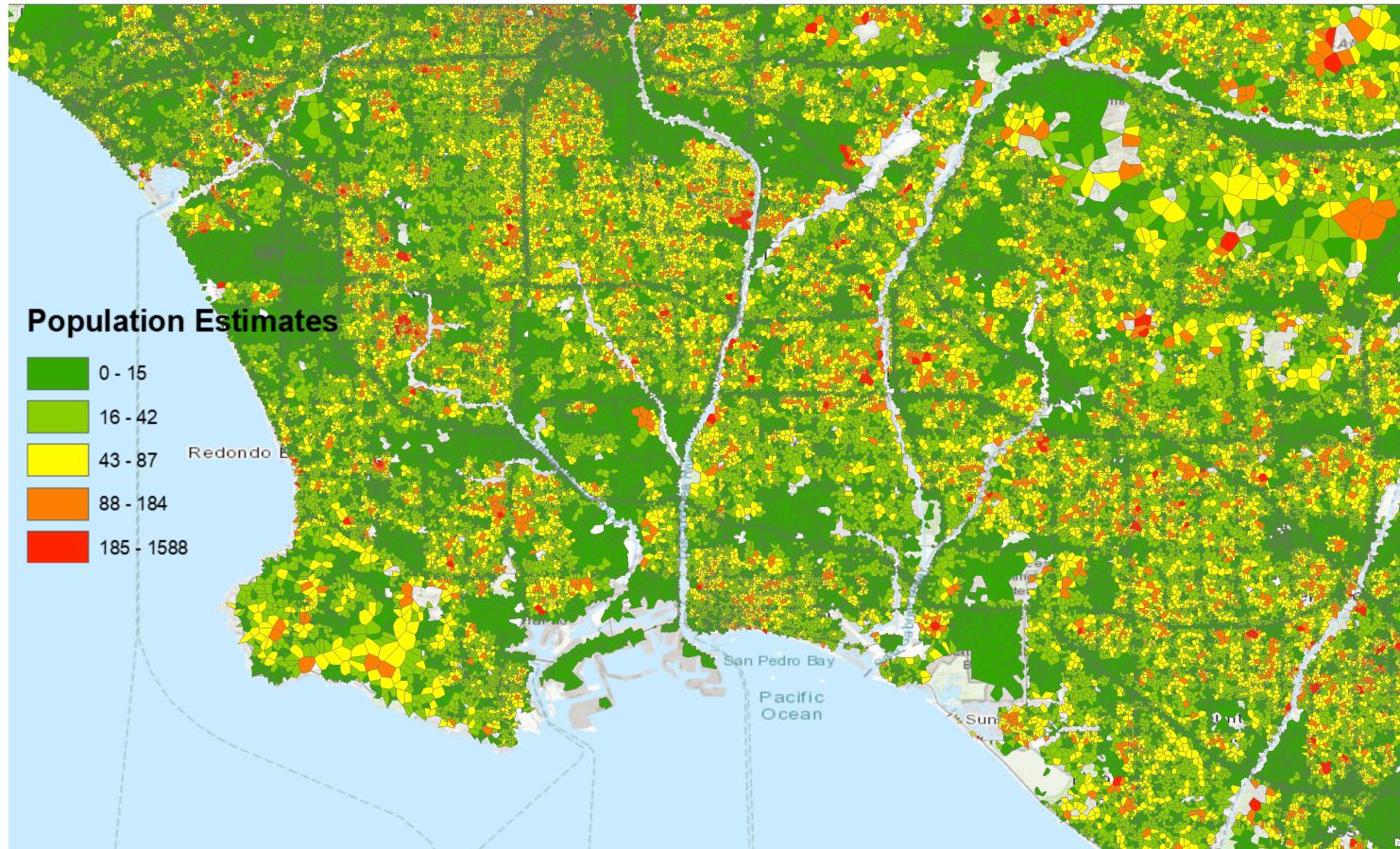


# Cell tower proximity classification – NY MSA





# Cell tower proximity classification – LA MSA



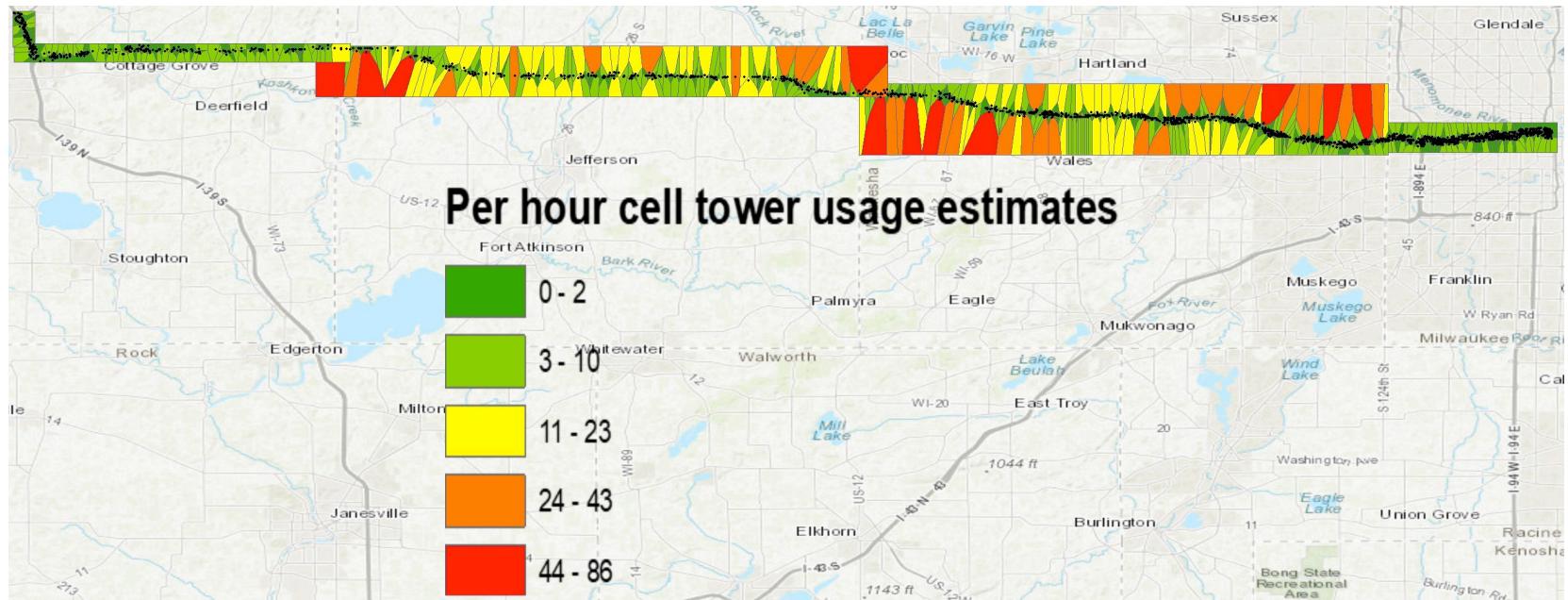


# Proximity analysis near highways

- Utilizes Average Annual Daily Traffic (AADT) counters
- Cell towers within quarter mile from highway
- Assumptions
  - Drivers are evenly distributed
  - Drivers are active over a 20 hour period
  - 1 Driver / cell per vehicle
- Calculate per-hour estimate of drivers served per Voronoi cell
  1. Compute area of each Voronoi cell
  2. Manually draw the highway section boundary
  3. Compute total area within boundary
  4. Assign proportioned value of per-hour estimates as per area covered
  5. Categorize the cell towers into 5 classes based on drivers served



# Cell tower proximity classification - highway

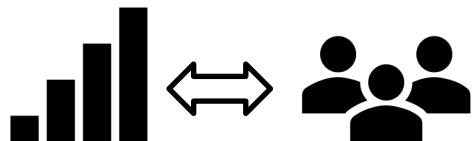


Per cell tower driver estimate variation for I-94 in Wisconsin



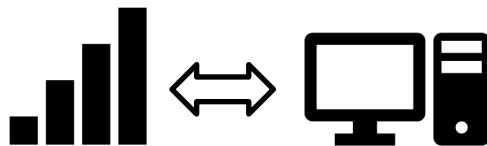
# Talk outline

Cell tower proximity  
to population



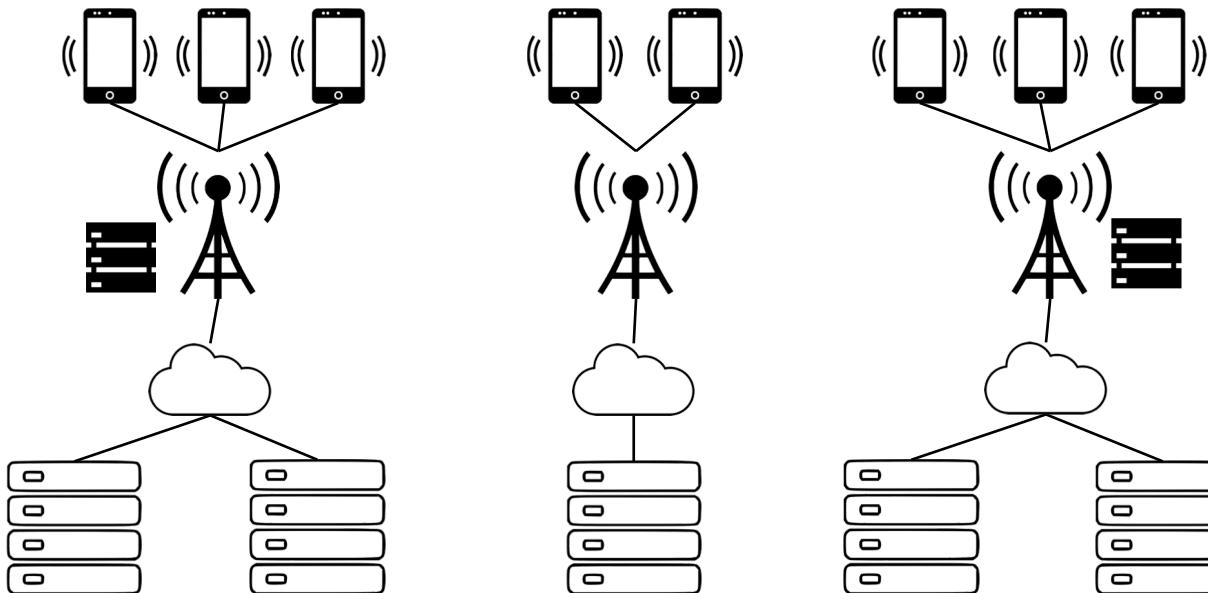
Proximity Analysis

Cell tower proximity  
to compute



MEC Deployment Analysis

# MEC deployment model



Source: [www.onlinewebfonts.com/icon](http://www.onlinewebfonts.com/icon)

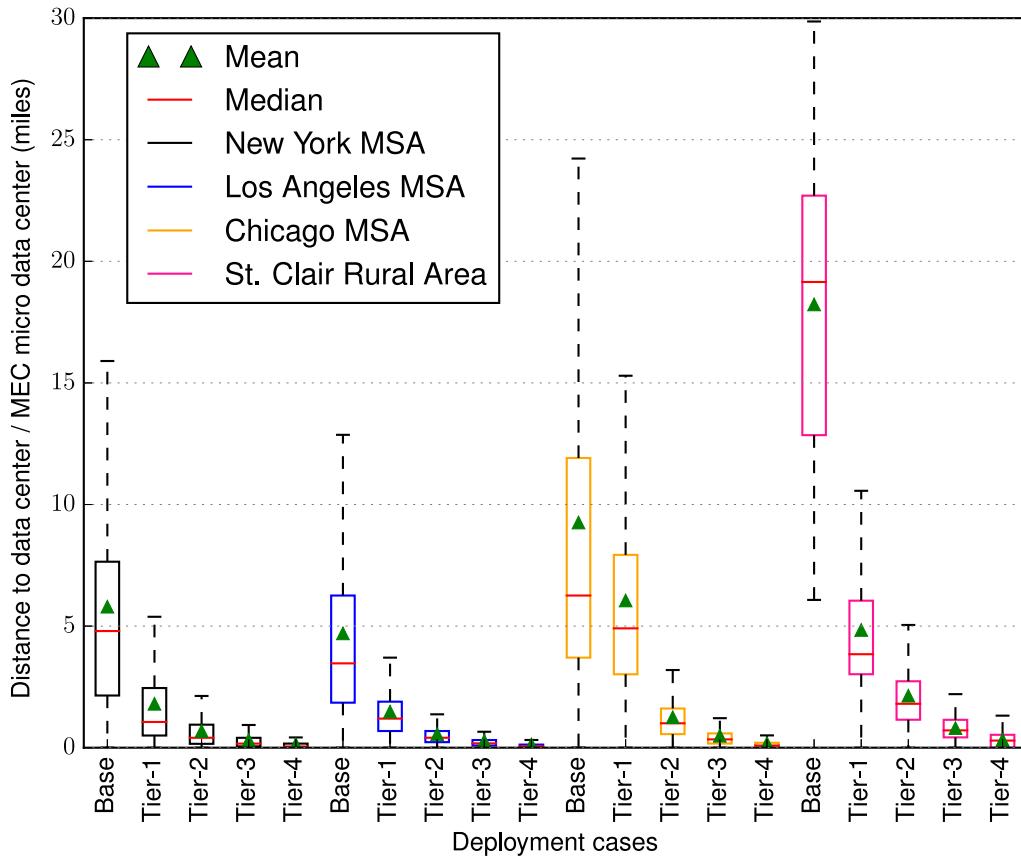
*Deploy MEC micro data centers at the “Edge”*

# MEC deployment analysis

*Objective: Reduce latency – modelled as distance to closest compute*

- Base case
  - Existing data centers from Internet Atlas dataset
  - Latency: closest compute for each tower – geographically nearest data center
- Tier-1 case
  - Deployment of MEC micro data centers co-located with cell towers in **red** class
  - Latency: closest compute for each tower – geographically nearest data center or deployed MEC micro data center
- Tier-2 case: MEC deployment at cell towers in **orange** class
- And so on up to Tier-4

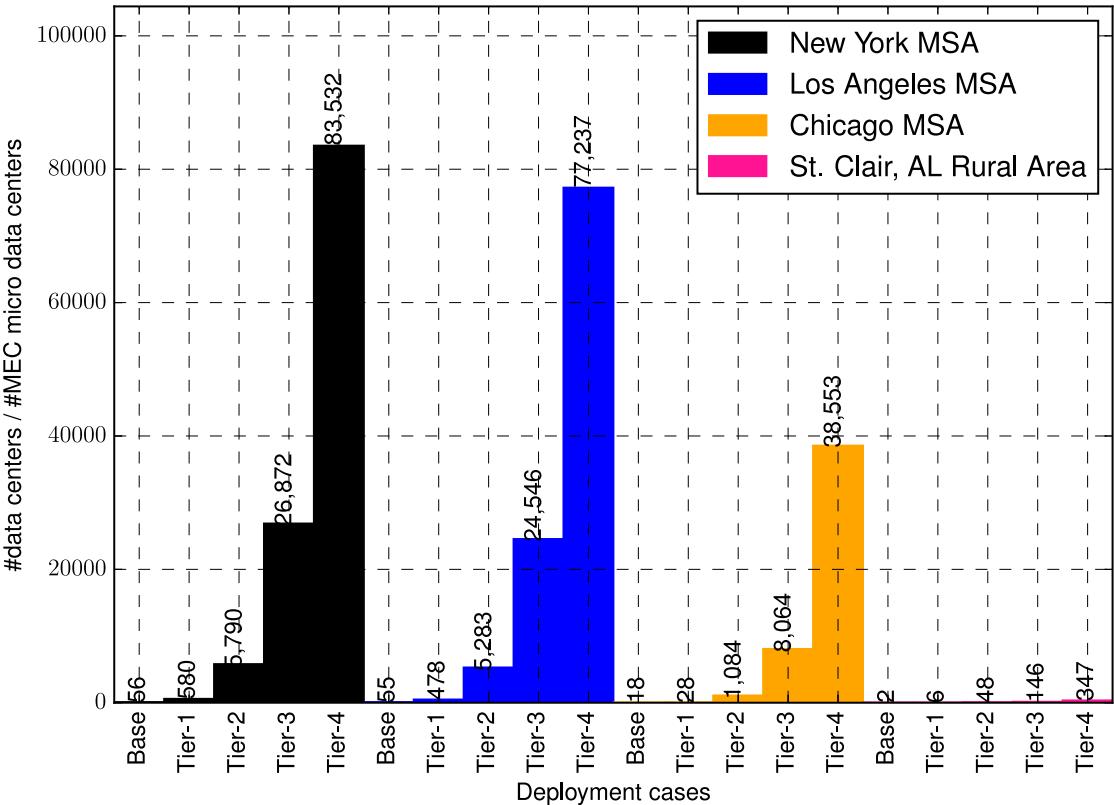
# Distance reduction to compute



Reduction in distance (latency)  
to closest data center or MEC  
micro data center



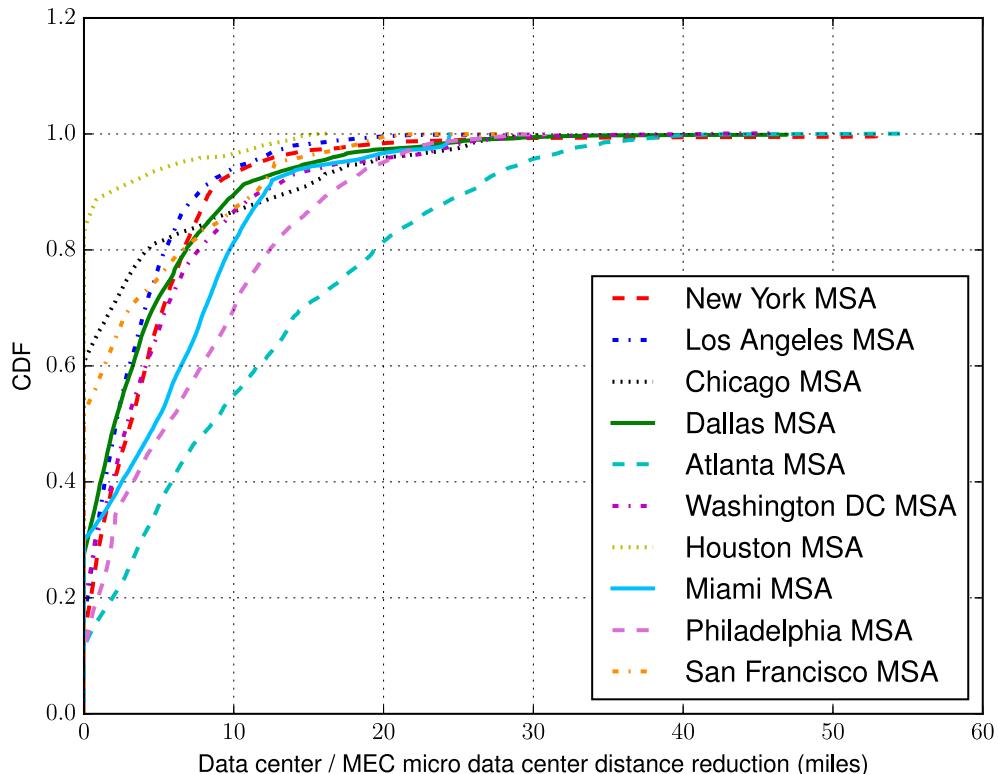
# Deployed MEC micro data centers



Number of existing data centers  
and MEC micro data centers  
deployed at each deployment tier



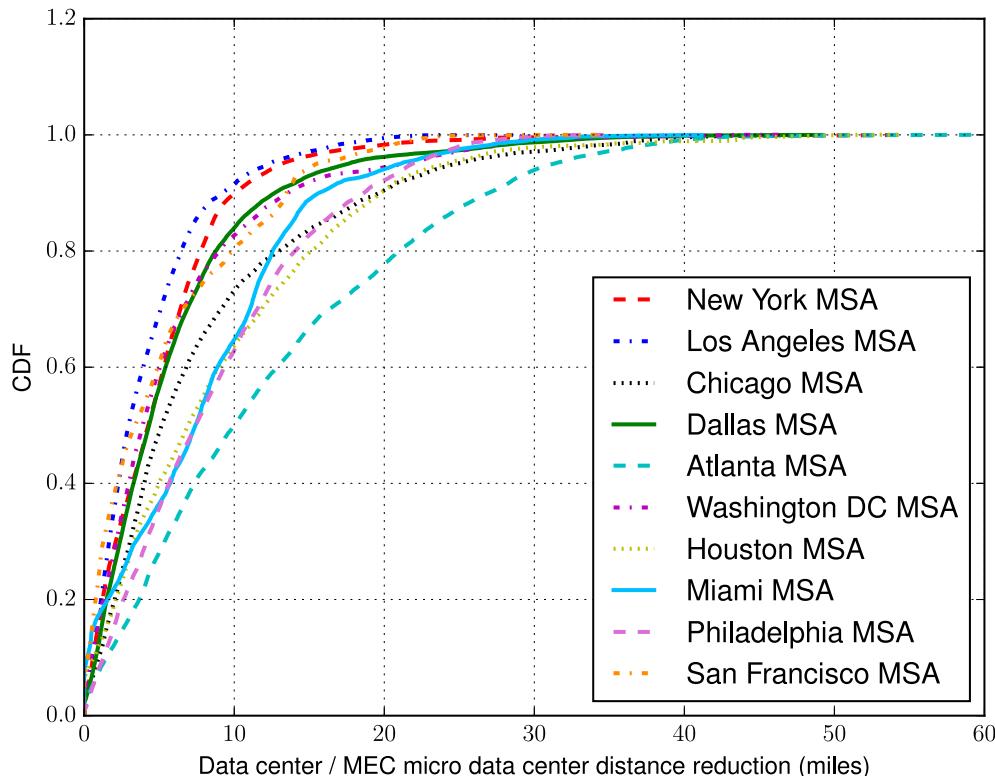
# Per cell tower distance reduction (Tier-1)



Distance reduction for Tier-1 deployment in top 10 MSAs



# Per cell tower distance reduction (Tier-2)



Distance reduction for Tier-2 deployment in top 10 MSAs

# Conclusions and future directions

- US consists of at least 5 million cellular towers
  - Deploying MEC micro data center at each location is impractical!
  - We propose a tiered MEC deployment which brings compute closer to population
  - Tier-1 deployment reduces distance by 12 miles for greater than 10% of cell towers
  - Ability to incorporate dynamic counters like AADT
- Future work
  - Extend proximity analysis to include dynamism
    - Incorporate Call Detail Record (CDR) datasets
  - Extend deployment analysis to include metrics:
    - Individual server capacity
    - Links capacity

