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CSC249: Computer Networks

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# Project 4: ICMP Ping and Traceroute: Testing & Analysis Written Report

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

```
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py smith.edu
             Pinging smith.edu [131.229.65.117] 3 times using Python:
             Ping 1 RTT 0.003131866455078125 sec.
             Ping 2 RTT 0.003178119659423828 sec.
             Ping 3 RTT 0.011637687683105469 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py harvard.edu
             Pinging harvard.edu [151.101.66.133] 3 times using Python:
             Ping 1 RTT 0.007533073425292969 sec.
             Ping 2 RTT 0.0076541900634765625 sec.
             Ping 3 RTT 0.0072939395904541016 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py chicago.gov
             Pinging chicago.gov [23.55.235.203] 3 times using Python:
             Ping 1 RTT 0.014320850372314453 sec.
             Ping 2 RTT 0.014084100723266602 sec.
             Ping 3 RTT 0.014312028884887695 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py lacity.gov
             Pinging lacity.gov [23.39.229.18] 3 times using Python:
             Ping 1 RTT 0.02391338348388672 sec.
             Ping 2 RTT 0.027363061904907227 sec.
             Ping 3 RTT 0.01835799217224121 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py columbia.edu
             Pinging columbia.edu [128.59.105.24] 3 times using Python:
             Ping 1 RTT 0.01729583740234375 sec.
             Ping 2 RTT 0.017764806747436523 sec.
             Ping 3 RTT 0.017299890518188477 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py gov.ie
             Pinging gov.ie [178.79.175.148] 3 times using Python:
             Ping 1 RTT 0.07531309127807617 sec.
             Ping 2 RTT 0.07554316520690918 sec.
             Ping 3 RTT 0.07573795318603516 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py unam.mx
             Pinging unam.mx [132.248.166.17] 3 times using Python:
             Ping 1 RTT 0.10302591323852539 sec.
             Ping 2 RTT 0.1044926643371582 sec.
             Ping 3 RTT 0.10304427146911621 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py gov.kg
             Pinging gov.kg [212.112.98.134] 3 times using Python:
             Ping 1 RTT 0.16777920722961426 sec.
             Ping 2 RTT 0.16695308685302734 sec.
             Ping 3 RTT 0.1680011749267578 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py msu.ru
             Pinging msu.ru [178.154.243.30] 3 times using Python:
             Ping 1 RTT 0.13745689392089844 sec.
             Ping 2 RTT 0.13790106773376465 sec.
             Ping 3 RTT 0.1368119716644287 sec.
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPpinger.py seoulsolution.kr
```

```
Pinging seoulsolution.kr [211.38.10.9] 3 times using Python:
Ping 1 RTT 0.19988393783569336 sec.
Ping 2 RTT 0.1999659538269043 sec.
Ping 3 RTT 0.20046210289001465 sec.
```

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

```
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py smith.edu
       1. Hostname not available, rtt=11 ms, 131.229.141.254
       2. Hostname not available, rtt=16 ms, 131.229.11.142
       3. bouncenode01.smith.edu, rtt=3 ms, 131.229.65.117
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py harvard.edu
       1. Hostname not available, rtt=8 ms, 131.229.141.254
       2. Hostname not available, rtt=12 ms, 131.229.11.142
       3. Hostname not available, rtt=18 ms, 131.229.10.104
       4. Hostname not available, rtt=5 ms, 134.241.249.33
       5. Hostname not available, rtt=8 ms, 69.16.1.33
       6. Hostname not available, rtt=8 ms, 69.16.0.9
       7. be4691.rcr51.orh01.atlas.cogentco.com, rtt=7 ms, 38.104.218.13
       8. be2731.ccr32.bos01.atlas.cogentco.com, rtt=8 ms, 154.54.41.129
       9. Hostname not available, rtt=8 ms, 38.140.158.82
       10. Hostname not available, rtt=8 ms, 151.101.194.133
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py chicago.gov
       1. Hostname not available, rtt=4 ms, 131.229.141.254
       2. Hostname not available, rtt=20 ms, 131.229.11.142
       3. Hostname not available, rtt=21 ms, 131.229.10.104
       4. Hostname not available, rtt=3 ms, 134.241.249.33
       5. Hostname not available, rtt=2 ms, 69.16.1.33
       6. umassnet-cps2-nox-mghpcc-gw1.nox.org, rtt=4 ms, 18.2.136.89
       7. Hostname not available, rtt=7 ms, 192.5.89.57
       8. ae4.ecx-bos2.netarch.akamai.com, rtt=10 ms, 206.53.143.2
       9. a23-40-60-154.deploy.static.akamaitechnologies.com, rtt=7 ms,
      23.40.60.154
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py lacity.gov
       1. Hostname not available, rtt=10 ms, 131.229.141.254
       2. Hostname not available, rtt=73 ms, 131.229.11.142
       3. Hostname not available, rtt=21 ms, 131.229.10.104
       4. Hostname not available, rtt=3 ms, 134.241.249.33
       5. Hostname not available, rtt=2 ms, 69.16.1.33
       6. ae6-201.cr1-bos1.ip4.gtt.net, rtt=6 ms, 65.175.24.205
       7. ae24.cr4-nyc6.ip4.gtt.net, rtt=61 ms, 213.200.121.6
       8. ip4.gtt.net, rtt=12 ms, 98.124.184.66
       9. ae2.r02.lga01.icn.netarch.akamai.com, rtt=12 ms, 23.203.156.40
       * * * Request timed out.
       * * * Request timed out.
       11. ae9.r22.iad04.icn.netarch.akamai.com, rtt=18 ms, 23.32.63.169
       12. ae6.r22.iad02.mag.netarch.akamai.com, rtt=18 ms, 23.209.170.86
       13. ae1.r23.iad04.ien.netarch.akamai.com, rtt=18 ms, 23.209.170.111
       14. ae36.r03.border101.iad03.fab.netarch.akamai.com, rtt=20 ms,
      23.203.152.147
       * * * Request timed out.
       * * * Request timed out.
       * * * Request timed out.
       * * * Request timed out.
       * * * Request timed out.
       * * * Request timed out.
       18. a23-212-251-24.deploy.static.akamaitechnologies.com, rtt=19 ms,
      23.212.251.24
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py columbia.edu
       1. Hostname not available, rtt=3 ms, 131.229.141.254
       2. Hostname not available, rtt=7 ms, 131.229.11.142
       3. Hostname not available, rtt=24 ms, 131.229.10.104
```

```
        4. Hostname not available, rtt=2 ms, 134.241.249.33
        5. Hostname not available, rtt=2 ms, 69.16.1.33
        6. umassnet-re2-nox-mghpcc-gw1.nox.org, rtt=4 ms, 18.2.8.89
        7. Hostname not available, rtt=13 ms, 192.5.89.53
        8. Hostname not available, rtt=15 ms, 192.5.89.34
        9. nyc-9208-nox.nysernet.net, rtt=15 ms, 199.109.4.177
        10. columbia-nyc-9208.nysernet.net, rtt=15 ms, 199.109.4.14
        11. cc-core-1-x-nyser32-gw-1.net.columbia.edu, rtt=15 ms, 128.59.255.5
        12. cc-conc-1-x-cc-core-1.net.columbia.edu, rtt=14 ms, 128.59.255.21
        13. columbiauniversity.us, rtt=16 ms, 128.59.105.24
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py gov.ie
        1. Hostname not available, rtt=8 ms, 131.229.141.254
        2. Hostname not available, rtt=8 ms, 131.229.11.142
        3. Hostname not available, rtt=24 ms, 131.229.10.104
        4. Hostname not available, rtt=2 ms, 134.241.249.33
        5. Hostname not available, rtt=2 ms, 69.16.1.33
        6. ae6-201.cr1-bos1.ip4.gtt.net, rtt=6 ms, 65.175.24.205
        7. ae6.cr3-lon8.ip4.gtt.net, rtt=78 ms, 213.200.112.210
        8. ip4.gtt.net, rtt=74 ms, 154.14.69.238
        9. ae4.r02.lon01.icn.netarch.akamai.com, rtt=74 ms, 23.210.49.40
        10. ae2.r02.lon01.ien.netarch.akamai.com, rtt=74 ms, 23.210.48.41
        11. a23-210-48-17.deploy.static.akamaitechnologies.com, rtt=75 ms,
       23.210.48.17
        12. Hostname not available, rtt=74 ms, 10.207.32.2
        13. Hostname not available, rtt=75 ms, 10.207.35.22
        14. Hostname not available, rtt=75 ms, 10.207.6.147
        15. nb-178-79-175-148.tc.nodebalancer.linode.com, rtt=75 ms, 178.79.175.148
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py unam.mx
        1. Hostname not available, rtt=10 ms, 131.229.141.254
        2. Hostname not available, rtt=70 ms, 131.229.11.142
        3. Hostname not available, rtt=16 ms, 131.229.10.104
        4. Hostname not available, rtt=3 ms, 134.241.249.33
        5. Hostname not available, rtt=2 ms, 69.16.1.33
        6. umassnet-re2-nox-mghpcc-gw1.nox.org, rtt=4 ms, 18.2.8.89
        7. nox-mghpcc-gw1-i2-re-chic.nox.org, rtt=8 ms, 192.5.89.254
        8. fourhundredge-0-0-0-2.4079.core2.clev.net.internet2.edu, rtt=56 ms,
       163.253.1.21
        9. fourhundredge-0-0-0-22.4079.core1.clev.net.internet2.edu, rtt=57 ms,
       163.253.2.144
        10. fourhundredge-0-0-0-2.4079.core1.eqch.net.internet2.edu, rtt=55 ms,
       163.253.1.211
        11. fourhundredge-0-0-0-1.4079.core1.chic.net.internet2.edu, rtt=58 ms,
       163.253.1.206
        12. fourhundredge-0-0-0-1.4079.core2.kans.net.internet2.edu, rtt=57 ms,
       163.253.2.29
        13. fourhundredge-0-0-0-1.4079.core2.denv.net.internet2.edu, rtt=57 ms,
       163.253.1.250
        14. fourhundredge-0-0-0-1.4079.core2.elpa.net.internet2.edu, rtt=57 ms,
       163.253.2.105
        15. Hostname not available, rtt=54 ms, 187.251.32.245
        16. 201-139-176-146.rniba.cudi.edu.mx, rtt=83 ms, 201.139.176.146
        17. Hostname not available, rtt=81 ms, 132.247.254.77
        18. Hostname not available, rtt=599 ms, 132.248.133.22
        19. 1004-iimas.redunam.unam.mx, rtt=101 ms, 132.247.237.214
        20. Hostname not available, rtt=106 ms, 132.248.166.19
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py gov.kg
        1. Hostname not available, rtt=4 ms, 131.229.141.254
        2. Hostname not available, rtt=15 ms, 131.229.11.142
        3. Hostname not available, rtt=17 ms, 131.229.10.104
        4. Hostname not available, rtt=2 ms, 134.241.249.33
        5. Hostname not available, rtt=3 ms, 69.16.1.33
        6. Hostname not available, rtt=9 ms, 69.16.0.9
```

```
        7. be4691.rcr51.orh01.atlas.cogentco.com, rtt=14 ms, 38.104.218.13
        8. be2729.ccr31.bos01.atlas.cogentco.com, rtt=14 ms, 154.54.40.181
        9. be2099.ccr41.lon13.atlas.cogentco.com, rtt=71 ms, 154.54.82.33
        10. be12194.ccr41.ams03.atlas.cogentco.com, rtt=77 ms, 154.54.56.94
        11. be2813.ccr41.fra03.atlas.cogentco.com, rtt=85 ms, 130.117.0.122
        12. be2845.rcr22.fra06.atlas.cogentco.com, rtt=92 ms, 154.54.56.190
        * * * Request timed out.
        13. Hostname not available, rtt=658 ms, 149.14.210.146
        * * * Request timed out.
        14. Hostname not available, rtt=122 ms, 185.140.148.155
        15. Hostname not available, rtt=164 ms, 5.143.240.34
        16. gw4.aknet.kg, rtt=176 ms, 212.112.96.4
        17. relay.bishkek.gov.kg, rtt=166 ms, 212.112.98.134
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py msu.ru
        1. Hostname not available, rtt=7 ms, 131.229.141.254
        2. Hostname not available, rtt=8 ms, 131.229.11.142
        3. Hostname not available, rtt=18 ms, 131.229.10.104
        4. Hostname not available, rtt=3 ms, 134.241.249.33
        5. Hostname not available, rtt=2 ms, 69.16.1.33
        6. ae6-201.cr1-bos1.ip4.gtt.net, rtt=6 ms, 65.175.24.205
        7. ae0.cr2-bos1.ip4.gtt.net, rtt=7 ms, 89.149.130.30
        8. lag-18.bear2.boston1.level3.net, rtt=6 ms, 4.68.37.109
        * * * Request timed out.
        * * * Request timed out.
        10. carquadrin.bear2.washington111.level3.net, rtt=17 ms, 4.14.99.138
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
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        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        20. Hostname not available, rtt=139 ms, 130.193.63.246
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        * * * Request timed out.
        27. Hostname not available, rtt=137 ms, 178.154.243.30
Kylas-MacBook-Air:P4 kygamcs$ sudo python3 ICMPtraceroute.py seoulsolution.kr
        1. Hostname not available, rtt=14 ms, 131.229.141.254
        2. Hostname not available, rtt=23 ms, 131.229.11.142
        3. Hostname not available, rtt=16 ms, 131.229.10.104
        4. Hostname not available, rtt=2 ms, 134.241.249.33
```

```
5. Hostname not available, rtt=3 ms, 69.16.1.33
6. ae6-201.cr1-bos1.ip4.gtt.net, rtt=11 ms, 65.175.24.205
7. ae21.cr4-sea2.ip4.gtt.net, rtt=70 ms, 89.149.130.78
8. as4766.cr3-sea2.ip4.gtt.net, rtt=79 ms, 199.229.230.222
9. Hostname not available, rtt=186 ms, 112.174.88.25
10. Hostname not available, rtt=185 ms, 112.174.86.181
11. Hostname not available, rtt=191 ms, 112.174.47.170
* * * Request timed out.
* * * Request timed out.
13. Hostname not available, rtt=194 ms, 211.38.10.253
14. Hostname not available, rtt=201 ms, 211.38.10.9
```

## III. Data Collection:

After running the ICMPpinger.py and ICMPtraceroute.py programs, and capturing their corresponding execution traces, the following data was collected from the traces and with the help of keycdn.com's IP geolocation tool. The distance between the smith.edu IP address and 9 other IP addresses was calculated using Meridian Outpost's latitude/longitude distance calculator. The average round-trip-time (RTT) was obtained with the average calculator on calculator.net. Finally, all data and calculations were compiled into the following spreadsheet:

| Domain | IP | Location | Distance | Ping Date | Avg RTT | Trace Date | Trace RTT | # Hops |
|---|---|---|---|---|---|---|---|---|
| smith.edu | 131.229.65.117 | Northampton, MA | 0 mi | 12/03 | 0.0059825579325358 sec | 12/04 | 3 ms | 3 |
| harvard.edu | 151.101.194.133 | Cambridge, MA | 77.15 mi | 12/03 | 0.0074937343597412 sec | 12/04 | 8 ms | 10 |
| chicago.gov | 23.40.60.145 | Chicago, IL | 70.63 mi | 12/03 | 0.014238993326823 sec | 12/04 | 7 ms | 9 |
| lacity.gov | 23.39.229.18 | Los Angeles, CA | 210.42 mi | 12/03 | 0.023211479187012 sec | 12/04 | 19 ms | 18 |
| columbia.edu | 128.59.105.24 | New York City, NY | 125.39 mi | 12/03 | 0.01745351155599 sec | 12/04 | 16 ms | 13 |
| gov.ie | 178.79.175.148 | London, England | 3,337.58 mi | 12/03 | 0.075531403223674 sec | 12/04 | 75 ms | 15 |
| unam.mx | 132.248.166.17 | Mexico City, Mexico | 2,211.69 mi | 12/03 | 0.1035209496816 sec | 12/04 | 106 ms | 20 |
| gov.kg | 212.112.98.134 | Bishkek, Kyrgyzstan | 6,208.15 mi | 12/03 | 0.16757782300313 sec | 12/04 | 166 ms | 17 |
| msu.ru | 178.154.243.30 | Moscow, Russia | 4,534.75 mi | 12/03 | 0.13738997777303 sec | 12/04 | 137 ms | 27 |
| seoulsolution.kr | 211.38.10.9 | Seoul, South Korea | 6,784.23 mi | 12/03 | 0.2001039981842 sec | 12/04 | 201 ms | 14 |

## IV. Ping Analysis:

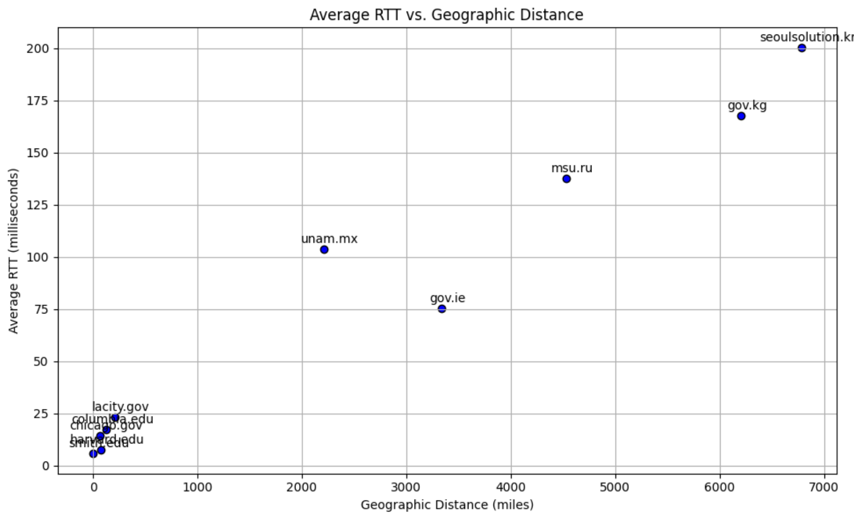


**Fig. 1.** *Average RTT in milliseconds compared to geographic distance in miles (graphed with MatPlotLib).*

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).*

Looking at the visualization for the average round-trip-time (RTT) in milliseconds in comparison to the geographic distance in miles of ten IP addresses (5 domestic, 5 international) in Fig. 1, the data indicates that **there is a strong, positive correlation between RTT and geographic distance.**

Interestingly, the servers for the chicago.gov and lacity.gov domains are based out of Billerica, Massachusetts and Philadelphia, Pennsylvania respectively. These geographical discrepancies are better reflected in the enlargement for domestic IP addresses in **Fig. 2**.

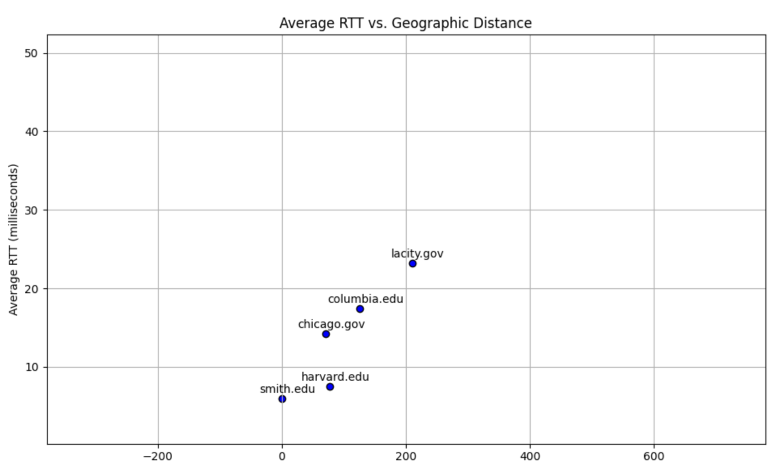


**Fig. 2.** *Enlargement of domestic IP addresses' comparison (graphed with MatPlotLib).*

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

The reason this trend is observed in the graph of *Average RTT vs. Geographic Distance* is due to several factors. First and foremost, this trend is consistent with the principles and physical capabilities of network communication.

Physically, data travels across vast stretches of land, oceans, and mountains through mediums like fiber optic cables. As a result of these long distances, geographic obstacles, and complex connections, the RTT of pings may be impacted in the form of time delays and more 'hops' being required to reach a destination (see **Fig. 3** on *Traceroute Analysis*).

Another fundamental aspect of networking that is reflected in this trend is routing algorithms. In internet infrastructure, routing algorithms are generally used to find the shortest and fastest path between a source and destination. Longer geographic distances between these two points as well as network congestion–when a network experiences more data packet traffic than it can sustain–are both factors that influence the efficiency of routes prescribed by routing algorithms and can cause significant RTT delays.

Finally, better connectivity and faster RTTs are most often related to robust network infrastructures within and across transnational borders. For example, a majority of the United States has a high-capacity network infrastructure which allows for smaller RTTs when pinging from a domestic IP address to another domestic IP address since data travels across shorter geographic distances within the country (as evidenced in **Fig. 2**). In comparison, when pinging from an American IP address to international IP addresses, data travels through different network infrastructures, physical geographic obstacles, and longer distances which contributes to delays in RTTs.

## V. Traceroute Analysis:

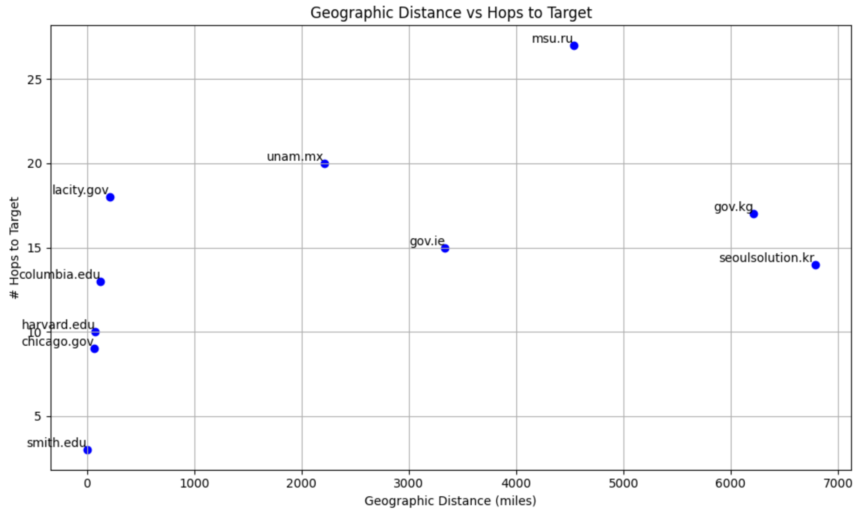


**Fig. 3.** *Number of hops to target compared to geographic distance in miles (MatPlotLib).*

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).*

In the visualization for the number of hops in comparison to the geographic distance in miles of ten IP addresses (5 domestic, 5 international) in **Fig. 3**, the **data does not reflect any significant correlation between the number of hops and geographic distance**. In the *Geographic Distance vs. Hops to Target* graph, we can observe that the number of hops is positively correlated with the geographic distance between the sending smith.edu domain and the four receiving US domains (chicago.gov, harvard.edu, columbia.edu, and lacity.gov). This is due to the fact that geographically, the distance between the smith.edu and other four servers is as follows (in increasing order, with the number of hops respectively added):

1. chicago.gov (9 hops for 70.63 mi)[1]
2. harvard.edu (10 hops for 77.15 mi)
3. columbia.edu (16 hops for 125.39 mi)
4. lacity.gov (18 hops for 210.42 mi)[2]

[1] Despite being the website for the government of the city of Chicago, the servers for the IP address pinged are hosted in Billerica, Massachusetts.
[2] Like in the case of the chicago.gov, the servers for the government of the city of Los Angeles are located in Philadelphia, Pennsylvania.

**Therefore, in the case of the five domestic IP addresses, there is a strong correlation between the number of hops required for data to reach a certain destination and geographic distance. This is not the same among the five international IP addresses**.

Discrepancies in the relationship between the number of hops and distance arise when analyzing the visualization of the five international IP addresses. **The *Geographic Distance vs. Hops to Target* graph reflects no distinguishable correlation between the number of hops and geographic distance among the international IP addresses**. This is due to several variations in the number of hops regardless of geographical proximity:

1. unam.mx (2,211.69 mi) required 20 hops
2. gov.ie (3,337.58 mi) required 15 hops
3. msu.ru (4,534.75 mi) required 27 hops
4. gov.kg (6,208.15 mi) required 17 hops
5. seoulsolution.kr (6,784.23 mi) required 14 hops

If there was a positive correlation between these five international IP addresses, the number of hops required to reach each domain would increase as the physical distance increased. As we can see in **Fig. 3**, the data spreadsheet, and in the above organized list, there is no relationship of any kind–no positive or negative correlation– between the five international IP addresses like there was among the five domestic IP addresses.

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

As previously mentioned, several factors such as network topology or congestion coupled with lacking internet infrastructures and geographical obstacles can influence the number of hops necessary to reach a particular destination.  In this case, I believe the absence of any correlation between the number of hops and geographic distances for the international IP addresses is caused by potentially lacking network infrastructures–most likely in countries like Mexico, Kyrgyzstan, and Russia–or the presence of optimized routing algorithms between countries. Particularly in the case of optimized routing algorithms, shorter routes reduce the number of hops between long distances, causing positive, negative, or no correlations between hops and geographic distance. Optimized routes between countries like the United States, Korea, and England is what seems to be influencing the number hops represented in the graph.

## VI. Resources & Link to View Graphs Online:


1. https://sock-raw.org/papers/sock_raw
2. https://www.rfc-editor.org/rfc/rfc792
3. https://www.calculator.net/average-calculator.html
4. https://www.meridianoutpost.com/resources/etools/calculators/calculator-latitude-longitude-distance.php
5. https://tools.keycdn.com/geo
6. Graphs: https://replit.com/@KylaGarcia/traceroute