Investigating the Effect of Rainfall on the Performance of 5G Networks Zachary Hine, Igor Kadota, Dror Jacoby, Shuyue Yu

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 \geq 5 GHz
- Repeatedly call /device/{id}/statistics endpoint of NYCMesh API

request string = https://uisp.mesh.nycmesh.net/nms/api/v2.1/devices/ 5000&interval=range&period=3600000 request string = https://uisp.mesh.nycmesh.net/nms/api/v2.1/devices/ 5000&interval=range&period=3600000

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Data Points by Frequency Range 400 350 300 250 200 150 100 50 ·

iceStatistics ~ (
irTime	airTime > ()	
cq	List%20of%20time%20series%2	20coordinates >
lients	List of time series coordinates	> []
pu	List of time series coordinates	×
lownlinkCapacity	List of time series coordinates	× ()
lownlinkUtilization	List of time series coordinates	× ()
rrors	List of time series coordinates	× ()
frequency	frequency .	
interfaces	interference > {}	
interval	Internaces2 > []	
inkScore	Interval > {}	
localChainl	List of time series coordinates	> []
logal Chain0	localChain1 > []	
	localChain0 > []	
period	number	
ing	List of time series coordinates	> []
su	string	
	string	
	List of time series coordinates	> []
emotechaini	remoteChain1 > []	
remotechaino	remoteChain0 > []	
remoteSignal60g	List of time series coordinates	> []
remoteSignal	List of time series coordinates	> []
signal60g	List of time series coordinates	> ()
signal	List of time series coordinates	> []
stations	stations2 > ()	
emperature	temperature > []	
plinkCapacity	List of time series coordinates	Freedom
plinkUtilization	List of time series coordinates	> ()
itilization	List of time series coordinates	> []
rirelessActiveInterfaceIds	List of time series coordinates	> []





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										
Septemb	er 1, 2022										
Time	Temperature	Dew Point	Humidity	Wind	Speed	Gust	Pressure	Precip. Rate.	Precip. Accum.	UV	Sola
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	win
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	win
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
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	wim
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	wim
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
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	wim
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
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	wim
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	wim
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	win

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:

$$r = rac{\sum \left(x_i - ar{x}
ight) \left(y_i - ar{y}
ight)}{\sqrt{\sum \left(x_i - ar{x}
ight)^2 \sum \left(y_i - ar{y}
ight)^2}}$$

- 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!