# Lab1: Basic Networking Tools - Solutions COM-208: Computer Networks

Welcome to the first Computer Networks lab! The goal of the lab is to get you familiar with basic networking tools. Before you start, please watch the lecture videos and read the "Doing the Labs" document posted on Moodle.

### Network interfaces and their names

Every computer in the world has at least one **network interface**. Whenever an entity outside the computer wants to communicate with the computer, it needs to name one of its network interfaces. Different entities use different names to refer to a computer's network interface: the network layer uses **IP addresses**, the link layer uses **MAC addresses**, the computer's operating system (OS) uses **local interface names**.

The **ifconfig** utility lists a computer's network interfaces and displays or updates their configuration.

Type ifconfig in the command line and answer the following questions:

• How many network interfaces does your computer have?

TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0 lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536 inet 127.0.0.1 netmask 255.0.0.0 inet6 ::1 prefixlen 128 scopeid 0x10<host> loop txqueuelen 1000 (Local Loopback) RX packets 110162 bytes 370030090 (370.0 MB) RX errors 0 dropped 0 overruns 0 frame 0 TX packets 110162 bytes 370030090 (370.0 MB) TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

This computer has two interfaces: a wired Ethernet interface with local name ens160, and what is called a **loopback** interface, with local name lo (more on this in a moment).

If you are using an INF3 computer, the output may look like the following:

```
$ ifconfig -a
eno2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
       inet 128.178.158.142 netmask 255.255.255.0
                                        broadcast 128.178.158.255
       inet6 fe80::a6bb:6dff:fe4f:c56b prefixlen 64
                                               scopeid 0x20<link>
       ether a4:bb:6d:4f:c5:6b txqueuelen 1000 (Ethernet)
       RX packets 1093229 bytes 580963781 (580.9 MB)
       RX errors 0 dropped 0 overruns 0 frame 0
       TX packets 56084 bytes 12509105 (12.5 MB)
       TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
       device interrupt 20 memory 0xe4400000-e4420000
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
       inet 127.0.0.1 netmask 255.0.0.0
       inet6 ::1 prefixlen 128 scopeid 0x10<host>
       loop txqueuelen 1000 (Local Loopback)
       RX packets 19946 bytes 2182828 (2.1 MB)
       RX errors 0 dropped 0 overruns 0 frame 0
       TX packets 19946 bytes 2182828 (2.1 MB)
       TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
wlo1: flags=4099<UP, BROADCAST, MULTICAST> mtu 1500
       ether 3c:58:c2:30:70:c8 txqueuelen 1000 (Ethernet)
       RX packets 0 bytes 0 (0.0 B)
```

```
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

This computer has three interfaces: a wired Ethernet interface named eno2, a wireless Ethernet interface named wlo1, and a loopback interface named lo.

• Can you guess why it has more than one?

If a computer is connected to the network through multiple network links, then it has one network interface for each link. E.g., the INF3 computer is connected through a wired Ethernet link, as well as a wireless Ethernet link.

The loopback interface is what we call a **virtual** network interface. This means that it is not associated with an actual physical link. It is typically used for testing and debugging, and when a process running locally on the computer wants to communicate with another process also running locally on the computer. In the latter case, there is no need to communicate through a "normal" network interface, associated with an actual physical link, since both processes are running on the same computer.

• What is the IP address of each interface?

In the vdi computer, the IP addresses are 10.93.20.34 for ens160 and 127.0.0.1 for the loopback interface.

In the INF3 computer, the IP addresses are 128.178.158.142 eno2 and 127.0.0.1 for the loopback interface. The wireless interface, wlo1, has no IP address, which means that it cannot be used for Internet communication.

• What is the MAC address of each interface?

In the vdi computer, ens160's MAC address is 00:50:56:b8:ce:2b.

In the INF3 computer, the MAC addresses are a4:bb:6d:4f:c5:6b for eno2 and 3c:58:c2:30:70:c8 for wlo1. Note that wlo1 does have a MAC address, even if it is not up. This is because, as we will see during the semester, a MAC address is an *inherent* property of a network interface that is associated with a physical link; so, it is there, whether the network interface is actually connected to a network or not. In contrast, an IP address is a property that is *assigned* to a network interface; so, a network interface may not have an IP address associated with it yet.

The loopback interfaces do not have MAC addresses.

• Why could it be that some interfaces do not have a MAC address? (This is a tough question. It's normal if you don't know how to approach it yet. Come back to it at the end of the lab, after having worked on the Internet layers.)

Recall that the role of the link layer is to get a packet across a single link. A virtual interface (like the loopback interface) does not have a MAC address, because it is not associated with an actual physical link, so it does not need to support a link-layer interface. Think about what happens when two processes running locally on your computer communicate over the loopback interface. Their packets do not cross any network link, so, they are not processed by any packet switch, and they do not need to carry any link-layer header.

## **DNS** names and IP addresses

Humans use special names, called **DNS names**, to refer to computers (more precisely, to the network interfaces of computers). When you instruct your computer to communicate with a remote computer that has a given DNS name, your computer translates, under the covers, the given DNS name to an IP address.

The **host** utility helps you map DNS names to IP addresses. E.g., if you type **host** *target* in the command line, where *target* is a DNS name or IP address, that will display the IP address(es) and potentially other DNS names of the target network interface.

Use the **host** utility to answer the following questions:

• What are the IP addresses of www.epfl.ch?

The IP addresses of www.epfl.ch are 104.20.228.42, 104.20.229.42, and 172.67.2.106. (There are also 3 IPv6 addresses, but we have not talked about IPv6 yet.)

• Why could it be that www.epfl.ch maps to more than one IP addresses?

#### For fault tolerance and/or what we call load balancing.

You already know that a computer can be connected through multiple network links, hence have multiple network interfaces and IP addresses: if one link fails, then the computer can be reached through another.

Moreover, popular services are typically **replicated** over multiple computers. In our particular example, when a user types in their web browser www.epfl.ch, there are multiple computers running web-server processes that can serve that user. Each of these computers has, of course, its own IP address.

Such replication provides fault tolerance: if one computer fails, then another can serve. It also provides load balancing: different users can be served by different computers, such that the load if not concentrated on one computer.

• What is the IP address of www.google.com?

\$ host www.google.com

www.google.com has address 172.217.168.68 www.google.com has IPv6 address 2a00:1450:400a:801::2004

The IP address of www.google.com is 172.217.168.68.

• Answer the same question again in an hour or so. Has anything changed? If so, what could be the reason for the change?

This is another approach to load balancing:

We said above that a service may be replicated over multiple computers, which means that a DNS name, like www.epfl.ch, maps to multiple IP addresses, each belonging to a different computer serving the target DNS name.

In the above example, when you typed host www.epfl.ch, you were given the IP addresses of all the computers serving www.epfl.ch.

An alternative is to be given the IP address of only one computer: the one that you should use at the moment to access the target DNS name, because it happens to be the closest to you, or it happens to be the least busy (among the ones serving the target DNS name). At a later moment, you may be given a different IP address that belongs to a different computer, which happens to be the least busy at that moment.

Google recently implemented this alternative, and this is why you were given only one IP address for www.google.com. Things were different a few years back, when we typed the same command:

```
$ host www.google.com
www.google.com has address 173.194.40.32
www.google.com has address 173.194.40.33
www.google.com has address 173.194.40.34
www.google.com has address 173.194.40.35
www.google.com has address 173.194.40.37
www.google.com has address 173.194.40.38
www.google.com has address 173.194.40.38
www.google.com has address 173.194.40.39
www.google.com has address 173.194.40.40
www.google.com has address 173.194.40.41
www.google.com has address 173.194.40.41
```

#### Reachability

The **ping** utility helps you check whether a remote computer is "reachable" from your computer. E.g., if you type **ping** *target* in the command line, where *target* is a DNS name or IP address, that will tell you whether your computer can reach the target network interface.

When one computer pings another, it sends to it a small packet, requesting a response, and it measures the time it takes from the moment each request is sent until the corresponding response is received. This time has a special name: it is called the **round-trip time** (**RTT**) between your computer and the target.

Use ping to answer the following questions:

• Are the following computers (more precisely, network interfaces) reachable from yours: www.epfl.ch, www.20min.ch, www.swisscom.ch, 8.8.8.8, www.microsoft.com, www.auth.gr, en.sjtu.edu.cn, www.adelaide.edu.au?

```
$ ping www.epfl.ch
PING www.epfl.ch.cdn.cloudflare.net (104.20.229.42)
56(84) bytes of data.
64 bytes from 104.20.229.42 (104.20.229.42):
icmp_seq=1 ttl=57 time=1.34 ms
64 bytes from 104.20.229.42 (104.20.229.42):
icmp_seq=2 ttl=57 time=1.33 ms
64 bytes from 104.20.229.42 (104.20.229.42):
icmp_seq=3 ttl=57 time=1.40 ms
```

--- www.epfl.ch.cdn.cloudflare.net ping statistics ---3 packets transmitted, 3 received, 0% packet loss, time 2002ms rtt min/avg/max/mdev = 1.338/1.362/1.406/0.052 ms

\$ ping www.20min.ch

--- www.20min.ch ping statistics ---3 packets transmitted, 3 received, 0% packet loss, time 2002ms rtt min/avg/max/mdev = 3.316/3.332/3.365/0.052 ms

\$ ping www.swisscom.ch

PING www-swisscom-ch.hdb-cs04.ellb.ch (195.186.208.154) 56(84) bytes of data.

--- www-swisscom-ch.hdb-cs04.ellb.ch ping statistics ---3 packets transmitted, 0 received, 100% packet loss, time 2040ms

\$ ping 8.8.8.8

PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data. 64 bytes from 8.8.8.8: icmp\_seq=2 ttl=117 time=3.98 ms icmp\_seq=3 ttl=117 time=3.97 ms

--- 8.8.8.8 ping statistics ---3 packets transmitted, 3 received, 0% packet loss, time 2001ms rtt min/avg/max/mdev = 3.972/3.980/3.989/0.007 ms

\$ ping www.microsoft.com

PING e13678.dspb.akamaiedge.net (23.54.112.217) 56(84) bytes of data.
64 bytes from a23-54-112-217.deploy.static.akamaitechnologies.com (23.54.112.217): icmp\_seq=1 ttl=57 time=3.22 ms
64 bytes from a23-54-112-217.deploy.static.akamaitechnologies.com (23.54.112.217): icmp\_seq=2 ttl=57 time=3.23 ms
64 bytes from a23-54-112-217.deploy.static.akamaitechnologies.com (23.54.112.217): icmp\_seq=3 ttl=57 time=3.28 ms

--- e13678.dspb.akamaiedge.net ping statistics ---

3 packets transmitted, 3 received, 0% packet loss, time 2002ms rtt min/avg/max/mdev = 3.229/3.249/3.280/0.022 ms

\$ ping www.auth.gr

--- www.ccf.auth.gr ping statistics ---3 packets transmitted, 3 received, 0% packet loss, time 2001ms rtt min/avg/max/mdev = 43.022/43.046/43.066/0.018 ms

\$ ping en.sjtu.edu.cn

--- en.sjtu.edu.cn ping statistics ---3 packets transmitted, 3 received, 0% packet loss, time 2001ms rtt min/avg/max/mdev = 225.300/225.367/225.465/0.070 ms

\$ ping www.adelaide.edu.au

All computers are reachable through ping, except www.swisscom.ch.

• Notice the RTT reported by ping for each target computer. Do you see a pattern? Which targets tend to have longer RTTs?

In general, RTT increases with the physical distance to the target. For example, www.epfl.ch (which should be somewhere in Switzerland) replies much faster than www.adelaide.edu.au (which should be somewhere in Australia).

• If you let it run, **ping** makes many efforts to reach each target. As you can see, the RTT (to the *same* target) changes with every effort. What could possibly be the reason for this change?

It could be that the path from your computer to the target changes, or that the traffic on this path changes, making communication over the path faster/slower.

• At least one of the targets should be unreachable through **ping**. Try to reach it by typing its DNS name in your web browser. How could it be that the same target is unreachable through **ping** but reachable through your browser?

Indeed, www.swisscom.ch is unreachable through **ping** but reachable through a web browser. This could happen because a packet switch inside the Swisscom network inspects packets and drops the ones that are carrying ping messages, while it accepts and forwards those that are carrying web (HTTP) messages.

#### Network paths and packet switches

When two computers (end-systems) communicate with each other over the Internet, their communication traverses multiple **packet switches**. There are two general types of packet switches on the Internet: link-layer switches and network-layer switches (the latter are also called **routers**).

The **traceroute** utility lists the routers that are located between your computer and a remote one. E.g., if you type **traceroute** *target* in the command line, where *target* is a DNS name or IP address, that will display a list of router DNS names and/or IP addresses and the RTTs that were measured between your computer and each router.

(The idea behind how traceroute works is a little wonder, and we will explore it later in the semester. If you feel curious, you can already google it.)

Use traceroute to answer the following questions:

• How many routers are there between your computer and www.mcgill.ca?

```
$ traceroute www.mcgill.ca
traceroute to www.mcgill.ca (132.216.177.160), 30 hops max,
                                              60 byte packets
 1
   nx-srv1-13-1-v812.epfl.ch (10.93.16.2)
                                0.390 ms 0.724 ms
                                                    0.831 ms
   backbone-nx-srv1-13-1-26.epfl.ch (10.0.2.26)
 2
                                0.141 ms 0.310 ms
                                                    0.335 ms
   c6-ext-cv-backbone-97.epfl.ch (10.0.2.97)
 3
                                0.290 ms 0.327 ms
                                                    0.316 ms
   swiel2.epfl.ch (192.33.209.33)
 4
                                0.716 ms
                                         0.739 ms
                                                    0.720 ms
 5
   swige3-100ge-0-0-1-1.switch.ch (130.59.36.82)
                                1.704 ms 1.736 ms
                                                    1.713 ms
   swice1-100ge-0-1-0-6.switch.ch (130.59.38.193)
 6
                                1.603 ms 1.613 ms
                                                    1.925 ms
7
   switch.mx1.gen.ch.geant.net (62.40.124.21)
                                1.532 ms 1.561 ms 1.463 ms
   ae6.mx1.par.fr.geant.net (62.40.98.183)
 8
                                8.834 ms 8.865 ms 8.838 ms
   canarie-bckp-gw.mx1.par.fr.geant.net (62.40.124.226)
 9
                                91.108 ms 91.108 ms 91.117 ms
   otwa3rtr1.canarie.ca (205.189.32.178)
10
                                93.982 ms 93.884 ms 93.923 ms
```

```
205.189.32.57 (205.189.32.57)
11
                                93.896 ms 93.527 ms 93.566 ms
12
   * * *
13
   * * *
14
    * * *
15
   mcgill-canet-membre1.risq.net (206.167.128.50)
                                96.875 ms 96.875 ms 96.873 ms
16
   *
17
18
    *
19
   * * *
20
   www.mcgill.ca (132.216.177.160)
                                98.335 ms 98.355 ms 98.275 ms
```

There are 20 routers.

If the x-th row is "\* \* \*", that means that the xth router between your computer and the target could not be identified.

Note that your traceroute output may slightly differ from the above, as network paths may change.

• How many of these routers are inside the EPFL network? How many, would you guess, are inside EPFL's Internet Service Provider (ISP)?

We can guess by looking at the DNS names of the routers:

The DNS names of the first 4 routers have suffix epfl.ch, so they should be inside the EPFL network.

The first router that is after the EPFL routers (so, the 5th router) should belong to EPFL's ISP. Moreover, we notice that the DNS name of the 6th router has the same suffix as that of the 5th router (switch.ch), so, that should also belong to EPFL's ISP. (EPFL's ISP is called SWITCH, by the way.)

• Between which of these routers, do you think, your packets cross the Atlantic?

Observe how RTT "jumps" from 8.8ms to 91.1ms between routers 8 and 9.

It makes sense to assume that these two routers are located at opposite ends of a transatlantic link.

• Now traceroute to www.google.com. Does the network path from your computer to www.mcgill.ca overlap with the path from your computer to www.google.com?

```
$ traceroute www.google.com
traceroute to www.google.com (172.217.168.4), 30 hops max,
                                               60 byte packets
   nx-srv1-13-1-v812.epfl.ch (10.93.16.2)
 1
                                  0.468 ms 0.670 ms 0.745 ms
   backbone-nx-srv1-13-1-26.epfl.ch (10.0.2.26)
 2
                                  0.151 ms 0.316 ms 0.394 ms
 3
   c6-ext-cv-backbone-97.epfl.ch (10.0.2.97)
                               15.245 ms 15.271 ms
                                                     15.300 ms
   swiel2.epfl.ch (192.33.209.33)
 4
                                            0.714 ms 0.719 ms
                                  0.728 ms
   swils1-100ge-0-0-0.switch.ch (130.59.38.54)
 5
                                  1.227 ms
                                            1.257 ms
                                                      1.238 ms
   swizh3-100ge-0-0-0-1.switch.ch (130.59.36.94)
 6
                                            3.436 ms 3.465 ms
                                  3.463 ms
   72.14.195.4 (72.14.195.4)
7
                                  4.059 ms
                                            4.045 ms
                                                     4.066 ms
   74.125.243.145 (74.125.243.145)
 8
                                  4.002 ms
                                           4.019 ms
                                                      3.997 ms
 9
   172.253.50.17 (172.253.50.17)
                         5.030 ms 172.253.50.19 (172.253.50.19)
                                            4.766 ms 4.771 ms
   zrh11s03-in-f4.1e100.net (172.217.168.4)
10
                                  3.978 ms 4.012 ms 3.994 ms
```

Yes, the network paths from our computer to www.mcgill.ca and to www.google.com overlap in routers 1-4. This indicates that the two paths are the same inside the EPFL network, but then diverge. • Traceroute again to www.google.com in an hour or so. Is the output (the sequence of routers) the same as before? What does the answer say about the network path from your computer to www.google.com?

```
$ traceroute www.google.com
traceroute to www.google.com (172.217.168.4), 30 hops max,
                                                    60 byte packets
   nx-srv1-13-1-v812.epfl.ch (10.93.16.2)
 1
                                       0.772 ms 1.359 ms
                                                           1.391 ms
 2
   backbone-nx-srv1-13-1-26.epfl.ch (10.0.2.26)
                                       0.159 ms
                                                 0.309 ms
                                                           0.330 ms
   c6-ext-cv-backbone-97.epfl.ch (10.0.2.97)
 3
                                       0.277 ms
                                                 0.299 ms
                                                           0.319 ms
 4
   swiel2.epfl.ch (192.33.209.33)
                                       0.718 ms 0.741 ms
                                                           0.710 ms
 5
   swils1-100ge-0-0-0.switch.ch (130.59.38.54)
                                       0.855 ms 0.881 ms
                                                            0.868 ms
    swizh3-100ge-0-0-0-1.switch.ch (130.59.36.94)
 6
                                       3.523 ms
                                                 3.540 ms
                                                           3.468 ms
   72.14.195.4 (72.14.195.4)
7
                                       4.159 ms
                                                 4.160 ms
                                                           4.127 ms
   74.125.243.161 (74.125.243.161)
 8
                                       4.952 ms 4.896 ms
                         74.125.243.145 (74.125.243.145)
                                                            4.012 ms
 9
   172.253.50.19 (172.253.50.19)
                                       4.927 ms
                                                 4.955 ms
                                                           4.924 ms
   zrh11s03-in-f4.1e100.net (172.217.168.4)
10
                                       3.999 ms
                                                 3.983 ms
                                                           3.991 ms
```

The output changed, in particular, the 8th and 9th rows. This indicates that the path from our computer to www.google.com changed, or that there are multiple paths, and our traffic followed a different one each time.

• There exist traceroute servers that allow you to traceroute from them to any other computer in the world. For example, this one, or this one. Traceroute from a traceroute server to your computer, then from your computer to that server. Are the two paths symmetric? You can find other traceroute servers at www.traceroute.org and play around with them, e.g., traceroute from one server to another, check if the paths are symmetric, and try to guess the geographic locations of the servers.

The output typically indicates that the paths traversed by a packet from one computer to another and vice versa are not necessarily symmetrical.

#### **Remote connection**

The ssh utility enables you to establish a secure communication channel between your computer and a remote one. E.g., you can type ssh username@target in the command line, where target is the remote computer's DNS name or IP address.

Use ssh to connect to one of the computers in INF3, e.g., icin3pc01.epfl.ch, using your gaspar username. If you are working through vdi, you may be unsuccessful, but this does not really affect the next steps of the lab; just leave the ssh command running, waiting to be prompted for your gaspar password.

#### \$ ssh mygasparname@icin3pc42.epfl.ch

If you were successful, you are now logged into the remote INF3 computer, until you run exit.

#### Port numbers

A computer's Operating System (OS) assigns a **port number** to every process running on the computer. Certain processes are always assigned the *same* port number on every computer where they run. Differently said, certain port numbers are universally reserved for specific processes. In any Unix-like environment, the file **/etc/services** lists these special processes and port numbers.

Either over the ssh connection you previously established or, if you were unsuccessful, on your own computer, open /etc/services and take a look at the contents, e.g., by typing cat /etc/services in the command line.

• Do you recognize any of the special processes (also called "services") listed on the left?

You should recognize at least http (the "World Wide Web", as the comments helpfully indicate).

• Which is the port number that is reserved for ssh-server processes? What about web-server processes and mail-server processes?

```
For ssh-server processes:
$ grep "ssh" /etc/services
               22/udp
                                 # SSH Remote Login Protocol
ssh
               22/tcp
                                 # SSH Remote Login Protocol
ssh
For web-server processes:
$ grep "http" /etc/services
http
                 80/tcp
                                                  # WorldWideWeb HTTP
                                  ឃឃឃ
https
                 443/tcp
                                        # http protocol over TLS/SSL
                 8080/tcp
                                                # WWW caching service
http-alt
                                  webcache
                 8080/udp
http-alt
For mail-server processes:
$ grep "smtp" /etc/services
                 25/tcp
                                  mail
smtp
```

• Next to each port number, there is a "udp" or "tcp" label. Do you remember what these are from the video lectures?

They are transport-layer technologies/protocols. Their role is to transfer a packet from one end-system to another.

• Interspersed with the protocol names and port numbers are some human names. What do you think those are? Do you recognize any of them?

In MacOS, this file typically includes the names of the people who registered the various port numbers, who typically also invented the corresponding protocols. Notice "Tim Berners-Lee" next to http.

This is typically not the case in Ubuntu – other than protocol names and port numbers, the file contains only human-friendly descriptions of the protocols.

## Active "communication sessions"

The **netstat** utility displays the contents of various network-related data structures that are stored in your computer. E.g., if you type **netstat** -t in the command line, that will display the list of "communication sessions" that are active between your computer and remote computers (actually, they are TCP connections, but you are not supposed to know about them yet...)

• The "Local Address" column lists processes that are running in the application layer of your computer. Notice that the names of all (or most of) these processes share a common prefix. Why is that? What does this prefix correspond to? (Did you run into it earlier in this lab?)

\$ netstat -	-t			
Active Inte	ernet c	onr	nections (w/o servers)	
Proto Recv-	-Q Send	-Q	Local Address	Foreign Address
				State
tcp	0	0	localhost:6101	localhost:32944
				ESTABLISHED
tcp	0	0	localhost:53366	localhost:34451
				ESTABLISHED
tcp	0	0	localhost:6101	localhost:32796
				ESTABLISHED
tcp	0	0	localhost:54152	localhost:34451
				ESTABLISHED
tcp	0	0	localhost:51522	localhost:38337
				ESTABLISHED
tcp	0	39	CO-IN-SC-13:22443	itvdigw02.epfl.ch:29570
				ESTABLISHED
tcp	0	0	CO-IN-SC-13:981	files8.epfl.ch:nfs
				ESTABLISHED
tcp	0	0	CO-IN-SC-13:44464	dashboard.snapcra:https
				ESTABLISHED
tcp	0	0	CO-IN-SC-13:60970	api.snapcraft.io:https
				ESTABLISHED
tcp	0	0	CO-IN-SC-13:34424	api.snapcraft.io:https
				ESTABLISHED
tcp	0	0	localhost:32944	localhost:6101
				ESTABLISHED
tcp	0	0	CO-IN-SC-13:52254	ad2.epfl.ch:3268
				ESTABLISHED

tcp	0	0 localhost:38337	localhost:51522
tcp	0	0 CO-IN-SC-13:37522	ESTABLISHED oscp-router02.gno:https ESTABLISHED
tcp	128	0 localhost:32796	localhost:6101 ESTABLISHED
tcp	0	0 CO-IN-SC-13:33354	oscp-router03.gno:https FSTABLISHED
tcp	0	0 localhost:53364	localhost:34451
tcp	0	0 CO-IN-SC-13:52754	dashboard.snapcra:https
tcp	0	0 CO-IN-SC-13:42316	ad5.epfl.ch:ldap
tcp6	0	0 localhost:34451	Localhost:53364
tcp6	0	0 localhost:34451	localhost:54152
tcp6	0	0 CO-IN-SC-13:44230	ESTABLISHED itvdibroker01.epfl:4002
tcp6	0	0 localhost:34451	ESTABLISHED localhost:53366
			ESTABLISHED

In our computer, most local processes have names that start with localhost or CO-IN-SC-13.

As we said in class, the first part of a process's name identifies a network interface that belongs to the computer where the process is running. Since all the local processes are, of course, running on our computer, the first part of their names identifies a network interface of our computer.

• The "Foreign Address" column lists all the processes that are running in the application layer of a remote computer that your computer is communicating with. Can you tell which one corresponds to INF3 computer you have ssh-ed into? (Reminder: if you are working through vdi, you may have been unable to connect to an INF3 computer, in which case **ssh** is still waiting to be prompted for a password; do not kill it and do not exit the password prompt.)

The new connection is:

0

#### Layers and headers

The Internet architecture operates in **layers**. As a result, a packet that traverses the Internet looks, in a way, like an onion: On the "outside," it is "wrapped up" in a link-layer header (which can be understood only by the link layer of computers and packet switches). If we "peel away" the link-layer header, we will find a network-layer header (which can be understood only by the network layer of computers and packet switches). If we also peel away the network-layer header, we will find a transport-layer header. And if we peel that away, too, we will find the application-layer header and data, which is the actual message that this packet is carrying.

So, if we look inside an Internet packet, we will find a lot more information than the application-layer message that the packet is carrying: we will find meta-data, in the form of headers, which are needed by the various Internet layers in order to get the message from its source to its destination.

We will now use an application called **Wireshark** to do precisely that: look inside Internet packets. To get started, do the following:

- Start your web browser and clear its cache. If you are using Firefox, click on the  $\equiv$  symbol on the upper-right, go to Preferences  $\longrightarrow$  Privacy & Security  $\longrightarrow$  Cookies and Site Data  $\longrightarrow$  Clear Data.
- Start the Wireshark tool, e.g., by typing wireshark in the command line. You should see a list of your computer's network interfaces. Identify the one whose packets you will capture. If you are working through an INF3 computer or connected through vdi, you want to capture packets from your ethernet network interface. If you are working on a wirelessly connected computer, you want to capture packets from your WiFi interface.
- Start a capture by double-clicking on the target network interface. You should see data rolling inside the top part of your Wireshark window. These are the packets that are departing from and arriving at your network interface. They most likely make no sense, and that's normal (by the end of the course, they will).
- Use your web browser to visit www.mit.edu.
- Stop capturing packets when the web page is fully loaded, by clicking on the square red button at the left of the top menu.
- Right underneath the top menu, you can specify a filter that you want to apply to the packets that you see.

Answer the following questions:

• What messages were exchanged at the **application layer**, i.e., between your web browser and the MIT web server? The communication protocol used between web browsers and web servers is HTTP (Hypertext Transfer Protocol), so type http in the filter line to see all the packets carrying HTTP messages. What information are these messages carrying?

As we can see in the "Info" column of Fig 1, two types of application-layer messages were exchanged:

- GET HTTP/1.1 requests, sent by the web browser, to get content from the web server;
- HTTP/1.1 responses, sent by the web server providing the requested content.
- Which technology/communication protocol was used at the **transport layer**? There are two of them, TCP (Transmission Control Protocol) and UDP (User Datagram Protocol), and you need to figure out which one was used. To answer, click on one of the packets in the top section of your Wireshark window, then check the detailed information about this packet that appears in the middle section of your window. You should see information about each layer. Near the bottom, you should see a line that refers to the application layer (it says "Hypertext Transfer Protocol"). What does the line on top of that say?

TCP.

The         Source         Decination         Protocol Length info           212 372(11)3023         10(3)21213         10(3)2123 <td< th=""><th>Image: Source         Descination         Protocol (engh Info           027001133         10102 2010         10102 2010         10102 2010         10102 2010           027001133         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10103 2010         10102 2010         10102 2010           027001130         10103 2010         10103 2010         10102 2010         10102 2010           027001130         10103 2010         10103 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010 2010 2010 20100         1010010 2010 2010 20100</th><th></th><th></th><th></th><th></th><th></th><th></th></td<>	Image: Source         Descination         Protocol (engh Info           027001133         10102 2010         10102 2010         10102 2010         10102 2010           027001133         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10103 2010         10102 2010         10102 2010           027001130         10103 2010         10103 2010         10102 2010         10102 2010           027001130         10103 2010         10103 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010         10102 2010         10102 2010         10102 2010           027001130         10103 2010         10102 2010 2010 2010 20100         1010010 2010 2010 20100						
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bes 4.969522907 194 d8.135.155 19 193.21.3 HTTP 480 HTTP/1.1200 K (PPE JFE mage) 87 4.22083250 19.33.21.3 194.83.155.155 HTTP 44 0 GT /spcllhts-export/suggested-links/_formatijson HTTP/1.1 88 4.2308474 19.33.21.3 194.83.155.155 HTTP 48 0 GT /spcllhts-export/suggested-links/_formatijson HTTP/1.1 88 4.2308474 19.33.21.3 194.83.155.155 HTTP 48 0 GT /spcllhts-export/suggested-links/_formatijson HTTP/1.1 88 4.2308474 19.33.21.3 194.83.155.155 HTTP 18 0 GT /spcllhts-export/suggested-links/_formatijson HTTP/1.1 88 4.2308474 19.33.21.3 194.83.155.155 HTTP 130 GT /spcllhts-export/suggested-links/_formatijson HTTP/1.1 83 4.34970623 194.83.115.155 10.93.21.3 HTTP 130 GT /rtf/1.1200 K (rext/htm]) 83 4.34970623 194.83.115.155 10.93.21.3 HTTP 750 HTTP/1.1 000 K (rext/htm]) 84 4.430970623 194.83.115.155 10.93.21.3 HTTP 750 HTTP/1.1 000 K (rext/htm]) 84 4.430970623 194.83.115.155 10.93.21.3 HTTP 120 HTTP/1.1 000 K (rext/htm]) 84 4.430970623 194.83.115.155 10.93.21.3 HTTP 234 HTTP/1.1 000 K (rext/htm]) 84 4.89970623 194.83.115.155 10.93.21.3 HTTP 234 HTTP/1.1 000 K (rext/htm]) 84 4.89970628 194.83.115.155 10.93.21.3 HTTP 24 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 120 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 84 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 85 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 85 4.8984180 194.83.115.155 10.93.21.3 HTTP 130 HTTP/1.1 000 K (rext/htm]) 85 4.9224080 195.33.21.3 HTTP.100 HTTP/1.1 000 K (rext/htm]) 85 4.9224080 197.27.180.33 193.93.11 HTTP 100 HTTP/1.1 000 K (rext/htm]) 86 4.9324196 177.27.180.35 193.93.93.155 HTTP 195 HTTP/1.1 00	23995229 10.43.15.155 10.93.21.3 104.83.155 HTTP 43 0f //poliphts-coptrof/formation HTP/1.1 2399528 10.93.21.3 104.83.151 55 HTTP 440 0f //poliphts-coptrof/formation HTP/1.1 23200456 10.93.21.3 104.83.155 HTTP 440 0f //poliphts-coptrof/formation/formati	094 3 099500350	104.03.115.155	10.03.21.3	UTTD	570 HTTP/1.1 200 0K (text/plain)	
987       42.999350       10.33.21.3       104.85.115       155       HTP       44.96ET //ppillpht-scpor//suprate-links/7.formatijon HTP/1.1         988       42.399350       10.33.21.3       104.85.115.155       HTP       44.96ET //ppillpht-scpor//suprate-links/7.formatijon HTP/1.1         988       42.3980506       10.83.21.3       104.85.115.155       HTP       386 GET //thees/mit/asscrip/short/strat-loo//.formatijon HTP/1.1         984       42.3884764       10.83.2.1.3       104.85.115.155       HTP       386 GET //thees/mit/asscrip/short/strat-loo//.formatijon HTP/1.1         94       42.3884764       10.83.2.1.3       104.85.115.155       HTP       380 GET //thees/mit/asscrip/short/strat-loo//.formatijon HTP/1.1         94       42.3884764       10.83.2.1.3       HTP       830 GET //thees/mit/asscrip/short/strat-loo//.formatijon HTP/1.1         94       42.48976224       10.83.2.1.3       HTP       50 HTP/1.1       200 KT/1.1       (ppilatis-sport/record/.formatijon HTP/1.1         74       44.48756228       10.83.2.1.3       104.83.115.155       HTP       40 GET //spoilights-seport/record/.formatijon HTP/1.1       104.48756238         74       458577428       10.83.2.1.3       104.83.115.155       HTP       40 GET //spoilights-seport/record/.formatijon HTP/1.1       104.83.115         74       458578228	22998239 19 93.21.3 104 83.115.155 HTTP 449 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 22986359 19 93.21.3 104.83.115.155 HTTP 380 GTT /thems/sit/sets/js/Spolights-export/suggested=link/7_formatigs MTTP/1.1 23063774 10.93.21.3 104.83.115.155 HTTP 380 GTT /thems/sit/sets/js/Spolights-export/suggested=link/7_formatigs MTTP/1.1 23063778 19.83.21.3 104.83.115.155 HTTP 380 GTT /thems/sit/sets/js/Spolights-export/suggested=link/7_formatigs MTTP/1.1 23063778 19.83.21.3 104.83.115.155 HTTP 380 GTT /thems/sit/sets/js/Spolights-export/suggested=link/7_formatigs MTTP/1.1 23063778 19.83.151.55 10.93.21.3 HTTP 597 HTTP/1.1 200 KC (tet/html) 267767385 19.83.115.155 10.93.21.3 HTTP 487 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 267877828 19.83.115.155 10.93.21.3 HTTP 447 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 26787785 19.83.21.3 104.83.115.155 HTTP 447 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 26787785 19.83.21.3 104.83.115.155 HTTP 447 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 26787785 19.83.21.3 104.83.115.155 HTTP 447 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 267892628 10.93.21.3 104.83.115.155 HTTP 447 GTT /spolights-export/suggested=link/7_formatigs MTTP/1.1 267892628 10.93.21.3 104.83.115.155 HTTP 356 GTT /thems/sit/sasts/faulon/faulon-1022192.png HTTP/1.1 267892689 10.93.21.3 104.83.115.155 HTTP 360 GTT /thems/sit/sasts/faulon/faulon-1022192.png HTTP/1.1 267892689 10.93.21.3 10.93.21.3 HTTP 242 HTTP/1.1 200 KC (PMG) 267892689 10.93.21.3 10.93.21.3 HTTP 242 HTTP/1.1 200 KC (PMG) 278950458 10.93.21.3 10.93.21.3 HTTP 242 HTTP/1.1 200 KC (PMG) 278950458 10.93.21.3 10.93.21.3 HTTP 242 HTTP/1.1 200 KC (PMG) 278950458 10.93.21.3 Strong ff322 (09.950 651651631, 051 651 650 651 651 651 651 651 651 651 651 651 651	065 4 050512087	104.03.115.155	10.03.21.3	NTTP	837 HTTP/1.1 200 OK (IDEC IETE imane)	
088 4.22008450       10.83.21.3       104.85.15.155       HTP       44 0 ET /pptilghts-spor//strats.log//.format-tjood HTP/1.1         084 4.22008450       10.83.21.3       104.85.15.155       HTP       380 GT //bees/mit/Asstrijs/stopilghts/stopo/rth/mit/asstrijs/stopilghts/stopo/rth/mit/asstrijs/stopilghts/stopo/rth/mit/asstrijs/stopilghts/stopo/rth/mit/asstrijs/stopilghts/stopo/rth/mit/asstrijs/stopilghts	<pre>222898389 10.03.21.3 10.48.3115.155 HTTP 440 GTT /pptLipTs-support/attract.log/7.format=json HTTP/1.1 22804744 15.03.21.3 10.48.3115.155 HTTP 380 GTT /themes/it/assts//spol1ptRecent.htm3083fT59060764.5 gtTP/1.1 22804744 15.03.21.3 10.48.3115.155 HTTP 380 GTT /themes/it/assts//spol1ptRecent.htm3083fT59060764.5 gtTP/1.1 22804744 15.03.21.3 10.48.3115.155 HTTP 380 GTT /themes/it/assts//spol1ptRecent.htm3083fT59060764.5 gtTP/1.1 22804744 15.03.21.3 10.48.3115.155 HTTP 380 GTT /themes/it/assts//spol1ptRecent.htm3083fT59060764.5 gtTP/1.1 38054469 130.48.3115.155 10.93.21.3 HTTP 577 HTTP/1.1 200 K (text/htm1) 268077788 10.93.21.3 10.48.3115.155 HTTP 440 GTT /pptLipTs-support/assts/pt) 268077788 10.93.21.3 10.48.3115.155 HTTP 440 GTT /pptLipTs-support/assts/faulon/and/di-ion-1920129 m HTTP/1.1 268077788 10.93.21.3 10.48.3115.155 HTTP 440 GTT /pptLipTs-support/assts/faulon/and/di-ion-1920129 m HTTP/1.1 26807788 10.93.21.3 10.48.3115.155 HTTP 440 GTT /pptLipTs-support/assts/faulon/and/di-ion-1920129 m HTTP/1.1 26807878 10.93.21.3 10.48.3115.155 HTTP 440 GTT /pptLipTs-support/assts/faulon/and/di-ion-1920129 m HTTP/1.1 26807878 10.93.21.3 112.27.188.35 HTTP 104 HTTP/1.1 200 K (text/htm1) 278080660 104.83.115.155 10.93.21.3 HTTP 124 HTTP/1.1 200 K (text/htm1) 278080660 104 48.3115.155 10.93.21.3 HTTP 440 GTT /pptLipTs-support 278080660 104 48.3115.155 10.93.21.3 HTTP 440 GTT /pptLipTs-100 HTTP/1.1 278080678 104.83.115.155 HTTP/1.200 K (text/htm1) 278080678 104.83.115.155 HTTP/1.200 K (text/htm1) 278080678 104.83.115.155 HTTP/1.200 K (text/htm1) 278080678 104.83.115.155 HTTP/1.200 K (text/htm1) 278080678 104.83.115.155 HTTP/1.200 K (text/htm1) 2780878478 104.83.115.155 HTTP/1.200 K (text/htm1) 2780878478 104.83.115.155 HTTP/1.200 K (text/htm1) 2780878478 104.83.115.155 HTTP/1.200 K (text/htm1</pre>	BR7 4 220803520	10 93 21 3	104 83 115 155	HTTP	449 GET /englights.evport/suggested.links/2 format=ison HTTP/1 1	
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333 4.349970623       104.83.115.155       10.93.21.3       HTTP       1040 HTTP/1.1 200 K (text/html)         354 4.34970623       104.83.115.155       10.93.21.3       HTTP       70 HTTP/1.1 200 K (text/html)         354 4.34970623       104.83.115.155       10.93.21.3       HTTP       70 HTTP/1.1 200 K (text/html)         355 4.35950460       104.83.115.155       10.93.21.3       HTTP       70 HTTP/1.1 200 K (text/html)         355 4.35950460       10.93.22.1       10.93.21.3       HTTP       400 HTTP/1.1 200 K (text/html)         356 4.349502282       10.93.21.3       104.83.115.155       HTTP       420 GT /pollights-xport/aconstrol/sign HTTP/1.1         864 7.20803257       10.93.21.3       104.83.115.155       HTTP       234 HTTP/1.1 200 K (text/html)         864 7.20803257       10.93.21.3       HTTP       234 HTTP/1.1 200 K (text/html)       104 HTTP/1.1         864 7.20803250       10.93.21.3       10.93.21.3       HTTP       134 GET /rest/HTP/1.1       104 HTTP/1.1         864 7.20803250       10.93.21.3       172.217.106.35       CSP       43 Haquest       104 HTTP/1.1       104 HTTP/1.1       104 HTTP/1.1         864 7.20803250       10.93.21.3       10.93.21.3       CCP       70 Preprome       0K (PNG)       104 HTTP/1.1       104 HTTP/1.1       104 HTTP	34997082 104.83.151.55 10.93.21.3 HTTP 1940 HTTP/1.1 200 K (text/ntl) 44750228 104.83.151.55 10.93.21.3 HTTP 130 HTTP/1.1 200 K (text/ntl) 44750228 104.83.151.55 10.93.21.3 HTTP 557 HTTP/1.1 200 K (text/ntl) 44750228 104.83.151.55 10.93.21.3 HTTP 557 HTTP/1.1 200 K (text/ntl) 5577758 10.93.21.3 104.83.115.155 HTTP 447 GT /spollphts-supprt/reserv/? format=json HTP/1.1 58970228 10.93.21.3 104.83.115.155 HTTP 447 GT /spollphts-supprt/reserv?/ format=json HTP/1.1 5897028 10.93.21.3 104.83.115.155 HTTP 447 GT /spollphts-supprt/reserv?/ format=json HTP/1.1 5897028 10.93.21.3 104.83.115.155 HTTP 447 GT /spollphts-supprt/reserv?/ format=json HTP/1.1 5897028 10.93.21.3 104.83.115.155 HTTP 447 GT /spollphts-supprt/ranourcedus/2.format=json HTP/1.1 5897028 10.93.21.3 104.83.115.155 HTTP 344 HTP/1.1 200 K (text/ntl) 5897028 10.93.21.3 172.217.168.55 HTTP 349 GT /Hense/stt7assts/favicon/favi	998 4.239457441	10.93.21.3	104.83.115.155	HTTP	382 GET /themes/mit/assets/is/Notification_67f936de376c7a247e31.is HTTP/1.1	
338 4.35954809 194.83.115.155 10.93.21.3 HTP 720 HTP/1.1 200 GK (fex/fhtm) 174 4.57674356 194.83.115.155 10.93.21.3 HTP 557 HTP/1.1 200 GK (fex/fhtm) 174 4.57674356 194.83.115.155 10.93.21.3 HTP 440 GE / Gorl (fex/fhtm) 174 4.57674356 194.83.115.155 10.93.21.3 HTP 440 GE / Gorl (fex/fhtm) 184 4.726843752 194.83.115.155 11.93.21.3 HTP 1440 GE / Gorl (fex/fhtm) 184 4.726843752 194.83.115.155 10.93.21.3 HTP 104 HTP/1.120 GK (fex/fhtm) 184 4.726843752 194.83.115.155 HTP 336 GET / theses/mit/asst//asicon/fasicon-192x192.png HTP/1.1 184 4.726843752 194.83.115.155 11.93.21.3 HTP 330 GET / theses/mit/asst//asicon/fasicon-192x192.png HTP/1.1 184 4.726843752 194.83.115.155 HTP 330 GET / theses/mit/asst//asicon/fasicon-192x192.png HTP/1.1 184 4.726442185200 19.83.21.3 HTF/1.227.184.30 CCP 431 Request 184 94542190 19.83.21.3 HTF/1.227.186.35 UCP 431 Request 184 94542190 HT 194.216 HTP/1.1 200 K (fNG) 185 9.63596666 194.83.115.155 HTP 230 GET / theses/mit/asst//asicon/fasicon-16x16.png HTP/1.1 184 94542190 HTP/1.120 HTP/1.120 K (FNG) 185 9.63596666 194.83.115.155 HTP 242 HTP/1.1 200 K (FNG) 185 9.63596668 194.83.115.155 HTP 242 HTP/1.1 200 K (FNG) 185 9.63596668 194.83.115.155 HTP 242 HTP/1.1 200 K (FNG) 185 9.63596668 194.83.115.155 HTP 257 00.956; 195.050 HTP/1.1 00 K (FNG) 185 Franker Protocol. 187 Franker Protocol. 187 Franker Protocol. 187 Franker Protocol. 187 Franker Protocol. 198 96 c Ff 12 c 00 59 56 bb db ad 08 00 45 00, P V·····E	339954989 104.83.151.55 10.93.21.3 HTTP 710 HTTP/1.1 200 K (text/html) 43792268 104.83.151.55 10.93.21.3 HTTP 800 HTTP/1.1 200 K (text/html) 43792268 104.83.151.55 10.93.21.3 HTTP 800 HTTP/1.1 200 K (text/html) 50764798 104.83.151.55 10.93.21.3 HTTP 300 HTTP/1.1 200 K (text/html) 50764798 104.83.151.55 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/html) 518438180 104.83.155.55 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/html) 518438180 104.83.155.55 10.93.21.3 HTTP 300 HTTP/1.1 200 K (text/html) 518438180 104.83.155.55 10.93.21.3 HTTP 242 HTTP/1.1 200 K (text/html) 51843180 105.55 10.93.21.3 HTTP 242 HTTP/1.1 200 K (text/html) 5196 bytes nutric 3106 bits, 306 bytes captured (3106 bits) on interfice 0 11, 5rc: Wmare_b8:dbiad (06:56:56:b6:dbiad), bst: 65:scg=5f:f3:2c (09:56:56:b6:dbiad), bst: 65:scg=5f:f3:2c (09:56:56:56:56:56:56:56:56:56:56:56:56:56:	333 4 349976023	104 83 115 155	10 93 21 3	HTTP	1949 HTTP/1 1 209 OK (application/javascript)	
868 4.48792288 104.83.115.125       10.33.22.3       HTTP       557 HTTP/1.12 00 K (fext/httl)         774 5.5764758 104.83.115.155       10.33.21.3       104.83.115.155       10.74.757         774 5.5764758 104.83.115.155       10.73.21.3       HTTP       557 HTTP/1.12 00 K (fext/httl)         774 5.5764758 104.83.115.155       10.73.21.3       HTTP       480 GT / optilation/javascript)         774 5.5764758 104.83.115.155       10.93.21.3       HTTP       234 HTTP/1.12 00 K (fext/httl)         804 4.728043050 104.83.115.155       10.93.21.3       HTTP       324 HTTP/1.12 00 K (fext/httl)         804 4.728043050 104.83.115.155       10.93.21.3       HTTP       336 HTTP/1.12 00 K (fext/httl)         804 4.728043050 104.83.115.155       HTTP       336 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)         804 4.728043050 104.83.115.155       HTTP       336 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)         803 4.72804050 105.31.3       HTTP 105 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)         803 4.72804050 104.83.115.155       HTTP 104 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)         804 4.936123960 172.47.166.35       10.93.21.3       HTTP 124 HTTP/1.12 00 K (fext/httl)       100 HTTP/1.12 00 K (fext/httl)      <	487982288 104.83.151.55 10.93.21.3 HTTP 557 HTTP/1.1 200 KC (text/html) 56787358 10.93.21.3 104.83.151.55 HTTP 440 6FT /spollphts-export/recent/2_formation/avascript) 568977758 10.93.21.3 104.83.151.55 HTTP 440 6FT /spollphts-export/recent/2_formation/avascript) 56897228 10.93.21.3 104.83.151.55 HTTP 440 6FT /spollphts-export/recent/2_formation/avascript) 568972788 10.93.21.3 104.83.151.55 HTTP 420 6FT /spollphts-export/recent/2_formation/avascript) 568972788 10.93.21.3 104.83.151.55 HTTP 324 HTTP/1.1 200 KC (text/html) 578082680 10.93.21.3 104.83.155.55 HTTP 324 GFT /spollphts-export/recent/2_formation/avascript) 568972781 20.93.21.3 104.83.155.55 HTTP 324 GFT /spollphts-export/recent/2_formation/avascript) 568977781 20.93.21.3 104.83.155 HTTP 340 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 5826476080 10.93.21.3 104.83.155 HTTP 340 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 582647150 10.93.21.3 104.83.155 HTTP 340 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 582647150 11.72.271.08.05 10.93.21.3 HTTP 340 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 583654756 10.93.21.3 10.93.21.3 HTTP 340 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 583654756 10.93.21.3 10.93.21.3 HTTP 340 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 583654756 10.93.21.93 10.93.21.93 HTTP 342 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 583654756 10.95.55 10.93.21.3 HTTP 342 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 583654756 10.95.55 10.93.21.3 HTTP 342 GFT /benes/it/issets/favicon/favicon-16x10.png HTTP/1.1 583654756 10.95.55 10.95.55 10.95.55 10.95.55 10.95.55 10.95 10.95 10.95 10.95 10.95 10.95 10.95 10.95 10.95 10.95 10.95 10.	335 4 358594869	104 83 115 155	10 93 21 3	HTTP	710 HTTP/1 1 200 OK (text/html)	
0.764 4.59737830       104.83.115.125       HTP       B09 HTTP/1.1 200 0K (application/ywarript)         1764 4.5973782       10.83.21.3       104.83.115.155       HTP       440 GET /spollpits-scoper/recent/2.formatison HTP/1.1         1824 4.5972822       10.83.21.3       104.83.115.155       HTP       440 GET /spollpits-scoper/recent/2.formatison HTP/1.1         1824 4.5972822       10.83.21.3       104.83.115.155       HTP       234 HTP/1.1 200 K (ter/html)         1824 4.5972822       10.83.21.3       104.83.115.155       HTP       234 HTP/1.1 200 K (ter/html)         1824 4.592483222       10.83.21.3       104.83.115.155       HTP       330 GET /theses/mit/assets/faxicon/faxicon-16x16.png HTF/1.1         1824 4.592483222       10.83.21.3       104.83.115.155       HTP       330 GET /theses/mit/assets/faxicon/faxicon-16x16.png HTF/1.1         1824 4.592480320       10.83.21.3       104.83.115.155       HTP       330 GET /theses/mit/assets/faxicon/faxicon-16x16.png MTF/1.1         184 4.822480500       10.83.21.3       104.83.115.155       HTP       330 GET /theses/mit/assets/faxicon/faxicon/faxicon-16x16.png MTF/1.1         184 4.822480500       10.83.21.3       104.83.115.155       HTP       242 HTTP/1.1 200 K (FMG)         185 4.838060668       104.83.115.155       HTP       242 HTTP/1.1 200 K (FMG)         185 5.838060668<	isorder308       104.83.115.155       10.83.21.3       11TP       800 HTTP/1.1.200 KC (application/ayacript)         isorder308       104.83.115.155       104.83.115.155       HTTP       440 GT / spoilights-xcport/constr_format=jon HTP/1.1         isorder30758       104.83.115.155       HTTP       440 GT / spoilights-xcport/constr_format=jon HTP/1.1         isorder3022       10.93.21.3       104.83.115.155       HTTP       440 GT / spoilights-xcport/constr_format=jon HTP/1.1         isorder3022       10.93.21.3       104.83.115.155       HTTP       356 GT / themes/stificates/favicon/favicon-10.102.192.192.19         isorder3026       10.93.21.3       104.83.115.155       HTTP       356 GT / themes/stificates/favicon/favicon-10.102.192.192.19         isorder3026       10.93.21.3       104.83.115.155       HTTP       356 GT / themes/stificates/favicon/favicon-10.102.192.192.19         021805026       10.93.21.3       104.83.115.155       HTTP       356 GT / themes/stificates/favicon/favicon-10.102.192.192.190         021805026       10.93.21.3       172.217.108.05       OCSP       451 Request         021805026       10.93.21.3       HTTP       240 HTTP/1.1 200 K (PMG)         021805026       10.93.21.3       HTTP       24 HTTP/1.1 200 K (PMG)         021805026       10.93.21.3       HTTP       24 HTTP/1.1 200 K	061 4 487502268	104 83 115 155	10.93.21.3	HTTP	557 HTTP/1 1 200 0K (text/html)	
178<4.59877758	<pre>369327738 10.93.21.3 104.83.115.155 HTTP 440 GET /spollipts-export/recent//frametijon HTP/1.1 56972738 10.93.21.3 104.83.115.155 HTTP 440 GET /spollipts-export/recent//frametijon HTP/1.1 578098262 104.83.151.155 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/httl) 728098262 104.83.151.155 10.93.21.3 HTTP 324 HTTP/1.200 K (text/httl) 728098262 104.93.151.155 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/httl) 728182620 10.93.21.3 104.93.115.155 HTTP 324 HTTP/1.1 200 K (text/httl) 728182620 10.93.21.3 104.93.115.155 HTTP 324 HTTP/1.1 200 K (text/httl) 738182620 10.93.21.3 104.93.115.155 HTTP 324 HTTP/1.1 200 K (text/httl) 748182620 HA.83.151.155 10.93.21.3 HTTP 519 HTTP/1.1 200 K (text/httl) 748182620 HA.83.151.155 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/httl) 748182620 HA.83.151.155 10.93.21.3 HTTP 319 HTTP/1.1 200 K (text/httl) 748182600 HA.83.151.155 10.93.21.3 HTTP 319 HTTP/1.1 200 K (text/httl) 749182600 HA.83.151.155 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/httl) 749182600 HA.83.151.155 HTTP/1.1 200 K (text/httl) 74918210 HTTP/1.1 200 HTTP/1.1 20</pre>	76 4.567647936	104.83.115.155	10.93.21.3	HTTP	869 HTTP/1.1 200 OK (application/javascript)	
122         4.389722222         10.33.2.1.3         104.85.125.155         HTP         4.47 GET /*poilingits-scopt/channessents/7_format=jon HTTP/1.1           004         4.128083262         104.83.15.155         10.93.2.1.3         HTP         124 HTP/1.1 200 K (text/html)           004         4.128083261         104.83.115.155         10.93.2.1.3         HTP         124 HTP/1.1 200 K (text/html)           004         4.128083262         104.83.115.155         10.93.2.1.3         HTP         1340 HTP/1.1 200 K (text/html)           004         4.128083262         10.93.2.1.3         117.2.217.106.35         OCSP         431 Request           014         4.128243262         10.4.83.115.155         HTP         534 HTP/1.1 200 K (text/html)         MTP/1.1           014         4.22248082         10.93.2.1.3         HTP         534 HTP/1.1 200 K (Fext/html)         MTP/1.1           014         4.2224808         172.217.108.35         10.93.2.1.3         HTP         534 HTP/1.1 200 K (FeNG)           014         4.42242166         172.217.108.35         10.93.2.1.3         HTP         518 HTP/1.1 200 K (FNG)           015         2.99.299.299.299.299.299.299.299.299.29	<pre>369792222 10.93.21.3 104.63.115.155 HTTP 447 GFT /spollphts-export/announcements/f.formatijson HTTP/1.1 778983825 10.93.8.115.155 10.93.2.1.3 HTTP 447 GFT /spollphts-export/announcements/f.formatijson HTTP/1.1 31943B184 104.83.115.155 10.93.2.1.3 HTTP 1094 HTTP/1.1 200 K (text/html) 31943B184 104.83.115.155 10.93.2.1.3 HTTP 1094 HTTP/1.1 200 K (text/html) 321836200 10.93.2.1.3 172.217.108.35 HTTP 349 GFT /html=/straiseis/favicon/favico</pre>	78 4.569377758	10.93.21.3	104.83.115.155	HTTP	440 GET /spotlights-expert/recent/2 formataison HTTP/1.1	
088 4.29883826       104.83.115.155       10.93.21.3       HTP       324 HTP/1.1 200 K (tex/t/htm)         064 4.891433162       104.83.115.155       105.32.1.3       HTP       335 GET / themes/mit/asset/#aicon/droid-icon-192x192.png HTP/1.1         064 4.891433162       108.83.21.3       104.83.115.155       HTP       335 GET / themes/mit/asset/#aicon/facion-192x192.png HTP/1.1         064 4.891433162       108.83.21.3       104.83.115.155       HTP       335 GET / themes/mit/asset/#aicon/facion-192x192.png HTP/1.1         074 4.941274455       108.32.1.3       104.83.115.155       HTP       335 GET / themes/mit/asset/#aicon/facion-192x192.png HTP/1.1         074 4.941274455       108.32.1.3       HTP       335 GET / themes/mit/asset/#aicon/facion-192x192.png HTP/1.1         074 4.941274455       104.83.115.155       10.93.21.3       HTP       519 HTP/1.1 200 OK (FWO)         074 5.941274455       104.33.115.155       10.93.21.3       HTP       22 HTP/1.1 200 OK (FWO)         072 300 5/tres on uire (3160 104.30, 105.15, 365 bites captured (3160 bits) on interface 0       -       -         rmet 11, Src: Vmware_Bsitbitad (069:56:561:8d:ad), bits 10, interface 0       -       -         rmet 11, Src: Vmware_Bsitbitad (069:56:561:8d:ad), bits 0, interface 0       -       -         rmet Protocol_Urceinol_A src Port: 06334, bit Port: 00, Seq: 1, Ack: 1, Len: 330       -<	<pre>7280883282 104.83.115.155 10.93.21.3 HTTP 324 HTTP/1.1 200 K (text/html) 82943168 104.83.115.155 10.93.21.3 HTTP 336 GTT /themes/mit/assets/faulcon/mar/od-ion-192x192.prg HTTP/1.1 82948086 104.83.115.155 HTTP 360 K (text/html) 82943128 104.83.115.155 HTTP 340 GTT /themes/mit/assets/faulcon/faulcon-192x192.prg HTTP/1.1 830 GTT /themes/mit/assets/faulcon/faulcon-192x192.prg HTTP/1.1 830 GTT /themes/mit/assets/faulcon/faulcon-192x192.prg HTTP/1.1 830 GTT /themes/mit/assets/faulcon/faulcon-192x192.prg HTTP/1.1 830 GTT /themes/mit/assets/faulcon/faulcon-192x192.prg HTTP/1.1 840 GTT /themes/mit/assets/faulcon/faulcon-10x61.prg HTTP/1.1 840 GTT /themes/mit/assets/faulcon/fa</pre>	82 4.589702282	10.93.21.3	104.83.115.155	HTTP	447 GET /spotlights-export/appouncements/2 format=ison HTTP/1.1	
1004 4.5542160 104.83.155.155 10.93.21.3 HTTP 1004 HTTP/1.1 200 CK (text/httl) 1054 4.52432163 10.93.21.3 104.83.155.155 HTTP 336 GET /themes/mit/assets/favicon/ido/id.con-192x192.png HTTP/1.1 1053 4.522408966 10.93.21.3 104.83.155.155 HTTP 336 GET /themes/mit/assets/favicon/favicon-16x16.png HTTP/1.1 1054 4.522408966 10.93.21.3 107.221.768.35 0.59 451 Request 1054 4.504216506 110.93.21.3 107.221.768.35 0.59 107.778 451 451 451 451 451 451 451 451 451 451	383493328       104.83.15.155       10.83.21.3       104.83.151.55       117       1094 HTTP/1.1 200 DK (text/html)         38248322       104.83.151.55       117       340 GFT /thmes/stifassets/favicon/adroid-icon-192x192.png HTTP/1.1         38248328       108.93.21.3       104.83.151.55       HTT       340 GFT /thmes/stifassets/favicon/adroid-icon-192x192.png HTTP/1.1         38248328       108.93.21.3       104.83.151.55       HTT       340 GFT /thmes/stifassets/favicon/adroid-icon-192x192.png HTTP/1.1         38248028       108.92.21.3       104.83.151.55       10.53.21.3       HTTP       519 HTTP/1.1         38050665       108.92.21.3       10.75.21.7       110.72.02       0K (PMG)         38050666       108.92.21.3       HTTP       519 HTTP/1.1       200 OK (PMG)         38050666       108.92.15.155       10.93.22.1.3       HTTP       242 HTTP/1.1       200 OK (PMG)         21.305 Bytes on wirs (1368 bits), 306 bytes captured (1366 bits) on interfnoc θ       11.300 OK (PMG)       11.300 OK (PMG)         21.305 Bytes on All Src: 10.93.21.3, 081: 194.08.115.155       10.081: 194.08.115.155       10.081: 194.08.115.155       11.080 OK (PMG)         21.305 Bytes on All Src: 10.93.21.3, 081: 194.08.115.155       11.300 OK (PMG)       11.300 OK (PMG)       11.300 OK (PMG)         21.305 Bytes on All Src : 10.93.21.3, 081: 194.	08 4.728083625	104.83.115.155	10.93.21.3	HTTP	324 HTTP/1.1 200 0K (text/html)	
102 4.02143322       10.03.21.3       104.83.15.155       HTTP       336 GET (themes/mit/assets/faxicon/david-icon-192x132.png HTTP/1.1         05 4.02240806       10.03.21.3       104.83.15.155       HTTP       336 GET (themes/mit/assets/faxicon/david-icon-192x132.png HTTP/1.1         05 4.02240806       10.03.21.3       104.83.15.155       HTTP       336 GET (themes/mit/assets/faxicon/f	#32183322       10.9.3.21.3       104.83.115.155       HTTP       356 GET //thems/st/14/sets/favico//favicon-132x152.png HTTP/1.1         #32280868       10.93.21.3       172.217.108.35       OCSP       431 Request         #02180208       10.93.21.3       172.217.108.35       OCSP       431 Request         #02180208       10.93.21.3       172.217.108.35       OCSP       431 Request         #02180208       10.93.21.3       172.217.108.35       OCSP       431 Request         #031804       17.2.277.108.35       10.95.21.3       HTTP       242 HTTP/1.1         #031806       12.2.277.108.35       10.95.21.3       HTTP       242 HTTP/1.1         #031806       12.2.277.108.35       10.95.21.3       HTTP       242 HTTP/1.1         #03808068       104.483.115.155       10.95.21.3       HTTP       242 HTTP/1.1       260 WC (PMG)         #038080681       104.483.115.155       10.95.21.3       HTTP       242 HTTP/1.1       260 WC (PMG)         #038080681       (050:565.056.056.056.036.03.01.051       0.01.051.761.60       III.       370       HTTP/3.1       260 WC (PMG)         #000001712       Protocol       Frainsfer Protocol       Frainsfer Protocol       Frainsfer Protocol       Frainsfer Protocol       Frainsfer Protocol	60 4.819438168	104.83.115.155	10.93.21.3	HTTP	1084 HTTP/1.1 208 0K (text/html)	
083 4.022400080 10.03.21.3 104.85.15.155 HTTP 340 GET (/themse/mit/assets/favicon/favicon-fok16.png MTTP/1.1 074 0.439179455 104.83.115.155 10.03.21.48.3 DTP 519 MTTP/1.1 200 GK (PMG) 084 0.450421060 172.217.168.3 GL 053 0.13.3 CTP 707 Response 0752 300 ptros on wire (3160 bits), 396 ptros captured (3160 bits) on interface 0 0772 130 ptros on wire (3160 bits), 396 ptros captured (3160 bits) on interface 0 0771 Mark 10.1 CTP 10	822480880       10, 93, 21, 3       104, 83, 115, 155       117       349 GFT / themes/stifasets/favicon/	62 4.821843322	10.93.21.3	104.83.115.155	HTTP	356 GET /themes/mit/assets/favicon/android-icon-192x192.png HTTP/1.1	
067 4.0232832000 10.03.21.3       172.217.106.35       0CSP       431 Request         176 4.04321340 10.04.33 11.5.35       10.03.21.3       0CSP       707 Response         080 4.05421960 172.217.106.35       10.03.21.3       0CSP       707 Response         176 4.04321436 172.217.106.35       10.03.21.3       0CSP       707 Response         177 Response       00.05 P       707 Response       00.05 P         178 175 Response       00.05 P       707 Response       00.05 P         178 175 Response       00.05 P       707 Response       00.05 P         178 175 Response       00.05 P       10.03 Response       00.05 P         178 175 Response       00.05 P       10.03 Response       00.05 P         178 175 Response       01.05 Response       00.05 P       00.05 P         178 175 Response       01.05 Response       00.05 P       00.05 P         178 175 Response       01.05 Response       00.05 P       00.05 P         178 175 Response       01.05 Response       00.05 P       10.05 Response         178 175 Response       01.05 Response       01.05 Response       10.05 Response         178 175 Response       01.05 Response       10.05 Response       10.05 Response         178 175 Response       01.05	9218382308 16.93.21.3 172.217.168.35 0CSP 411 Request 9219382308 16.83.115.155 10.93.21.3 0CSP 707 Response 949179455 16.83.115.155 10.93.21.3 0CSP 707 Response 949179455 16.94.3115.155 2398 bytes on wire (3186 bits), 396 bytes catured (3166 bits) on interface 0 II, Src: Wmarp DB:db:db:060:96:96:96:96:060:01; 00:0167:63.2c (976:32c (976:	63 4.822408086	10.93.21.3	104.83.115.155	HTTP	349 GET /themes/mit/assets/favicon/favicon-16x16.png HTTP/1.1	
778<4.342179435	949129435 104.83.115.155 10.93.21.3 HTTP 519 HTP/1.1 200 0K (PMG) 939129606 12.27.150.35 10.93.21.3 HTTP 22 HTTP/1.1 200 0K (PMG) 339506660 104.83.151.515 10.93.21.3 HTTP 22 HTTP/1.1 200 0K (PMG) 23950Ht50 nxtre 3106 bits, 306 byts captured (3106 bits) on interface 0 II, src: Wmare_b8:db:add (00:506:506:506:304, Dat: Cisco_97:f3:2C (00:00:0:0ff3:2C) Protocol Version 4, src: 10.33.21.3, bot: T04:33.115.155 E Transfer Protocol E Transfer Protocol 0 0 oc 9f f3 2C 00 50 56 b8 db ad 08 00 45 00 ····, P V····E 6 a db 54 00 64 06 of f7 66 as 51 55 06 65 3····0 00 P····). MS 10 0 oc 9f f3 21 ac ef5 00 137 40 01 8 ····) P·····E	67 4,921836200	10.93.21.3	172,217,168,35	OCSP	451 Request	
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Figure 1: Messages containing the HTTP protocol

• What messages were exchanged at the **transport layer**, i.e., between the transport layer on your computer and the transport layer on the computer running the MIT web server? This is a little bit trickier to answer. First of all, you need enter in the filter line the correct transport-layer technology/communication protocol, which you figured out in the previous question. But if you do just that, then you will see ALL the messages exchanged by your computer using that protocol, whereas you only want the ones exchanged with the computer running the MIT web server. So, you need to add something more to the filter. Poke around a bit in Wireshark documentation on how to specify filters, and you should figure it out.

A key point here is that the application-layer messages and the transport-layer messages were not carried in separate Internet packets. Rather, the same packets carried BOTH transport-layer and application-layer information, but the transportlayer information was stored inside the transport-layer header of each packet, whereas the application-layer information was stored inside the application-layer header and data.

The filter we need to apply is tcp and (ip.src==104.83.115.155 or ip.dst==104.83.115.155), because it displays all the TCP messages sent or received by the computer running the MIT web server (which has IP address 104.83.115.155). You may need to change this IP address to

a different one, if you happened to access the MIT web site through a different computer.

As we can see in Fig 2, the messages exchanged at the transport layer are:

- SYN (to initiate a TCP connection),
- SYN ACK,
- data packets,
- FIN (to end a connection),
- FIN ACK.

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📕 tcp a	and (ip.src == 104.83.)	115.155 or ip.dst == 104.8	33.115.155)				Expression +	
No.	Time	Source	Destination	Protocol	Length Info			
E 1	747 3.180884470	10.93.21.3	104.83.115.155	TCP	74 56334 → 80 [SYN	Seg=0 Win=64240 Len=0 MSS=1460 SACK PERM=1 TSval=3412153836 TSecr=0 WS=128		
	760 3.194054218	104.83.115.155	10.93.21.3	TCP	74 80 → 56334 [SYN	, ACK] Seq=0 Ack=1 Win=28960 Len=0 MSS=1380 SACK_PERM=1 TSval=2608176211 TSecr=3412	153836 WS=128	
	761 3.194076497	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 [ACK	] Seq=1 Ack=1 Win=64256 Len=0 TSval=3412153849 TSecr=2608176211		
	792 3.278930353	10.93.21.3	104.83.115.155	HTTP	396 GET / HTTP/1.1			
	800 3.292025781	104.83.115.155	10.93.21.3	TCP	66 80 → 56334 [ACK	Seq=1 Ack=331 Win=30080 Len=0 TSval=2608176309 TSecr=3412153934	c 13 1 mm3	
	801 3.297959922	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	5 Seq=1 Ack=331 Win=30080 Len=1308 ISVA1=20081/0315 ISecT=3412153934 [ICP segment of	7 a reassembled PDUJ	
	902 3.29/9/0030	10.03.21.3	10 02 21 2	TCP	1424 80 - 56224 [ACK	] 364-331 ACK-1309 W1H-04120 L0H-0 13941-3412133533 13001-20001/0513 ] Can-1360 Ack-231 WiH-30000 Lan-1360 TCual-2600176315 TCarr-3412153034 [TCD saman]	t of a reassembled PD	
	804 3 298009823	10.93.21.3	184 83 115 155	TCP	66 56334 → 89 [ACK	3 Sen 331 Ack=2737 Win=53488 Len:0 TSval=241215353 TSec=2698176315	. of a reasoning cu ro	
	805 3.298017112	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	Seg=2737 Ack=331 Win=30080 Len=1368 TSval=2608176315 TSecr=3412153934 [TCP segment	t of a reassembled PD	
	806 3.298021374	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 ACK	Seq=331 Ack=4105 Win=62592 Len=0 TSval=3412153953 TSecr=2608176315		
	807 3.298027327	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	Seq=4105 Ack=331 Win=30080 Len=1368 TSval=2608176315 TSecr=3412153934 [TCP segment	t of a reassembled PD	
	808 3.298029703	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 [ACK	Seq=331 Ack=5473 Win=61568 Len=0 TSval=3412153953 TSecr=2608176315		
	809 3.298035294	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	] Seq=5473 Ack=331 Win=30080 Len=1368 TSval=2608176315 TSecr=3412153934 [TCP segment	t of a reassembled PD	
	810 3.298047680	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 [ACK	] Seq=331 Ack=6841 Win=63360 Len=0 TSval=3412153953 TSecr=2608176315		
	811 3.298052981	104.83.115.155	10.93.21.3	HTTP	1342 HTTP/1.1 200 OK	(text/html)		
	812 3.298064086	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 [ACK	J Seq=331 Ack=8117 Win=62208 Len=0 TSval=3412153953 TSecr=2608176315		
1	119 3.002/933/1	10.93.21.3	104.83.115.155	TCD	377 GET / themes/mit	/4559E5/C55/main.C55/dF1//y HTTP/1.1		
1	120 3.0009143/8	10.93.21.3	104.03.115.155	TCP	74 50342 → 80 [STN 74 56344 - 80 [STN	504-0 Win-04240 LEI-0 MSS-1400 SAUK_PERM-1 ISVAI-3412104310 ISECI-0 WS-120		
1	131 3 668285435	10/ 83 115 155	18 93 21 3	TCP	1434 80 - 56334 [ACK	] 36440 Will04240 Leleo M33-1400 3402 Texal=1341-3412134310 13611-0 W3-120   Sents117 ArtsA2 Win=3104   Jon=3368 TSVA]=2608176686 TSCert=3412154308 [TCD senten:	t of a reassembled PD	
1	132 3.668303635	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 FACK	Sec. 542 Ack=9485 Win=64128 Len=0 TSval=3412154323 TSecr=2698176686	. of a reasoning of the	
1	133 3.668338027	104.83.115.155	10.93.21.3	TCP	1434 80 - 56334 [ACK	Seg=9485 Ack=642 Win=31104 Len=1368 TSval=2608176686 TSecr=3412154308 [TCP segment	t of a reassembled PD	
1:	134 3.668342402	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 ACK	Seg=642 Ack=10853 Win=64128 Len=0 TSval=3412154323 TSecr=2608176686		
1:	135 3.668350166	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	Seq=10853 Ack=642 Win=31104 Len=1368 TSval=2608176686 TSecr=3412154308 [TCP segme	nt of a reassembled P	
1	136 3.668354574	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 [ACK	] Seq=642 Ack=12221 Win=63488 Len=0 TSval=3412154323 TSecr=2608176686		
1	137 3.668356221	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	Seq=12221 Ack=642 Win=31104 Len=1368 TSval=2608176686 TSecr=3412154308 [TCP segments]	nt of a reassembled P	
1	138 3.668359728	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 [ACK	Seq=642 Ack=13589 Win=62592 Len=0 TSval=3412154323 TSecr=2608176686		
1	139 3.668366710	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	Seq=13589 Ack=642 Win=31104 Len=1368 TSval=2608176686 TSecr=3412154308 [TCP segment	it of a reassembled P	
1	140 3.668369639	10.93.21.3	104.83.115.155	TCP	66 56334 - 88 [ACK	Seq=642 Ack=14957 Win=61568 Len=0 ISVA1=3412154323 ISeCF=2608176686	the first state while the provided of the state of the st	
1	141 3.0003/0440	104.03.113.133	10.93.21.3	TCP	1434 00 → 50334 [ACK 66 56224 - 90 [ACK	] 384-14937 ACK-042 WIN-51104 L8N-1300 ISV41-20001/0000 IS8CT-3412134300 [TCP SEGNET Can-842 Ark-18235 Win-80872 Lan-6 TSV41-2412164292 TSer-2609178808	it of a reassembled P	
1	142 3 669509070	104 92 115 155	10 92 21 2	TCP	1434 80 - 56334 FACK	] 364-042 ACK-10323 MIN-00072 ECH-0 13VAI-3412134323 1300-20010000 10000 1000 1000 1000 1000 10	nt of a reassembled P	
1	144 3 668512466	10.93.21.3	184 83 115 155	TCP	66 56334 → 89 [ACK	3 Sen:642 Ack=17693 Win=64128 Len: 1000 T3V1=3412154001 T000 T3CT=2608176686	ie of a reassembled r	
1	145 3.668564712	104.83.115.155	10.93.21.3	TCP	1434 80 → 56334 [ACK	Seg=17693 Ack=642 Win=31104 Len=1368 TSval=2608176686 TSecr=3412154308 [TCP segment	nt of a reassembled P	
1:	146 3.668568672	10.93.21.3	104.83.115.155	TCP	66 56334 → 80 ACK	Seg=642 Ack=19061 Win=64128 Len=0 TSval=3412154323 TSecr=2608176686		
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▶ Inte	ernet Protocol V	ersion 4, Src: 10.9	3.21.3, Dst: 104.83.1	15.155				
Trans	nsmission Contro	l Protocol, Src Por	t: 56334, Dst Port: 80	0, Seq: 0,	Len: 0			
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0000	00 00 0c 9f f3	2c 00 50 56 b8 db	ad 08 00 45 00 · · · ·	., .P V	···E·			
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0 7	lab1.pcapng					Packets: 8032 · Displayed: 1120 (13.9%)	Profile: Default	

Figure 2: TCP messages exchanged with www.mit.edu

Now we will examine the concept of **encapsulation**, meaning that each message encapsulates a message that belongs to a higher layer. E.g., a network-layer message consists of a network-layer header plus a transport-layer message, which consists of a transport-layer header plus an application-layer message, which consists of an application-layer header plus data.

Display the messages that were exchanged at the application layer (the HTTP messages) and click on one of them:

• How many bytes does the HTTP message contain? To answer, check the packet details in the middle section of your Wireshark window. Look at the transport-

layer information and, in particular, the Len field, which specifies the size of the application-layer message that is encapsulated inside the transport-layer message.

- How many bytes do the transport-layer and network-layer headers add to the HTTP message?
- How many bytes does the link layer add?

See Fig 3.

This HTTP message contains 330 bytes, as shown in the Len field of the Transmission Control Protocol.

The TCP header adds 32 bytes, and the IP header 20 bytes.

The link layer adds 14 bytes.

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1119 3.652793371	10.93.21.3	104.83.115.155	HTTP	377 GET /themes/mit/assets/css/main.css?qf177y	HTTP/1.1			
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Figure 3: HTTP message

Finally, go to Statistics  $\longrightarrow$  Conversations window and check the "Limit to display filter" checkbox. This shows you a summary of the communications that your computer participated in in order to download the MIT web page. Can you tell how many remote computers (servers) your computer had to access?

See Fig 4.

According to this figure you accessed two servers, as there are two unique IP addresses in the "Address B" column. However, in reality, only one of them provided website content, the other one provided security related information that we will discuss later in the semester.

Wireshark - Conversations - lab 1.pcapng 🕒 💿 💿							
Ethernet-3 IPV4-2 IPV6 TCP-7 UDP							
Address A $\rightarrow$ Port A Address B Port B Packets Bytes Bytes Packets A $\rightarrow$ B Bytes A $\rightarrow$ B Packets B $\rightarrow$ A Bytes B $\rightarrow$ A Rel Start Dural	Bits/s $A \rightarrow B$ Bits/s $B \rightarrow A$						
10.93.21.3 56334 104.83.115.155 80 6 3,272 3 1,245 3 2,027 3.278930 0.	14k 23k						
10.93.21.3 56342 104.83.115.155 80 6 3,527 3 1,220 3 2,307 3,674866 0 10.93.21.3 56344 104.83.115.155 80 8 4.351 4 1602 4 2749 3,676866 0	14k 27k 10k 17k						
10.93.21.3 56348 104.83.115.155 80 4 2,394 2 855 2 1,539 3.800285 0.	8,913 16 k						
10.93.21.3 56350 104.83.115.155 80 8 4,432 4 1,639 4 2,793 3.840313 1.	10k 18k						
10.95.21.3 3522 104.83.115.155 80 2 1,448 1 408 1 1,040 3.842237 0. 10.93.21.3 35212 172.217.168.35 80 2 1.218 1 451 1 767 4.921836 0.0	5 209 K 533 K						
Name resolution I Limit to display filter	Conversation Types *						
Copy *	Follow Stream Graph XClose						

Figure 4: TCP conversations

This is it! If you feel like it, use Wireshark to capture your computer's communications (outside the lab). You may be surprised...