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2. Ping Execution Trace

I made a batch file that looked like this:

```
:: Prevent commands from being displayed. The @ symbol hides this command from
view as well.
@echo off
py ICMPpinger.py www.vermont.gov
py ICMPpinger.py www.lostrivercave.org
py ICMPpinger.py stanford.edu
py ICMPpinger.py www.idaho.gov
py ICMPpinger.py www.nm.gov
py ICMPpinger.py www.canada.ca
py ICMPpinger.py www.gov.ph
py ICMPpinger.py www.irangov.ir
py ICMPpinger.py www.gov.cn
py ICMPpinger.py www.government.is
:: Prevent the command window from closing until I press enter.
:: I got "set /p=" from StackOverflow:
https://stackoverflow.com/questions/16302351/ms-dos-batch-file-pause-with-enter
-key
set /p=
```

Execution trace of ping output tested against ten (10) different IP addresses.

Pinging www.vermont.gov [199.107.32.183] 3 times using Python with 8 bytes of data:

Ping 1: RTT 14.28 ms, TTL=239

Ping 2: RTT 17.8 ms, TTL=239

Ping 3: RTT 10.4 ms, TTL=239

Average RTT: 14.161 ms

Pinging www.lostrivercave.org [172.67.203.218] 3 times using Python with 8 bytes of data:

Ping 1: RTT 0.0 ms, TTL=52

Ping 2: RTT 14.09 ms, TTL=52

Ping 3: RTT 8.18 ms, TTL=52

Average RTT: 7.421 ms

Pinging stanford.edu [171.67.215.200] 3 times using Python with 8 bytes of data:

Ping 1: RTT 69.31 ms, TTL=234

Ping 2: RTT 57.36 ms, TTL=234

Ping 3: RTT 64.27 ms, TTL=234

Average RTT: 63.646 ms

Pinging www.idaho.gov [206.16.212.39] 3 times using Python with 8 bytes of data:

Ping 1: RTT 12.24 ms, TTL=239

Ping 2: RTT 21.12 ms, TTL=239

Ping 3: RTT 13.88 ms, TTL=239

Average RTT: 15.744 ms

Pinging www.nm.gov [34.120.13.181] 3 times using Python with 8 bytes of data:

Ping 1: RTT 14.53 ms, TTL=115

Ping 2: RTT 9.9 ms, TTL=115

Ping 3: RTT 12.63 ms, TTL=115

Average RTT: 12.355 ms

Pinging www.canada.ca [104.102.99.231] 3 times using Python with 8 bytes of data:

Ping 1: RTT 0.0 ms, TTL=56

Ping 2: RTT 4.17 ms, TTL=56

Ping 3: RTT 1.31 ms, TTL=56

Average RTT: 1.825 ms

Pinging www.gov.ph [172.64.151.154] 3 times using Python with 8 bytes of data:

Ping 1: RTT 4.63 ms, TTL=55

Ping 2: RTT 0.0 ms, TTL=55

Ping 3: RTT 5.68 ms, TTL=55

Average RTT: 3.435 ms

Pinging www.irangov.ir [185.143.234.120] 3 times using Python with 8 bytes of data:

Ping 1: RTT 121.16 ms, TTL=44

Ping 2: RTT 117.64 ms, TTL=44

Ping 3: RTT 122.11 ms, TTL=44

Average RTT: 120.304 ms

Pinging www.gov.cn [4.34.134.109] 3 times using Python with 8 bytes of data:

Ping 1: RTT 46.92 ms, TTL=48
Ping 2: RTT 44.1 ms, TTL=48
Ping 3: RTT 43.19 ms, TTL=48
Average RTT: 44.735 ms

Pinging www.government.is [172.67.42.86] 3 times using Python with 8 bytes of data:
Ping 1: RTT 10.34 ms, TTL=56
Ping 2: RTT 9.21 ms, TTL=56
Ping 3: RTT 5.67 ms, TTL=56
Average RTT: 8.408 ms

3. Traceroute Execution Trace

I modified the batch file to replace: "ICMPpinger.py" with "ICMPtraceroute.py".

Execution trace of traceroute output tested against the same ten (10) IP addresses.

Traceroute to www.vermont.gov [199.107.32.183]:

```
1 rtt= 0 ms 131.229.119.254
2 rtt= 27 ms 131.229.11.142
3 rtt= 16 ms 131.229.10.104
4 rtt= 16 ms 134.241.249.33
5 rtt= 0 ms 69.16.1.33
6 rtt= 8 ms 65.175.24.205 ae6-201.cr1-bos1.ip4.gtt.net
7 rtt= 21 ms 89.149.129.194 ae3.cr1-nyc2.ip4.gtt.net
8 rtt= 15 ms 192.205.37.37
* * * Request timed out.
* * * Request timed out.
* * * Request timed out.
* * * Request timed out.
13 rtt= 15 ms 12.250.98.10
14 rtt= 20 ms 206.17.31.84
15 rtt= 26 ms 199.107.32.183 vt-prd-drupal10b.vermont-gl.com
```

Traceroute to www.lostrivercave.org [172.67.203.218]:

```
1 rtt= 14 ms 131.229.119.254
2 rtt= 16 ms 131.229.11.142
3 rtt= 22 ms 131.229.10.104
4 rtt= 14 ms 134.241.249.33
5 rtt= 0 ms 69.16.1.33
```

6 rtt= 0 ms 65.175.24.205 ae6-201.cr1-bos1.ip4.gtt.net

7 rtt= 10 ms 213.200.112.166 ae0.cr2-nyc4.ip4.gtt.net

* * * Request timed out.

9 rtt= 16 ms 162.158.156.3

10 rtt= 22 ms 172.67.203.218

Traceroute to stanford.edu [171.67.215.200]:

1 rtt= 28 ms 131.229.119.254

2 rtt= 97 ms 131.229.11.142

3 rtt= 27 ms 131.229.10.104

4 rtt= 7 ms 134.241.249.33

5 rtt= 0 ms 69.16.1.33

6 rtt= 15 ms 18.2.8.89 umassnet-re2-nox-mghpcc-gw1.nox.org

7 rtt= 9 ms 192.5.89.254 nox-mghpcc-gw1-i2-re-chic.nox.org

8 rtt= 71 ms 163.253.1.21 fourhundredge-0-0-0-2.4079.core2.clev.net.internet2.edu

9 rtt= 70 ms 163.253.2.146 fourhundredge-0-0-0-23.4079.core1.clev.net.internet2.edu

10 rtt= 71 ms 163.253.1.211 fourhundredge-0-0-0-2.4079.core1.eqch.net.internet2.edu

11 rtt= 68 ms 163.253.1.206 fourhundredge-0-0-0-1.4079.core1.chic.net.internet2.edu

12 rtt= 66 ms 163.253.2.29 fourhundredge-0-0-0-1.4079.core2.kans.net.internet2.edu

13 rtt= 66 ms 163.253.1.250 fourhundredge-0-0-0-1.4079.core2.denv.net.internet2.edu

14 rtt= 59 ms 163.253.1.169 fourhundredge-0-0-0-3.4079.core2.salt.net.internet2.edu

15 rtt= 68 ms 163.253.1.186 fourhundredge-0-0-0-2.4079.core2.sacr.net.internet2.edu

16 rtt= 67 ms 163.253.1.36 fourhundredge-0-0-0-22.4079.core1.sacr.net.internet2.edu

17 rtt= 69 ms 163.253.1.193 fourhundredge-0-0-0-0.4079.core1.sunn.net.internet2.edu

18 rtt= 71 ms 137.164.26.126 hpr-svl-agg10--internet2r&e-100ge.cenic.net

19 rtt= 69 ms 137.164.25.95 hpr-oak-agg8--svl-hpr3-100g.cenic.net

20 rtt= 71 ms 137.164.25.77 oak-agg8-hpr--emv11-agg-01-hpr--100g--01.cenic.net

21 rtt= 69 ms 137.164.26.241

22 rtt= 70 ms 171.64.255.232 campus-ial-nets-a-vl1020.SUNet

* * * Request timed out.

24 rtt= 66 ms 171.67.215.200 web.stanford.edu

Traceroute to www.idaho.gov [206.16.212.39]:

1 rtt= 5 ms 131.229.119.254

2 rtt= 17 ms 131.229.11.142

3 rtt= 29 ms 131.229.10.104

4 rtt= 2 ms 134.241.249.33

5 rtt= 1 ms 69.16.1.33

6 rtt= 23 ms 65.175.24.205 ae6-201.cr1-bos1.ip4.gtt.net

7 rtt= 16 ms 89.149.129.194 ae3.cr1-nyc2.ip4.gtt.net

8 rtt= 16 ms 192.205.37.37

* * * Request timed out.

* * * Request timed out.

* * * Request timed out.

* * * Request timed out.

13 rtt= 20 ms 12.250.98.10

14 rtt= 31 ms 206.17.31.72

15 rtt= 26 ms 206.16.212.39 id.vprod.cdc.nicusa.com

Traceroute to www.nm.gov [34.120.13.181]:

1 rtt= 12 ms 131.229.119.254

2 rtt= 41 ms 131.229.11.142

3 rtt= 32 ms 131.229.10.104

4 rtt= 0 ms 134.241.249.33

5 rtt= 4 ms 69.16.1.33

6 rtt= 7 ms 18.2.136.89 umassnet-cps2-nox-mghpcc-gw1.nox.org

7 rtt= 8 ms 192.5.89.46

8 rtt= 17 ms 18.2.145.18

9 rtt= 16 ms 142.251.78.65

10 rtt= 16 ms 216.239.40.187

11 rtt= 15 ms 34.120.13.181 181.13.120.34.bc.googleusercontent.com

Traceroute to www.canada.ca [104.102.99.231]:

1 rtt= 5 ms 131.229.119.254

2 rtt= 20 ms 131.229.11.142

3 rtt= 25 ms 131.229.10.104

4 rtt= 0 ms 134.241.249.33

5 rtt= 18 ms 69.16.1.33

6 rtt= 13 ms 18.2.136.89 umassnet-cps2-nox-mghpcc-gw1.nox.org

7 rtt= 6 ms 192.5.89.57

8 rtt= 16 ms 206.53.143.2 ae4.ecx-bos2.netarch.akamai.com

9 rtt= 10 ms 104.102.99.231 a104-102-99-231.deploy.static.akamaitechnologies.com

Traceroute to www.gov.ph [104.18.36.102]:

1 rtt= 3 ms 131.229.119.254

2 rtt= 17 ms 131.229.11.142

3 rtt= 60 ms 131.229.10.104

4 rtt= 6 ms 134.241.249.33

5 rtt= 0 ms 69.16.1.33

6 rtt= 10 ms 18.2.136.89 umassnet-cps2-nox-mghpcc-gw1.nox.org

7 rtt= 9 ms 192.5.89.57

8 rtt= 10 ms 206.53.143.9 mass-ix.as13335.net

9 rtt= 5 ms 104.18.36.102

Traceroute to www.irangov.ir [185.143.234.120]:

1 rtt= 7 ms 131.229.119.254

2 rtt= 37 ms 131.229.11.142

3 rtt= 22 ms 131.229.10.104

4 rtt= 5 ms 134.241.249.33
5 rtt= 13 ms 69.16.1.33
6 rtt= 9 ms 69.16.0.9
7 rtt= 7 ms 38.104.218.13 be4691.rcr51.orh01.atlas.cogentco.com
8 rtt= 11 ms 154.54.41.129 be2731.ccr32.bos01.atlas.cogentco.com
9 rtt= 78 ms 154.54.82.37 be2101.ccr42.lon13.atlas.cogentco.com
10 rtt= 116 ms 130.117.51.42 be12488.ccr42.ams03.atlas.cogentco.com
11 rtt= 88 ms 130.117.0.142 be2814.ccr42.fra03.atlas.cogentco.com
12 rtt= 95 ms 154.54.36.254 be2960.ccr22.muc03.atlas.cogentco.com
13 rtt= 109 ms 154.54.59.181 be3462.ccr52.vie01.atlas.cogentco.com
14 rtt= 120 ms 154.54.59.186 be3463.ccr22.bts01.atlas.cogentco.com
15 rtt= 128 ms 154.54.59.178 be3263.ccr31.bud01.atlas.cogentco.com
16 rtt= 128 ms 154.54.38.246 be3262.ccr31.buh01.atlas.cogentco.com
17 rtt= 120 ms 154.54.77.237 be3572.rcr71.ist01.atlas.cogentco.com
18 rtt= 123 ms 204.68.252.143 cogent-100---et2---mx1.comnet.com.tr
19 rtt= 125 ms 185.17.115.222 reverse.comnetnetwork.com
20 rtt= 130 ms 185.143.234.120

Traceroute to www.gov.cn [156.251.65.4]:

1 rtt= 11 ms 131.229.119.254
2 rtt= 29 ms 131.229.11.142
3 rtt= 21 ms 131.229.10.104
4 rtt= 15 ms 134.241.249.33
5 rtt= 0 ms 69.16.1.33
6 rtt= 8 ms 69.16.0.9
7 rtt= 9 ms 38.104.218.13 be4691.rcr51.orh01.atlas.cogentco.com
8 rtt= 10 ms 154.54.41.129 be2731.ccr32.bos01.atlas.cogentco.com
9 rtt= 14 ms 154.54.46.34 be3472.ccr42.jfk02.atlas.cogentco.com
10 rtt= 26 ms 154.54.40.110 be2807.ccr42.dca01.atlas.cogentco.com
11 rtt= 36 ms 154.54.24.222 be2113.ccr42.atl01.atlas.cogentco.com
12 rtt= 41 ms 154.54.44.78 be3373.agr22.atl01.atlas.cogentco.com
13 rtt= 38 ms 154.24.16.42 be3912.nr01.b021596-1.atl01.atlas.cogentco.com
14 rtt= 33 ms 38.32.168.186
15 rtt= 44 ms 156.251.65.4

Traceroute to www.government.is [104.22.53.203]:

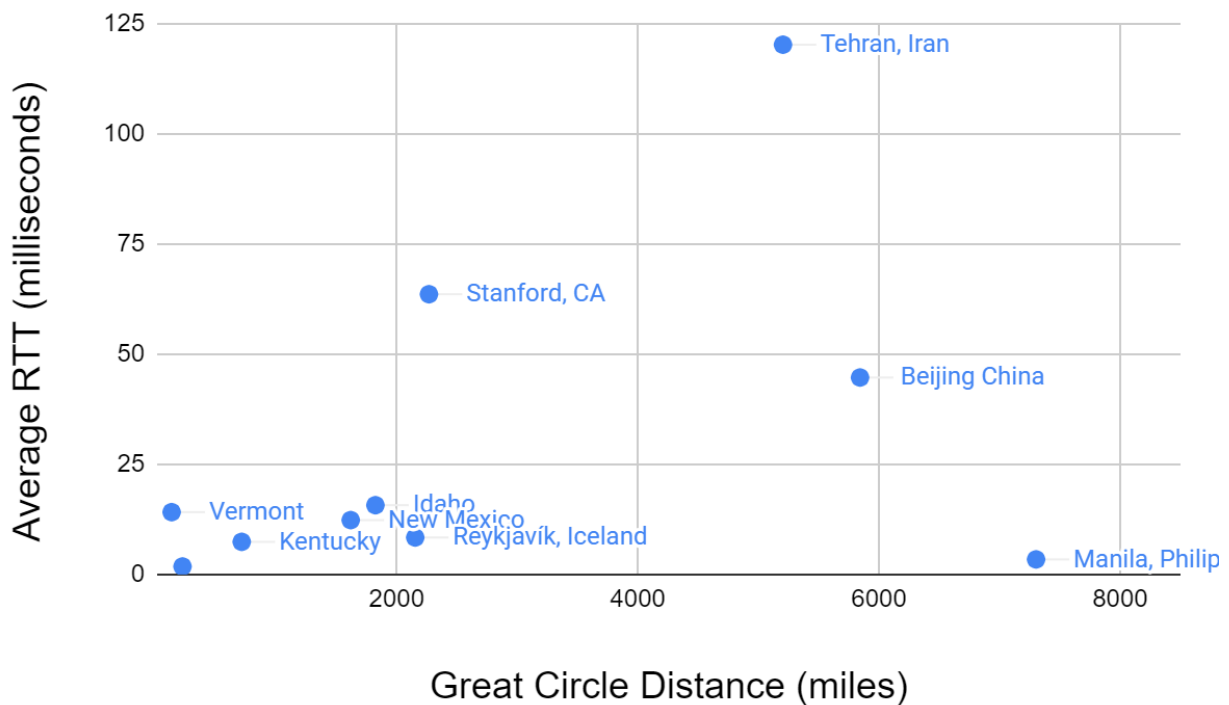
1 rtt= 13 ms 131.229.119.254
2 rtt= 28 ms 131.229.11.142
3 rtt= 20 ms 131.229.10.104
4 rtt= 7 ms 134.241.249.33
5 rtt= 14 ms 69.16.1.33
6 rtt= 5 ms 18.2.136.89 umassnet-cps2-nox-mghpcc-gw1.nox.org
7 rtt= 7 ms 192.5.89.57
8 rtt= 11 ms 206.53.143.9 mass-ix.as13335.net

Analysis Note:

The web domains I settled on are all localized institutions: governments, a university, and a tourist attraction. I located them on Google Maps to find geographic coordinates: the capital cities for countries, the approximate centers of states, and the explicit site of the university (Stanford) and tourist attraction (Lost River Cave in Kentucky).

4. Ping Analysis

scatterplot plus answers to the two associated questions.



1. **Are RTT and geographic distance correlated positively, negatively, or not at all? If applicable, also comment on the strength of correlation (weak vs. strong).**

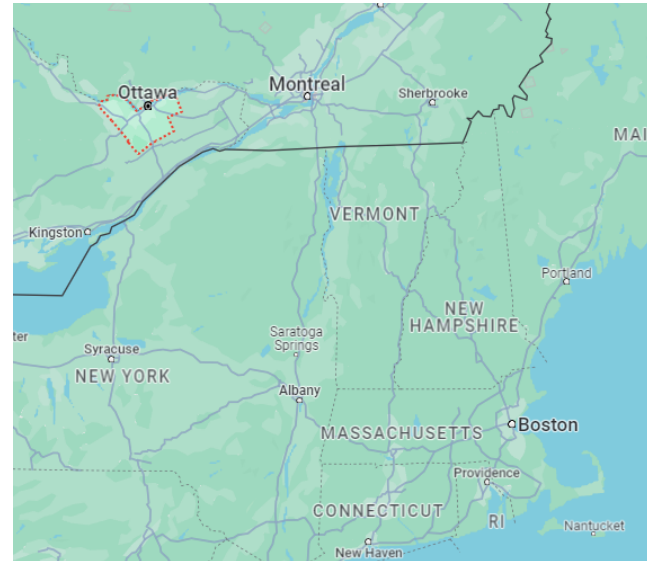
There is a weak positive correlation. Most pings are returned in under 20 milliseconds, there are 3 outliers, and since I only have 10 data points, this makes up a significant portion of my data. The outliers are farther away geographically than most, and their round trip times are longer, but they don't form a trend by themselves.

2. **Why do you think you observe this trend (or lack thereof)?**

The domains that returned pings in less than 20 milliseconds are either very close, or they are using virtualization and I'm actually reaching a server from Cloudflare or another such company. Vermont or Ottawa, Canada (label did not render but it is close to Vermont) might be close enough to receive a ping from in under 20 ms, but I'm rather certain the others are not.

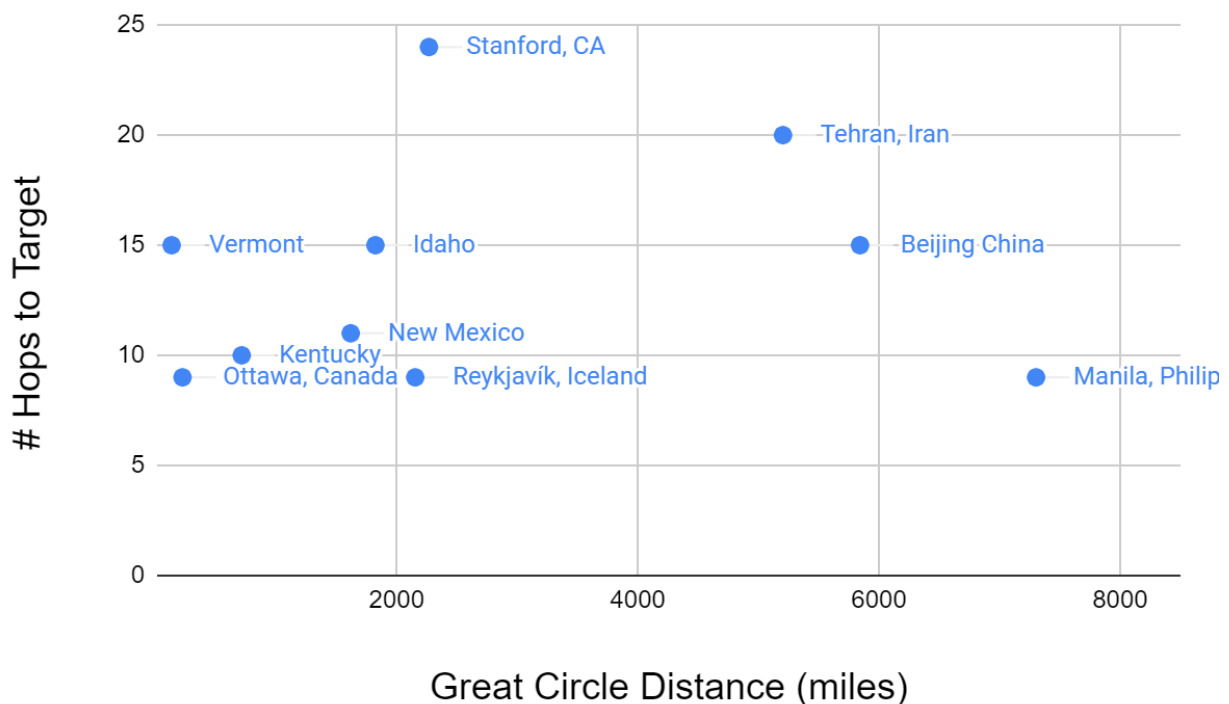
Iran and Stanford's website may be hosted by their own servers. The round trip time goes up with geographic distance and a line through the two points would cross vaguely near the origin, zero RTT for zero distance.

Even though China is geographically furthest of the three high RTT points, it has the lowest RTT. I assumed at first that this meant they virtualized their server, but that would get in the way of tracking everyone who visits their site. See Traceroute Analysis.



5. Traceroute Analysis

scatterplot plus answers to the two associated questions.



1. Are # hops and geographic distance correlated positively, negatively, or not at all? If applicable, also comment on the strength of correlation (weak vs. strong).

There is a very weak positive correlation. So little of the variation is described by a positive trendline that I had to ask google sheets to estimate one to be sure. If I wasn't biased to believe that a positive correlation is a part of the story, I'd say it arose out of randomness. The data doesn't give evidence for it.

2. Why do you think you observe this trend (or lack thereof)?

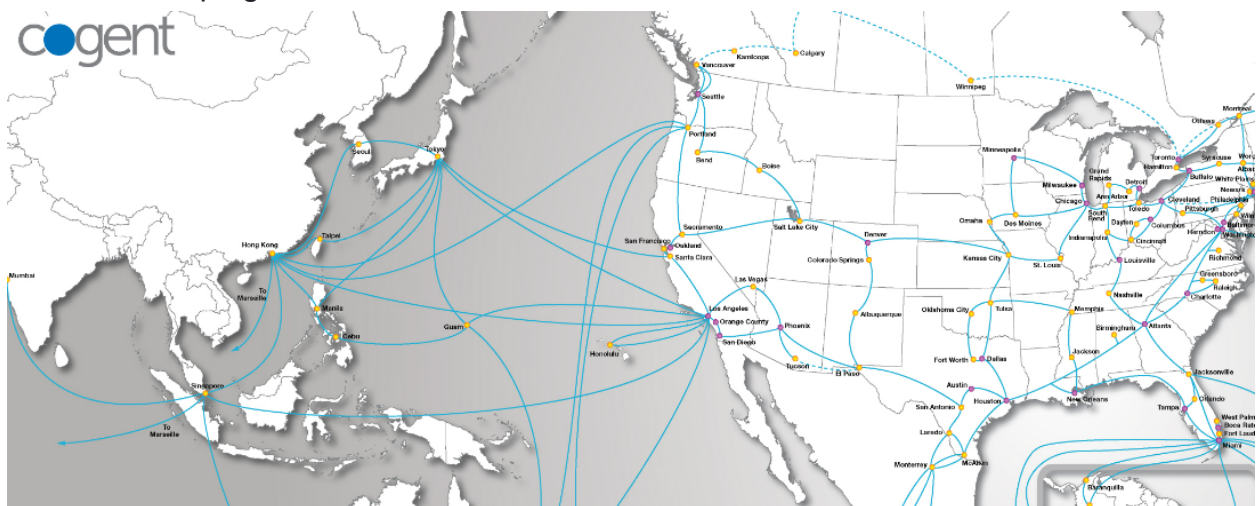
As stated in Ping Analysis, many of these sites are outsourcing their servers to companies like Cloudflare. This lets them present their website from a more central server, so users see shorter delays in accessing content, and takes care of the increasing overhead of security or high traffic. This explains why the hop count is similar (10 to 15) for most of them. I'm reaching similar places (just a few nearby centralized server farms).

The ones that aren't outsourcing their servers should show a positive correlation between geographic distance and hop count, but that trend would still be noisy. Some hops are way bigger than others. For instance, China is connected to

California by undersea fiber optics that go $\sim\frac{1}{3}$ the way around the world in one or two hops. Lastly, Economically wealthy or developed regions will have a large number of routers close together. This may explain why Stanford had the highest hop count of all.

Also, I am using great circle distances between locations. For Iran and China, the great circle goes over the north pole. I think that's unlikely as an actual communications route; this underestimates the distance to locations on the other side of the northern hemisphere.

The router closest to www.gov.cn that had a domain name was be3912.nr01.b021596-1.atl01.atlas.cogentco.com. Cogent Communications is a giant Internet Service Provider. Looking at their map, I can't tell where that router is, and their website doesn't have a search. (Probably for the best). I can see however that the difference between California and China is just 1 or 2 hops by fiber optic. That means that, over the network, they are a similar distance as Stanford. I believe that they are not outsourcing their servers. This explains why the RTT from ping was similar to that from Stanford.



6. Link to Spreadsheet

ping and traceroute performance data

[+ Statistical Summary for Ping Results](#)

Testing

I tried to determine why my code sometimes gives me 0 ms round trip times (when the built-in ping or tracert gives low values like 3ms or 5 ms). My round trip times are consistently a little lower than that recorded by the built-ins, not just for the small numbers where it is glaring.

First guess: the time stamps can't vary by such small increments.

Timing the sleep(0.001) function a few consecutive times gave me about 5 milliseconds the first time, then about 1.6 milliseconds the following times. The timestamps can resolve delays on the scale of a few ms.

I tried a different module for timing: "timeit". The results were unchanged so I went back to the cleaner code with "time".

I ran Wireshark to get the ground truth. The built-ins report time differences closer to the Wireshark time differences.