COMS W4119: Computer Networks
Homework 2

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Network Applications & Socket Programming

(a) The two predominant modern application architectures are client-server and peer to peer.

(b) Client-server features an always on host that clients communicate with and receive resources from. There is no direct client to client interaction, as the server would handle the communication. This system is not auto-scaling, as hosts can be overwhelmed as more clients come online.

Peer to peer has no always on server, so peers directly request resources from other peers and provides resources in return. This system is self-scaling, as more peers create more capability.

(c) Alice has both a client and server process, the client to download the movie from Bob, and a server process to upload chunks to other peers.

If Bob isn't downloading anything, then he just has a server process running to send the movie to Alice. If he is downloading files, then he would have both processes (same logic as Alice above).

(d) (a) No, because he needs the port number that her application is running on her machine.

(b) TSL/SSL should be implemented in the application layer. She should use the SSL socket API or an SSL library that communicates with the TCP protocol.

(e) (a) Each socket is used for a bidirectional communication channel between a client and the server. A socket is needed for the server process to listen for clients. Then additional sockets are needed for the TCP server to handle any additional number of clients.

(b) There must be $n + 1$ sockets for the TCP server.

(c) UDP does not support connections between clients and servers, thus no handshaking is needed. A UDP server just needs a single socket that can accept and handle multiple connections.

(f) (i) A "Connection Refused" error occurs when running the TCPClient process first before running the TCPServer process. This happens because the client is unable to receive a handshake (and thus establish a connection) with a TCP server, as it is not running.

(ii) The same "Connection Refused" error occurs for the same reason (the client is unable to receive a handshake from the server and this fails to establish a connection)

(iii) No errors occur, but the server does not receive the message. This is because server is not running when the client unreliably sends the message, and is thus unable to receive it. No errors occur (unlike in the TCP case), since the client does not actually establish a connection via a handshake.

(iv) The server receives the message sent by the client. In this situation, the server happened to be online as the message was being unreliably sent by the client.

(v) A "Connection Refused" error occurs because a server process runs on a unique combination of an IP and port number, and thus sending a TCP connection request to the wrong port number will fail to deliver a connection request to the server process.

(vi) No error occurs (since no handshaking is necessary), but the message fails to be delivered to the server, since again the server process is uniquely identified by an IP and port number, and so sending the message to the wrong port will not send it to the server process.

The Web and HTTP

(a) Non-persistent HTTP with a single TCP connection will require 11 total TCP connections to be established sequentially.

The RTT will be:

$$\frac{3 * 10^7}{3 * 10^8} = 0.1 \text{ seconds}$$

To establish a single TCP connection, three control messages are exchanged between the client and server. Since the control messages are 2000 bits, it will take 0.002 seconds to fully transmit one control message, and thus 0.006 seconds to transmit all the bits to establish the TCP connection.

To send one 100 kBit object back to the client, it will take 0.1 seconds.

Thus to establish one TCP connection and send one object, it will take:

$$2 * \text{RTT} + 0.006 + 0.1 = 0.306 \text{ seconds}$$

Thus, in order to send all 11 objects from the server:

$$11 * 0.306 = \boxed{3.366 \text{ seconds}}$$

(b) A TCP connection needs to be initiated to retrieve the the first downloaded object, and then the client has access to the references to the other ten objects, and can thus establish 10 connections in parallel.

The RTT is still 0.1 seconds, and the time to transmit the control messages per TCP connection is 0.006 seconds.

To transmit the initial 100 kBit object in the first TCP connection, it will take 0.1 seconds. Thus, the time to establish the first TCP connection is:

$$2 * \text{RTT} + 0.006 + 0.1 = 0.306 \text{ seconds}$$

To send the remaining ten 100-kBit objects in parallel, it would be equivalent to sending 1 million bits through the link at once, and thus take 1 second to fully transmit the 10 objects.

Because the client would send out 10 control messages simultaneously to establish 10 parallel connections, the client would be sending out $2000 * 10 = 20$ Kbits through the link, which would take 0.02 seconds, and thus 0.06 seconds to establish the 3-way handshake across all ten simultaneous connections.

The time to establish parallel TCP connections and transmit the next ten objects is:

$$2 * \text{RTT} + 0.06 + 1 = 1.26 \text{ seconds}$$

The time to retrieve all 11 objects is just:

$$0.306 + 1.26 = \boxed{1.566 \text{ seconds}}$$

(c) When using a persistent HTTP, the propagation delay will be 2∗RTT to retrieve the first object (since it needs to set up the TCP connection), but then drop to 1RTT for the remaining file transmissions.

From part (a), establishing and transmitting the first object takes 0.306 seconds.

Transmitting the remaining objects will individually take:

$$\text{RTT} + 0.002 + 0.1 = 0.202 \text{ seconds}$$

Note the 0.002 instead of 0.006, this is because only one control message needs to be sent from the client to the server.

Thus, the total time it takes to get 11 objects using persistent HTTP is:

$$0.306 + 10 * 0.202 = \boxed{2.326 \text{ seconds}}$$

(d) The gains are decent (but not by orders of magnitude), as it shaved off 1.04 seconds, or around 30 percent of the total time.

(e) If the link length is $3 * 10^{10}$ meters, then the RTT would be 100 seconds, which would make using persistent HTTP significant more efficient by orders of magnitude as it cuts down on one RTT, or 100 seconds, for every object retrieved.

(f) When Jeff first visits Amazon, Amazon's server creates a unique ID for Jeff, stores it in a database, and then sets a cookie in Jeff's client to store his unique ID. This way next time Jeff visits Amazon, his browser sends the cookie with his unique ID to the Amazon server, which is able to retrieve Jeff's latest session from the database.

(g) Different devices and browsers are different clients, and thus cookies stored in one client are not accessible from another.

(h) As the video was being streamed for the first time, it was being cached in a proxy server (with a faster transmission speed). This made a later retrieval much faster for Jeff.

(i) The cache hit rate is just the complement of the access link utilization rate, thus $1 - 0.45 = \boxed{0.55}$

(j) Because the transmission delay from the cache servers are negligible compared to the delay from the origin servers, the total delay is entirely comprised of the access link utilization multiplied by the delay from origin servers:

$$0.45 * \text{RTT} = \boxed{0.45 \text{ seconds}}$$

Developer Tools and the Web

(a) www.ee.columbia.edu

(b) files/seasdepts/clg2168@columbia.edu/person/person_images/ethanKatzBassett.png

(c) The browser is requesting a persistent connection because of the field: `Connection: Keep-Alive`

(d) 128.59.64.28

(e) The persistent TCP connection should be held open for a minimum of 5 seconds, and support a maximum of 99 requests from this connection before closing the connection.

(f) 128.59.105.24

(g) The request URL of `https://www.columbia.edu/` sends a GET request for the HTML file, because the response header from the server has the field: `Content-Type: text/html`

(h) The response status code is `304 Not Modified`, and it is returned when a cached copy of the file is up to date with the server.

Video Streaming and CDN

(a) Stored video streaming services want to interact with the client to provide a seamless streaming experience as a user's bandwidth fluctuates

(b) Rather than directly implementing TCP, QUIC reduces the time it takes to set up a connection (by reducing the RTT), and also doesn't block multiple resources if one resource loses packets along the way. [1]

(c) The server offers a manifest file that provides resource locations for different chunks so that the client is able to retrieve the correct chunk based on the resolution that it has decided to stream at.

(d) If the chunks are a fixed size, the client has less flexibility in adjusting the resolution that it is fetching in case if the bandwidth changes in the middle of downloading a specific chunk.

If the video is divided into a fixed number of chunks, then the client could ensure that each chunk takes roughly the same time to download, and thus could adjust resolution much more consistently.

(e) 31 GET requests: One for the HTML page and 30 for each of the chunks.

(f) DNS allows a service to connect the client to the closest, highest bandwith CDN server storing the object that the client is requesting, without the client needing to intervene.

(g) Yes, we can tell the Youtube server Bob is connect to is not in North America.

Speed of light is $3 * 10^8 m/s$, thus the amount of time it takes for data to traverse an undersea ocean fiberoptic cable roundtrip is:

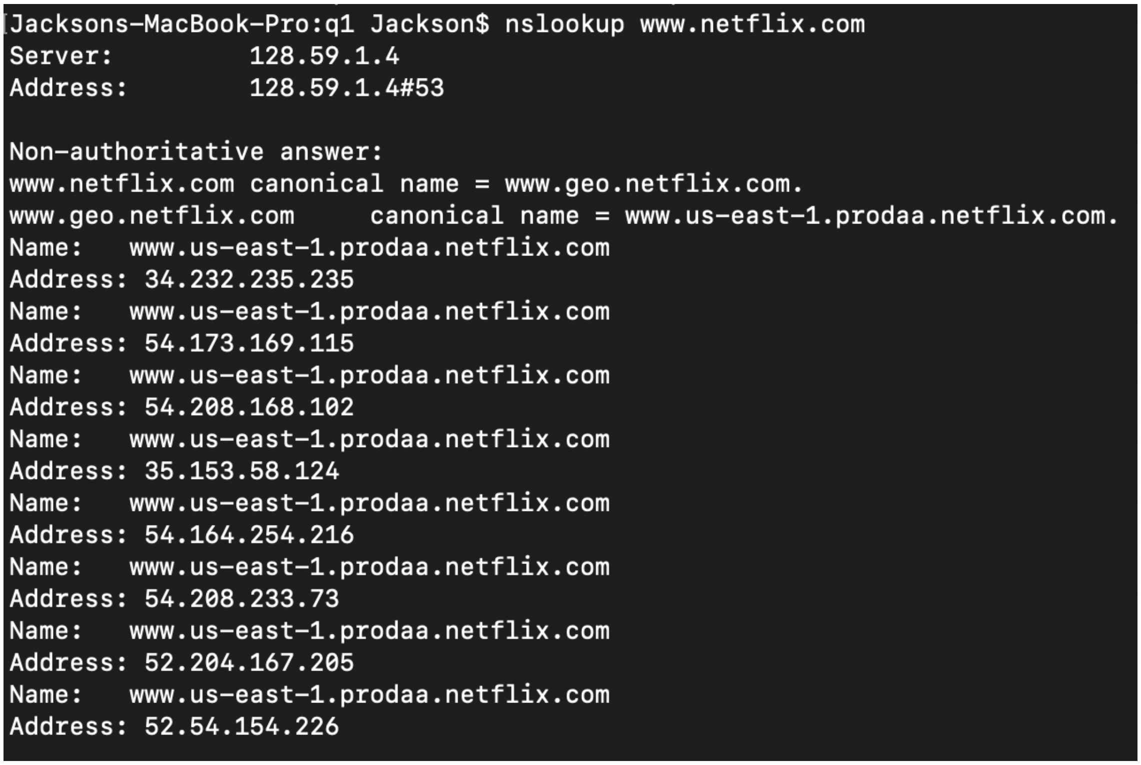
$$2 * \frac{1 * 10^7 m}{3 * 10^8 m/s} = .066s = 66ms$$

[1] https //en.wikipedia.org/wiki/QUIC#QUIC

Thus it takes at least 66 milliseconds to traverse the transcontinental cables, and the fact that Bob's computer shows a ping less than that means the request cannot be travelling transcontinent.

(h) We cannot tell in this situation since there are several factors that could contribute to the slow RTT beyond just propagation delay: for example network congestion via queueing delay could be a factor.

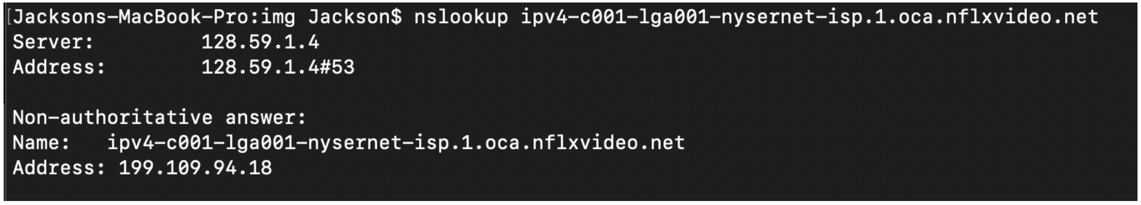
(i) A records for `www.netflix.com`



```
[Jacksons-MacBook-Pro:q1 Jackson$ nslookup www.netflix.com
Server:         128.59.1.4
Address:        128.59.1.4#53

Non-authoritative answer:
www.netflix.com canonical name = www.geo.netflix.com.
www.geo.netflix.com     canonical name = www.us-east-1.prodaa.netflix.com.
Name:   www.us-east-1.prodaa.netflix.com
Address: 34.232.235.235
Name:   www.us-east-1.prodaa.netflix.com
Address: 54.173.169.115
Name:   www.us-east-1.prodaa.netflix.com
Address: 54.208.168.102
Name:   www.us-east-1.prodaa.netflix.com
Address: 35.153.58.124
Name:   www.us-east-1.prodaa.netflix.com
Address: 54.164.254.216
Name:   www.us-east-1.prodaa.netflix.com
Address: 54.208.233.73
Name:   www.us-east-1.prodaa.netflix.com
Address: 52.204.167.205
Name:   www.us-east-1.prodaa.netflix.com
Address: 52.54.154.226
```

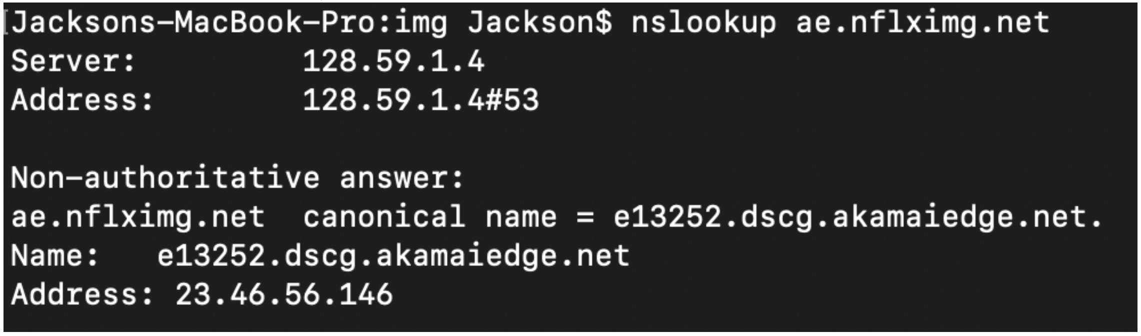
A records for `ipv4-c001-lga001-nysernet-isp.1.oca.nflxvideo.net`



```
[Jacksons-MacBook-Pro:img Jackson$ nslookup ipv4-c001-lga001-nysernet-isp.1.oca.nflxvideo.net
Server:         128.59.1.4
Address:        128.59.1.4#53

Non-authoritative answer:
Name:   ipv4-c001-lga001-nysernet-isp.1.oca.nflxvideo.net
Address: 199.109.94.18
```

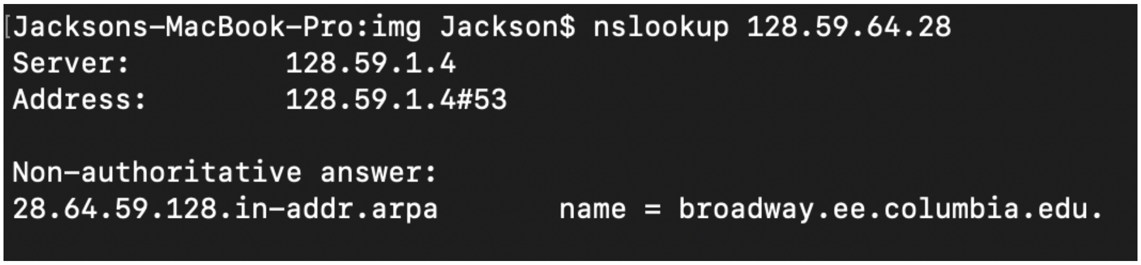
A records for `ae.nflximg.net`



```
[Jacksons-MacBook-Pro:img Jackson$ nslookup ae.nflximg.net
Server:         128.59.1.4
Address:        128.59.1.4#53

Non-authoritative answer:
ae.nflximg.net  canonical name = e13252.dscg.akamaiedge.net.
Name:   e13252.dscg.akamaiedge.net
Address: 23.46.56.146
```

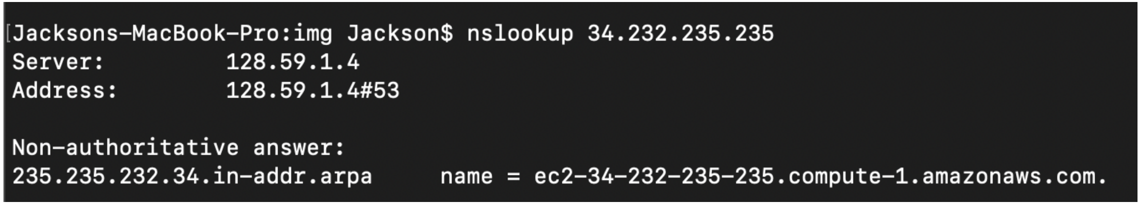
(j) The hostname of `128.59.64.28`



```
[Jacksons-MacBook-Pro:img Jackson$ nslookup 128.59.64.28
Server:         128.59.1.4
Address:        128.59.1.4#53

Non-authoritative answer:
28.64.59.128.in-addr.arpa       name = broadway.ee.columbia.edu.
```

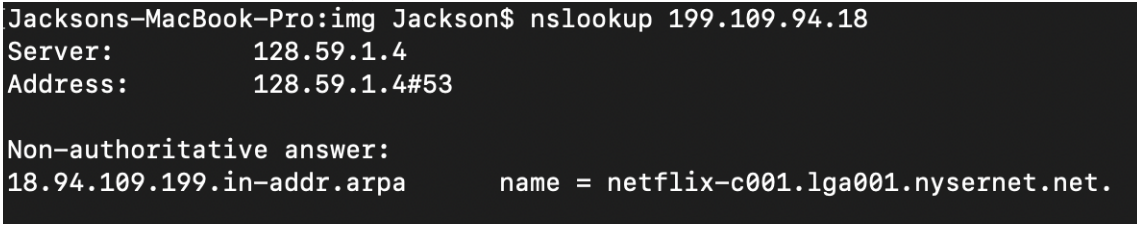
(k) `nslookup` for the IP address does not return `www.netflix.com`, this is because AWS servers handle requests from that hostname.



```
[Jacksons-MacBook-Pro:img Jackson$ nslookup 34.232.235.235
Server:         128.59.1.4
Address:        128.59.1.4#53

Non-authoritative answer:
235.235.232.34.in-addr.arpa     name = ec2-34-232-235-235.compute-1.amazonaws.com.
```

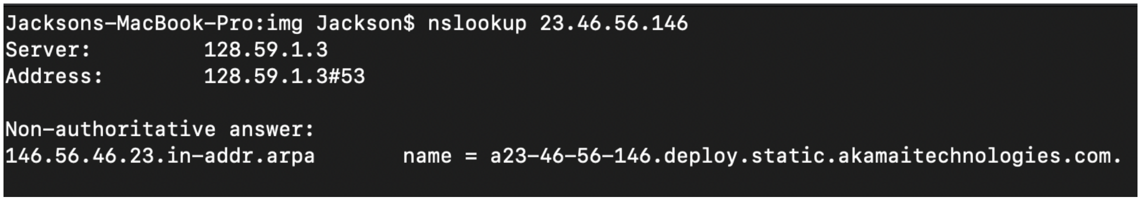
(l) No, because NYSernet, an education focused ISP that provides internet for Columbia, is handling video chunk streaming for Netflix for the Columbia network.



```
Jacksons-MacBook-Pro:img Jackson$ nslookup 199.109.94.18
Server:         128.59.1.4
Address:        128.59.1.4#53

Non-authoritative answer:
18.94.109.199.in-addr.arpa      name = netflix-c001.lga001.nysernet.net.
```

(m) No because Akamai, a CDN provider, handles image resource delivery for Netflix.

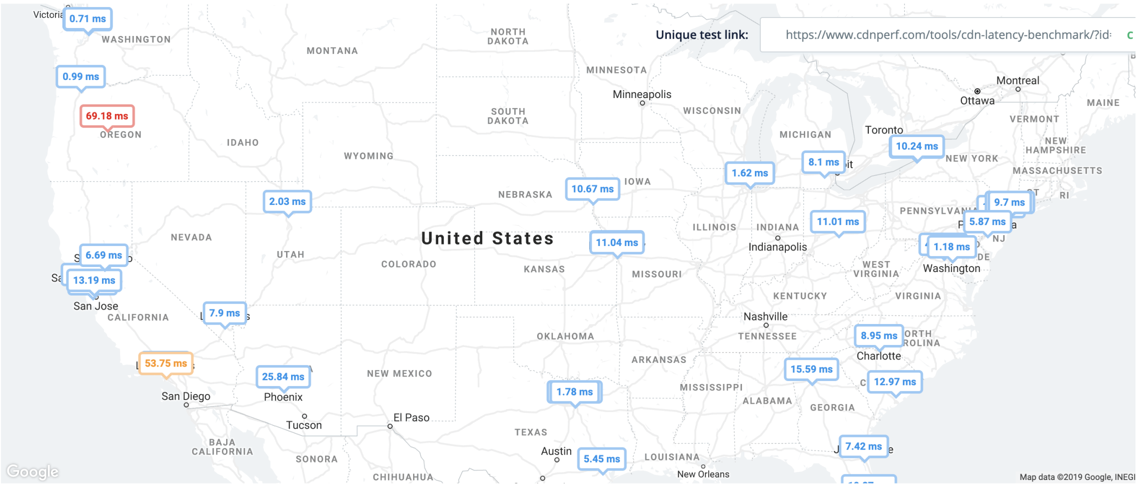


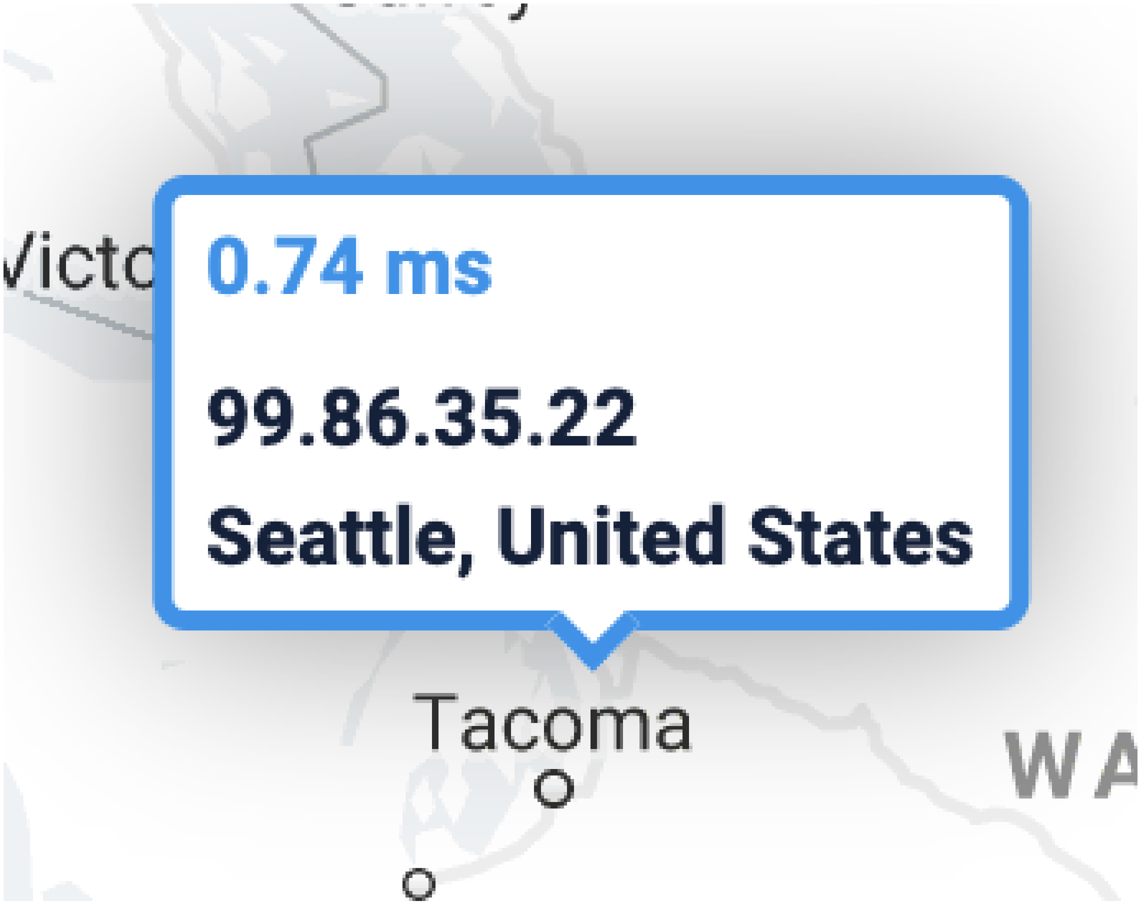
```
Jacksons-MacBook-Pro:img Jackson$ nslookup 23.46.56.146
Server:         128.59.1.3
Address:        128.59.1.3#53

Non-authoritative answer:
146.56.46.23.in-addr.arpa       name = a23-46-56-146.deploy.static.akamaitechnologies.com.
```

(n) In Seattle, the IP address is 99.86.35.22
In New York, the IP address is 99.84.46.77

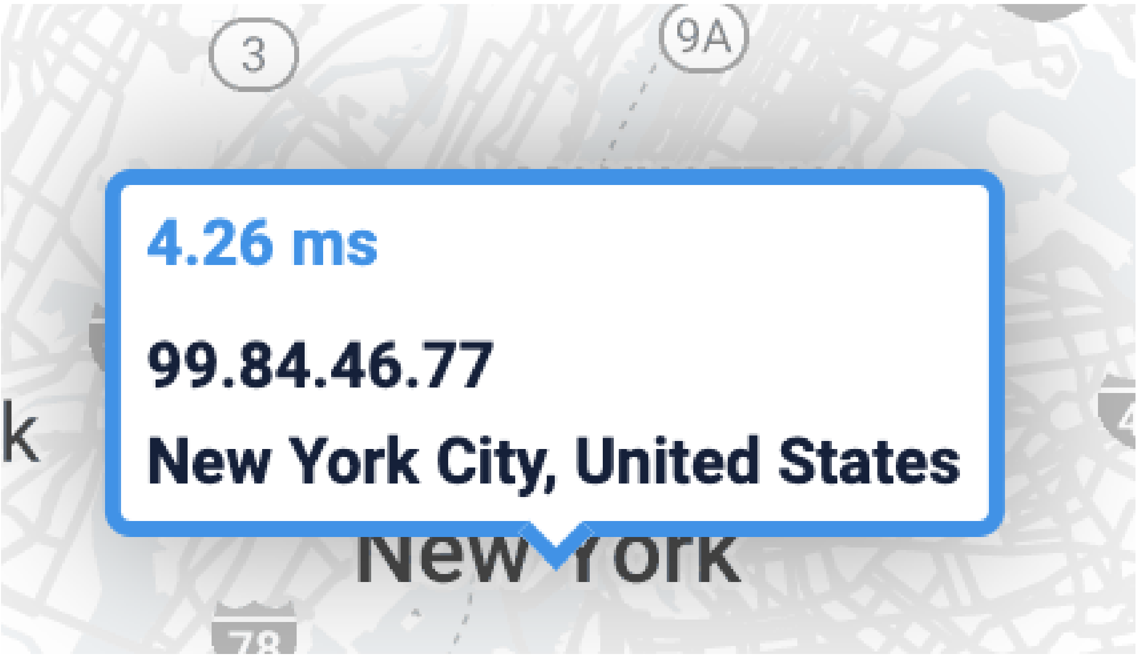
These two IP addresses are different because Amazon has different servers that handle requests in different geographic regions to minimize overall delay.


Unique test link: https://www.cdnperf.com/tools/cdn-latency-benchmark/?id


0.74 ms

99.86.35.22

Seattle, United States

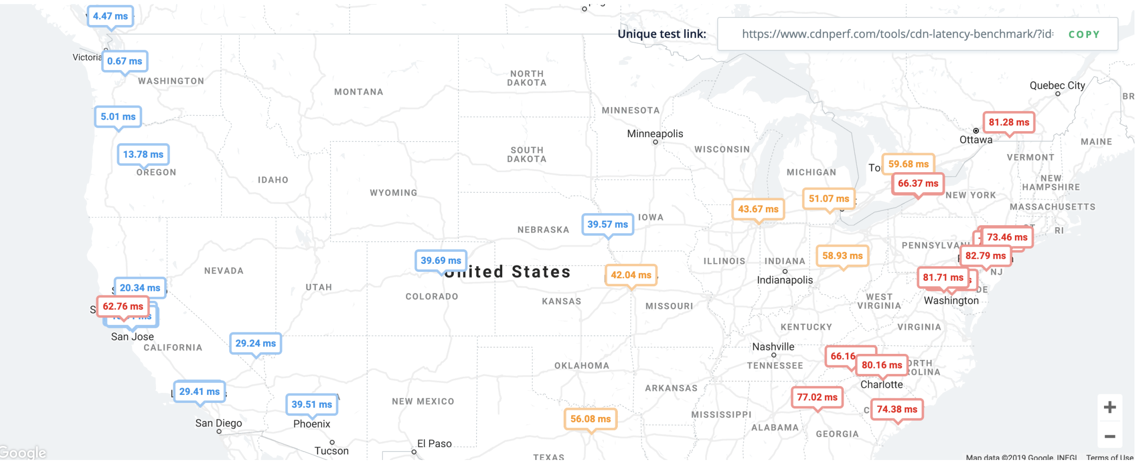


4.26 ms

99.84.46.77

New York City, United States

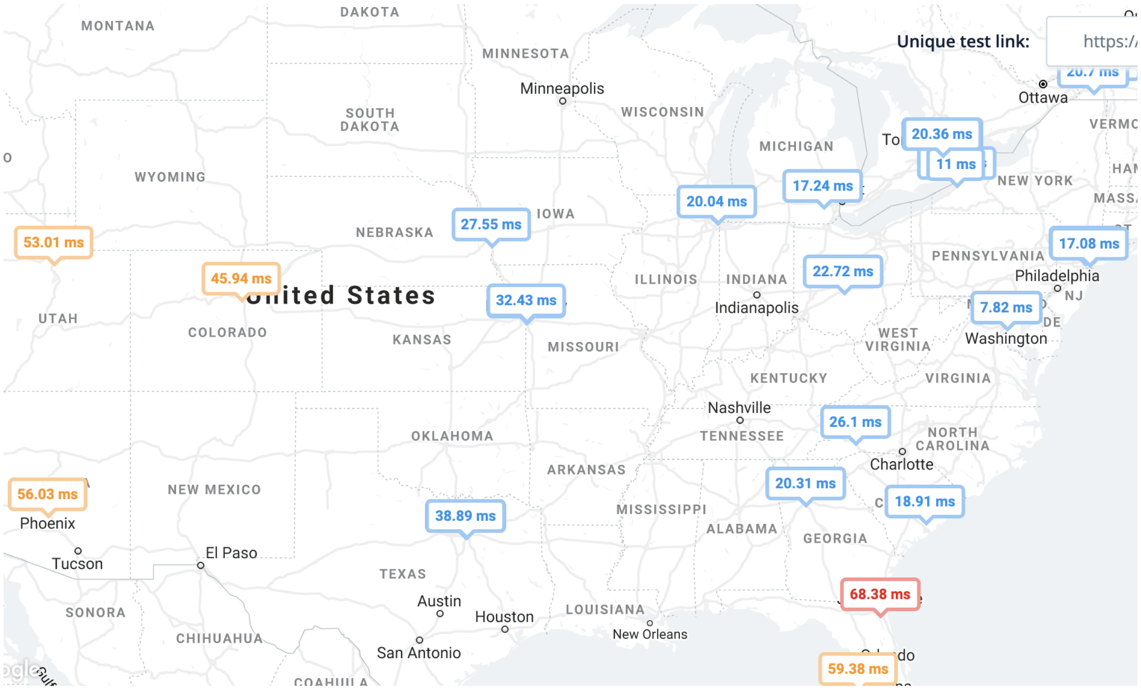
(o) The server 99.86.35.22 is most likely in the Seattle region based on the ping map:



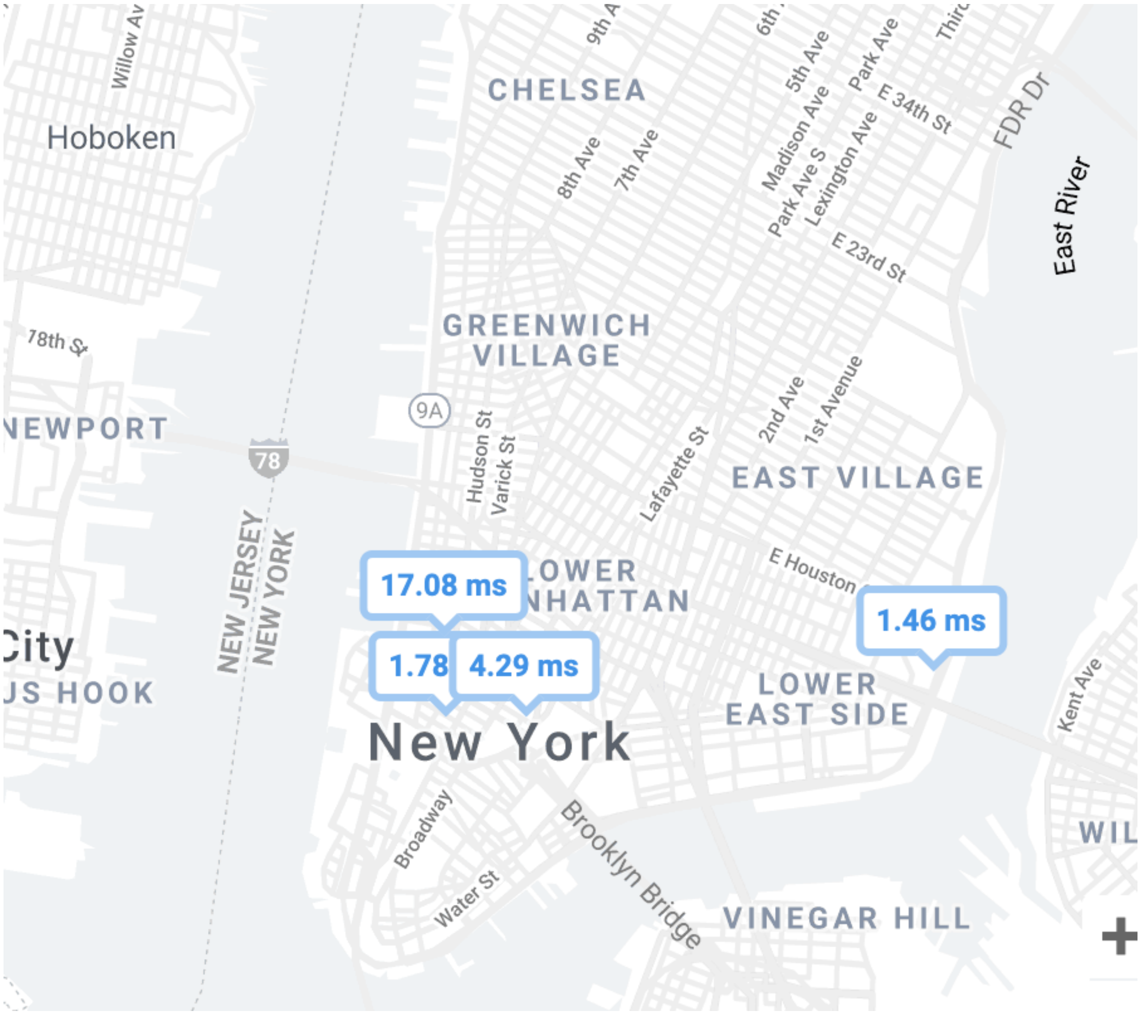
Unique test link: https://www.cdnperf.com/tools/cdn-latency-benchmark/?id COPY

Note how the pings gradually get larger as you move away from Seattle, with the shortest ping in the Seattle area.

Meanwhile the server 99.84.46.77 is most likely in the New York City region based on the ping map:



See how the pings gradually become larger as you move away from the New York City area. Furthermore, upon closer inspection within NYC:



The pings get very small once we are in NYC. This means the server is most likely in New York City.

Bonjour, Le Monde!

(a) The Columbia local DNS server

(b) DNS protocol

(c) UDP

(d) Port 53

(e) UDP is significantly faster since there is no overhead of establishing a connection for every client that is trying to resolve a domain name

(f) Smaller packet header overhead with UDP segments

(g) The application protocol does not use conditional requests. It uses TTL as an expiration date instead. This is better because it saves the amount of requests that are made to upper level servers.

(h) Local DNS Server -> Root DNS -> .fr TLD DNS server -> lemonde.fr Authoritative DNS server

(i) Yes – a deployment could exist where the authoritative DNS server is closer to the TLD DNS server, which is closer to the root DNS server than to the local DNS server.

(j) DNS poisoning may have happened, where an attacker set a bogus redirection that is cached within the DNS server

(k) DNS is vulnerable because the local DNS conducts the caching and once is set, the false redirection won't change until the cache expires.