



# LTE Throughput Test

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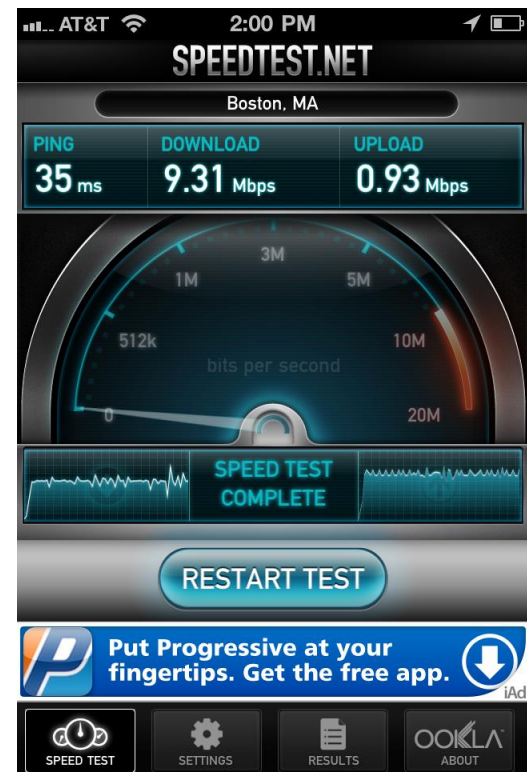
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# LTE Throughput Test

- Informal drive-through testing of initial Verizon LTE deployments in the Boston area
- Measure throughput using [www.speedtest.net](http://www.speedtest.net)
- Based on our sniffer measurements of the speedtest.net running on the desktop and iPhone:
  - The program uses HTTP protocol to download and upload large images multiple times
- The test runs for about 10 sec in each direction
- Ookla operates speedtest.net using many servers around the world and routing the test traffic to the nearest server
  - <http://www.ookla.com/speedtest.php>



# Verizon Service and Equipment

- Subscribed to Verizon 10 GB plan
- Equipment: Galaxy tablet
  - Android based

**WELCOME TO THE LIGHTNING FAST SAMSUNG GALAXY TAB™ 10.1.**

Powered by Verizon 4G LTE, it's a tablet experience like you've never imagined.



**2GB – \$30.00/Month**

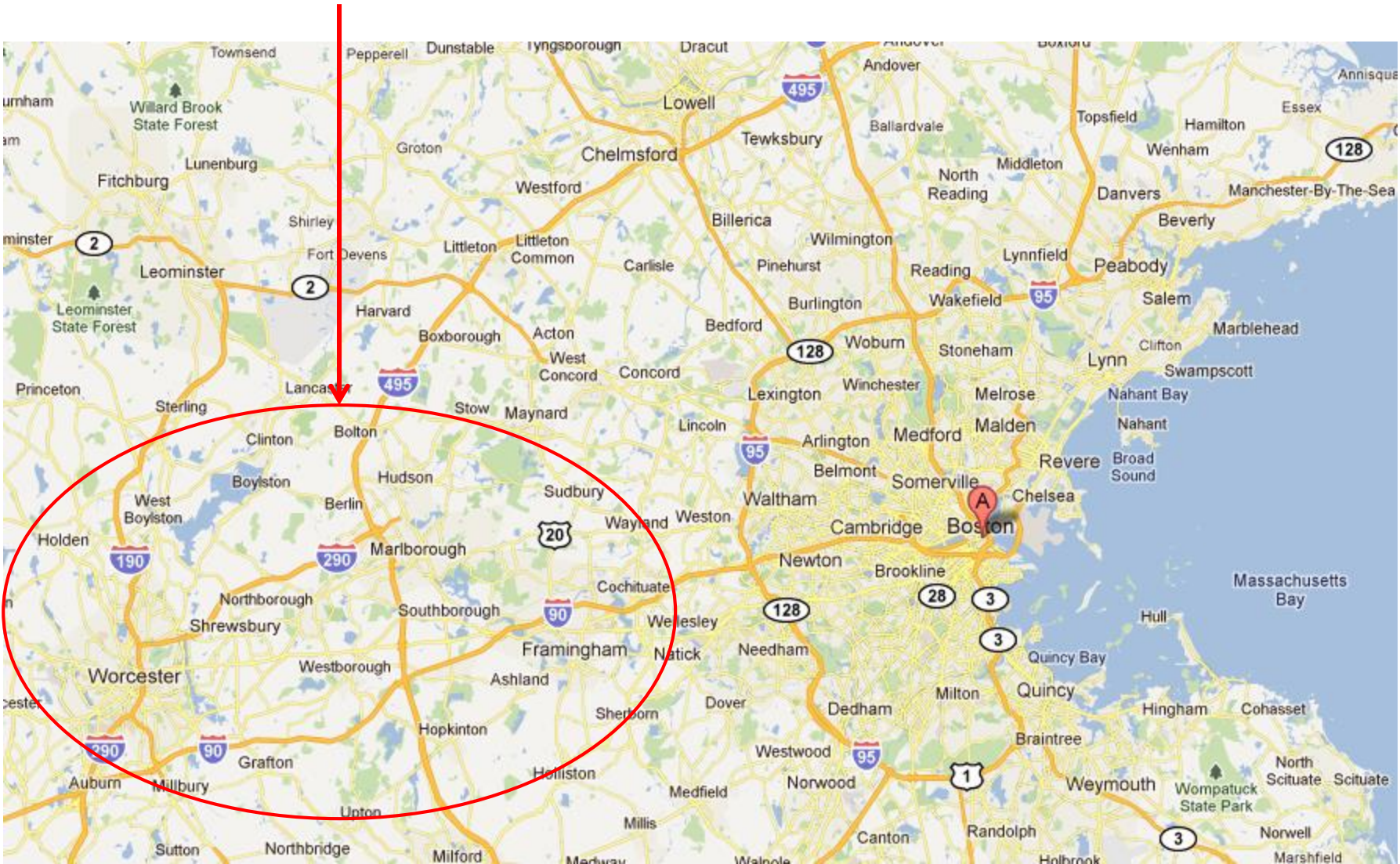
**5GB – \$50.00/Month**

**10GB – \$80.00/Month**

	2GB – \$30.00/Month	5GB – \$50.00/Month	10GB – \$80.00/Month
Tablet/Netbook	●	●	●
USB Modem/Notebook /Dedicated Mobile Hotspot		●	●

Overage \$10.00/GB (Overage charges occur when you exceed your plan's monthly allowance.)

# Area of Test Coverage



# Points of Measurements in MA (DL/UL in Mbps)



# Output Captured by speedtest.com

— kbps — msec

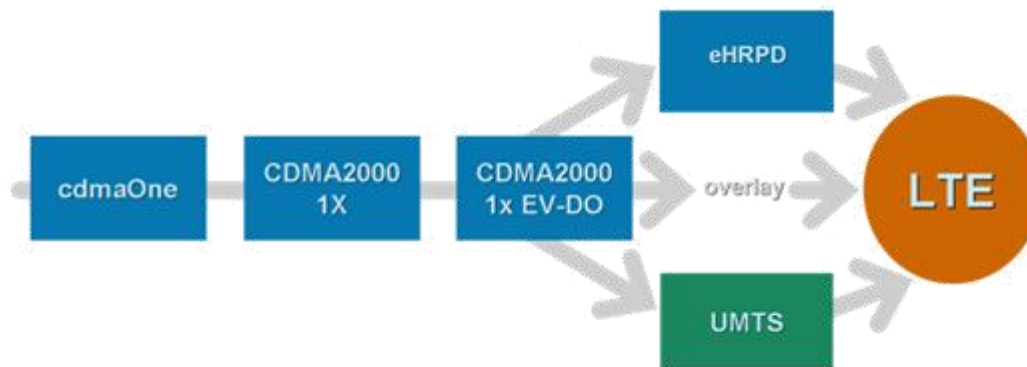
Date	ConnType	Lat	Lon	Download	Upload	Latency	ServerName	Internal IP	External IP
10/2/2011 11:10	Lte	42.41827	-71.6034	19518	4920	98	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 11:10	Lte	42.41827	-71.6034	19518	3983	106	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 11:09	Lte	42.41827	-71.6034	17300	2772	96	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 11:05	Ehrpd	42.28415	-71.6087	1917	1000	194	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 11:00	Ehrpd	42.28415	-71.6087	742	1000	148	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:57	Ehrpd	42.28415	-71.6087	1373	842	150	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:56	Ehrpd	42.28415	-71.6087	1910	901	180	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:55	Lte	42.28415	-71.6087	11467	309	98	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:55	Lte	42.28415	-71.6087	35694	6542	96	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:54	Lte	42.28415	-71.6087	31827	7324	97	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:53	Lte	42.28415	-71.6087	21281	7423	90	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:53	Lte	42.28415	-71.6087	9455	6937	90	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:52	Lte	42.28415	-71.6087	18291	4633	94	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:39	Ehrpd	42.28415	-71.6087	2341	954	179	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:37	Lte	42.28415	-71.6087	14298	989	94	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:36	Lte	42.28415	-71.6087	41880	7882	92	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:36	Lte	42.28415	-71.6087	34324	7346	92	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:36	Lte	42.28415	-71.6087	42962	8904	90	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:35	Lte	42.28415	-71.6087	44814	7583	94	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:35	Lte	42.28415	-71.6087	22561	9205	100	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:35	Lte	42.28415	-71.6087	14173	3284	104	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:32	Ehrpd	42.28415	-71.6087	1593	830	192	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:29	Lte	42.28415	-71.6087	8507	262	92	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:29	Lte	42.28415	-71.6087	12333	1002	97	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:28	Lte	42.28415	-71.6087	34996	10387	88	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:28	Lte	42.28415	-71.6087	49833	14801	85	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:25	Lte	42.28415	-71.6087	29931	8027	90	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:25	Lte	42.28415	-71.6087	20394	8460	100	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123
10/2/2011 10:25	Lte	42.28415	-71.6087	17250	5815	99	Boston, MA	10.133.86.195, 10.165.70.146	166.248.1.123



Geolocation recorded by speedtest.com is incorrect

# What's eHRPD?

- eHRPD is Verizon's 3G; upgrade path to LTE
  - CDMA based; enhanced HRPD (EVDO )
  - Maintains the same private IP when handset moves from tower to tower
  - Reduces dropped sessions and decreases the handover latency
- eHRPD will be used by Verizon for VOIP calls until 2020

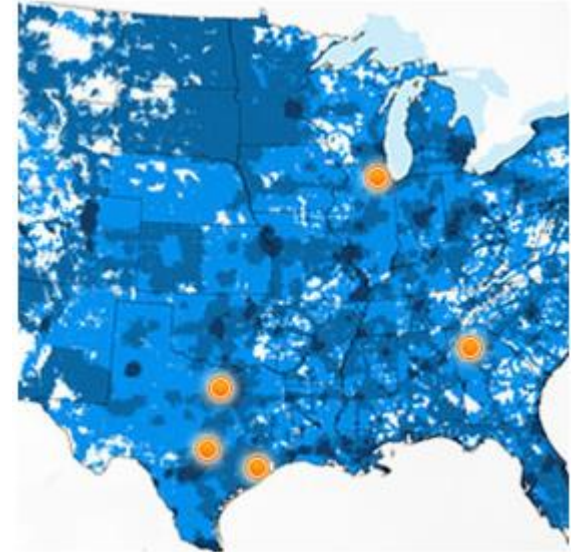


CDMA upgrade paths to LTE

eHRPD = enhanced high rate packet data  
 EVDO = Evolution-Data Optimized

# AT&T Test

- AT&T launched its LTE network in 5 cities on 9/18/11
- PC Magazine article: AT&T vs. Verizon: LTE, Head-to-Head
  - <http://www.pcmag.com/article2/0,2817,2393182,00.asp#fbid=fD0LI0UpHxz>
  - Unable to roam between AT&T and Verizon LTE networks
  - AT&T has put coverage maps on its site advocating merger with T-Mobile



AT&T LTE vs. Verizon Wireless: PCMAG.com results in Houston, TX

Device	Speedtest.net avg download (Mbps)	Speedtest.net max download (Mbps)	Speedtest.net avg upload (Mbps)	Average ping (ms)	Web time to first byte (sec)	Average Web page load speed (Mbps)
AT&T USBConnect Momentum 4G (modem)	24.65	42.85	11.44	45.00	0.30	0.27
AT&T USBConnect Elevate 4G (hotspot)	24.63	39.09	11.53	50.00	0.32	0.24
Pantech UML290 for Verizon Wireless	16.70	23.81	4.01	51.00	0.27	0.25

Dallas-Fort Worth  
 San Antonio  
 Houston  
 Atlanta  
 Chicago



# Wake-up Time

- Test:
  - Measure the time for the device to connect to an LTE network
- Results:
  - From sleep: 0 seconds
    - It appears the device stays connected while in sleep mode. We let the device sleep 10 minutes and still got the same result.
  - From power up: 52 seconds
    - 18 seconds for the unit to boot and show a network status of "no internet", and then an additional 34 seconds from the "no internet" to the "4G" status symbol
  - From airplane mode: 21 seconds
    - The airplane mode disables the radios. It took 21 seconds from disabling airplane mode until the "4G" network status showed up.
  - All times were measured using a digital stop watch and are average over 3 attempts.

# Throughput vs. Location in the Car

- Test
  - Throughput with device
    - In the middle of the car
    - At driver/passenger front windows
    - Outside of the car
  - Average 5 tests per location
- Results
  - Degraded throughput inside the car versus outside
    - Throughput at all locations inside the car was ~14Mbps
    - Throughput outside the car averaged ~ 20Mbps

# Average Throughput vs. Location in the Car

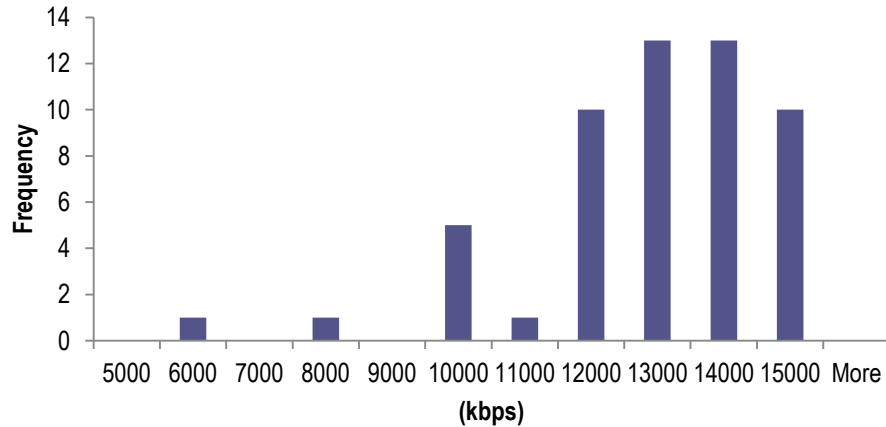
Location in the car	DL (kbps)	UL (kbps)	Latency (ms)
Inside center of the car	14800	5499	112
Inside driver front window	14527	8824	107
Inside passenger front window	13687	8001	111
Outside the car	19703	8587	112

# Stability of Throughput

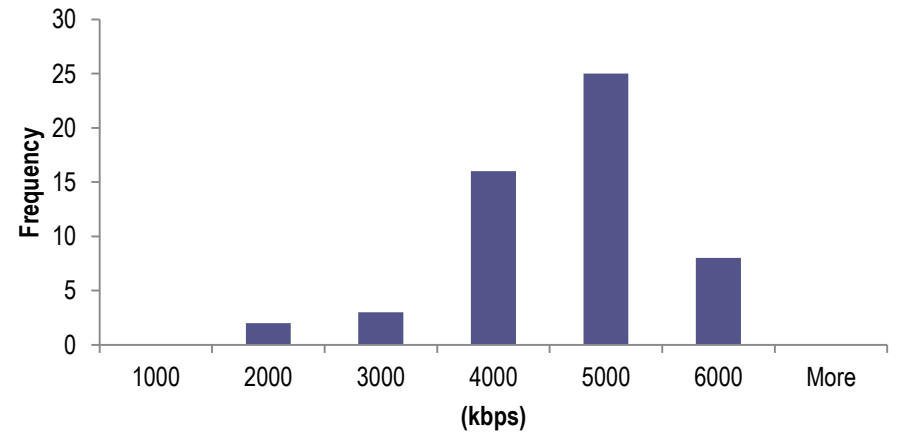
- Test
  - Stability test – measure throughput at the same location for 20 minutes to see if throughput fluctuates
- Results
  - Both download and upload throughput data have fairly normal distributions but with some random outliers

# Stability of Throughput - Distribution

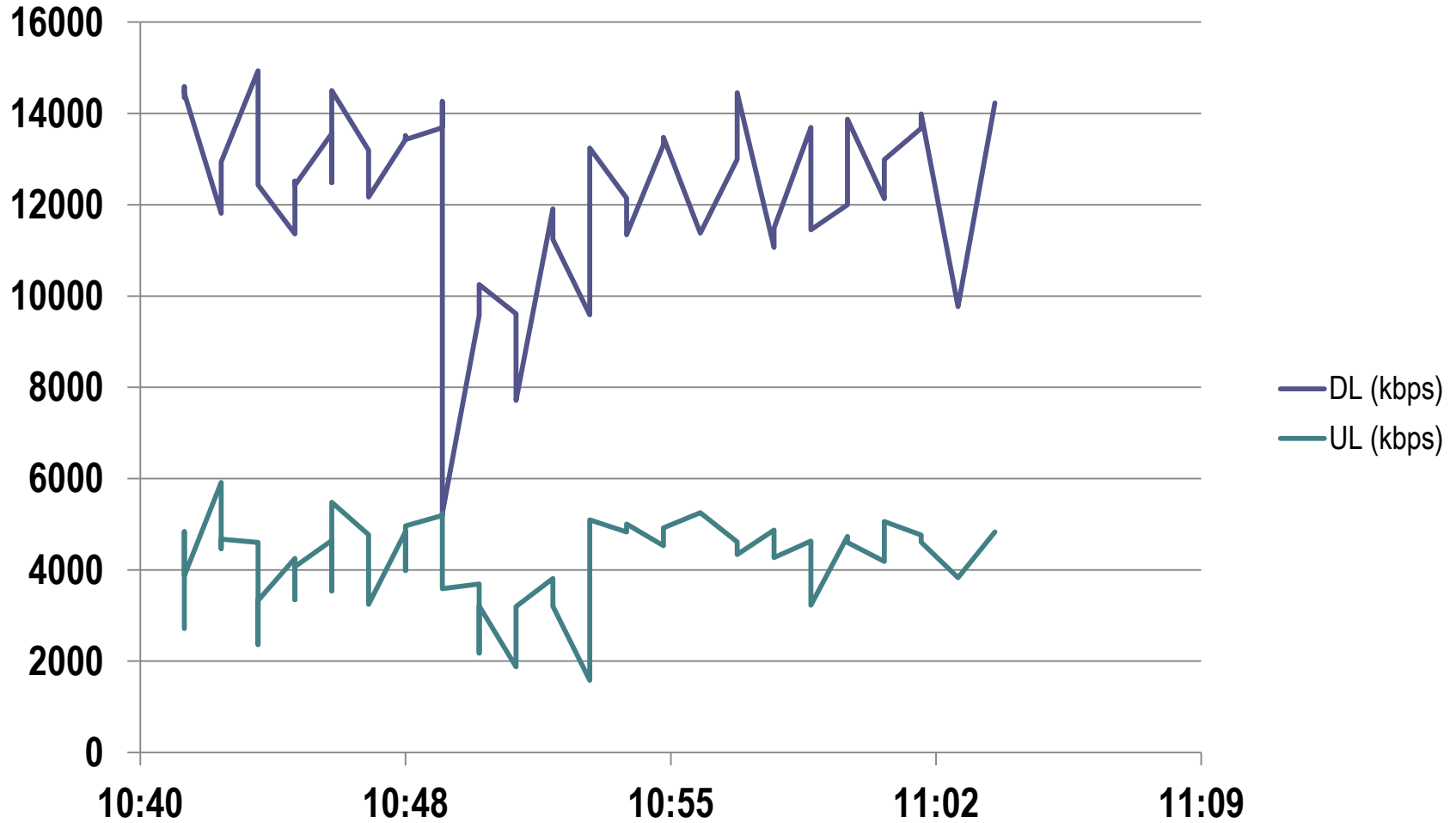
## Download Throughput Distribution



## Upload Throughput Distribution



# Stability of Throughput – vs. Time

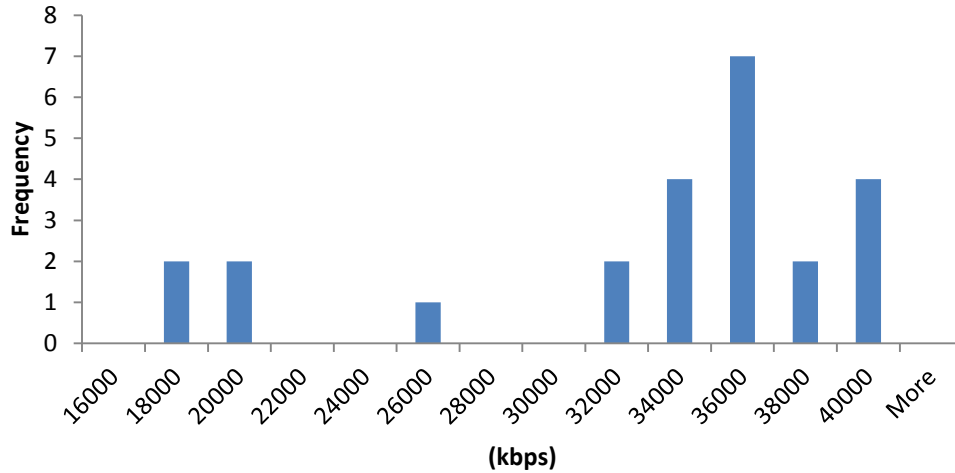


# Impact of Speed

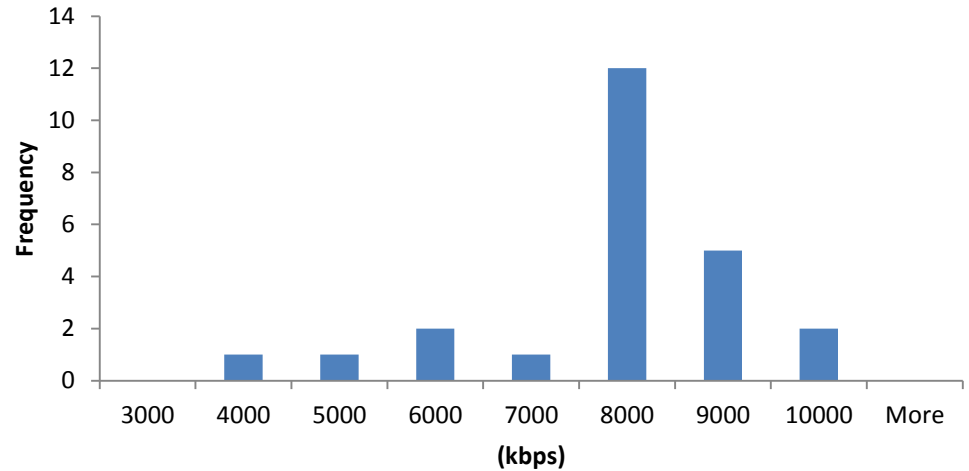
- Test
  - Measure impact of speed on throughput
    - Open space (country) vs. city with buildings
- Results
  - Open space on highway at ~60mph
    - Wide statistical distribution of download and upload data with random outliers
  - City environment
    - *Measurements in process*

# Impact of Speed (60mph in open space)

## Download Throughput Distribution



## Upload Throughput Distribution





# Measure Impact of Roaming

- Test:
  - Try to find a place between towers (e.g. in our spreadsheet where the coverage changes from LTE to eHRPD)
    - See if connection drops between towers
    - See whether throughput is impacted
- Results:
  - Throughput test failed with lost connection when roaming from LTE to eHRPD

# Impact of Speed & Roaming

Date	ConnType	Download(kbps)	Upload(kbps)	Latency(ms)	ServerName	Internal IP	External IP
10/25/2011 13:03	Ehrpd	564	578	183	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:03	Ehrpd	783	734	187	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:02	Ehrpd	268	330	215	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:01	Lte	18209	4430	99	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:01	Lte	37263	8048	94	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:00	Lte	35722	7566	111	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:00	Lte	35596	8374	106	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:00	Lte	32816	7150	118	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 13:00	Lte	38081	7598	121	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:59	Lte	36286	7854	106	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:59	Lte	35714	9027	113	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:59	Lte	38519	7755	93	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:59	Lte	18927	8435	112	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:58	Lte	31436	3336	111	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:58	Lte	35918	7699	101	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:58	Lte	34811	7283	114	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:57	Lte	38550	9488	116	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:57	Lte	34797	8880	102	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:57	Lte	25581	7609	117	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:56	Lte	17514	6964	102	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:56	Lte	16636	5468	101	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:56	Lte	31238	5676	118	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:56	Lte	33350	7442	108	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:55	Lte	38943	7735	104	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:55	Lte	35389	7616	109	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:55	Lte	33942	8162	100	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8
10/25/2011 12:54	Lte	33057	7225	116	Boston, MA	10.131.110.240, 10.174.56.202	166.248.3.8



**Connection lost at LTE to eHRPD transition**

LTE Average

32012

7368

LTE Median

34804

7612.5



# Contact

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