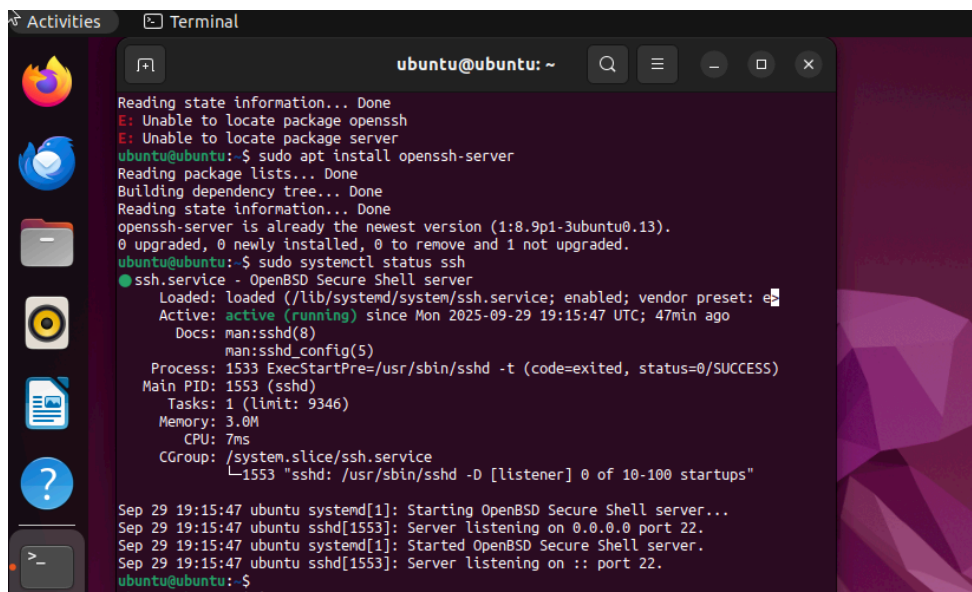


0.1,0.2, 0.3, 0.4:

```
ubuntu@ubuntu:~$ sudo apt update
[sudo] password for ubuntu:
Hit:1 http://ports.ubuntu.com/ubuntu-ports jammy InRelease
Get:2 http://ports.ubuntu.com/ubuntu-ports jammy-updates InRelease [128 kB]
Get:3 http://ports.ubuntu.com/ubuntu-ports jammy-backports InRelease [127 kB]
Get:4 http://ports.ubuntu.com/ubuntu-ports jammy-security InRelease [129 kB]
Get:5 http://ports.ubuntu.com/ubuntu-ports jammy/main arm64 DEP-11 Metadata [423 kB]
Get:6 http://ports.ubuntu.com/ubuntu-ports jammy/main DEP-11 48x48 Icons [100.0 kB]
Get:7 http://ports.ubuntu.com/ubuntu-ports jammy/main DEP-11 64x64 Icons [148 kB]
Get:8 http://ports.ubuntu.com/ubuntu-ports jammy/main DEP-11 64x6402 Icons [15.8 kB]
Get:9 http://ports.ubuntu.com/ubuntu-ports jammy/universe arm64 DEP-11 Metadata [3,360 kB]
Get:10 http://ports.ubuntu.com/ubuntu-ports jammy/universe DEP-11 48x48 Icons [3,447 kB]
Get:11 http://ports.ubuntu.com/ubuntu-ports jammy/universe DEP-11 64x64 Icons [7,609 kB]
Get:12 http://ports.ubuntu.com/ubuntu-ports jammy/universe DEP-11 64x6402 Icons [69.3 kB]
Get:13 http://ports.ubuntu.com/ubuntu-ports jammy/multiverse arm64 DEP-11 Metadata [38.8 kB]
Get:14 http://ports.ubuntu.com/ubuntu-ports jammy/multiverse DEP-11 48x48 Icons [42.7 kB]
Get:15 http://ports.ubuntu.com/ubuntu-ports jammy/multiverse DEP-11 64x64 Icons [193 kB]
Get:16 http://ports.ubuntu.com/ubuntu-ports jammy/multiverse DEP-11 64x6402 Icons [214 B]
Get:17 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main arm64 Packages [2,738 kB]
Get:18 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main arm64 DEP-11 Metadata [112 kB]
Get:19 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main DEP-11 48x48 Icons [37.0 kB]
Get:20 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main DEP-11 64x64 Icons [56.3 kB]
Get:21 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main DEP-11 64x6402 Icons [29 B]
Get:22 http://ports.ubuntu.com/ubuntu-ports jammy-updates/restricted arm64 DEP-11 Metadata [212 B]
Get:23 http://ports.ubuntu.com/ubuntu-ports jammy-updates/restricted DEP-11 48x48 Icons [29 B]
Get:24 http://ports.ubuntu.com/ubuntu-ports jammy-updates/restricted DEP-11 64x64 Icons [29 B]
Get:25 http://ports.ubuntu.com/ubuntu-ports jammy-updates/restricted DEP-11 64x6402 Icons [29 B]
Get:26 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe arm64 Packages [1,239 kB]
Get:27 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe arm64 DEP-11 Metadata [356 kB]
Get:28 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe DEP-11 48x48 Icons [250 kB]
Get:29 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe DEP-11 64x64 Icons [402 kB]
Get:30 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe DEP-11 64x6402 Icons [29 B]
Get:31 http://ports.ubuntu.com/ubuntu-ports jammy-updates/multiverse arm64 DEP-11 Metadata [212 B]
Get:32 http://ports.ubuntu.com/ubuntu-ports jammy-updates/multiverse DEP-11 48x48 Icons [1,867 B]
Get:33 http://ports.ubuntu.com/ubuntu-ports jammy-updates/multiverse DEP-11 64x64 Icons [2,497 B]
Get:34 http://ports.ubuntu.com/ubuntu-ports jammy-updates/multiverse DEP-11 64x6402 Icons [29 B]
Get:35 http://ports.ubuntu.com/ubuntu-ports jammy-backports/main arm64 DEP-11 Metadata [3,572 B]
```



```
Activities Terminal
ubuntu@ubuntu: ~
Reading state information... Done
E: Unable to locate package openssh
E: Unable to locate package server
ubuntu@ubuntu:~$ sudo apt install openssh-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
openssh-server is already the newest version (1:8.9p1-3ubuntu0.13).
0 upgraded, 0 newly installed, 0 to remove and 1 not upgraded.
ubuntu@ubuntu:~$ sudo systemctl status ssh
● ssh.service - OpenBSD Secure Shell server
   Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
   Active: active (running) since Mon 2025-09-29 19:15:47 UTC; 47min ago
     Docs: man:sshd(8)
           man:sshd_config(5)
   Process: 1533 ExecStartPre=/usr/sbin/sshd -t (code=exited, status=0/SUCCESS)
   Main PID: 1533 (sshd)
     Tasks: 1 (limit: 9346)
    Memory: 3.0M
       CPU: 7ms
   CGroup: /system.slice/ssh.service
           └─1533 "sshd: /usr/sbin/sshd -D [listener] 0 of 10-100 startups"

Sep 29 19:15:47 ubuntu systemd[1]: Starting OpenBSD Secure Shell server...
Sep 29 19:15:47 ubuntu sshd[1533]: Server listening on 0.0.0.0 port 22.
Sep 29 19:15:47 ubuntu systemd[1]: Started OpenBSD Secure Shell server.
Sep 29 19:15:47 ubuntu sshd[1533]: Server listening on :: port 22.
ubuntu@ubuntu:~$
```


1.2

OpenSSH creates a secure server, the SSH Daemon on the Ubuntu virtual machine which listens on TCP port 22. The client will send a TCP SYN packet to the virtual machine's IP address on port 22. The virtual machine will reply with a SYN-ACK packet, and the client will respond with an ACK packet to complete the TCP three-way handshake. This allows the client to use the SSH protocol: typing `ssh username@IP`. The virtual machine will accept encrypted packets with username and password, decrypt them and respond. If the authentication is accepted, the terminal can be then interacted with and streamed over the connection.

1.3

```
status: active
((base) gabrielurbaitis@Gabriels-MacBook-Pro ~ % ssh ubuntu@192.168.64.4
The authenticity of host '192.168.64.4 (192.168.64.4)' can't be established.
ED25519 key fingerprint is SHA256:Y0J9kT4KlqiQEZmvZZf2bXCSwuSw0AR4C1BKc0/m4RI.
This key is not known by any other names.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '192.168.64.4' (ED25519) to the list of known hosts.
[ubuntu@192.168.64.4's password:
Welcome to Ubuntu 22.04.5 LTS (GNU/Linux 5.15.0-156-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/pro

System information as of Mon Sep 29 10:33:58 PM UTC 2025

System load:          0.43
Usage of /:           44.0% of 29.82GB
Memory usage:        24%
Swap usage:          0%
Processes:           262
Users logged in:     1
IPv4 address for enp0s1: 192.168.64.4
IPv6 address for enp0s1: fdab:f349:27a2:63b3:c8c9:72ff:fe01:4e78

Expanded Security Maintenance for Applications is not enabled.

1 update can be applied immediately.
1 of these updates is a standard security update.
To see these additional updates run: apt list --upgradable

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

New release '24.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Mon Sep 29 17:48:34 2025
ubuntu@ubuntu:~$ █
```

2.1

```
(base) gabrielurbaitis@Gabriels-MacBook-Pro ~ % ping -c 4 unn.edu
ping -c 4 mit.edu
ping -c 4 unam.mx
ping -c 4 home.iitd.ac.in
ping -c 4 cmu.edu
ping -c 4 kaust.edu.sa
ping -c 4 cornell.edu
ping -c 4 ufl.edu
ping -c 4 berkeley.edu
ping -c 4 192.168.64.4
PING unn.edu (129.24.172.124): 56 data bytes
64 bytes from 129.24.172.124: icmp_seq=0 ttl=243 time=29.979 ms
64 bytes from 129.24.172.124: icmp_seq=1 ttl=243 time=34.301 ms
64 bytes from 129.24.172.124: icmp_seq=2 ttl=243 time=34.647 ms
64 bytes from 129.24.172.124: icmp_seq=3 ttl=243 time=31.842 ms

--- unn.edu ping statistics ---
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 29.979/32.492/34.647/2.021 ms
PING mit.edu (184.72.113.150): 56 data bytes
64 bytes from 184.72.113.150: icmp_seq=0 ttl=44 time=48.995 ms
64 bytes from 184.72.113.150: icmp_seq=1 ttl=44 time=53.341 ms
64 bytes from 184.72.113.150: icmp_seq=2 ttl=44 time=52.472 ms
64 bytes from 184.72.113.150: icmp_seq=3 ttl=44 time=49.590 ms

--- mit.edu ping statistics ---
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 48.995/51.099/53.341/1.865 ms
PING unam.mx (132.248.166.19): 56 data bytes
64 bytes from 132.248.166.19: icmp_seq=0 ttl=47 time=64.147 ms
64 bytes from 132.248.166.19: icmp_seq=1 ttl=47 time=68.934 ms
64 bytes from 132.248.166.19: icmp_seq=2 ttl=47 time=67.696 ms
64 bytes from 132.248.166.19: icmp_seq=3 ttl=47 time=65.928 ms

--- unam.mx ping statistics ---
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 64.147/66.676/68.934/1.809 ms
PING home.iitd.ac.in (183.27.9.24): 56 data bytes
Request timeout for icmp_seq 0
Request timeout for icmp_seq 1
Request timeout for icmp_seq 2

--- home.iitd.ac.in ping statistics ---
4 packets transmitted, 0 packets received, 100.0% packet loss
PING cmu.edu (128.2.42.10): 56 data bytes
64 bytes from 128.2.42.10: icmp_seq=0 ttl=239 time=51.770 ms
64 bytes from 128.2.42.10: icmp_seq=1 ttl=239 time=55.191 ms
64 bytes from 128.2.42.10: icmp_seq=2 ttl=239 time=55.480 ms
64 bytes from 128.2.42.10: icmp_seq=3 ttl=239 time=51.884 ms

--- cmu.edu ping statistics ---
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 51.770/53.581/55.480/1.758 ms
PING kaust.edu.sa (45.223.20.138): 56 data bytes
64 bytes from 45.223.20.138: icmp_seq=0 ttl=57 time=36.686 ms
64 bytes from 45.223.20.138: icmp_seq=1 ttl=57 time=41.400 ms
64 bytes from 45.223.20.138: icmp_seq=2 ttl=57 time=38.438 ms
64 bytes from 45.223.20.138: icmp_seq=3 ttl=57 time=37.338 ms

--- kaust.edu.sa ping statistics ---
```

--- kaust.edu.sa ping statistics ---

```
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 36.686/38.465/41.400/1.806 ms
PING cornell.edu (128.253.173.242): 56 data bytes
Request timeout for icmp_seq 0
Request timeout for icmp_seq 1
Request timeout for icmp_seq 2
```

--- cornell.edu ping statistics ---

```
4 packets transmitted, 0 packets received, 100.0% packet loss
PING ufl.edu (128.227.36.35): 56 data bytes
64 bytes from 128.227.36.35: icmp_seq=0 ttl=234 time=71.102 ms
64 bytes from 128.227.36.35: icmp_seq=1 ttl=234 time=70.625 ms
64 bytes from 128.227.36.35: icmp_seq=2 ttl=234 time=74.520 ms
64 bytes from 128.227.36.35: icmp_seq=3 ttl=234 time=70.574 ms
```

--- ufl.edu ping statistics ---

```
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 70.574/71.705/74.520/1.638 ms
PING berkeley.edu (141.193.213.20): 56 data bytes
64 bytes from 141.193.213.20: icmp_seq=0 ttl=55 time=32.845 ms
64 bytes from 141.193.213.20: icmp_seq=1 ttl=55 time=33.188 ms
64 bytes from 141.193.213.20: icmp_seq=2 ttl=55 time=33.793 ms
64 bytes from 141.193.213.20: icmp_seq=3 ttl=55 time=37.039 ms
```

--- berkeley.edu ping statistics ---

```
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 32.845/34.216/37.039/1.665 ms
PING 192.168.64.4 (192.168.64.4): 56 data bytes
64 bytes from 192.168.64.4: icmp_seq=0 ttl=64 time=0.303 ms
64 bytes from 192.168.64.4: icmp_seq=1 ttl=64 time=0.489 ms
64 bytes from 192.168.64.4: icmp_seq=2 ttl=64 time=0.344 ms
64 bytes from 192.168.64.4: icmp_seq=3 ttl=64 time=0.483 ms
```

--- 192.168.64.4 ping statistics ---

```
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.303/0.405/0.489/0.083 ms
(base) gabrielurbaitis@Gabriels-MacBook-Pro ~ % █
```

Geolocation data from IP2Location	Product: DB6, 2025-9-15	Geolocation data from IP2Location	Product: DB6, 2025-9-15	Geolocation data from IP2Location	Product: DB6, 2025-9-15
<p>IP ADDRESS: 129.24.172.124</p> <p>COUNTRY: United States</p> <p>REGION: New Mexico</p> <p>CITY: Albuquerque</p> <p>ISP: University of New Mexico</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 35.0845</p> <p>LONGITUDE: -106.6511</p>		<p>IP ADDRESS: 104.72.113.150</p> <p>COUNTRY: United States</p> <p>REGION: Pennsylvania</p> <p>CITY: Pittsburgh</p> <p>ISP: Akamai Technologies Inc.</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 40.4406</p> <p>LONGITUDE: -79.9959</p>		<p>IP ADDRESS: 132.248.166.19</p> <p>COUNTRY: Mexico</p> <p>REGION: Ciudad de Mexico</p> <p>CITY: Mexico City</p> <p>ISP: Universidad Nacional Autonoma de Mexico</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 19.4285</p> <p>LONGITUDE: -99.1276</p>	
<p>IP ADDRESS: 103.27.9.24</p> <p>COUNTRY: India</p> <p>REGION: Delhi</p> <p>CITY: Delhi</p> <p>ISP: Indian Institute of Technology</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 28.6688</p> <p>LONGITUDE: 77.2167</p>		<p>IP ADDRESS: 128.2.42.10</p> <p>COUNTRY: United States</p> <p>REGION: Pennsylvania</p> <p>CITY: Bloomfield</p> <p>ISP: Carnegie Mellon University</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 40.4609</p> <p>LONGITUDE: -79.9508</p>		<p>IP ADDRESS: 45.223.20.138</p> <p>COUNTRY: United States</p> <p>REGION: California</p> <p>CITY: San Mateo</p> <p>ISP: Incapsula Inc</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 37.5629</p> <p>LONGITUDE: -122.3257</p>	
<p>IP ADDRESS: 128.253.173.242</p> <p>COUNTRY: United States</p> <p>REGION: New York</p> <p>CITY: East Ithaca</p> <p>ISP: Cornell University</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 42.4396</p> <p>LONGITUDE: -76.4787</p>		<p>IP ADDRESS: 128.227.36.35</p> <p>COUNTRY: United States</p> <p>REGION: Florida</p> <p>CITY: Gainesville</p> <p>ISP: University of Florida</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 29.6516</p> <p>LONGITUDE: -82.3250</p>		<p>IP ADDRESS: 141.193.213.20</p> <p>COUNTRY: United States</p> <p>REGION: Texas</p> <p>CITY: Austin</p> <p>ISP: WPEngine Inc.</p> <p>ORGANIZATION: Not available</p> <p>LATITUDE: 30.2672</p> <p>LONGITUDE: -97.7431</p>	


Tried again 30 min later

```
[(base) gabrielurbaitis@Gabriels-MacBook-Pro ~ % ping -c 4 home.iitd.ac.in
PING home.iitd.ac.in (103.27.9.24): 56 data bytes
Request timeout for icmp_seq 0
Request timeout for icmp_seq 1
Request timeout for icmp_seq 2

--- home.iitd.ac.in ping statistics ---
4 packets transmitted, 0 packets received, 100.0% packet loss
[(base) gabrielurbaitis@Gabriels-MacBook-Pro ~ % ping -c 4 cornell.edu
PING cornell.edu (128.253.173.241): 56 data bytes
Request timeout for icmp_seq 0
Request timeout for icmp_seq 1
Request timeout for icmp_seq 2

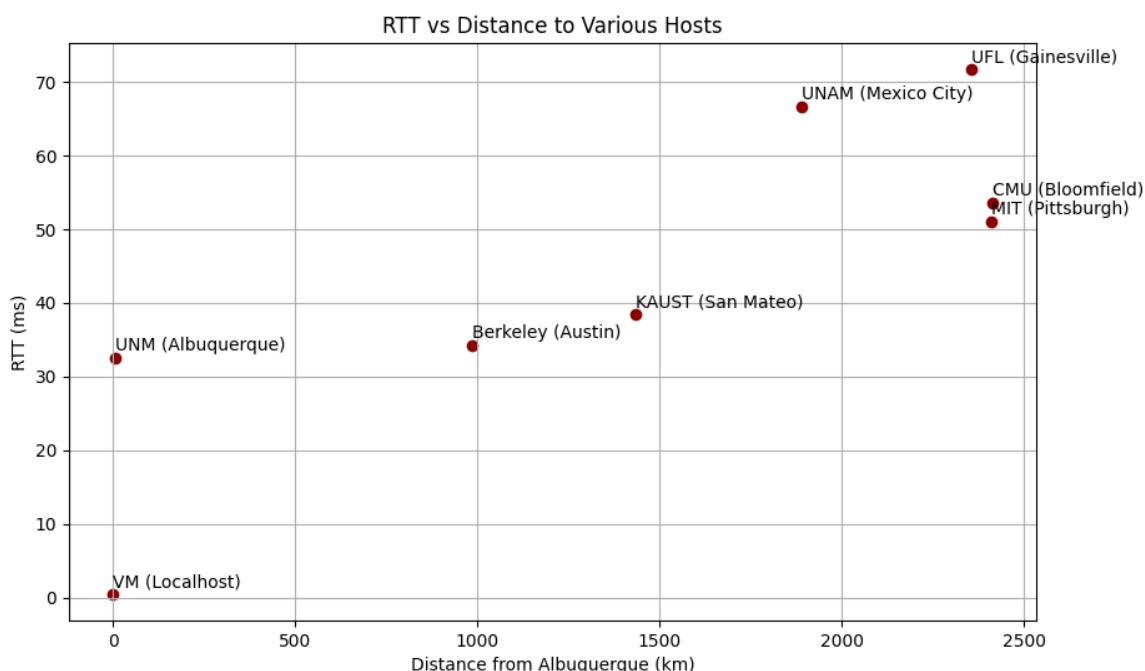
--- cornell.edu ping statistics ---
4 packets transmitted, 0 packets received, 100.0% packet loss
```

2.2

Host name	City	Distance (km)	RTT (avg) (ms)
unm.edu	Albuquerque	4.54	32.492
mit.edu	Pittsburgh	2408.8	51.099
unam.mx	Mexico City	1889.08	66.676
home.iitd.ac.in	Delhi	12932.49	100% packet drop
cmu.edu	Bloomfield	2412.85	53.581
kaust.edu.sa	San Mateo 	1434.55	38.465
cornell.edu	East Ithaca	2726.36	100% packet drop
ufl.edu	Gainesville	2355.77	71.705
berkeley.edu	Austin	987.2	34.216
virtual machine	Albuquerque	0.00	0.489

2.3

It seems like, as we would expect, distance is mostly correlated with greater RTT. The exceptions are the Pennsylvania servers, which have lower RTT than UNAM and UFL despite being further away. Perhaps this is due to better infrastructure, or in UNAM's case not having to switch ISPs in different countries. It is also notable that Cornell and Delhi had 100% packet drop, even after checking twice. They are both further than 2500 km away and the two furthest servers, however we have seen that we can ping Cambridge in class, so the distance is probably just coincidence.



3.0

Filesize = 3MB = $3 * 2^{20}$ bytes = 3,145,728 bytes

Packetsize = 1Kb = 2^{10} bytes = 1,024 bytes

Payload = Packetsize - header = 1024 - 40 = 984 bytes

Number of packets = Filesize/Payload = 3,145,728 bytes/984 bytes = 3196.878 round up = 3,197 packets

Total bits sent = Packets * Packet size * 8 bits/byte = 3,197 * 1,024 * 8 = 26,189,824 bits

Bandwidth = 10^6 bits/sec = 1,000,000 bits/sec

Transmission time for bits = 26,189,824 bits / 1,000,000 bits/sec = 26.189824 seconds

One way delay = 40ms

RTT = $2 * \text{OWD}$ = $2 * 40$ = 80ms

Handshake time = RTT = 80ms

3.1

Total time = handshake + transmission time for bits + one way delay for last bit

Total time = .08 + 26.189824 + .04 = 26.309824 seconds

3.2

3197 packets = 3196 RTTs waiting between packets

Delay = 3196 RTTs = 3196*.80 = 2556.8s

Total time = 26.309824s+ 2556.8s = 2583.109824s

4.1

Network Working Group
Request for Comments: 1035

P. Mockapetris
ISI
November 1987

Obsoletes: RFCs 882, 883, 973

DOMAIN NAMES - IMPLEMENTATION AND SPECIFICATION

1. STATUS OF THIS MEMO

This RFC describes the details of the domain system and protocol, and assumes that the reader is familiar with the concepts discussed in a companion RFC, "Domain Names - Concepts and Facilities" [RFC-1034].

The domain system is a mixture of functions and data types which are an official protocol and functions and data types which are still experimental. Since the domain system is intentionally extensible, new data types and experimental behavior should always be expected in parts of the system beyond the official protocol. The official protocol parts include standard queries, responses and the Internet class RR data formats (e.g., host addresses). Since the previous RFC set, several definitions have changed, so some previous definitions are obsolete.

Experimental or obsolete features are clearly marked in these RFCs, and such information should be used with caution.

The reader is especially cautioned not to depend on the values which appear in examples to be current or complete, since their purpose is primarily pedagogical. Distribution of this memo is unlimited.

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Mockapetris

[Page 1]

Domain names are arguments to local agents called resolvers, which retrieve information associated with the domain name. They are needed because otherwise every application would have to implement the full DNS logic themselves. The resolver starts with knowledge of at least one name server. When the resolver processes a user query it asks a known name server for the information; in return, the resolver either receives the desired

information or a referral to another name server. Name servers are needed to provide an authoritative source of truth for domain records.

Name servers manage caches, and zones. . Cached data is a kind of data which is acquired by a local resolver. It improves the performance of the retrieval process when non-local data is repeatedly accessed. Cached data is eventually timed out. Cache data is needed to reduce network traffic and latency. As for the zones, each zone is the complete database for a particular "pruned" subtree of the domain space, and the data is authoritative. The internet is too large to be managed centrally so zones are needed to allow DNS to be distributed. A name server periodically checks to make sure that its zones are up to date, and if not, obtains a new copy of updated zones from master files stored locally or in another name server.

Master files are text files that contain Resource Records in text form. Since the contents of a zone can be expressed in the form of a list of Resource Records, a master file is most often used to define a zone, though it can be used to list a cache's contents. Master files are needed to provide a structured way to store and update DNS data.

4.2

The root is the null label at the top of the DNS tree which delegates responsibility to the top-level domains like .edu, .com, etc. It is represented by a null label, written as a dot. If a resolver doesn't have information, the root will be asked and a referral to a TLD will be given.

4.3

Zones make the DNS database easier to organize. Each zone holds the resource records for that part of the Internet, such as the IP addresses of its servers. By splitting the DNS into zones, responsibility is delegated from one level to another, the root points to the .edu zone, and .edu points to the unm.edu zone. This allows for scalability as each group manages only its own zone, but together all the zones create the full domain database.

4.4

When asking the resolver for the ice.edu, the root name server is queried, it provides a referral to the TLD server for .edu. The .edu authoritative name server is queried and it provides a referral to isi.edu which is queried to get the resource record containing the IP address. Subdomains are names under a higher level domain, such as cs.unm.edu under unm.edu. unm.edu can either store the records for that subdomain or delegate it to another name server just for cs.unm.edu.