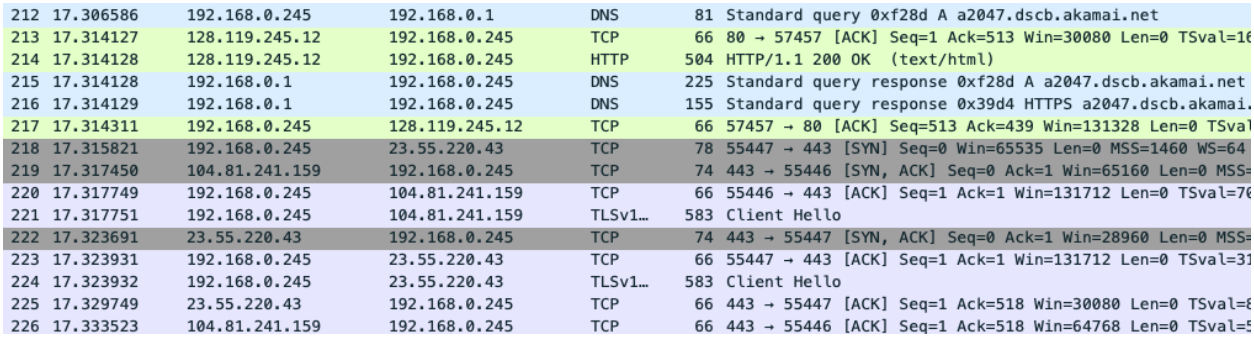
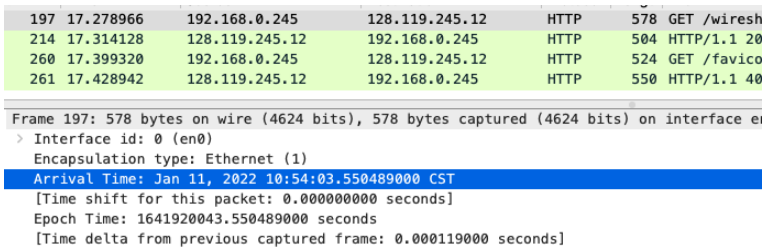
# Part A:

1. There are HTTP, DNS, TCP, etc.

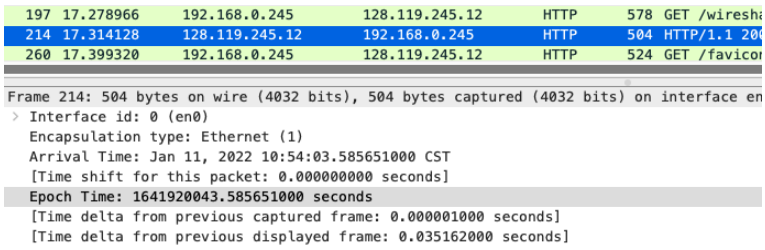


```
212  17.306586   192.168.0.245   192.168.0.1      DNS      81  Standard query 0xf28d A a2047.dscb.akamai.net
213  17.314127   128.119.245.12  192.168.0.245    TCP      66  80 → 57457 [ACK] Seq=1 Ack=513 Win=30080 Len=0 TSval=16
214  17.314128   128.119.245.12  192.168.0.245    HTTP    504  HTTP/1.1 200 OK  (text/html)
215  17.314128   192.168.0.1     192.168.0.245    DNS     225  Standard query response 0xf28d A a2047.dscb.akamai.net
216  17.314129   192.168.0.1     192.168.0.245    DNS     155  Standard query response 0x39d4 HTTPS a2047.dscb.akamai.
217  17.314311   192.168.0.245   128.119.245.12   TCP      66  57457 → 80 [ACK] Seq=513 Ack=439 Win=131328 Len=0 TSval
218  17.315821   192.168.0.245   23.55.220.43     TCP      78  55447 → 443 [SYN] Seq=0 Win=65535 Len=0 MSS=1460 WS=64
219  17.317450   104.81.241.159  192.168.0.245    TCP      74  443 → 55446 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=
220  17.317749   192.168.0.245   104.81.241.159   TCP      66  55446 → 443 [ACK] Seq=1 Ack=1 Win=131712 Len=0 TSval=70
221  17.317751   192.168.0.245   104.81.241.159   TLSv1…  583  Client Hello
222  17.323691   23.55.220.43    192.168.0.245    TCP      74  443 → 55447 [SYN, ACK] Seq=0 Ack=1 Win=28960 Len=0 MSS=
223  17.323931   192.168.0.245   23.55.220.43     TCP      66  55447 → 443 [ACK] Seq=1 Ack=1 Win=131712 Len=0 TSval=31
224  17.323932   192.168.0.245   23.55.220.43     TLSv1…  583  Client Hello
225  17.329749   23.55.220.43    192.168.0.245    TCP      66  443 → 55447 [ACK] Seq=1 Ack=518 Win=30080 Len=0 TSval=8
226  17.333523   104.81.241.159  192.168.0.245    TCP      66  443 → 55446 [ACK] Seq=1 Ack=518 Win=64768 Len=0 TSval=5
```

2. From the below image we can see the GET arrival time is 10:54:03.550489000, the OK arrival time is 10:54:03.585651000, so it takes 0.585651000 - 0.550489000 = 0.035162secs

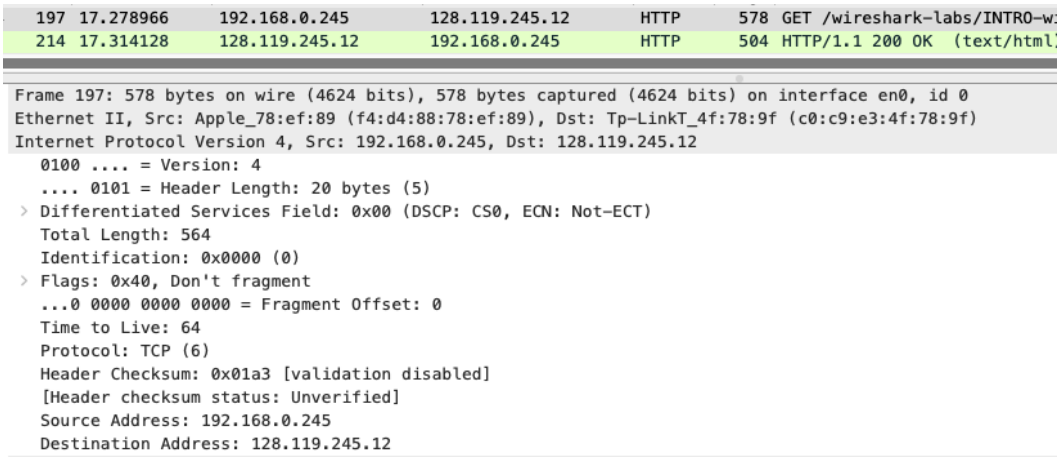


```
197  17.278966   192.168.0.245   128.119.245.12   HTTP    578  GET /wiresh
214  17.314128   128.119.245.12  192.168.0.245    HTTP    504  HTTP/1.1 20
260  17.399320   192.168.0.245   128.119.245.12   HTTP    524  GET /favico
261  17.428942   128.119.245.12  192.168.0.245    HTTP    550  HTTP/1.1 40

Frame 197: 578 bytes on wire (4624 bits), 578 bytes captured (4624 bits) on interface e
  Interface id: 0 (en0)
  Encapsulation type: Ethernet (1)
  Arrival Time: Jan 11, 2022 10:54:03.550489000 CST
  [Time shift for this packet: 0.000000000 seconds]
  Epoch Time: 1641920043.550489000 seconds
  [Time delta from previous captured frame: 0.000119000 seconds]
```



```
197  17.278966   192.168.0.245   128.119.245.12   HTTP    578  GET /wiresha
214  17.314128   128.119.245.12  192.168.0.245    HTTP    504  HTTP/1.1 20
260  17.399320   192.168.0.245   128.119.245.12   HTTP    524  GET /favicon

Frame 214: 504 bytes on wire (4032 bits), 504 bytes captured (4032 bits) on interface en
  Interface id: 0 (en0)
  Encapsulation type: Ethernet (1)
  Arrival Time: Jan 11, 2022 10:54:03.585651000 CST
  [Time shift for this packet: 0.000000000 seconds]
  Epoch Time: 1641920043.585651000 seconds
  [Time delta from previous captured frame: 0.000001000 seconds]
  [Time delta from previous displayed frame: 0.035162000 seconds]
```

3. From the image below, my address (the source) is 192.168.0.245, the website's address (the destination) is 128.119.245.12



```
197  17.278966   192.168.0.245   128.119.245.12   HTTP    578  GET /wireshark-labs/INTRO-w
214  17.314128   128.119.245.12  192.168.0.245    HTTP    504  HTTP/1.1 200 OK  (text/html

Frame 197: 578 bytes on wire (4624 bits), 578 bytes captured (4624 bits) on interface en0, id 0
Ethernet II, Src: Apple_78:ef:89 (f4:d4:88:78:ef:89), Dst: Tp-LinkT_4f:78:9f (c0:c9:e3:4f:78:9f)
Internet Protocol Version 4, Src: 192.168.0.245, Dst: 128.119.245.12
  0100 .... = Version: 4
  .... 0101 = Header Length: 20 bytes (5)
  Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
  Total Length: 564
  Identification: 0x0000 (0)
  Flags: 0x40, Don't fragment
  ...0 0000 0000 0000 = Fragment Offset: 0
  Time to Live: 64
  Protocol: TCP (6)
  Header Checksum: 0x01a3 [validation disabled]
  [Header checksum status: Unverified]
  Source Address: 192.168.0.245
  Destination Address: 128.119.245.12
```

# Part B:

1. In circuit-switched networks, the resources are limited but reserved. Therefore the people on the phone can transfer voice messages to each other at the guaranteed constant rate and expect the minimum delay under the dedicated channel. However, packet-switching will be a nightmare for constant voice transfer. If the voice packets are lost during high-traffic times, the conversation no longer makes sense. And it doesn't have an end-to-end & dedicated connection between two hosts.
2. Because web browsing includes large pieces of data to be transferred and it asks for efficiency. Since packet-switching doesn't require a dedicated channel, it can use all bandwidth and make good use of space to transfer data at high speed. Also, it allows many users to 'communicate' at the same time (as opposed to two people talking on the phone). And if data fails to get transferred, it will be re-routed and re-sent, which is very convenient.
3. 1) It can happen due to congestion. If the current data exceeds the capacity, packets at the end of the queue might be dropped or missed.

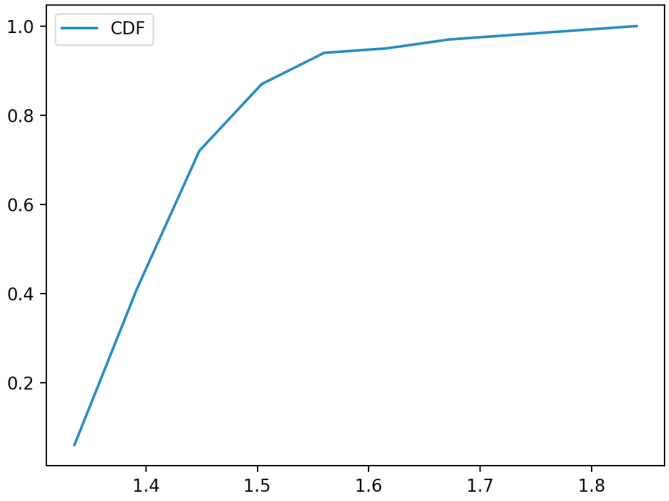
   2) It can also happen due to hardware problems. Say, the network work is down, and the many network switches and routers were out of power, then the packets can be missed.
4. 121 minutes = 7260 secs
   4K-resolution time: 13GB/10Mbps = 13*8*10^9 bits/10^7 bps = 10400 secs > 7260
   HD-resolution time: 6GB/10Mbps = 6*8*10^9 bits/10^7 bps = 4800 secs < 7260
   SD-resolution time: 2GB/10Mbps = 2*8*10^9 bits/10^7 bps = 1600 secs < 7260
   So the best version is with HD resolution.
5. Fiber-optic connection is much faster than the ADSL connection at home. It helps reduce chances of internet congestion and greatly decreases delay time. Though the average bandwidth on campus is less than that at home, the data travels much faster than that at home.
6. a) It may happen because of network congestion. The traffic can be terrible if there are too many simultaneous active users sharing the same network service. So the aggregate arrival rate of packets exceeds the output capacity of the link. It may also be due to some outage in the area so that the data fails to/slowly get transferred.

   b) Some certain websites might be very popular, but the web server is old and can only deal with a certain number of visitors→bad performance. It can also happen if the web server is located far away from where we are (like in another continent). The third possibility is that your router is improperly set.
7. I chose RFC 9156: https://www.rfc-editor.org/rfc/rfc9156.pdf to explain.

   Almost every activity on the internet involves DNS queries. So it's very important to keep the privacy during information exchange. DNS queries can be something like "what are the QTYPE records of the QNAME? However, when the recursive resolver and name servers exchange information multiple rounds, the DNS queries reveal more information than needed even though the specific name server doesn't need to know the full QNAME. This is highly risky. This article is trying to minimize QNAME to improve privacy performance.

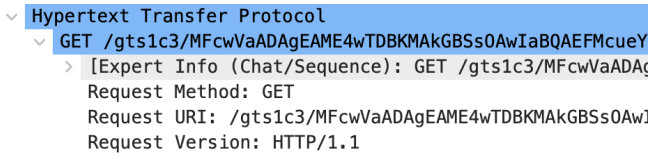
8. Left hand side is a screenshot of the output. Right hand side is CDF

```
64 bytes from 129.105.0.1: icmp_seq=67 ttl=252 time=1.37 ms
64 bytes from 129.105.0.1: icmp_seq=68 ttl=252 time=1.43 ms
64 bytes from 129.105.0.1: icmp_seq=69 ttl=252 time=1.33 ms
64 bytes from 129.105.0.1: icmp_seq=70 ttl=252 time=1.40 ms
64 bytes from 129.105.0.1: icmp_seq=71 ttl=252 time=1.41 ms
64 bytes from 129.105.0.1: icmp_seq=72 ttl=252 time=1.38 ms
64 bytes from 129.105.0.1: icmp_seq=73 ttl=252 time=1.36 ms
64 bytes from 129.105.0.1: icmp_seq=74 ttl=252 time=1.47 ms
64 bytes from 129.105.0.1: icmp_seq=75 ttl=252 time=1.40 ms
64 bytes from 129.105.0.1: icmp_seq=76 ttl=252 time=1.39 ms
64 bytes from 129.105.0.1: icmp_seq=77 ttl=252 time=1.41 ms
64 bytes from 129.105.0.1: icmp_seq=78 ttl=252 time=1.45 ms
64 bytes from 129.105.0.1: icmp_seq=79 ttl=252 time=1.39 ms
64 bytes from 129.105.0.1: icmp_seq=80 ttl=252 time=1.42 ms
64 bytes from 129.105.0.1: icmp_seq=81 ttl=252 time=1.44 ms
64 bytes from 129.105.0.1: icmp_seq=82 ttl=252 time=1.38 ms
64 bytes from 129.105.0.1: icmp_seq=83 ttl=252 time=1.51 ms
64 bytes from 129.105.0.1: icmp_seq=84 ttl=252 time=1.39 ms
64 bytes from 129.105.0.1: icmp_seq=85 ttl=252 time=1.39 ms
64 bytes from 129.105.0.1: icmp_seq=86 ttl=252 time=1.39 ms
64 bytes from 129.105.0.1: icmp_seq=87 ttl=252 time=1.39 ms
64 bytes from 129.105.0.1: icmp_seq=88 ttl=252 time=1.44 ms
64 bytes from 129.105.0.1: icmp_seq=89 ttl=252 time=1.58 ms
64 bytes from 129.105.0.1: icmp_seq=90 ttl=252 time=1.67 ms
64 bytes from 129.105.0.1: icmp_seq=91 ttl=252 time=1.46 ms
64 bytes from 129.105.0.1: icmp_seq=92 ttl=252 time=1.51 ms
64 bytes from 129.105.0.1: icmp_seq=93 ttl=252 time=1.42 ms
64 bytes from 129.105.0.1: icmp_seq=94 ttl=252 time=1.51 ms
```

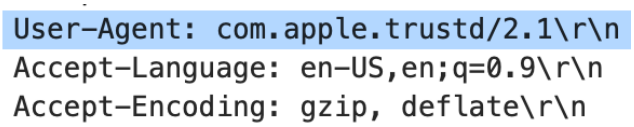


# Part C:

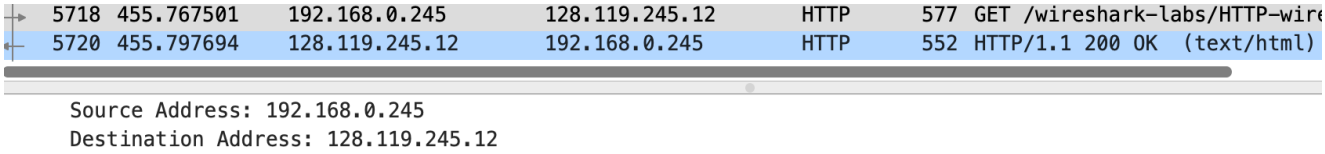
1. Running HTTP 1.1



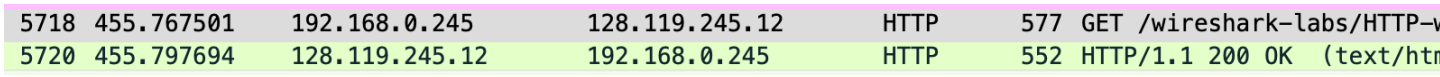

2. en-US (US English)



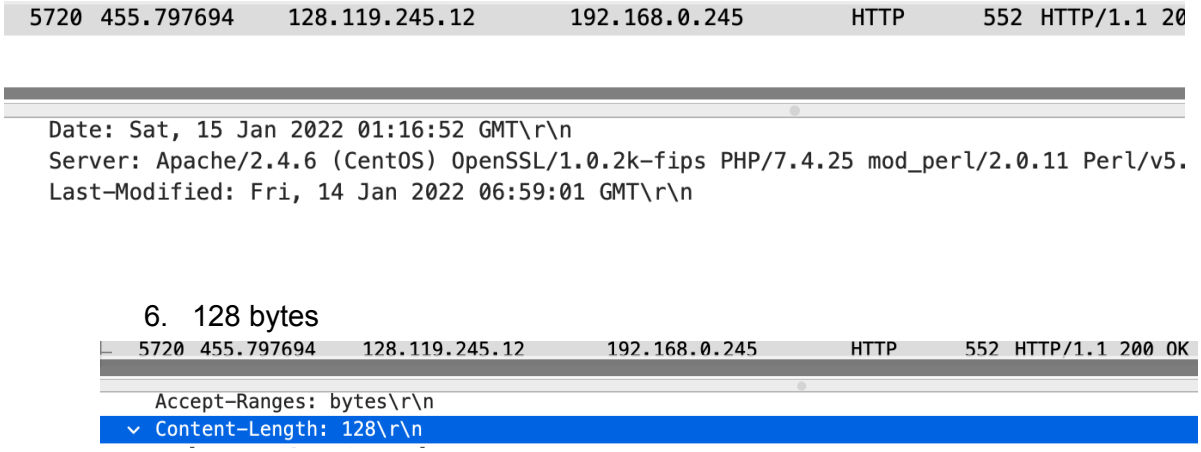

3. From the screenshot below, my IP address is 192.168.0.245, the server's is 128.119.245.12




4. The status code is 200 OK



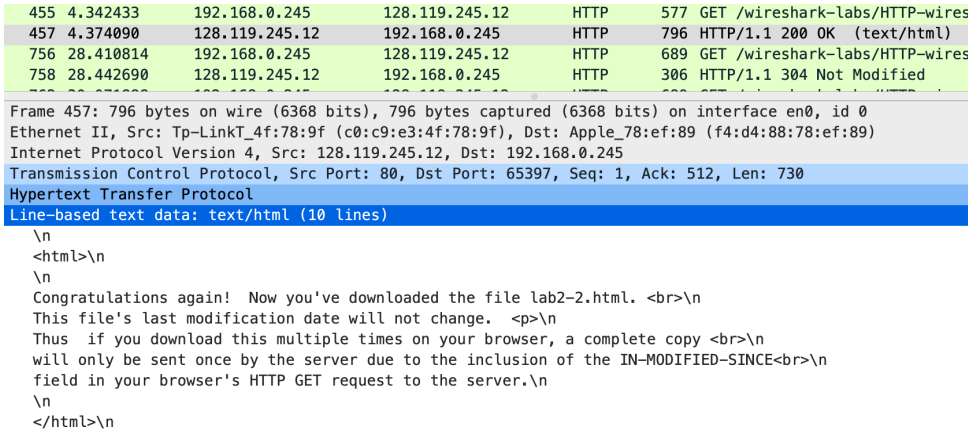

5. From the screenshot below, it's last modified on Fri, 14 Jan 2022 06:59:01 GMT



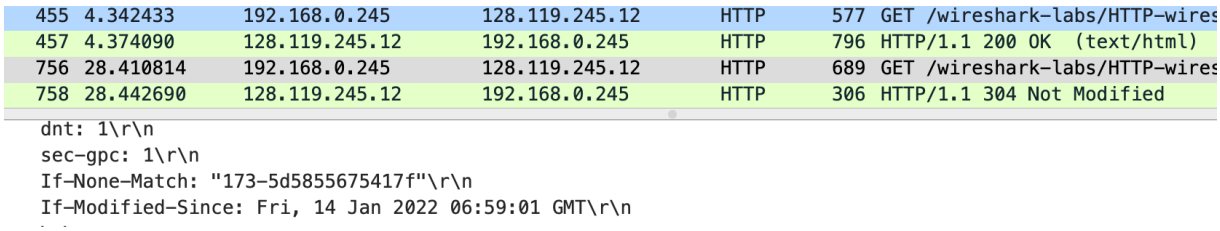

6. 128 bytes



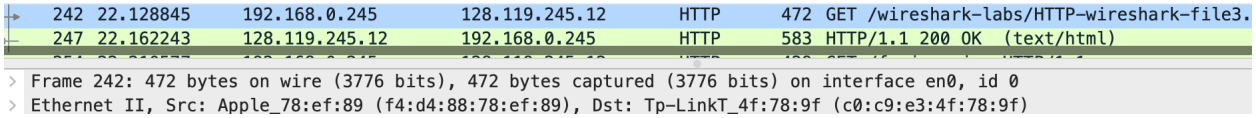

7. No they match exactly
8. No there is not.
9. Yes. I can tell from the "Line-based text data".



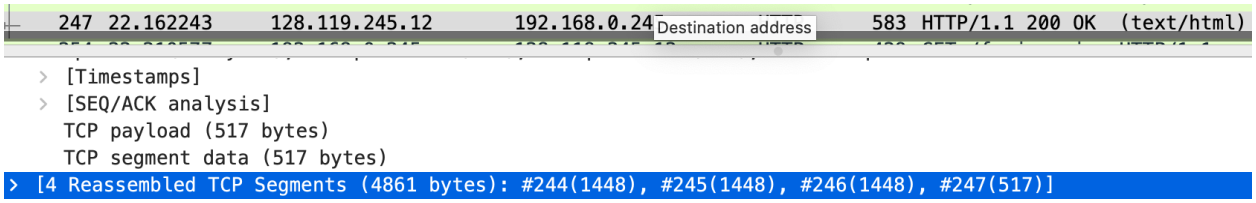

10. Yes, the second request has “IF-MODIFIED-SINCE”. What follows is the last time that I access the page.




11. HTTP status code is: 304 Not modified. It didn’t return the explicit content because the content is stored in cache. And we can just retrieve it from the cache.
12. Only one. Packet 242. (shown in the screenshot below problem 14)
13. Packet 247 (screenshot shown below problem 14)
14. 200 OK




15. 5 TCP segments




16. Sent three messages. They are 128.119.245.12 (the web page itself), 128.119.245.12(the pearson.png), 178.79.137.164(8e_cover_small.jpg). (Screenshot shown below problem 17)

17. My browser downloaded them serially. I can tell from the time of the response that the Pearson image comes first. And the second image is requested even after the first image request gets responded.

| | | | | | | |
|---|---|---|---|---|---|---|
| 45 | 2.627042 | 192.168.0.245 | 128.119.245.12 | HTTP | 472 | GET /wireshark-labs/HTTP-wireshark-file4.html HTTP/1.1 |
| 47 | 2.658747 | 128.119.245.12 | 192.168.0.245 | HTTP | 1367 | HTTP/1.1 200 OK (text/html) |
| 49 | 2.662204 | 192.168.0.245 | 128.119.245.12 | HTTP | 498 | GET /pearson.png HTTP/1.1 |
| 53 | 2.695405 | 128.119.245.12 | 192.168.0.245 | HTTP | 781 | HTTP/1.1 200 OK (PNG) |
| 58 | 2.762343 | 192.168.0.245 | 178.79.137.164 | HTTP | 465 | GET /8E_cover_small.jpg HTTP/1.1 |
| 60 | 2.862551 | 178.79.137.164 | 192.168.0.245 | HTTP | 237 | HTTP/1.1 301 Moved Permanently |

18. It says “401 Unauthorized”

| | | | | | | |
|---|---|---|---|---|---|---|
| 90 | 8.637323 | 192.168.0.245 | 128.119.245.12 | HTTP | 488 | GET /wireshark-labs/protected_pages/HTTP-wiresh |
| 92 | 8.669100 | 128.119.245.12 | 192.168.0.245 | HTTP | 783 | HTTP/1.1 401 Unauthorized (text/html) |
| 147 | 21.589696 | 192.168.0.245 | 128.119.245.12 | HTTP | 547 | GET /wireshark-labs/protected_pages/HTTP-wiresh |
| 149 | 21.624807 | 128.119.245.12 | 192.168.0.245 | HTTP | 556 | HTTP/1.1 200 OK (text/html) |

19. It sends with an Authorization Field:

| | | | | | | |
|---|---|---|---|---|---|---|
| 90 | 8.637323 | 192.168.0.245 | 128.119.245.12 | HTTP | 488 | GET /wireshark-labs/protected_pages/HTTP-wir |
| 92 | 8.669100 | 128.119.245.12 | 192.168.0.245 | HTTP | 783 | HTTP/1.1 401 Unauthorized (text/html) |
| 147 | 21.589696 | 192.168.0.245 | 128.119.245.12 | HTTP | 547 | GET /wireshark-labs/protected_pages/HTTP-wir |
| 149 | 21.624807 | 128.119.245.12 | 192.168.0.245 | HTTP | 556 | HTTP/1.1 200 OK (text/html) |
| 154 | 21.699183 | 192.168.0.245 | 128.119.245.12 | HTTP | 445 | GET /favicon.ico HTTP/1.1 |
| 156 | 21.729439 | 128.119.245.12 | 192.168.0.245 | HTTP | 551 | HTTP/1.1 404 Not Found (text/html) |

```
Host: gaia.cs.umass.edu\r\n
Connection: keep-alive\r\n
Upgrade-Insecure-Requests: 1\r\n
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8\r\n
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_15_7) AppleWebKit/605.1.15 (KHTML, like Gecko) Version/15.2 Safa
Accept-Language: en-US,en;q=0.9\r\n
Accept-Encoding: gzip, deflate\r\n
Authorization: Basic d2lyZXNoYXJrLXN0dWRlbnRzOm5ldHdvcms=\r\n
\r\n
```

# Part D:

1. Chose one in Korea: www.aiit.or.kr : the IP address is 192.168.0.1

```
meimeisun@Meimeisuns-MacBookpro ~ % nslookup www.aiit.or.kr
Server:         192.168.0.1
Address:        192.168.0.1#53

Non-authoritative answer:
Name:   www.aiit.or.kr
Address: 58.229.6.225
```

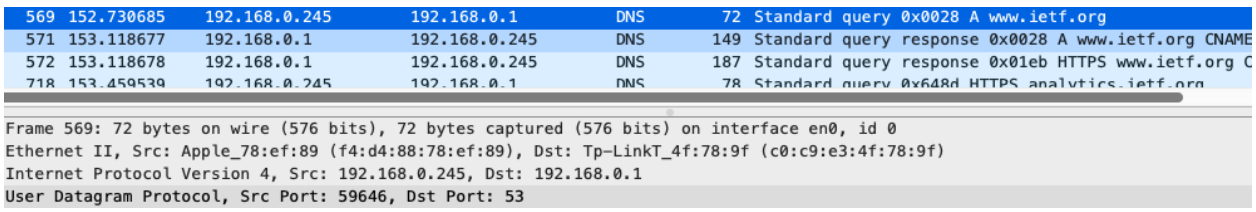
2. This is an example of Cambridge

```
meimeisun@Meimeisuns-MacBookpro ~ % nslookup -type=NS cam.ac.uk
Server:         192.168.0.1
Address:        192.168.0.1#53

Non-authoritative answer:
cam.ac.uk       nameserver = ns3.mythic-beasts.com.
cam.ac.uk       nameserver = ns2.ic.ac.uk.
cam.ac.uk       nameserver = ns1.mythic-beasts.com.
cam.ac.uk       nameserver = auth0.dns.cam.ac.uk.
cam.ac.uk       nameserver = dns0.eng.cam.ac.uk.
cam.ac.uk       nameserver = dns0.cl.cam.ac.uk.

Authoritative answers can be found from:
ns1.mythic-beasts.com   internet address = 45.33.127.156
ns3.mythic-beasts.com   internet address = 185.24.221.32
dns0.cl.cam.ac.uk       internet address = 128.232.0.19
dns0.eng.cam.ac.uk      internet address = 129.169.8.8
auth0.dns.cam.ac.uk     internet address = 131.111.8.37
ns1.mythic-beasts.com   has AAAA address 2600:3c00:e000:19::1
ns3.mythic-beasts.com   has AAAA address 2a02:2770:11:0:21a:4aff:febe:759b
dns0.cl.cam.ac.uk       has AAAA address 2001:630:212:200::d:a0
auth0.dns.cam.ac.uk     has AAAA address 2001:630:212:8::d:a0
```

3. nslookup -type=MX mail.yahoo.com
4. As shown in the screenshot

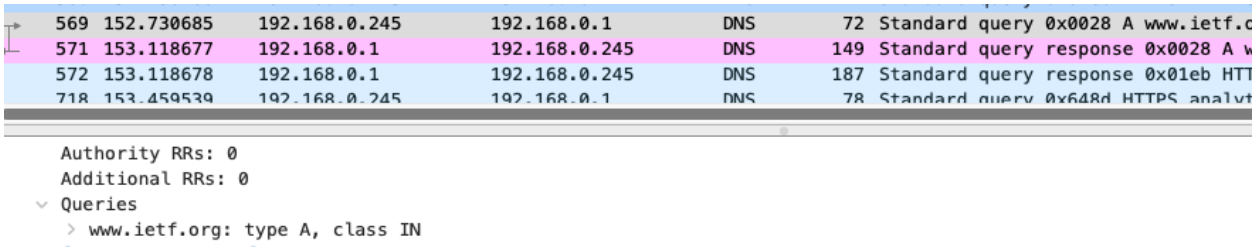
```
meimeisun@Meimeisuns-MacBookpro ~ % nslookup mail.yahoo.com ns1.mythic-beasts.com
Server:         ns1.mythic-beasts.com
Address:        45.33.127.156#53

** server can't find mail.yahoo.com: REFUSED
```

5. Sent over via UDP

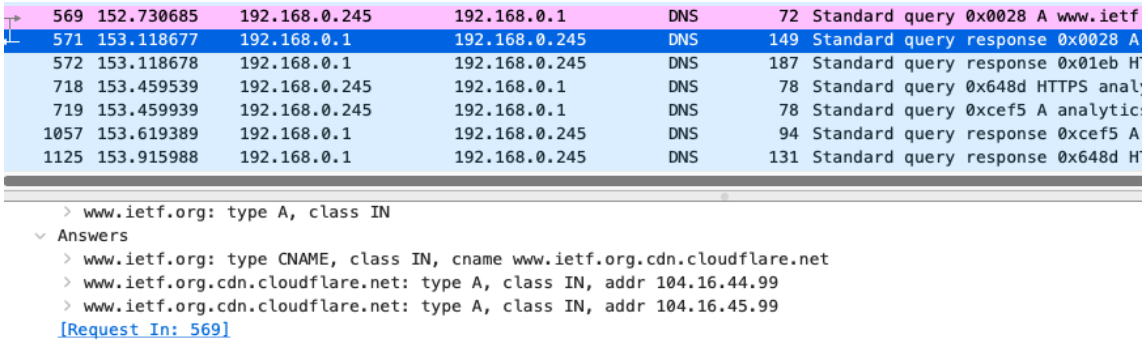



6. From the above screenshot, we see the Destination port is 53, the source port is 59646
7. From the above screenshot, the destination is 192.168.0.1. The two IP addresses are the same.

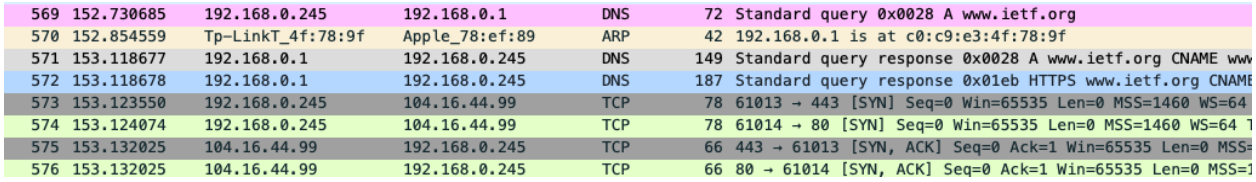
8. It's type A, without any answers.



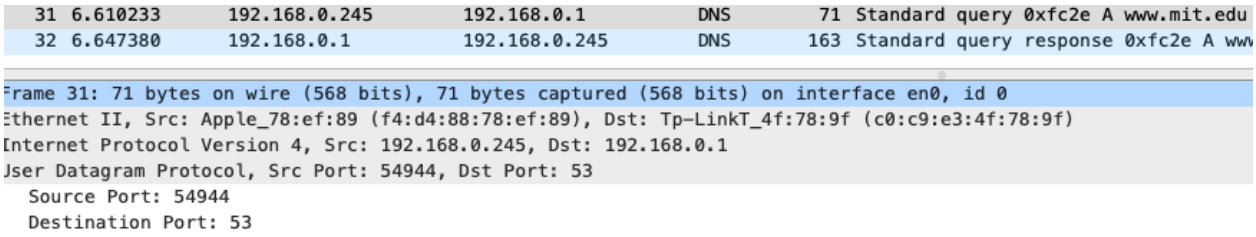

9. Three answers. One answer contains the canonical name of the ietf website, and two other answers contain the ip addresses of the website which is the canonical version of ietf




10. The destination IP address is 104.16.44.99. Yes, it matches with the one provided previously.

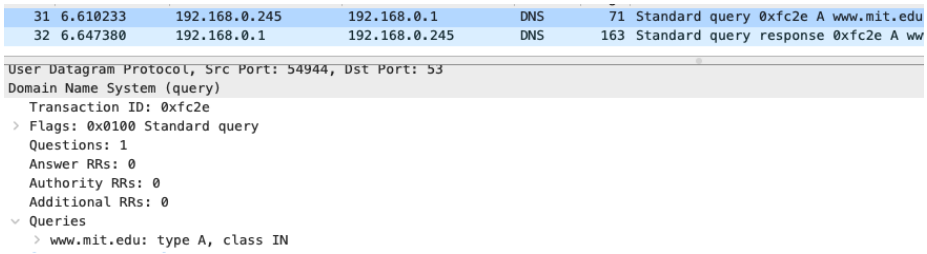



11. No there's not.
12. The destination port is 53, the source port is 54944.

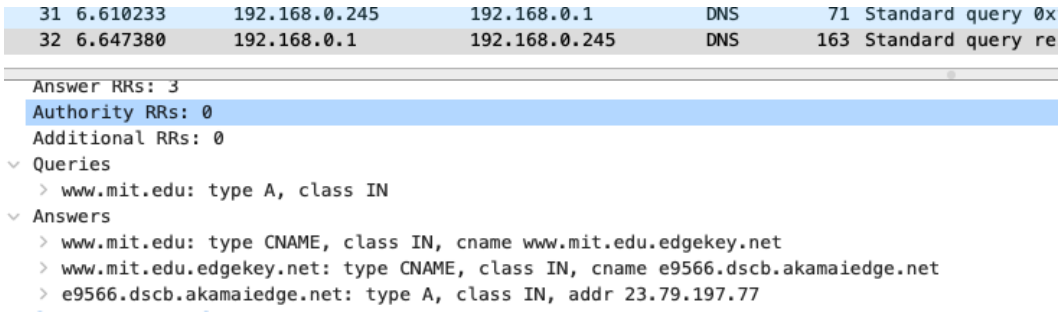



13. The IP address is 192,168.0.1. Yes, the same IP address.

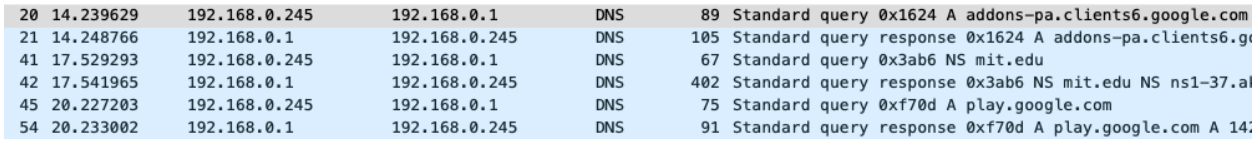
14. Type A, no answers.



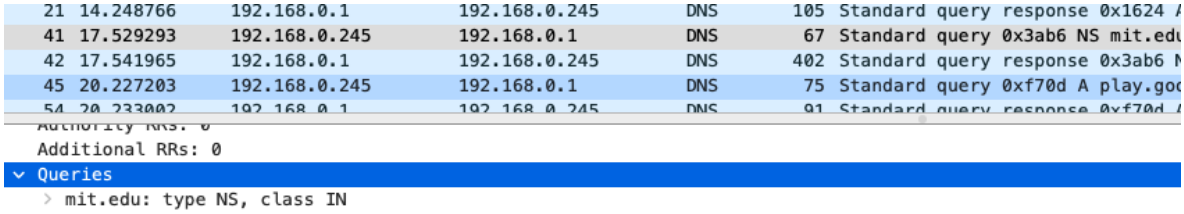

15. Three answers are provided: The first answer contains the CNAME of the second answer, the second answer contains the CNAME for the third answer, the third answer provides the corresponding IP address for the website.



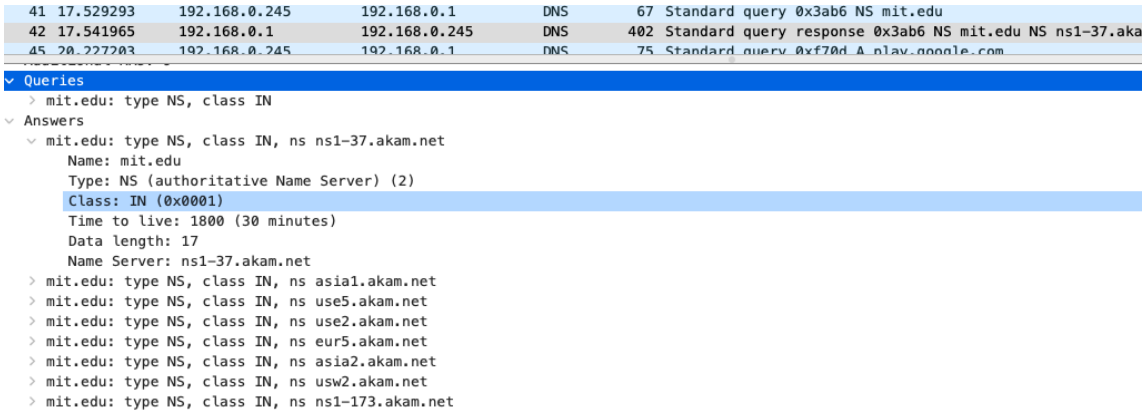

16. It is sent to my IP address: 192.168.0.1



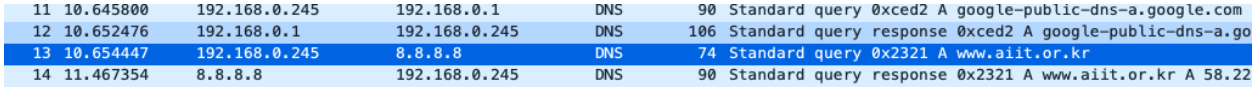

17. Type NS query with no answers




18. The servers can be seen from the screenshot below. As you can see from the first example, it doesn't provide any IP addresses.

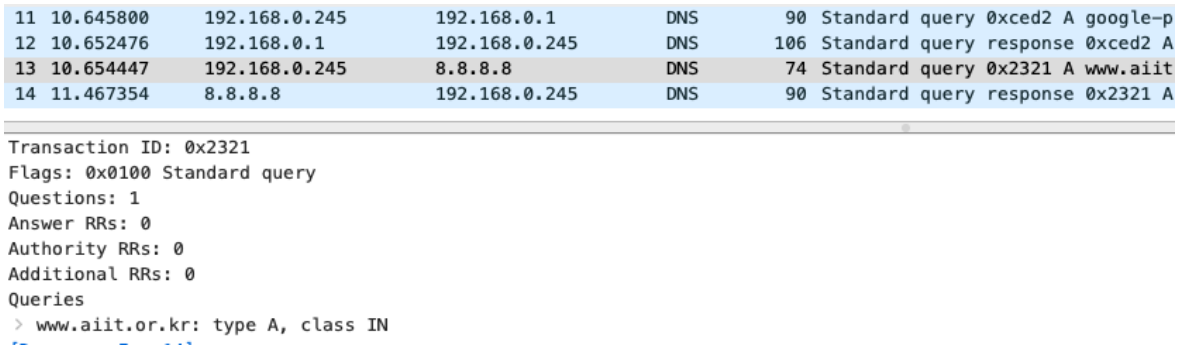


19. It is sent to 8.8.8.8. No, it's not the one for my default DNS server. It corresponds to Google's server.



| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 10.645800 | 192.168.0.245 | 192.168.0.1 | DNS | 90 | Standard query 0xced2 A google-public-dns-a.google.com |
| 12 | 10.652476 | 192.168.0.1 | 192.168.0.245 | DNS | 106 | Standard query response 0xced2 A google-public-dns-a.go |
| 13 | 10.654447 | 192.168.0.245 | 8.8.8.8 | DNS | 74 | Standard query 0x2321 A www.aiit.or.kr |
| 14 | 11.467354 | 8.8.8.8 | 192.168.0.245 | DNS | 90 | Standard query response 0x2321 A www.aiit.or.kr A 58.22 |

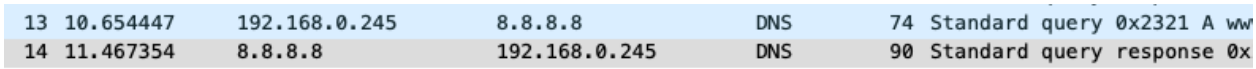
20. Type A. No answer



| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 10.645800 | 192.168.0.245 | 192.168.0.1 | DNS | 90 | Standard query 0xced2 A google-p |
| 12 | 10.652476 | 192.168.0.1 | 192.168.0.245 | DNS | 106 | Standard query response 0xced2 A |
| 13 | 10.654447 | 192.168.0.245 | 8.8.8.8 | DNS | 74 | Standard query 0x2321 A www.aiit |
| 14 | 11.467354 | 8.8.8.8 | 192.168.0.245 | DNS | 90 | Standard query response 0x2321 A |

```
Transaction ID: 0x2321
Flags: 0x0100 Standard query
Questions: 1
Answer RRs: 0
Authority RRs: 0
Additional RRs: 0
Queries
> www.aiit.or.kr: type A, class IN
```

21. There's one answer, containing the IP address of the website.



| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | 10.654447 | 192.168.0.245 | 8.8.8.8 | DNS | 74 | Standard query 0x2321 A ww |
| 14 | 11.467354 | 8.8.8.8 | 192.168.0.245 | DNS | 90 | Standard query response 0x |

```
> www.aiit.or.kr: type A, class IN
Answers
> www.aiit.or.kr: type A, class IN, addr 58.229.6.225
[Request In: 13]
```

# Part E:

1. a) Query Name is a sequence of one or more labels, each beginning with a 1-byte count that specifies the number of bytes that follow. So the name is terminated with a byte of 0.

   b) DNS header(12 bytes) + one question (15 bytes domain name + 2 bytes qtype + 2 bytes qclass) + one answer (16 bytes using pointer) = 47 bytes in total
2. When doing VO-IP, eros such as packet loss have minimal impacts on the audio output. UDP cares less about packet loss (at most some unnoticeable silence). However, TCP makes sures the packets are all delivered (not even a single loss). But in that case, users will experience intolerable delay and lag of the audio sent over.
3. When: Often used by default; often happens especially when the web server is very busy so that users can experience less delay.
   Why: The web server and the client don't need to spend time establishing TCP, which consumes resources and results in significant delay. What's more, requests between the same server and the same client can be made back to back, without waiting for replies of pending requests.
4. Normally two parties must establish an SMTP connection to continue to send mail messages. Now, we can combine SMTP and the mail sending process. I.e., each mail message carries an SMTP connection request. I.e., sending a message and SMTP handshake happens at the same time. In this way, clients will experience more delays. But now SMTP is stateless.
5. Practically, the two will navigate you to the same website. But there is some underlying difference: when we enter the non-www address, we are actually being redirected to the one with www.
   Two different ways:

a) After you enter the URL, the browser will look up the IP address of the domain (northwestern.edu) with the help of DNS. Then, TCP connection is established. Then the browser sends HTTP a request to the web server and the server sends back a response.

b) You visited the website before. So the IP address is cached, and you will directly jump to the TCP connection. The rest is the same as procedure a).

6. A website is often replicated over multiple servers, each having a different IP address. When doing requests during maintenance time, we can tell DNS to avoid the affected/rebooted web server and at the same time perform load distribution to unaffected servers.
7. Like mentioned in question 6, a large and busy website like Google often has multiple web servers. When a client makes a DNS query for Google, it responds with a set of IP addresses, but rotates the order of the addresses in response. (because a client normally first sends requests to the primary address) In this way, the traffic is fairly distributed to multiple servers.