Investigating the Effect of Rainfall on the Performance of 5G Networks

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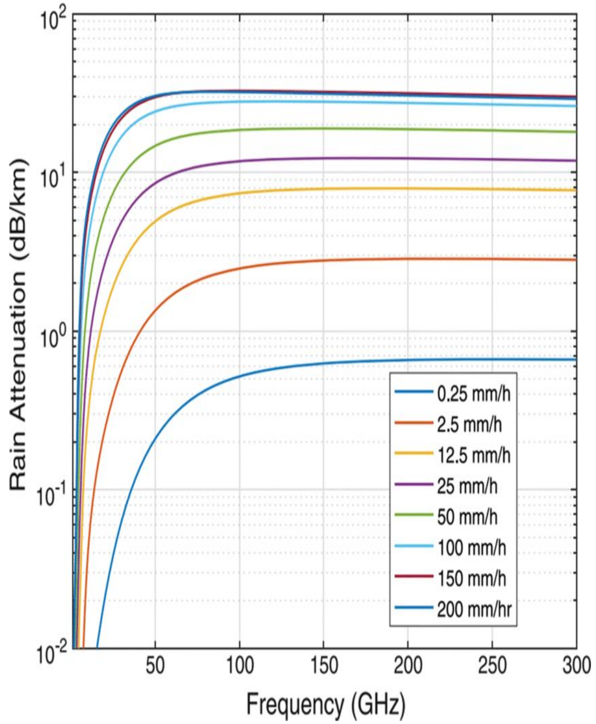
Motivation

- 5G networks use high frequency links to transmit and receive data
- High frequency links can be adversely affected by weather conditions
- The project sought to predict the future rain-induced link degradation (e.g., attenuation) in a high frequency city-scale network



Roadmap

1. Collect NYCMesh Data

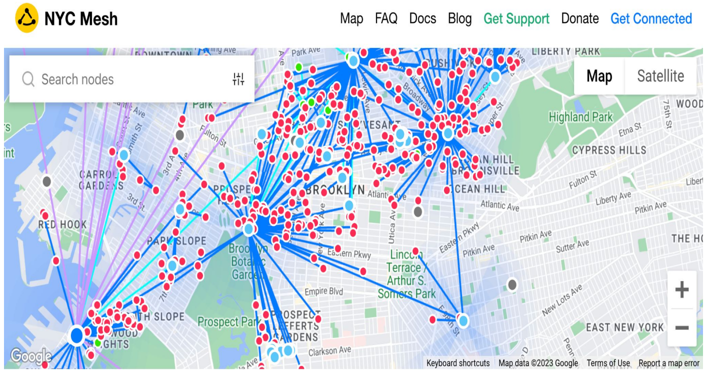
NYCMesh is a community built wireless network which offers internet to New Yorkers, aiming to address the digital divide.

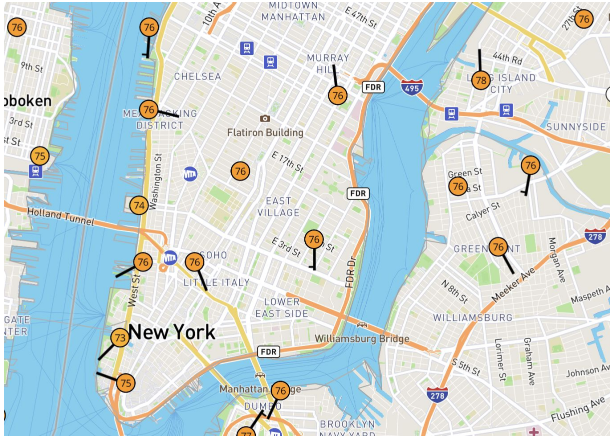
2. Collect Weather Data

Precipitation data was collected from Weather Underground, a commercial weather service

3. Correlate the Data

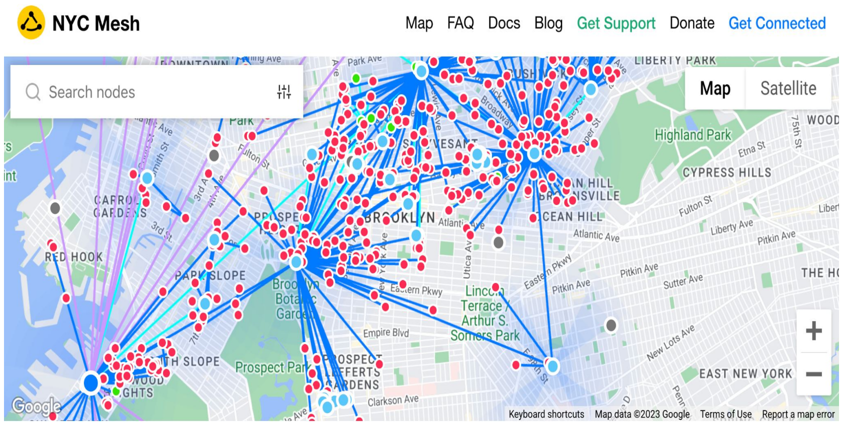
Examine the correlation between weather and network data and check whether the correlation can be used to predict rain-induced link degradation

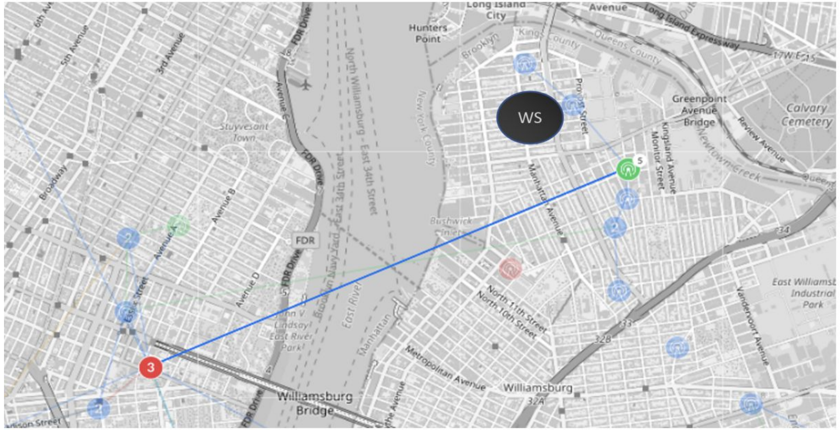




Overview of NYCMesh

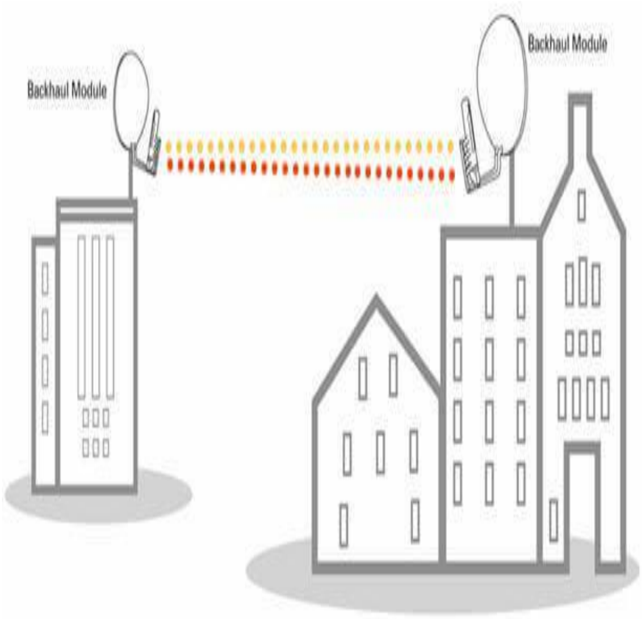
- NYCMesh is a city-scale wireless network
- Many of the links in NYCMesh are high frequency and thus susceptible to rain-induced link degradation





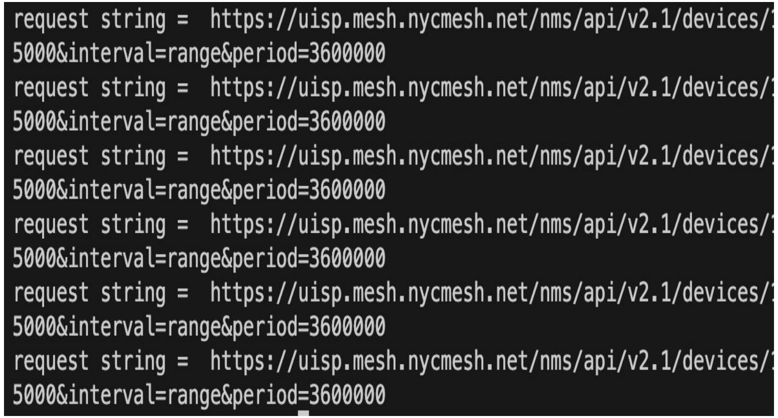
Some Helpful Information

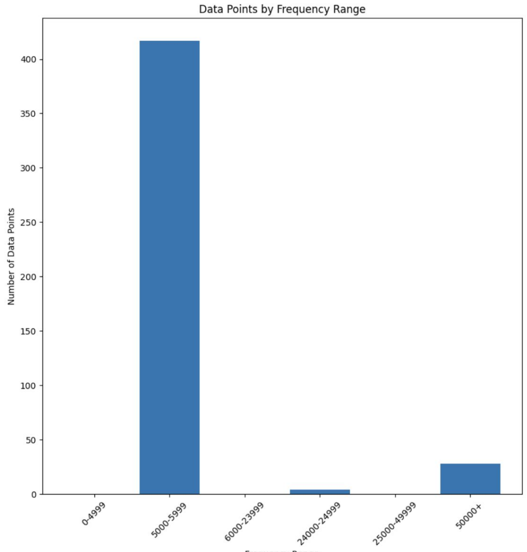
- A wireless link can be thought of as a pipe through which data is transmitted
- Each link has two endpoint devices (i.e. radios which transmit and receive data)
- Link data (including signal attenuation, data rate, link capacity, etc.) will be used to evaluate link performance

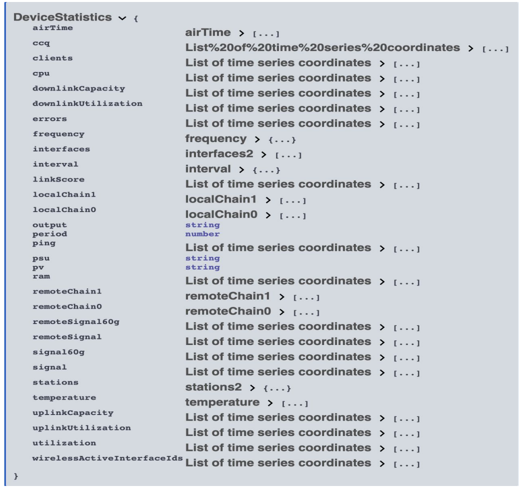


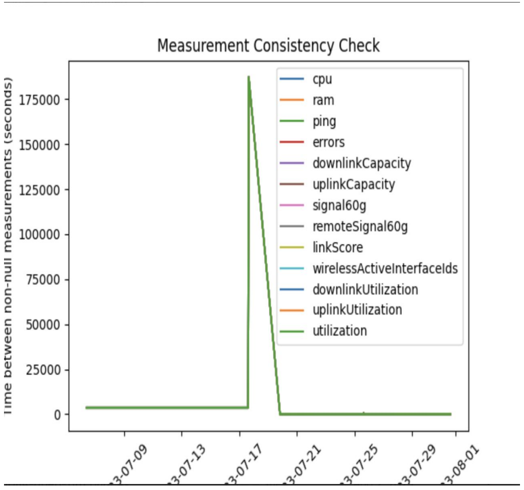
NYCMesh Data Collection

- Filter out links with frequency >= 5 GHz
- Repeatedly call /device/{id}/statistics endpoint of NYCMesh API









Collecting Precipitation Data

- Weather Underground — a commercial weather service — was used to collect the precipitation data
- WU has hundreds of Weather Stations throughout NYC, allowing hyperlocal measurements

Graph | Table

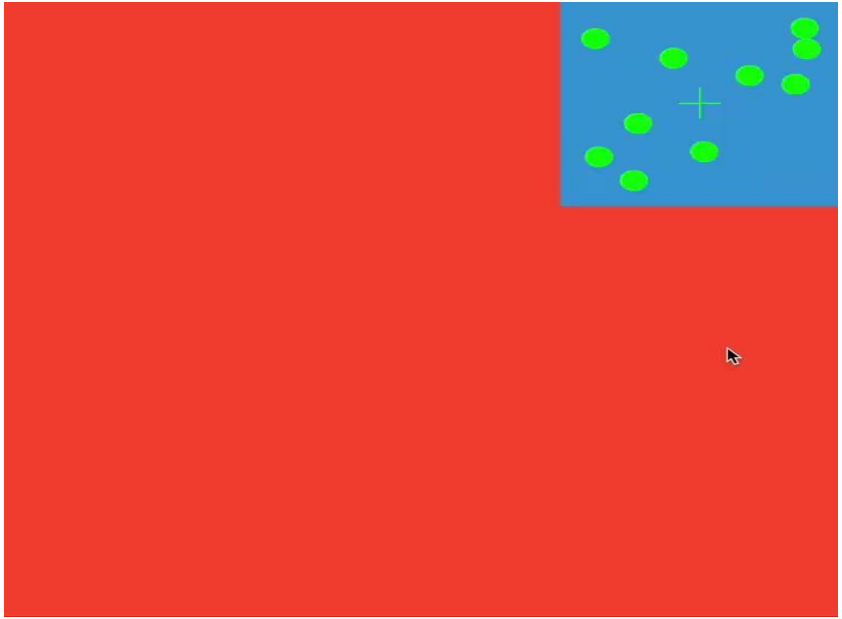
September 1, 2022

Time	Temperature	Dew Point	Humidity	Wind	Speed	Gust	Pressure	Precip. Rate.	Precip. Accum.	UV	Solar
12:04 AM	74.5 °F	56.6 °F	54 %	NE	4.2 mph	7.8 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:09 AM	74.5 °F	56.5 °F	53 %	NE	3.5 mph	9.3 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:14 AM	74.4 °F	56.7 °F	54 %	NE	3.1 mph	5.3 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:19 AM	74.4 °F	57.2 °F	55 %	NE	2.5 mph	6.0 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:24 AM	74.3 °F	57.6 °F	56 %	NNE	2.6 mph	5.5 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:29 AM	74.1 °F	57.5 °F	56 %	NNE	3.5 mph	4.6 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:34 AM	74.0 °F	57.0 °F	56 %	NE	3.7 mph	6.0 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:39 AM	73.9 °F	56.7 °F	55 %	NNE	1.9 mph	4.9 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:44 AM	73.8 °F	56.7 °F	55 %	NNE	2.2 mph	3.9 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:49 AM	73.7 °F	56.6 °F	55 %	NE	2.4 mph	2.9 mph	29.80 in	0.00 in	0.00 in	0	w/m^2
12:54 AM	73.6 °F	56.5 °F	55 %	NNE	2.9 mph	5.5 mph	29.81 in	0.00 in	0.00 in	0	w/m^2

1	Datetime	Precip. Rate.	Precip. Accum.
2	2022-09-01 00:04:00	0.00 °in	0.00 °in
3	2022-09-01 00:09:00	0.00 °in	0.00 °in
4	2022-09-01 00:14:00	0.00 °in	0.00 °in
5	2022-09-01 00:19:00	0.00 °in	0.00 °in
6	2022-09-01 00:24:00	0.00 °in	0.00 °in
7	2022-09-01 00:29:00	0.00 °in	0.00 °in
8	2022-09-01 00:34:00	0.00 °in	0.00 °in

Finding all Weather Stations in NYC

- I wrote a script to iterate over the latitude/longitude coordinates bounding NYC
- The WU API was called at each location to find “nearby” weather stations



Next Steps

- For each backhaul link, get PWS which are close to the invisible line connecting the two devices
  - Algorithm: Build a kd-tree on the PWS. Split a link into k-1 equal length segments (creating k points). For each point, traverse the kd-tree to find a ‘near neighbor’ (i.e. a PWS which is close to the point). Repeat for each link.
- For a link and nearby PWS, compute the Pearson Correlation Coefficient between the PWS time-series rainfall and time-series device ‘signal’ values for both device endpoints of the link:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

- x_i is the ith measurement of rainfall intensity for the PWS
- y_i is the ith measurement of ‘signal’ for the device
- time(x_i) should equal time(y_i)

Thank You!