Chapter 9
Sniffing

THE FOLLOWING CEH EXAM TOPICS ARE COVERED IN THIS CHAPTER:

- ✓ **Communication on protocols**
- ✓ **Network/wireless sniffers**
- ✓ **TCP/IP networking**
- ✓ **Detection techniques**

It used to be that sniffing was an expensive proposition. The reason is that there was a special network interface required to be able to capture the packets. On top of that was the software. If you wanted to capture packets, you needed special hardware and software, and there weren't many companies that could sell you that. Then came consumer network interfaces that didn't cost a fortune and could forward all packets up through the interface into the operating system. Finally, there was a piece of software called Ethereal. Suddenly, getting your packets captured was free.

Now there are several ways to capture packets. The most common software now to capture packets is freely available. Some of the software is command-line oriented, which is really helpful if you are connected to a system over SSH or other mechanisms that provide only a text-oriented interface. This sort of software is not great for analysis if you need to dig into the packet content and see entire streams, not to mention if you want to go deeper with your analysis and get statistics and graphs. Fortunately, there is software for that purpose. It was once called Ethereal, but it's currently called Wireshark, and it has a lot of capabilities to enable deep analysis of the packets.

A challenge we have today is that most networks are switched. This means the network is essentially segmented. Only packets that are addressed to you in some way will get sent to your network interface. Since we may have the ability to see the data anyway, through the applications transmitting the messages, packet capture isn't nearly as interesting, to just look at messages to and from the device you are on. We need ways to get the rest of the traffic on the network to a system we have control of. Fortunately, there are several ways we can do that. We can even take a targeted approach at it, determining exactly which systems we want to get traffic from.

We also need to deal with encryption. Web traffic today generally defaults to using Transport Layer Security (TLS), which encrypts all messages. This is an issue that is challenging, since one of the predominant protocols becomes obscured to us. Fortunately, there are some ways around that.

Packet Capture

Why is packet capture so important? If you can get to the right place in the network to be able to capture the data, you can potentially grab usernames and passwords or other authentication/authorization traffic. An attacker could potentially grab credit card information or other personally identifiable information (PII) that is marketable. Depending on the organization, there could also be personal health information (PHI). There may be other information available on the network that could be useful as you are maneuvering through your client's assets.

Packet capturing is the process of acquiring network traffic that is addressed to systems other than your own. You can certainly capture packets that are only addressed to your system, but that's not especially interesting since you're already getting those. Network interface cards (NICs) are programmed to only forward frames up to the operating system whose destination MAC address is either the MAC address of the NIC or the broadcast MAC address (ff:ff:ff:ff:ff:ff). To force the NIC to forward all messages up to the operating system, the card has to be put into what is called promiscuous mode. This just gets the NIC to forward all messages up, behaving promiscuously.

NOTE Each layer of the Open Systems Interconnection (OSI) model has a different name for the chunk of data associated with it. This is called the *protocol data unit* (PDU). At layer 2, where we are grabbing the messages off the network, since they include the layer 2 header with MAC addresses, the PDU is called a *frame*. Technically, we are capturing frames. It's called *packet capturing*, though. A packet is the PDU for layer 3, which is the IP layer. At layer 4, TCP's PDU is a segment, while UDP's is a datagram. For our purposes, I'll be talking about packet capturing unless there is something related to the MAC address or the NIC. Then I'll be using the term *frame*.

Once the operating system, really, the networking stack in the operating system, has the frames, they can be intercepted by a piece of software. Once the software has the message, packet capturing software will parse the message, extracting information out of each protocol header. A command-line program, like `tcpdump`, which we will be looking at, may display information out of the different headers. You could also be using a graphical user interface (GUI), which has more options for how to display the header data, as well as the payload data.

Headers are the fields that are specific to the protocol. They provide instructions, as it were, to the protocol on how to behave. The data that is being carried from one endpoint to another is called the *payload*. This payload may be broken up between multiple packets and certainly multiple frames. Fragmentation may be forced by the maximum transmission unit (MTU) at layer 2 (the Frame layer). This is one reason it's easier to use a GUI-based program to analyze packets, even if we are capturing them with another tool. A program like Wireshark helps to make packet analysis much easier than if we were trying to review all the details on the command line.

tcpdump

For decades now, Unix systems have had programs that could capture packets. The program `tcpdump` was first written in the late 1980s and was later ported to other Unix implementations. It is a fairly easy to use but also powerful utility that was standardized in the late 1990s, pulling all the divergent implementations together. You will find this tool available on most, if not all, Linux distributions as well as the different Berkeley Software Distribution (BSD) distributions. It is a command-line program that can be used to give you an idea of what is happening on the network, but it can also be used to capture traffic and store that traffic in a file that can be opened later on.

In the following code listing, you can see what it takes to run `tcpdump`. This was done from a Kali Linux system. This is all that would take. You can see that the output shows mostly essential header information about each packet that has been captured. This is one reason this is called *packet capturing*. You may notice that all the layer 2 information has been removed. All you see in the output is the layer 3 information, along with a little layer 4. `tcpdump` has also helpfully indicated some of the details of the Application layer traffic. You can see, first of all, that there are DNS requests. There is a lookup of a hostname from an IP address. This is a pointer (PTR) record that is sometimes called a *reverse lookup*.

`tcpdump` with No Parameters

```
 root@quiche:~# tcpdump
 tcpdump: verbose output suppressed, use -v or -vv for full
protocol decode
 listening on eth0, link-type EN10MB (Ethernet), capture size
262144 bytes
 18:48:25.045517 ARP, Request who-has testwifi.here tell
localhost.lan, length 46
 18:48:25.046237 IP quiche.lan.39988> testwifi.here.domain:
58469+ PTR? 1.86.168.192.in-addr.arpa. (43)
 18:48:25.048456 IP testwifi.here.domain> quiche.lan.39988:
58469* 1/0/0 PTR testwifi.here. (95)
 18:48:25.048594 IP quiche.lan.58395> testwifi.here.domain:
35036+ PTR? 22.86.168.192.in-addr.arpa. (44)
 18:48:25.050179 IP testwifi.here.domain> quiche.lan.58395:
35036* 1/0/0 PTR localhost.lan. (97)
 18:48:25.050311 IP quiche.lan.56311> testwifi.here.domain:
38920+ PTR? 57.86.168.192.in-addr.arpa. (44)
 18:48:25.051758 IP testwifi.here.domain> quiche.lan.56311:
38920* 1/0/0 PTR quiche.lan. (94)
 18:48:25.458252 IP6 fe80::3847:ce36:d1cd:7729.61478>
```

```
ff02::c.1900: UDP, length 146
 18:48:25.458501 IP quiche.lan.56653> testwifi.here.domain:
33204+ PTR?
 c.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.2.0.f.
f.ip6.arpa. (90)
 18:48:25.467112 IP testwifi.here.domain> quiche.lan.56653:
33204 NXDomain 0/1/0 (154)
 18:48:25.467781 IP quiche.lan.44374> testwifi.here.domain:
6986+ PTR?
 9.2.7.7.d.c.1.d.6.3.e.c.7.4.8.3.0.0.0.0.0.0.0.0.0.0.0.0.0.8.e.
f.ip6.arpa. (90)
 18:48:25.488710 IP testwifi.here.domain> quiche.lan.44374:
6986 NXDomain 0/1/0 (154)
```

One of the issues with `tcpdump`, which you can see in the preceding code, is that by default it resolves all numeric addresses to ones that are more human-friendly. The hostnames and also the service ports are resolved to names from numeric addresses. The second line, for instance, shows that the destination address is `testwifi.here`, and the port is called *domain*. The full address is listed in `tcpdump` as *w.x.y.z.p*, where *w.x.y.z* is the IP address and *p* is the port number. So, when we see `testwifi.here.domain` here, `testwifi.here` is the hostname, resolved from the IP address, and `domain` is the service port. This tells us it's a DNS request. Many of the DNS requests you see are a result of a packet that has come in. You'll see the DNS request show before the packet because in order to display the packet, the DNS request has to be issued and come back.

You can easily change this behavior, since the DNS requests can get very noisy and it's hard to weed your way through to get to the traffic you really want to see. This is done by just adding `-n` to the command line. What you end up with is something like you see here.

`tcpdump` with No Name Resolution

```
 root@quiche:~# tcpdump -n
 tcpdump: verbose output suppressed, use -v or -vv for full
protocol decode
 listening on eth0, link-type EN10MB (Ethernet), capture size
262144 bytes
 20:42:16.326940 IP 192.168.86.210.40608> 239.255.255.250.1900:
UDP, length 558
```

```
 20:42:16.587114 IP 192.168.86.210.40608> 239.255.255.250.1900:
UDP, length 546
 20:42:16.703469 IP 192.168.86.24.5353> 224.0.0.251.5353: 0
[5a] [5q] [1au] PTR (QM)? _homekit._tcp.local. PTR (QM)?
_companion-link._tcp.local. TXT (QM)?
 9EA05B22-BBCC-5F9C-9C4B-10A7538DAAD9._homekit._tcp.local. TXT
(QU)? milobloom (2)._companion-link._tcp.local. PTR (QM)?
_sleep-proxy._udp.local. (282)
 20:42:16.704314 IP6 fe80::10ba:d862:9623:e420.5353>
ff02::fb.5353: 0 [5a] [5q] [1au] PTR (QM)? _homekit._tcp.local.
PTR (QM)? _companion-link._tcp.local. TXT (QM)? 9EA05B22-BBCC-
5F9C-9C4B-10A7538DAAD9._homekit._tcp.local. TXT (QU)? milobloom
(2)._companion-link._tcp.local. PTR (QM)? _sleep-
proxy._udp.local. (282)
 20:42:16.832644 IP 192.168.86.210.40608> 239.255.255.250.1900:
UDP, length 536
 20:42:16.845825 IP 192.168.86.46.5353> 224.0.0.251.5353: 0*-
[0q] 1/0/1 (Cache flush) TXT "si=AAB36E20-CDBD-4E60-BEEB-
1BC0A3AB8E2D" (141)
 20:42:16.846030 IP6 fe80::1cbd:790c:b9f2:aeb0.5353>
ff02::fb.5353: 0*- [0q] 1/0/1 (Cache flush) TXT "si=AAB36E20-
CDBD-4E60-BEEB-1BC0A3AB8E2D" (141)
 20:42:16.885944 IP 192.168.86.49.5353> 224.0.0.251.5353: 0*-
[0q] 1/0/1 (Cache flush) TXT "rpBA=AC:C5:14:0E:E0:35"
"rpAD=c77102094021" "rpHI=f27b7868fd6f" "rpHN=ce75eb6a989e"
"rpVr=164.16" "rpHA=ae260764c13d" (192)
 20:42:16.885964 IP6 fe80::1882:675c:7bdd:2de3.5353>
ff02::fb.5353: 0*- [0q] 1/0/1 (Cache flush) TXT
"rpBA=AC:C5:14:0E:E0:35" "rpAD=c77102094021"
"rpHI=f27b7868fd6f" "rpHN=ce75eb6a989e" "rpVr=164.16"
"rpHA=ae260764c13d" (192)
```

Much of what we see is fairly straightforward, though it may or may not be especially useful. As an example, the first captured packet is an IP packet. It tells us that right after the time stamp. Then we see the source address followed by >, showing the direction and then the destination address. This tells us that the packet is UDP and the length is 558. What we can also tell there is that the UDP datagram is the simple service discovery protocol (SSDP), part of universal plug and play (UPnP). We can tell this even without the assistance of `tcpdump` by just looking up the destination port number, if we don't happen to know that 1900 is a UPnP port. The source port for the datagram is just an ephemeral port, assigned by the operating system when the message is sent out on the network.

NOTE You may have noticed that the user logged into the system is root. Because we have to set a parameter in the hardware, we have to run `tcpdump` as an administrative user. On Linux, this is root. On Windows, it would be anyone in the Administrators group or another group that had permissions to interface with the network hardware like that.

We don't have to live with just the default level of detail. We can also ask for more detail about the packets that have been captured. There are multiple levels of verbosity that we can request of `tcpdump`. To get more verbose, we add `-v` to the command line. If we want even more detail than that, we use `-vv` and then `-vvv`. In the following listing, you can see a `tcpdump` capture with `-vv` as a command-line parameter to get additional details. Additionally, there is a parameter setting the snapshot length to 0. In practice, this sets the number of bytes per packet to 262,144, which is the default setting. This wasn't always the case. It was once the case that the snapshot length was very short, so to get complete packets, you had to tell `tcpdump` not to limit the number of bytes captured.

`tcpdump` Capturing with Additional Verbosity

```
 root@quiche:~# tcpdump -vv -s 0
 tcpdump: listening on eth0, link-type EN10MB (Ethernet),
capture size 262144 bytes
 10:40:27.047708 IP (tos 0x0, ttl 1, id 48781, offset 0, flags
[DF], proto UDP (17), length 228)
     samsung.lan.8001> st-routers.mcast.net.8001: [udp sum ok]
UDP, length 200
 10:40:27.048568 IP (tos 0x0, ttl 64, id 64646, offset 0, flags
[DF], proto UDP (17), length 68)
     quiche.lan.45867> testwifi.here.domain: [bad udp cksum
0x2dcd -> 0x690e!] 26697+ PTR? 7.0.0.224.in-addr.arpa. (40)
 10:40:27.068536 IP (tos 0x0, ttl 64, id 16931, offset 0, flags
[DF], proto UDP (17), length 102)
     testwifi.here.domain> quiche.lan.45867: [udp sum ok] 26697
q: PTR? 7.0.0.224.in-addr.arpa. 1/0/0 7.0.0.224.in-addr.arpa.
PTR st-routers.mcast.net. (74)
```

```
 10:40:27.068803 IP (tos 0x0, ttl 64, id 64650, offset 0, flags
[DF], proto UDP (17), length 72)
     quiche.lan.46802> testwifi.here.domain: [bad udp cksum
0x2dd1 -> 0x7eb6!] 42424+ PTR? 22.86.168.192.in-addr.arpa. (44)
 10:40:27.070769 IP (tos 0x0, ttl 64, id 16932, offset 0, flags
[DF], proto UDP (17), length 123)
     testwifi.here.domain> quiche.lan.46802: [udp sum ok]
42424* q: PTR? 22.86.168.192.in-addr.arpa. 1/0/0
22.86.168.192.in-addr.arpa. PTR samsung.lan. (95)
 10:40:27.070930 IP (tos 0x0, ttl 64, id 64651, offset 0, flags
[DF], proto UDP (17), length 71)
     quiche.lan.49820> testwifi.here.domain: [bad udp cksum
0x2dd0 -> 0x05f9!] 46654+ PTR? 1.86.168.192.in-addr.arpa. (43)
 10:40:27.072770 IP (tos 0x0, ttl 64, id 16933, offset 0, flags
[DF], proto UDP (17), length 123)
     testwifi.here.domain> quiche.lan.49820: [udp sum ok]
46654* q: PTR? 1.86.168.192.in-addr.arpa. 1/0/0
1.86.168.192.in-addr.arpa. PTR testwifi.here. (95)
 10:40:27.072857 IP (tos 0x0, ttl 64, id 64652, offset 0, flags
[DF], proto UDP (17), length 72)
     quiche.lan.55520> testwifi.here.domain: [bad udp cksum
0x2dd1 -> 0x3ef4!] 48745+ PTR? 57.86.168.192.in-addr.arpa. (44)
 10:40:27.170687 STP 802.1d, Config, Flags [none], bridge-id
7000.2c:08:8c:1c:3b:db.8001, length 43
     message-age 0.00s, max-age 20.00s, hello-time 1.00s,
forwarding-delay 4.00s
     root-id 7000.2c:08:8c:1c:3b:db, root-pathcost 0
```

With default `tcpdump` settings, you get the IP header information where it's relevant to the packet—meaning fields of substance are set. When you add verbosity, you get details about the layer 4 headers. If you look at any of the UDP packets, you will see that there is a note saying the checksum is okay, meaning `tcpdump` performed the calculation of the checksum on the message and got the same value as the one in the packet. In the case of TCP segments, you would get details like the sequence and acknowledgment numbers as well as the flags set.

So far, all we have seen is the protocol headers. There hasn't been any payload data. We can take a look at the payload using the `-X` parameter. This performs a hex dump of the payload of the message. Hexadecimal (hex) dumps show each byte in its hexadecimal representation. It also provides an ASCII decode of each byte. This means if the ASCII value is a printable character, you will see that printable character on the right side. Even in cases where you see printable characters, the meaning of the byte to the protocol in use may not be that character. It may just be the numeric value of that byte.

Hexadecimal Representation of Packet

```
 root@quiche:~# tcpdump -i eth0 -X
 tcpdump: verbose output suppressed, use -v or -vv for full
protocol decode
 listening on eth0, link-type EN10MB (Ethernet), capture size
262144 bytes
 10:49:35.174771 STP 802.1d, Config, Flags [none], bridge-id
7000.2c:08:8c:1c:3b:db.8001, length 43
     0x0000:  0000 0000 0070 002c 088c 1c3b db00 0000
…..p.,…;….
     0x0010:  0070 002c 088c 1c3b db80 0100 0014 0001
.p.,…;……..
     0x0020:  0004 0000 0000 0000 0000 00             ………..
 10:49:35.578186 IP samsung.lan.8001> st-
routers.mcast.net.8001: UDP, length 200
     0x0000:  4500 00e4 c563 4000 0111 bcdf c0a8 5616
E….c@…….V.
     0x0010:  e000 0007 1f41 00d0 9a56 7b22 6461  …..A.A…V{"da
     0x0020:  7461 223a 7b22 7631 223a 7b22 7572 6922  ta":
{"v1":{"uri"
     0x0030:  3a22 6874 7470 3a2f 2f31 3932 2e31 3638
:"http://192.168
     0x0040:  2e38 362e 3232 3a38 3030 312f 6d73 2f31
.86.22:8001/ms/1
     0x0050:  2e30 2f22 7d2c 2276 3222 3a7b 2275 7269
.0/"},"v2":{"uri
     0x0060:  223a 2268 7474 703a 2f2f 3139 322e 3136
":"http://192.16
     0x0070:  382e 3836 2e32 323a 3830 3031 2f61 7069
8.86.22:8001/api
     0x0080:  2f76 322f 227d 7d2c 2272 656d 6f74 6522
/v2/"}},"remote"
     0x0090:  3a22 312e 3022 2c22 7369 6422 3a22 7575
:"1.0","sid":"uu
     0x00a0:  6964 3a32 6239 3562 6466 652d 6138 3033
id:2b95bdfe-a803
     0x00b0:  2d34 3234 662d 3931 3530 2d34 3532 3434  -424f-
9150-45244
     0x00c0:  6338 3162 3862 3022 2c22 7474 6c22 3a38
c81b8b0","ttl":8
```

```
     0x00d0:  3030 302c 2274 7970 6522 3a22 616c 6976
000,"type":"aliv
     0x00e0:  6522 7d0a                                e"}.
 10:49:35.578979 IP quiche.lan.60408> testwifi.here.domain:
10006+ PTR? 7.0.0.224.in-addr.arpa. (40)
     0x0000:  4500 0044 163c 4000 4011 f6e1 c0a8 5639  E..D.
<@.@…..V9
     0x0010:  c0a8 5601 ebf8 0035 0030 2dcd 2716 0100
..V….5.0-.'…
     0x0020:  0001 0000 0000 0000 0137 0130 0130 0332  ………
7.0.0.2
     0x0030:  3234 0769 6e2d 6164 6472 0461 7270 6100  24.in-
addr.arpa.
     0x0040:  000c 0001                                ….
 10:49:35.599038 IP testwifi.here.domain> quiche.lan.60408:
10006 1/0/0 PTR st-routers.mcast.net. (74)
     0x0000:  4500 0066 4230 4000 4011 cacb c0a8 5601
E..fB0@.@…..V.
     0x0010:  c0a8 5639 0035 ebf8 0052 c096 2716 8180  ..V9.5…
R..'…
     0x0020:  0001 0001 0000 0000 0137 0130 0130 0332  ………
7.0.0.2
     0x0030:  3234 0769 6e2d 6164 6472 0461 7270 6100  24.in-
addr.arpa.
     0x0040:  000c 0001 c00c 000c 0001 0000 0bbc 0016  …………….
     0x0050:  0a73 742d 726f 7574 6572 7305 6d63 6173  .st-
routers.mcas
     0x0060:  7403 6e65 7400                           t.net.
```

You will also see `-i eth0` on the command line. This tells `tcpdump` which interface to capture packets on. If you don't say, `tcpdump` will use the default interface. In most cases, that's the single interface in the system. Some systems have multiple interfaces, though. You may want to capture on an interface that isn't default. This means you need to tell `tcpdump` which interface to use. What you don't see here is any of the details from the layer 4 headers. This is because the `-v` parameter wasn't included, indicating we want more verbosity. You can add the verbosity parameters when you start `tcpdump`. You will get the layer 4 information along with the payload of the packet.

So far, we've been looking at `tcpdump` output on the command line. We don't have to look at it there, especially since it can be hard. On a busy network, you would see the messages just fly by without being able to keep up with them. It's probably better to write the packets out to a file. We can do this using `-w` on the command line, as you can see in the following listing. This tells `tcpdump` to write the packets out to the specified file. It does this in a packet capture (PCAP) file format, which includes metadata about the packet capture session. What you will see here is something you didn't see before, because you were only seeing the top of the capture. To stop capturing, you have to terminate `tcpdump` using Ctrl+C (^C).

Writing Packets to File with `tcpdump`

```
 root@quiche:~# tcpdump -w file.pcap
 tcpdump: listening on eth0, link-type EN10MB (Ethernet),
capture size 262144 bytes
 ^C116 packets captured
 119 packets received by filter
 0 packets dropped by kernel
```

Once we have the file written, we have a couple of options. Any program that can parse a PCAP file can open the file we have written. We can also use `tcpdump` to open the file and display the contents. To do that, we would use the `-r` parameter. This reads the file back in, and we can provide additional command-line parameters to tell `tcpdump` how to display the output.

tshark

Of course, `tcpdump` isn't the only program that can be used to capture packets from the command line. The program Wireshark, which we will look at later, includes the program `tshark`, which can also be used to capture packets. In the following code listing, you will see the program running without any parameters. `tshark` helpfully tells us that running the program as root could be dangerous. It says this because there have been cases of packet capture programs being affected by vulnerabilities where crafted packets could cause arbitrary code to be run. What this means is an attacker could cause `tshark` to be compromised to run code provided by the attacker. Beyond that, though, this looks a lot like the output from `tcpdump`. In the end, there is only so much data that can be displayed, and beyond that, there is data that someone capturing packets would really be looking to see.

Capturing Traffic with `tshark`

```
 root@quiche:~# tshark
 Running as user "root" and group "root". This could be
dangerous.
 tshark: Lua: Error during loading:
  [string "/usr/share/wireshark/init.lua"]:32: dofile has been
disabled due to running Wireshark as superuser. See
https://wiki.wireshark.org/CaptureSetup/CapturePrivileges for
help in running Wireshark as an unprivileged user.
 Capturing on 'eth0'
     1 0.000000000 SamsungE_94:ba:57 → Broadcast    ARP 60 Who
has 192.168.86.1? Tell 192.168.86.22
     2 0.196881172 Humax_1c:3b:db → Spanning-tree-(for-
bridges)_00 STP 60 Conf. Root = 28672/0/2c:08:8c:1c:3b:db  Cost
= 0  Port = 0x8001
     3 0.346721551 192.168.86.22 → 224.0.0.7    UDP 242 8001 →
8001 Len=200
     4 0.941773953 192.168.86.57 → 192.168.86.26 SSH 206
Server: Encrypted packet (len=140)
     5 0.941825969 192.168.86.57 → 192.168.86.26 SSH 246
Server: Encrypted packet (len=180)
     6 0.966582385 192.168.86.57 → 192.168.86.26 SSH 182
Server: Encrypted packet (len=116)
     7 1.033015866 192.168.86.57 → 192.168.86.26 TCP 182 [TCP
Retransmission] 22 → 64631 [PSH, ACK] Seq=321 Ack=1 Win=315
Len=116 TSval=4284989880 TSecr=1235189447
```

Just because there are some defaults that you may want to see doesn't mean that someone may not want to be more granular about what is displayed. This is an area in which `tshark` just plain outshines `tcpdump` and would be a principal reason for using `tshark` over `tcpdump`. In the following code listing, you will see an example of how you would select the individual fields you wanted to display. In this case, we are printing the frame number, the IP addresses, the IP type of service field, and the IP time to live field.

Using `tshark` to Print Fields

```
 root@quiche:~# tshark -Tfields -e frame.number  -e ip.src -e
```

```
ip.dst -e ip.tos -e ip.ttl
 Running as user "root" and group "root". This could be
dangerous.
 tshark: Lua: Error during loading:
  [string "/usr/share/wireshark/init.lua"]:32: dofile has been
disabled due to running Wireshark as superuser. See
https://wiki.wireshark.org/CaptureSetup/CapturePrivileges for
help in running Wireshark as an unprivileged user.
 Capturing on 'eth0'
 1    192.168.86.26    192.168.86.57        64
 2
 3    192.168.86.57    192.168.86.26        64
 4    192.168.86.26    192.168.86.57        64
 5    192.168.86.22    224.0.0.7        1
 6    192.168.86.57    192.168.86.26        64
 7    192.168.86.57    192.168.86.26        64
 8    192.168.86.57    192.168.86.26        64
 9    192.168.86.26    192.168.86.57        64
 10    192.168.86.26    192.168.86.57        64
 11    192.168.86.26    192.168.86.57        64
 12
 13
 14    192.168.86.57    192.168.86.26        64
 15    192.168.86.57    192.168.86.26        64
 16    192.168.86.57    192.168.86.26        64
 17    192.168.86.57    192.168.86.26        64
 18    192.168.86.57    192.168.86.26        64
 19    192.168.86.57    192.168.86.26        64
 20    192.168.86.57    192.168.86.26        64
 21    192.168.86.57    192.168.86.26        64
```

There are hundreds of fields that can be used. You will see from the preceding example that you can keep adding fields by using the `-e` flag. Many of the rest of the command-line flags are the same as the ones that are used in `tcpdump`. You can set the snapshot length, select an interface, and also write out a file. These all use the same parameters as seen earlier from `tcpdump`.

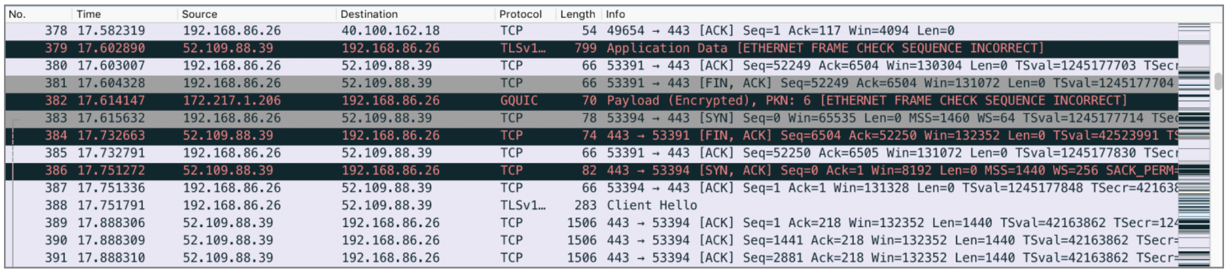
The program `tshark` comes installed with the Wireshark package. No matter which platform you are installing Wireshark on, you will get `tshark` and other command-line programs installed by default. However, there is no `tcpdump` for Windows. You would have to find `windump` and install it. This is a port of `tcpdump` to run on a Windows platform.

Hands-on Activity

Capture packets using `tcpdump` on your local network. Be sure to save the file. Also be sure to engage in some network activity, like browsing the web, to have something to capture.

Wireshark

Wireshark is a GUI-based packet capture program. As noted, it comes with some command-line programs. There are a lot of advantages to using Wireshark. First, it gives us a way to view the packets easily, moving around the complete capture. Unlike with `tcpdump` and `tshark`, we see the entire network stack in Wireshark, which technically makes what we have captured frames rather than packets. Wireshark also gives us the ability to easily scroll through the list of all frames captured. Figure 9.1 shows a list of frames from a capture session. Similar to `tcpdump`, we get what is essentially a summary of each frame.



No.	Time	Source	Destination	Protocol	Length	Info
378	17.582319	192.168.86.26	40.100.162.18	TCP	54	49654 → 443 [ACK] Seq=1 Ack=117 Win=4094 Len=0
379	17.602890	52.109.88.39	192.168.86.26	TLSv1…	799	Application Data [ETHERNET FRAME CHECK SEQUENCE INCORRECT]
380	17.603007	192.168.86.26	52.109.88.39	TCP	66	53391 → 443 [ACK] Seq=52249 Ack=6504 Win=130304 Len=0 TSval=1245177703 TSecr
381	17.604328	192.168.86.26	52.109.88.39	TCP	66	53391 → 443 [FIN, ACK] Seq=52249 Ack=6504 Win=131072 Len=0 TSval=1245177704
382	17.614147	172.217.1.206	192.168.86.26	GQUIC	70	Payload (Encrypted), PKN: 6 [ETHERNET FRAME CHECK SEQUENCE INCORRECT]
383	17.615632	192.168.86.26	52.109.88.39	TCP	78	53394 → 443 [SYN] Seq=0 Win=65535 Len=0 MSS=1460 WS=64 TSval=1245177714 TSec
384	17.732663	52.109.88.39	192.168.86.26	TCP	74	443 → 53391 [FIN, ACK] Seq=6504 Ack=52250 Win=132352 Len=0 TSval=42523991 TS
385	17.732791	192.168.86.26	52.109.88.39	TCP	66	53391 → 443 [ACK] Seq=52250 Ack=6505 Win=131072 Len=0 TSval=1245177830 TSecr
386	17.751272	52.109.88.39	192.168.86.26	TCP	82	443 → 53394 [SYN, ACK] Seq=0 Ack=1 Win=8192 Len=0 MSS=1440 WS=256 SACK_PERM=
387	17.751336	192.168.86.26	52.109.88.39	TCP	66	53394 → 443 [ACK] Seq=1 Ack=1 Win=131328 Len=0 TSval=1245177848 TSecr=421638
388	17.751791	192.168.86.26	52.109.88.39	TLSv1…	283	Client Hello
389	17.888306	52.109.88.39	192.168.86.26	TCP	1506	443 → 53394 [ACK] Seq=1 Ack=218 Win=132352 Len=1440 TSval=42163862 TSecr=124
390	17.888309	52.109.88.39	192.168.86.26	TCP	1506	443 → 53394 [ACK] Seq=1441 Ack=218 Win=132352 Len=1440 TSval=42163862 TSecr=
391	17.888310	52.109.88.39	192.168.86.26	TCP	1506	443 → 53394 [ACK] Seq=2881 Ack=218 Win=132352 Len=1440 TSval=42163862 TSecr=

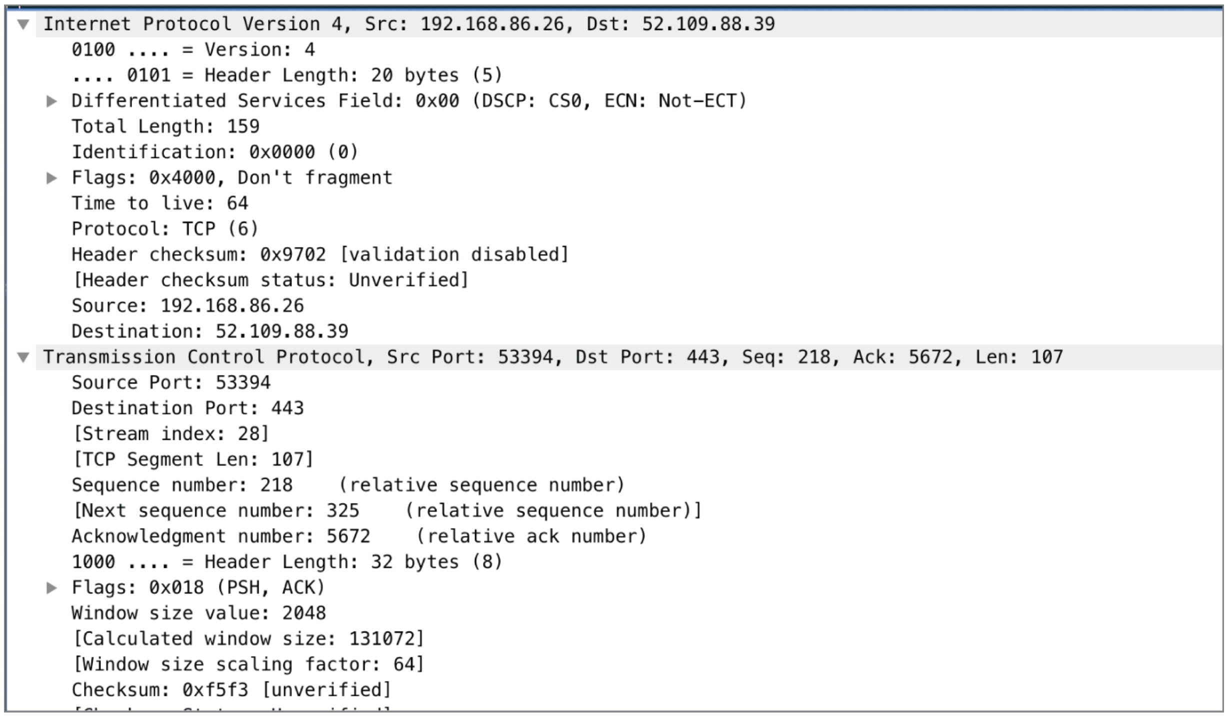
FIGURE 9.1 Wireshark frames list

The columns, which are configurable, are the frame number, relative time from the start of the capture, addresses, protocol, frame length, and then an info column. The information we get is a summary of each frame. This, again, is slightly similar to what we had from `tcpdump`, where there was a short summary. Wireshark provides more details in the summary. This is all information Wireshark can infer from the packets and the communications streams.

Wireshark doesn't just give you the list of frames so you can see who was communicating with what. It also provides you with full protocol decodes.

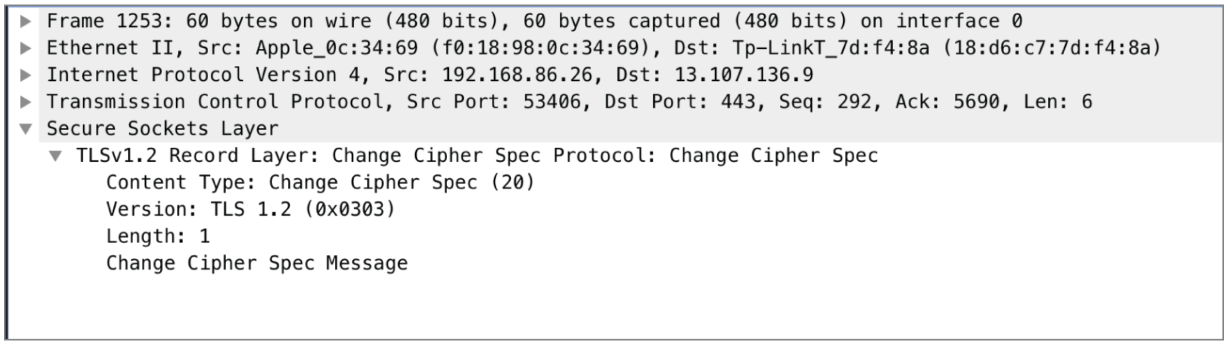
Figure 9.2 has two of the protocols expanded. Wireshark knows how to decode almost any protocol you can throw at it. What you can see in Figure 9.2 is a simple decode for two common protocols, IP and TCP. Every field is broken out in the decode, not only providing you with the name of the field and the value but also the meaning. For example, if you were just to look at the byte that contains the IP version and the header length, you would see 0x45. This is the byte value, but the byte contains two separate pieces of data in the two nibbles (4-byte values). The first is the version, which is 4. The second is the header length. You see 5, and if you didn't know the IP protocol very well, you might think the length was 5. Wireshark knows that you take the value 5 and multiply it by 4 because the value in that field actually means the number of 32-bit (4 bytes) double words. As a result, Wireshark will show you that the header length is 20.

This makes it so much easier to understand what you're looking at. Wireshark also knows loads of other protocols. It can even help you understand encrypted communications, to a degree. If you look at the frame list, you can see the different frames that are used to set up the encryption for a TLS session. Open the protocol in the decode pane in the middle of the Wireshark window and you can see the specifics, shown in Figure 9.3. What you can see is the version of TLS that is being used as well as the specific message that is being sent. You know this based on the header information because the entire message isn't yet being encrypted.



```
▼ Internet Protocol Version 4, Src: 192.168.86.26, Dst: 52.109.88.39
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  ▶ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 159
    Identification: 0x0000 (0)
  ▶ Flags: 0x4000, Don't fragment
    Time to live: 64
    Protocol: TCP (6)
    Header checksum: 0x9702 [validation disabled]
    [Header checksum status: Unverified]
    Source: 192.168.86.26
    Destination: 52.109.88.39
▼ Transmission Control Protocol, Src Port: 53394, Dst Port: 443, Seq: 218, Ack: 5672, Len: 107
    Source Port: 53394
    Destination Port: 443
    [Stream index: 28]
    [TCP Segment Len: 107]
    Sequence number: 218    (relative sequence number)
    [Next sequence number: 325    (relative sequence number)]
    Acknowledgment number: 5672    (relative ack number)
    1000 .... = Header Length: 32 bytes (8)
  ▶ Flags: 0x018 (PSH, ACK)
    Window size value: 2048
    [Calculated window size: 131072]
    [Window size scaling factor: 64]
    Checksum: 0xf5f3 [unverified]
```

FIGURE 9.2 Protocol details



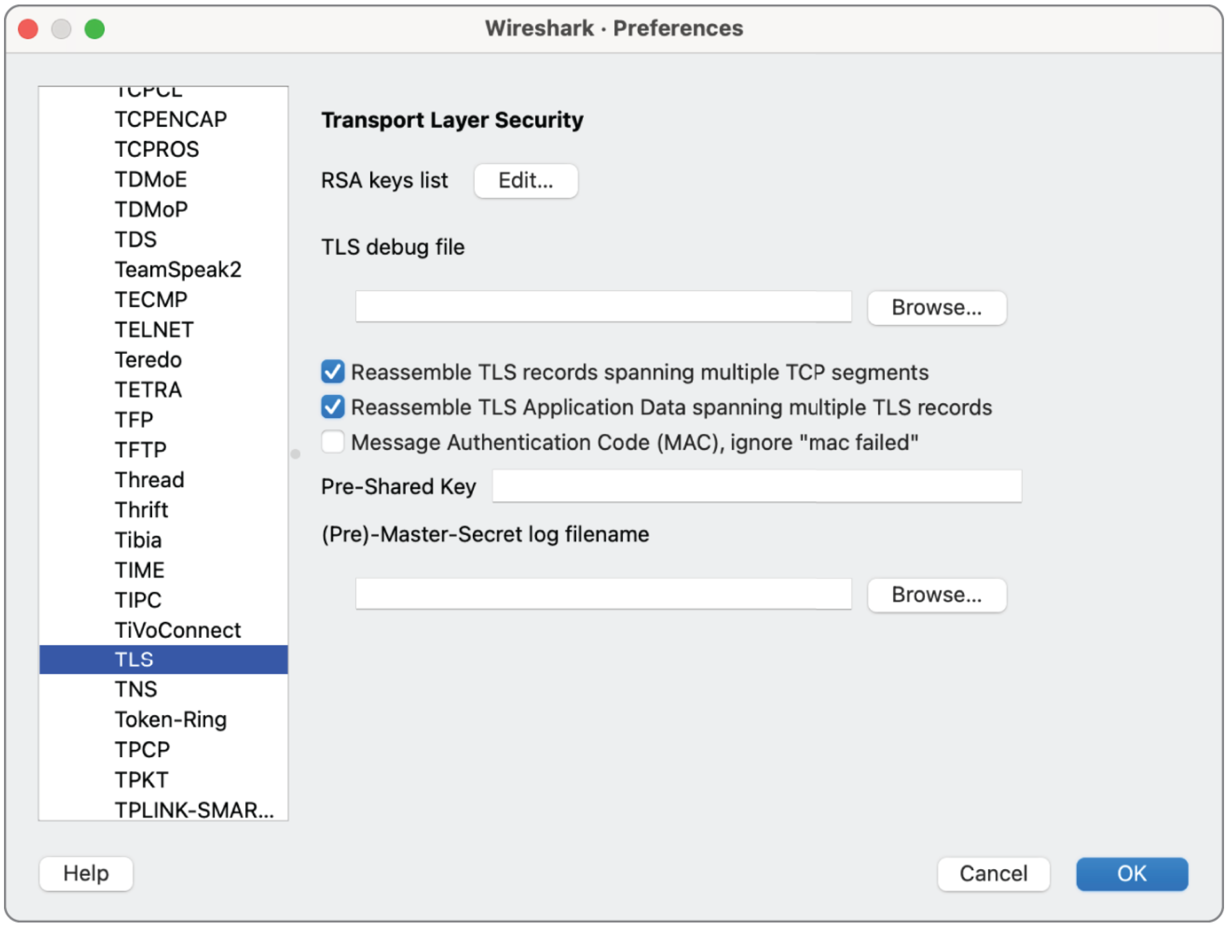
```
▶ Frame 1253: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
▶ Ethernet II, Src: Apple_0c:34:69 (f0:18:98:0c:34:69), Dst: Tp-LinkT_7d:f4:8a (18:d6:c7:7d:f4:8a)
▶ Internet Protocol Version 4, Src: 192.168.86.26, Dst: 13.107.136.9
▶ Transmission Control Protocol, Src Port: 53406, Dst Port: 443, Seq: 292, Ack: 5690, Len: 6
▼ Secure Sockets Layer
  ▼ TLSv1.2 Record Layer: Change Cipher Spec Protocol: Change Cipher Spec
      Content Type: Change Cipher Spec (20)
      Version: TLS 1.2 (0x0303)
      Length: 1
      Change Cipher Spec Message
```

FIGURE 9.3 TLS information

Encryption is always a problem when it comes to packet captures. The point of encryption is that only the sender and the recipient can read the message. Session keys, such as the ones used in TLS-encrypted web messages, are derived at the time of the session. This is done by using the certificates, which include public and private keys. These keys are used to share information while the symmetric key is being derived. To decrypt any information, you would need the session key, which means you would need to have certificate information so you could sit in the middle of the conversation, allowing you to get the key.

NOTE You may regularly see SSL/TLS referred to for encryption. Secure Sockets Layer (SSL) has been deprecated and is no longer in use by reputable websites. Many browsers won't even allow SSL-based connections. As a result, all you will see now is TLS, which means it doesn't make a lot of sense to keep referring to SSL.

Wireshark does have the ability to take RSA (Rivest, Shamir, Adleman, the names of the people who created the algorithm) keys to decrypt messages that have been TLS-encrypted. Figure 9.4 shows the preferences view where you can add your RSA keys. This may allow you to decrypt TLS messages. You can also see a place to enter pre-shared keys. In some cases, you may see encryption that uses a pre-shared key, which essentially means a password both parties already know about. The key has been shared ahead of time between them (pre-shared).



Transport Layer Security

RSA keys list

TLS debug file

- [✓] Reassemble TLS records spanning multiple TCP segments
- [✓] Reassemble TLS Application Data spanning multiple TLS records
- [ ] Message Authentication Code (MAC), ignore "mac failed"

Pre-Shared Key

(Pre)-Master-Secret log filename

FIGURE 9.4 RSA keys preferences

All of what you have seen so far can be used, regardless of whether you are opening a file that has been saved and has been opened in Wireshark or the capture was done live. Wireshark can open any file that has been written by `tcpdump` or `tshark`. Of course, it can also save its own captures. To create a capture from Wireshark, there are multiple avenues you could take. When you start up Wireshark, you will get a home screen, as shown in Figure 9.5. From here, you could just click the shark fin in the toolbar to start up a capture on the default, or primary, interface.

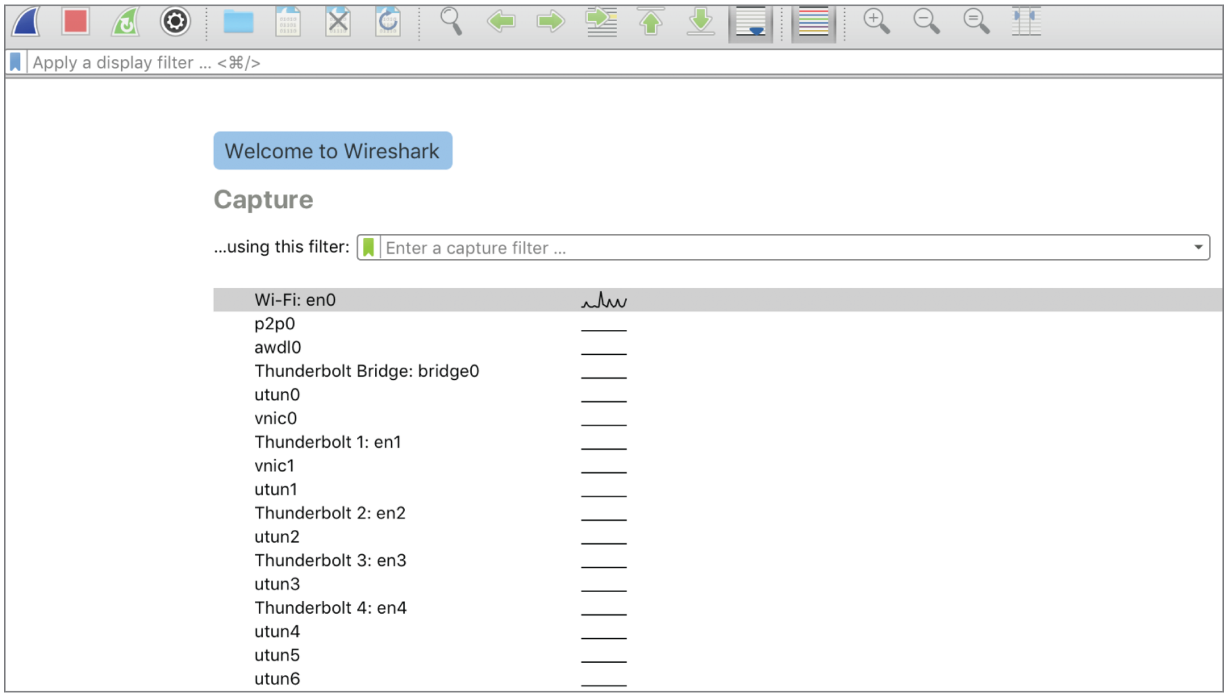


FIGURE 9.5 Wireshark home screen

If you want to be able to capture from a nondefault interface, you would just select one of the interfaces in the list on the home screen. Just double-clicking would start the capture. If you are unsure, you could take a look at the mini graph in the second column. This shows interfaces where there is traffic and the amount of traffic over time. It probably isn't worth capturing traffic from any interface that isn't showing traffic coming across it.

Wireshark also supports filtering. You can set up a filter at the time of capture, as you can see in Figure 9.5 right where it says “Capture … using this filter.” There is an edit box there where you could enter a filter, which would restrict what Wireshark captures. Once you have captured, you could also use a display filter. This keeps all the frames intact but displays only the ones that match the filter you put in. Wireshark helpfully provides you with hints as you go. Figure 9.6 shows a window with suggestions based on what you have typed. This makes it easier to create a filter that will work.

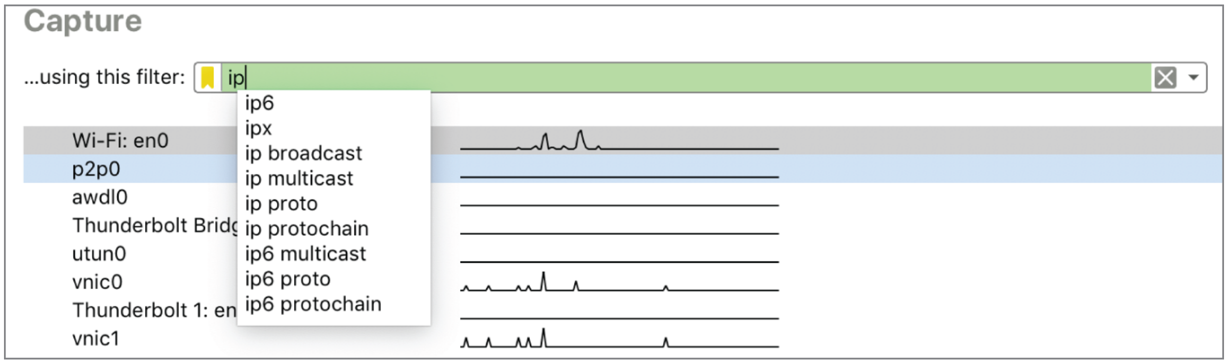


FIGURE 9.6 Capture filter in Wireshark

Figure 9.6 shows the capture filter, but Wireshark will also provide help if you are building a display filter. It also helpfully colors the edit box as you go. Once you have valid filter syntax entered, the box turns green. As soon as you start typing, until you have valid filter syntax, the box will be red. When it comes to the display filter, you can filter on any field of any protocol Wireshark understands. You may be looking for all packets where the IP TTL is 13, for instance. You can get granular with the filtering in Wireshark. It makes life a lot easier if you are looking through hundreds of thousands of frames that have been captured.

Hands-on Activity

Open the file you saved using `tcpdump`. Try to filter the web traffic so that all you see is the web browsing you were doing.

Berkeley Packet Filter

The packet-capturing tools we have looked at so far all can use Berkeley Packet Filter (BPF). BPF is an interface to the Data Link layer of a system. BPF is used across many systems and applications, including `tcpdump`, `tshark`, and Wireshark. Writing BPF consists of a number of primitives like `host`, `ether`, `net`, and `proto`. You can use modifiers like `src` or `dst` with each of these primitives. This means you could filter based on `src host` or `dst host`, as examples. You could also filter based on IPv4 or IPv6 by using the modifiers `ip4` and `ip6`. When you append a filter to a `tcpdump` command line, `tcpdump` will capture and display only packets that pass through the filter.

As an example, the `tcpdump` examples in the preceding paragraph were actually captured on a Linux system (where I had a simple prompt, to be completely honest) that I was SSH'ed into. When you are connected to a system over SSH and you run a packet capture, the vast majority of packets would be SSH packets. Any traffic you really cared about would get lost in the SSH traffic. Think about it for a second. You run `tcpdump` and `tcpdump` sends a message to you indicating it is running. `tcpdump` captures one packet and displays it. To display it, there are SSH packets containing the text of the display going to you. This text is captured, and the capture is sent to you. And so on, and so on. To capture something useful and not just all SSH packets, the actual command run to capture packets would be `tcpdump not port 22`.

Here you can see the output of `tcpdump` without any filters, where `tcpdump` was run through an SSH session. This is a small sample. You'll see that SSH and DNS requests are the messages that are sent, because every packet captured has to have IP addresses resolved to a hostname before it is displayed. You can just cycle through this loop for ages. In the second or two it took to kill the capture, more than 4,000 packets were captured.

Running `tcpdump` Without Filters

```
 root@quiche:~# tcpdump
 tcpdump: verbose output suppressed, use -v or -vv for full
protocol decode
 listening on eth0, link-type EN10MB (Ethernet), capture size
262144 bytes
 18:32:07.835797 IP quiche.lan.ssh> yazpistachio.lan.64631:
Flags [P.], seq 3616191731:3616191919, ack 453098787, win 315,
options [nop,nop,TS val 16893480 ecr 1259709774], length 188
 18:32:07.836406 IP quiche.lan.60511> testwifi.here.domain:
58726+ PTR? 26.86.168.192.in-addr.arpa. (44)
 18:32:07.838352 IP testwifi.here.domain> quiche.lan.60511:
58726* 1/0/0 PTR yazpistachio.lan. (100)
 18:32:07.838530 IP quiche.lan.60657> testwifi.here.domain:
4670+ PTR? 57.86.168.192.in-addr.arpa. (44)
 18:32:07.840275 IP testwifi.here.domain> quiche.lan.60657:
4670* 1/0/0 PTR quiche.lan. (94)
 18:32:07.840505 IP quiche.lan.ssh> yazpistachio.lan.64631:
```

```
Flags [P.], seq 188:408, ack 1, win 315, options [nop,nop,TS
val 16893485 ecr 1259709774], length 220
```

You can combine different filter primitives. For example, you can see in the following code listing how you would capture TCP packets that either came from or were going to the host 192.168.86.1. With complex filters and also for clarity, you can use parentheses to isolate one of the parameters. You'll notice the backslashes that are used here to make sure the Linux shell doesn't try to interpret them, and they are passed as parentheses to `tcpdump`.

Complex Filters with BPF

```
 root@quiche:~# tcpdump tcp and \(host 192.168.86.1\)
 tcpdump: verbose output suppressed, use -v or -vv for full
protocol decode
 listening on eth0, link-type EN10MB (Ethernet), capture size
262144 bytes
 18:41:33.287262 IP quiche.lan.43790> testwifi.here.http: Flags
[S], seq 674275431, win 29200, options [mss 1460,sackOK,TS val
2412954967 ecr 0,nop,wscale 7], length 0
 18:41:33.288206 IP testwifi.here.http> quiche.lan.43790: Flags
[S.], seq 239316039, ack 674275432, win 28960, options [mss
1460,sackOK,TS val 235265600 ecr 2412954967,nop,wscale 7],
length 0
 18:41:33.288269 IP quiche.lan.43790> testwifi.here.http: Flags
[.], ack 1, win 229, options [nop,nop,TS val 2412954968 ecr
235265600], length 0
 18:41:37.111956 IP quiche.lan.43790> testwifi.here.http: Flags
[F.], seq 1, ack 1, win 229, options [nop,nop,TS val 2412958792
ecr 235265600], length 0
 18:41:37.113495 IP testwifi.here.http> quiche.lan.43790: Flags
[F.], seq 1, ack 2, win 227, options [nop,nop,TS val 235265982
ecr 2412958792], length 0
 18:41:37.113515 IP quiche.lan.43790> testwifi.here.http: Flags
[.], ack 2, win 229, options [nop,nop,TS val 2412958793 ecr
235265982], length 0
```

Keep in mind that when you are using BPF on the command line with `tcpdump`, you are using a capture filter. This means that you won't see anything that doesn't pass the filter. If you are writing your capture to a file, you won't have anything that doesn't pass the filter. If you are expecting to perform analysis on the captured file later, you should make sure you won't need those packets later. Think carefully about the filters you use before applying them to capture.

Port Mirroring/Spanning

Back when everything used simple hubs, which were just electrical repeaters with no intelligence, getting traffic from everywhere on the network was easy. Then came switches. These are devices that improve the performance and security of a network by doing filtering at layer 2 of the network device. A switch knows which systems are connected to it at which port. When a frame comes in with a destination MAC address, the switch can look up the port where the MAC address is and send the frame out that port to the destination system. This way, other systems on the network never see that frame pass their network interface. This makes capturing packets more difficult if you are looking for traffic that isn't passing your network interface.

One way to get around that is to have access to the switch. This would allow you to configure the switch to mirror ports. It means any traffic that passes through one port would be mirrored to another port. You may be able to mirror multiple ports to a single port, which would let you monitor traffic to and from multiple systems. If you could monitor only a single port, you could consider mirroring the port that led to a gateway/routing device. This means you are seeing traffic entering and exiting the network, which could potentially give you more access to sensitive information than if you were to just monitor a single endpoint.

On Cisco devices, the feature used for configuring port mirroring is referred to as Switched Port Analyzer (SPAN). When you set up port mirroring, you are configuring a SPAN port. As a result, you may hear the process referred to as *port spanning*. Other switch vendors may use other terminology for this process.

One consideration when you are mirroring ports is the idea of oversubscription. If you have five 1-Gbps switch ports and you are mirroring them out to a single 1-Gbps port, you have the possibility of oversubscribing the receiving port. This means you could easily drop packets you were trying to capture and the packets would be basically random, depending on when you have too much data coming in to be able to send out.

Detecting Sniffers

While the sniffer is running on a single system and is collecting information, which you might think is a passive activity, there are ways of detecting when an interface is in promiscuous mode. The easiest way is to look on the system that has the interface in promiscuous mode. On a macOS system with `tcpdump` running, you will see the following output from `ifconfig`.

```
en0:
flags=8963<UP,BROADCAST,SMART,RUNNING,PROMISC,SIMPLEX,MULTICAST
> mtu 1500

options=50b<RXCSUM,TXCSUM,VLAN_HWTAGGING,AV,CHANNEL_IO>
                ether 14:98:77:31:b2:33
                inet6 fe80::10c6:713a:e86f:556d%en0 prefixlen
64 secured scopeid 0x7
                inet 192.168.1.144 netmask 0xffffff00 broadcast
192.168.1.255
                inet6 2601:18d:8b7f:e33a::52 prefixlen 64
dynamic
                inet6 fd23:5d5f:cd75:40d2:87:38bc:9448:3407
prefixlen 64 autoconf secured
                nd6 options=201<PERFORMNUD,DAD>
                media: autoselect (1000baseT <full-duplex,flow-
control,energy-efficient-ethernet>)
                status: active
```

If you look at the line that shows the flags, you will see PROMISC. This indicates the interface is in promiscuous mode, which means the interface is not doing any filtering of MAC addresses. Any packet that passes by the interface will be sent to the operating system. This is unfortunately not the case with all operating systems. On a recent Kali Linux installation, with `tcpdump` running, just as it was on the macOS system, `ifconfig` shows the following output.

```
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.128  netmask 255.255.255.0  broadcast
192.168.1.255
```

```
        inet6 fd23:5d5f:cd75:40d2:8922:b227:ed41:59a1
prefixlen 64  scopeid 0x0<global>
        inet6 fd23:5d5f:cd75:40d2:20c:29ff:fee9:f642  prefixlen
64  scopeid 0x0<global>
        inet6 fe80::20c:29ff:fee9:f642  prefixlen 64  scopeid
0x20<link>
        ether 00:0c:29:e9:f6:42  txqueuelen 1000  (Ethernet)
        RX packets 9145  bytes 6754039 (6.4 MiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 4214  bytes 913545 (892.1 KiB)
        TX errors 0  dropped 0 overruns 0  carrier 0
collisions 0
```

The newer way to get addressing information about interfaces, `ip a`, also doesn't show that the interface is in promiscuous mode. The same is true for getting the link state of the interface, `ip link`. Of course, `ipconfig` on Windows offers a slightly different function than `ipconfig` has on Unix-like operating systems. It just provides the IP configuration, rather than the interface configuration, so you won't see if the interface is in promiscuous mode there either.

You don't have to be on the machine, though, to identify whether a device is in promiscuous mode, though you do have to have access to the local network to be able to look at packets yourself in some way. A network administrator or the system administrator responsible for the DNS server may be able to identify a device that is sniffing packets. Tools like Wireshark and `tcpdump` will do hostname lookups by default, so for every new IP address that comes across, there will be a corresponding DNS lookup by the operating system where the packet capture is happening. This isn't a guarantee that someone is capturing packets on the device, though. It may be a useful indicator.

NOTE If you happen to have a network that uses hubs rather than switches, there are some differences in identifying devices capturing packets. For a start, it's a lot easier to observe traffic yourself, rather than needing access to the switch where the traffic is passing through. However, it would be very rare to run across a network that used hubs today, so we assume everything being done here is on a switched network. Getting traffic on a switched network relies on other tricks, including configuring a mirror port on a switch or some sort of spoofing attack.

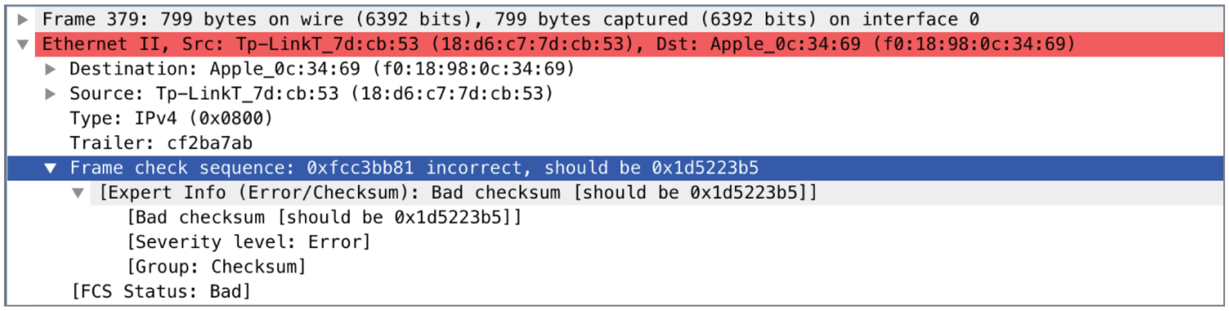
When a device is in promiscuous mode, all traffic that arrives at the interface is forwarded to the operating system. This may allow unusual or unexpected behavior. For example, if you were to craft a packet using packETH or another tool, you could send an ICMP echo request message to a device you suspected of capturing packets. You create the packet by setting the correct IP address but an incorrect MAC address. If the device's interface isn't in promiscuous mode, it won't receive the message. If it gets the message, it will notice the IP address is correct and respond. However, in a switched environment, the message simply won't get to the device, which would rely on an attack technique like ARP spoofing to get the message to the device. As a result, this technique may not be reliable.

Finally, you can observe spoofing attacks like ARP spoofing. An intrusion detection system will notice this as will other network monitoring tools that may be looking at traffic analysis, say packETH from the switch. If you see a large number of ARP messages on the network, especially ARP replies without corresponding requests, it's certain there is an ARP spoofing attack happening. This may indicate someone is capturing packets on the network.

Packet Analysis

Ultimately, packet analysis is probably a big part of why you are capturing the packets to begin with. Once you have the packets, you will want to take a closer look at them, including filtering, following communication streams, and maybe even looking at the statistics and other visualizations from the packet capture. This is another area where Wireshark really excels and can help you a lot. As noted earlier, Wireshark really understands protocols, which means it not only can decode the protocol, but it can also tell you places where there may be protocol violations. There are a number of other places where Wireshark can make reading through a packet capture significantly easier.

Wireshark is good at determining information that isn't directly provided. It will color frames where it identifies problems in the frame list based on rule sets. These rule sets may be changed and added to. The default rules are that color frames with errors have black backgrounds with red text. Once you open the packet in the window below the frame list, you can get the details about the error. Anywhere you see square brackets, [], in Wireshark, you are looking at data provided by Wireshark that it has calculated or inferred from the messages it has received. As an example, Figure 9.7 shows the details of a frame where there were errors. You'll see places where Wireshark provides information in square brackets to help you out. Colors referred to are in Wireshark but won't be represented in the book.



```
▶ Frame 379: 799 bytes on wire (6392 bits), 799 bytes captured (6392 bits) on interface 0
▼ Ethernet II, Src: Tp-LinkT_7d:cb:53 (18:d6:c7:7d:cb:53), Dst: Apple_0c:34:69 (f0:18:98:0c:34:69)
  ▶ Destination: Apple_0c:34:69 (f0:18:98:0c:34:69)
  ▶ Source: Tp-LinkT_7d:cb:53 (18:d6:c7:7d:cb:53)
    Type: IPv4 (0x0800)
    Trailer: cf2ba7ab
  ▼ Frame check sequence: 0xfcc3bb81 incorrect, should be 0x1d5223b5
    ▼ [Expert Info (Error/Checksum): Bad checksum [should be 0x1d5223b5]]
        [Bad checksum [should be 0x1d5223b5]]
        [Severity level: Error]
        [Group: Checksum]
    [FCS Status: Bad]
```

FIGURE 9.7 Packet analysis

Wireshark will take care of calculations that will make life easier for you. When a TCP connection starts up, sequence numbers are generated, and to prevent spoofing TCP connections, the initial sequence number should be random. A sequence number is 4 bytes, so they are large numbers. Sequence numbers increment based on the number of bytes that are transmitted. If you were to try to do this addition yourself, you would be spending some time tracking sequence numbers and acknowledgment numbers. Instead, to make it easier, Wireshark provides you with a relative sequence number. The first sequence number is 1 according to Wireshark.

The relative sequence number then increments as you would normally expect. Figure 9.8 shows the TCP headers with a relative sequence number.

Packets (or frames) that belong to a particular conversation can be spread through a packet capture. You may find it difficult to move from one packet in the conversation to another, especially if there are a lot of frames that pass by in between. Wireshark allows you to follow a stream. This can be done from a context menu that comes up when you right-click a frame that belongs to the conversation. If you select Follow TCP Stream, for example, Wireshark will create a display filter for you, only showing the frames that belong to that conversation. In addition, Wireshark will extract the data from the payload, presenting it to you. With an HTTP conversation, for example, you will see the text of the HTTP messages between the client and the server. Figure 9.9 shows the dialog box that comes up showing the text of an HTTP conversation. The client messages are colored with a pink background and red text, while the server messages are in blue with a lilac or light purple background. At the bottom, you will see it says Save and show data as and ASCII is selected. There are other options, including raw, C arrays, and YAML.

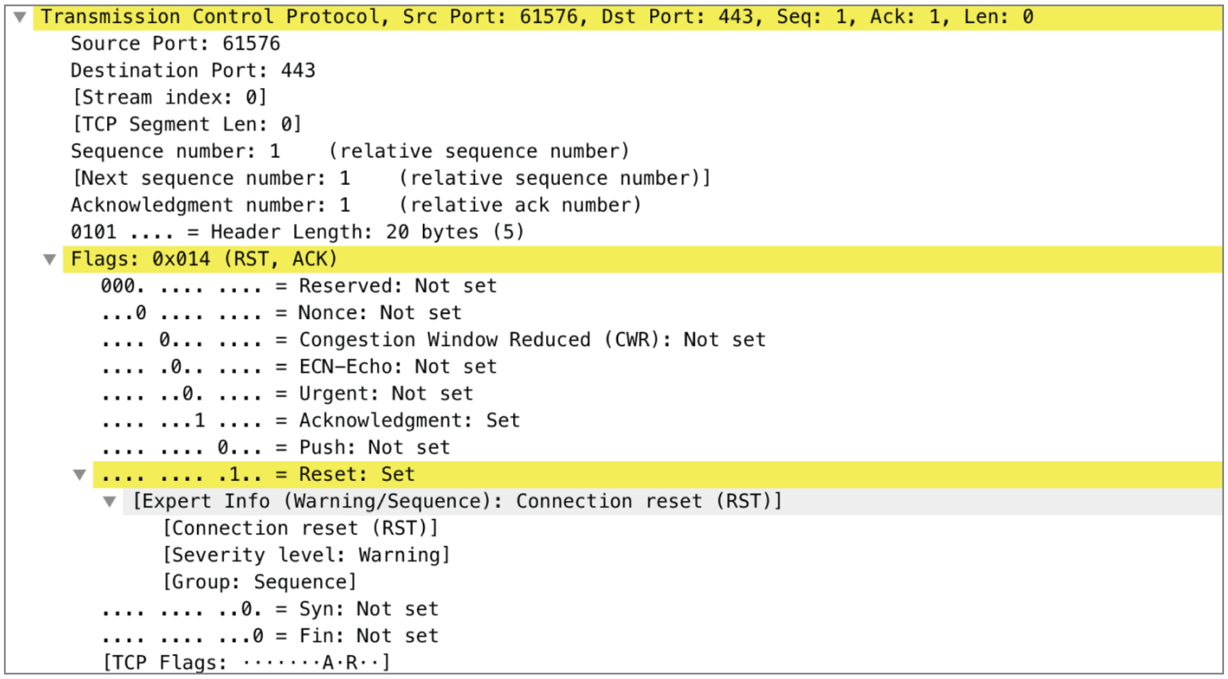
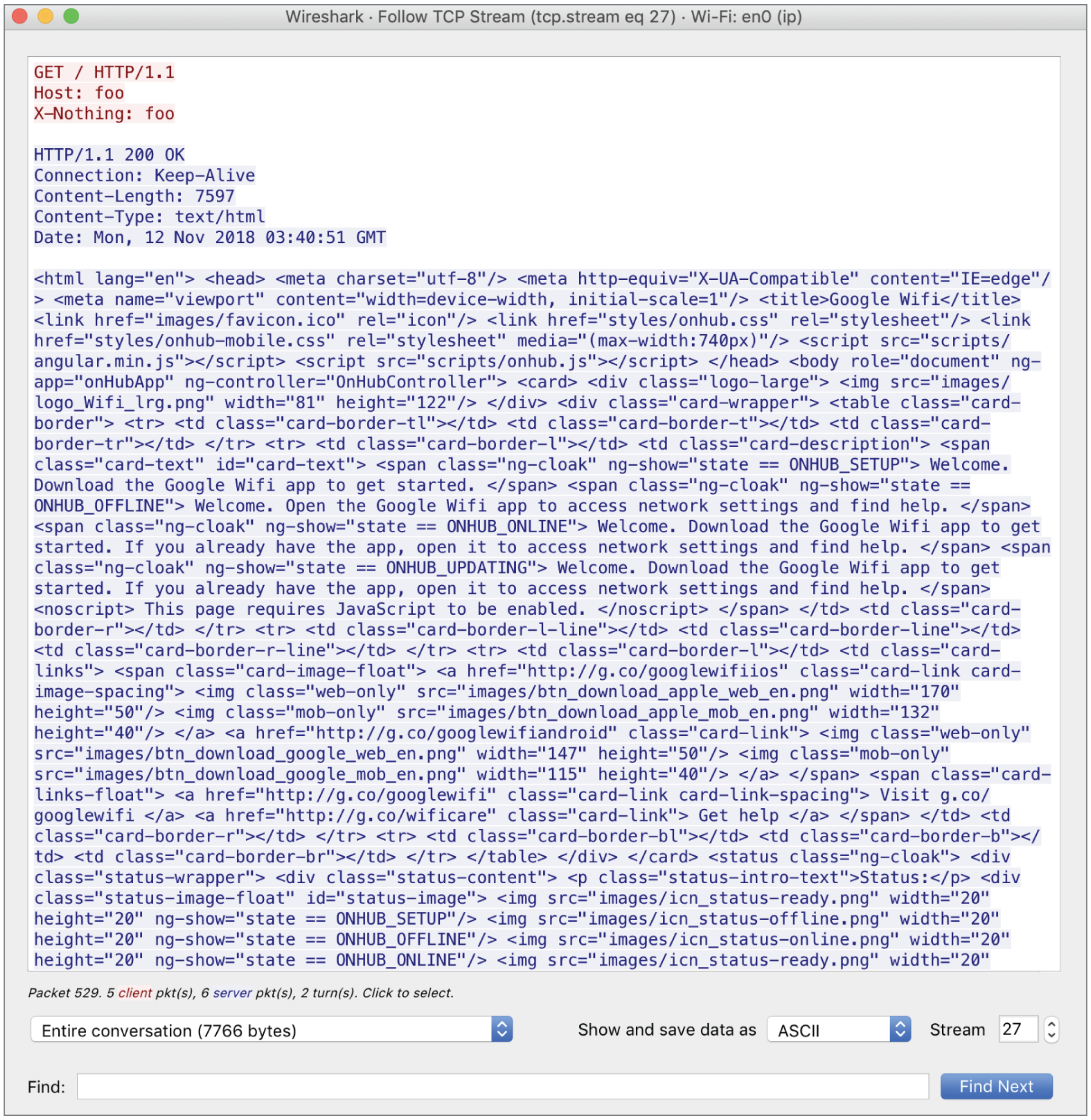

```
▼ Transmission Control Protocol, Src Port: 61576, Dst Port: 443, Seq: 1, Ack: 1, Len: 0
    Source Port: 61576
    Destination Port: 443
    [Stream index: 0]
    [TCP Segment Len: 0]
    Sequence number: 1    (relative sequence number)
    [Next sequence number: 1    (relative sequence number)]
    Acknowledgment number: 1    (relative ack number)
    0101 .... = Header Length: 20 bytes (5)
  ▼ Flags: 0x014 (RST, ACK)
      000. .... .... = Reserved: Not set
      ...0 .... .... = Nonce: Not set
      .... 0... .... = Congestion Window Reduced (CWR): Not set
      .... .0.. .... = ECN-Echo: Not set
      .... ..0. .... = Urgent: Not set
      .... ...1 .... = Acknowledgment: Set
      .... .... 0... = Push: Not set
    ▼ .... .... .1.. = Reset: Set
      ▼ [Expert Info (Warning/Sequence): Connection reset (RST)]
          [Connection reset (RST)]
          [Severity level: Warning]
          [Group: Sequence]
      .... .... ..0. = Syn: Not set
      .... .... ...0 = Fin: Not set
      [TCP Flags: ·······A·R··]
```

FIGURE 9.8 Relative sequence numbers

Wireshark also has substantial capabilities to present statistics from the packet capture. There is a Statistics menu that has a lot of options. One of them is Protocol Hierarchy. This shows every protocol identified in the capture in a hierarchy based on how the protocols are related. For example, as shown in Figure 9.10, everything is a frame, and all of these frames are Ethernet. Out of all of the Ethernet frames, everything in this particular capture is an IP packet. From there, 5.5 percent are UDP datagrams. SSDP, MDNS, and DNS are all protocols that make use of UDP as a Transport layer protocol. The majority of the packets captured are TCP segments. Most of those are SSL, though in reality they are all TLS, which is the successor protocol to SSL.

Another entry in the Statistics menu to look at is the Conversations view. This shows all the conversations between endpoints in the packet capture. Every layer of the capture has different sets of conversations, since layer 2 conversations are different than IP address conversations. Any IP conversation that passes out of the local network has a layer 2 conversation with the local gateway. This means you may likely have fewer Ethernet conversations than you do IP conversations. Additionally, your TCP conversations will be different from your IP conversations. You may have multiple sets of ports between two IP addresses. This may be especially true if your local browser sets up multiple connections to a web server to issue requests for images, HTML pages, and other resources that go into the rendering of a page. Figure 9.11 shows the Conversations statistics from a packet capture.


Wireshark · Follow TCP Stream (tcp.stream eq 27) · Wi-Fi: en0 (ip)
Packet 529. 5 client pkt(s), 6 server pkt(s), 2 turn(s). Click to select.
Entire conversation (7766 bytes)
Show and save data as
ASCII
Stream
27
Find:
Find Next

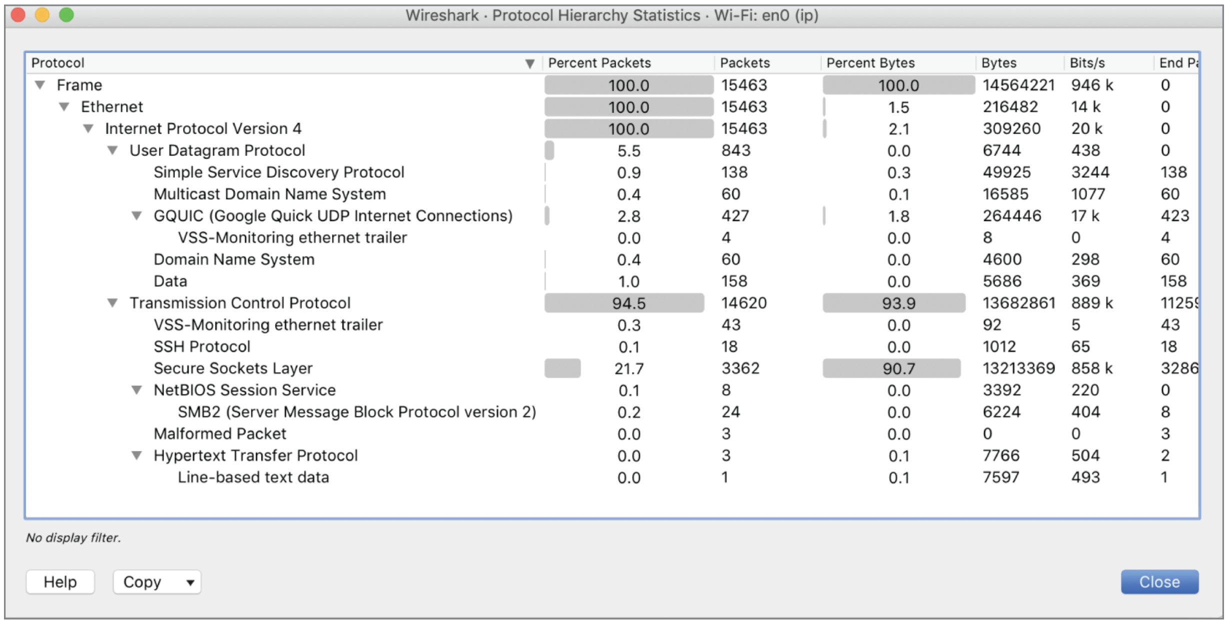
```
GET / HTTP/1.1
Host: foo
X-Nothing: foo

HTTP/1.1 200 OK
Connection: Keep-Alive
Content-Length: 7597
Content-Type: text/html
Date: Mon, 12 Nov 2018 03:40:51 GMT

<html lang="en"> <head> <meta charset="utf-8"/> <meta http-equiv="X-UA-Compatible" content="IE=edge"/
> <meta name="viewport" content="width=device-width, initial-scale=1"/> <title>Google Wifi</title>
<link href="images/favicon.ico" rel="icon"/> <link href="styles/onhub.css" rel="stylesheet"/> <link
href="styles/onhub-mobile.css" rel="stylesheet" media="(max-width:740px)"/> <script src="scripts/
angular.min.js"></script> <script src="scripts/onhub.js"></script> </head> <body role="document" ng-
app="onHubApp" ng-controller="OnHubController"> <card> <div class="logo-large"> <img src="images/
logo_Wifi_lrg.png" width="81" height="122"/> </div> <div class="card-wrapper"> <table class="card-
border"> <tr> <td class="card-border-tl"></td> <td class="card-border-t"></td> <td class="card-
border-tr"></td> </tr> <tr> <td class="card-border-l"></td> <td class="card-description"> <span
class="card-text" id="card-text"> <span class="ng-cloak" ng-show="state == ONHUB_SETUP"> Welcome.
Download the Google Wifi app to get started. </span> <span class="ng-cloak" ng-show="state ==
ONHUB_OFFLINE"> Welcome. Open the Google Wifi app to access network settings and find help. </span>
<span class="ng-cloak" ng-show="state == ONHUB_ONLINE"> Welcome. Download the Google Wifi app to get
started. If you already have the app, open it to access network settings and find help. </span> <span
class="ng-cloak" ng-show="state == ONHUB_UPDATING"> Welcome. Download the Google Wifi app to get
started. If you already have the app, open it to access network settings and find help. </span>
<noscript> This page requires JavaScript to be enabled. </noscript> </span> </td> <td class="card-
border-r"></td> </tr> <tr> <td class="card-border-l-line"></td> <td class="card-border-line"></td>
<td class="card-border-r-line"></td> </tr> <tr> <td class="card-border-l"></td> <td class="card-
links"> <span class="card-image-float"> <a href="http://g.co/googlewifiios" class="card-link card-
image-spacing"> <img class="web-only" src="images/btn_download_apple_web_en.png" width="170"
height="50"/> <img class="mob-only" src="images/btn_download_apple_mob_en.png" width="132"
height="40"/> </a> <a href="http://g.co/googlewifiandroid" class="card-link"> <img class="web-only"
src="images/btn_download_google_web_en.png" width="147" height="50"/> <img class="mob-only"
src="images/btn_download_google_mob_en.png" width="115" height="40"/> </a> </span> <span class="card-
links-float"> <a href="http://g.co/googlewifi" class="card-link card-link-spacing"> Visit g.co/
googlewifi </a> <a href="http://g.co/wificare" class="card-link"> Get help </a> </span> </td> <td
class="card-border-r"></td> </tr> <tr> <td class="card-border-bl"></td> <td class="card-border-b"></
td> <td class="card-border-br"></td> </tr> </table> </div> </card> <status class="ng-cloak"> <div
class="status-wrapper"> <div class="status-content"> <p class="status-intro-text">Status:</p> <div
class="status-image-float" id="status-image"> <img src="images/icn_status-ready.png" width="20"
height="20" ng-show="state == ONHUB_SETUP"/> <img src="images/icn_status-offline.png" width="20"
height="20" ng-show="state == ONHUB_OFFLINE"/> <img src="images/icn_status-online.png" width="20"
height="20" ng-show="state == ONHUB_ONLINE"/> <img src="images/icn_status-ready.png" width="20"
```

FIGURE 9.9 Follow TCP Stream dialog box

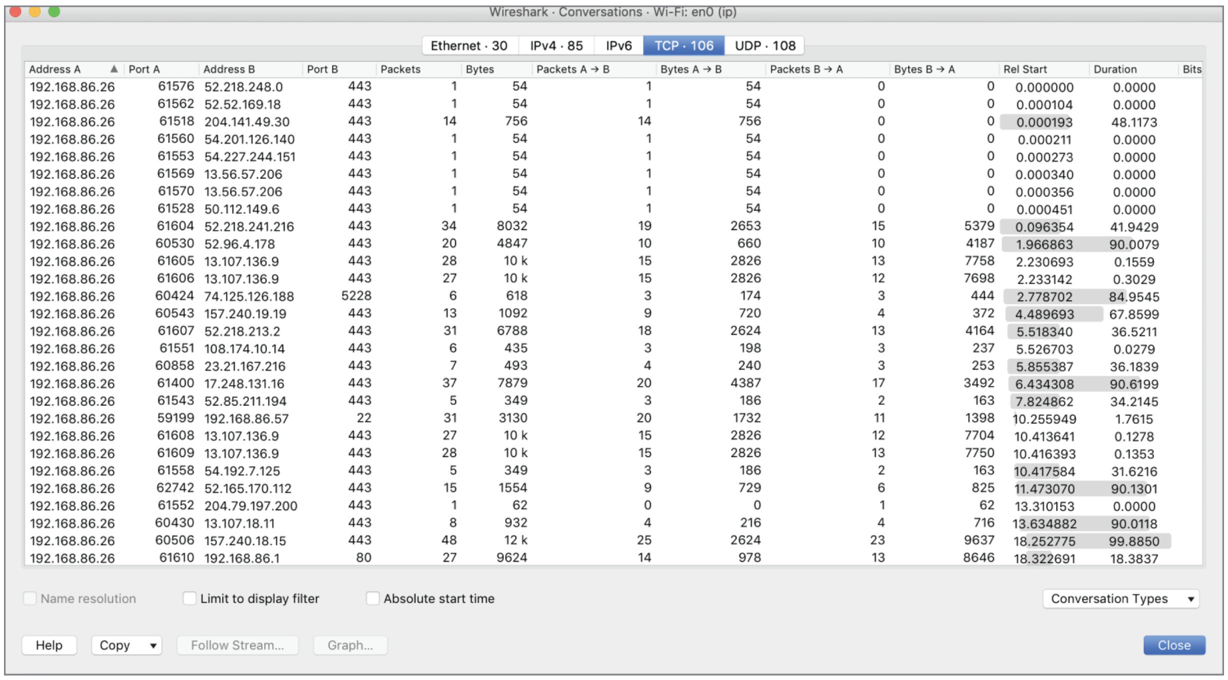
One last feature to look at is in the Analyze menu. Wireshark does perform analysis on frames and packets as it gets them. We looked at some of these earlier by looking at the list of frames and looking at colors. Additionally, when we looked at the protocol decode, you could see errors in cases where the information identified by Wireshark is in square brackets. You don't have to skim all the way through the packet capture file to find the errors one at a time. Instead, if you go to the Analyze menu, you can select Expert Information, and this will show you all of the frames that Wireshark has identified as problematic. In Figure 9.12, you can see all of the expert information by category. You see the errors, warnings, notes, and chat. If you were to open each of these entries, you would get a list of frames. Clicking one of these entries takes you to that frame in the capture so you can see its details.



Protocol	Percent Packets	Packets	Percent Bytes	Bytes	Bits/s	End Pa
▼ Frame	100.0	15463	100.0	14564221	946 k	0
▼ Ethernet	100.0	15463	1.5	216482	14 k	0
▼ Internet Protocol Version 4	100.0	15463	2.1	309260	20 k	0
▼ User Datagram Protocol	5.5	843	0.0	6744	438	0
Simple Service Discovery Protocol	0.9	138	0.3	49925	3244	138
Multicast Domain Name System	0.4	60	0.1	16585	1077	60
▼ GQUIC (Google Quick UDP Internet Connections)	2.8	427	1.8	264446	17 k	423
VSS-Monitoring ethernet trailer	0.0	4	0.0	8	0	4
Domain Name System	0.4	60	0.0	4600	298	60
Data	1.0	158	0.0	5686	369	158
▼ Transmission Control Protocol	94.5	14620	93.9	13682861	889 k	11259
VSS-Monitoring ethernet trailer	0.3	43	0.0	92	5	43
SSH Protocol	0.1	18	0.0	1012	65	18
Secure Sockets Layer	21.7	3362	90.7	13213369	858 k	3286
▼ NetBIOS Session Service	0.1	8	0.0	3392	220	0
SMB2 (Server Message Block Protocol version 2)	0.2	24	0.0	6224	404	8
Malformed Packet	0.0	3	0.0	0	0	3
▼ Hypertext Transfer Protocol	0.0	3	0.1	7766	504	2
Line-based text data	0.0	1	0.1	7597	493	1

No display filter.

FIGURE 9.10 Protocol Hierarchy Statistics

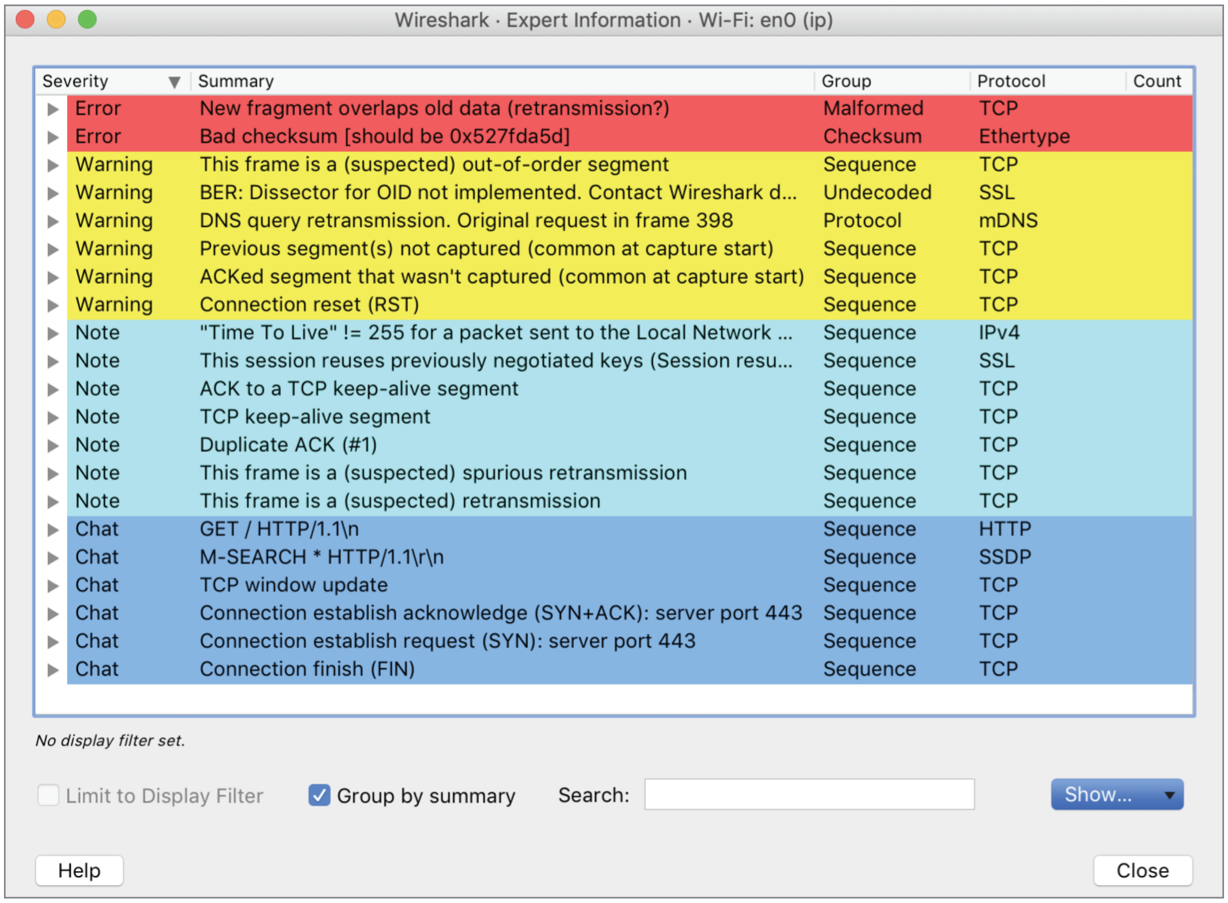


Address A ▲	Port A	Address B	Port B	Packets	Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits
192.168.86.26	61576	52.218.248.0	443	1	54	1	54	0	0	0.000000	0.0000	
192.168.86.26	61562	52.52.169.18	443	1	54	1	54	0	0	0.000104	0.0000	
192.168.86.26	61518	204.141.49.30	443	14	756	14	756	0	0	0.000193	48.1173	
192.168.86.26	61560	54.201.126.140	443	1	54	1	54	0	0	0.000211	0.0000	
192.168.86.26	61553	54.227.244.151	443	1	54	1	54	0	0	0.000273	0.0000	
192.168.86.26	61569	13.56.57.206	443	1	54	1	54	0	0	0.000340	0.0000	
192.168.86.26	61570	13.56.57.206	443	1	54	1	54	0	0	0.000356	0.0000	
192.168.86.26	61528	50.112.149.6	443	1	54	1	54	0	0	0.000451	0.0000	
192.168.86.26	61604	52.218.241.216	443	34	8032	19	2653	15	5379	0.096354	41.9429	
192.168.86.26	60530	52.96.4.178	443	20	4847	10	660	10	4187	1.966863	90.0079	
192.168.86.26	61605	13.107.136.9	443	28	10 k	15	2826	13	7758	2.230693	0.1559	
192.168.86.26	61606	13.107.136.9	443	27	10 k	15	2826	12	7698	2.233142	0.3029	
192.168.86.26	60424	74.125.126.188	5228	6	618	3	174	3	444	2.778702	84.9545	
192.168.86.26	60543	157.240.19.19	443	13	1092	9	720	4	372	4.489693	67.8599	
192.168.86.26	61607	52.218.213.2	443	31	6788	18	2624	13	4164	5.518340	36.5211	
192.168.86.26	61551	108.174.10.14	443	6	435	3	198	3	237	5.526703	0.0279	
192.168.86.26	60858	23.21.167.216	443	7	493	4	240	3	253	5.855387	36.1839	
192.168.86.26	61400	17.248.131.16	443	37	7879	20	4387	17	3492	6.434308	90.6199	
192.168.86.26	61543	52.85.211.194	443	5	349	3	186	2	163	7.824862	34.2145	
192.168.86.26	59199	192.168.86.57	22	31	3130	20	1732	11	1398	10.255949	1.7615	
192.168.86.26	61608	13.107.136.9	443	27	10 k	15	2826	12	7704	10.413641	0.1278	
192.168.86.26	61609	13.107.136.9	443	28	10 k	15	2826	13	7750	10.416393	0.1353	
192.168.86.26	61558	54.192.7.125	443	5	349	3	186	2	163	10.417584	31.6216	
192.168.86.26	62742	52.165.170.112	443	15	1554	9	729	6	825	11.473070	90.1301	
192.168.86.26	61552	204.79.197.200	443	1	62	0	0	1	62	13.310153	0.0000	
192.168.86.26	60430	13.107.18.11	443	8	932	4	216	4	716	13.634882	90.0118	
192.168.86.26	60506	157.240.18.15	443	48	12 k	25	2624	23	9637	18.252775	99.8850	
192.168.86.26	61610	192.168.86.1	80	27	9624	14	978	13	8646	18.322691	18.3837	

Name resolution ☐ Limit to display filter ☐ Absolute start time ☐

FIGURE 9.11 Conversations statistics

One element of packet capture that we haven't spent any time on is the time stamp. Packets don't contain time stamps, so just looking at most frames or packets won't give you the time the frame passed through the network. When you look at the time column in Wireshark, you will find a relative time. This is relative to the start of the capture. That may not be very useful to you. Helpfully, packet capture files will include the time of the start of the capture in the metadata. This means you can change the time shown in Wireshark to be absolute time. This assumes the time and the time zone in the capturing file were correct, since it does rely on the configuration of the capturing system.


Wireshark · Expert Information · Wi-Fi: en0 (ip)

Severity	Summary	Group	Protocol	Count
Error	New fragment overlaps old data (retransmission?)	Malformed	TCP	
Error	Bad checksum [should be 0x527fda5d]	Checksum	Ethertype	
Warning	This frame is a (suspected) out-of-order segment	Sequence	TCP	
Warning	BER: Dissector for OID not implemented. Contact Wireshark d...	Undecoded	SSL	
Warning	DNS query retransmission. Original request in frame 398	Protocol	mDNS	
Warning	Previous segment(s) not captured (common at capture start)	Sequence	TCP	
Warning	ACKed segment that wasn't captured (common at capture start)	Sequence	TCP	
Warning	Connection reset (RST)	Sequence	TCP	
Note	"Time To Live" != 255 for a packet sent to the Local Network ...	Sequence	IPv4	
Note	This session reuses previously negotiated keys (Session resu...	Sequence	SSL	
Note	ACK to a TCP keep-alive segment	Sequence	TCP	
Note	TCP keep-alive segment	Sequence	TCP	
Note	Duplicate ACK (#1)	Sequence	TCP	
Note	This frame is a (suspected) spurious retransmission	Sequence	TCP	
Note	This frame is a (suspected) retransmission	Sequence	TCP	
Chat	GET / HTTP/1.1\n	Sequence	HTTP	
Chat	M-SEARCH * HTTP/1.1\r\n	Sequence	SSDP	
Chat	TCP window update	Sequence	TCP	
Chat	Connection establish acknowledge (SYN+ACK): server port 443	Sequence	TCP	
Chat	Connection establish request (SYN): server port 443	Sequence	TCP	
Chat	Connection finish (FIN)	Sequence	TCP	

No display filter set.

☐ Limit to Display Filter ☑ Group by summary Search:

FIGURE 9.12 Expert Information

Spoofing Attacks

You may not have to be stuck with only capturing packets that are destined to your system or ones that you can get to you by reconfiguring the switch.

There are other ways to get messages to you. This can be done by using different types of spoofing attacks. A spoofing attack is where you pretend to be a system you aren't. You can approach this from different layers, starting at layer 2. You can also spoof at a higher layer, using DNS to get systems to send traffic to systems you want. Spoofing attacks allow you to sit in the middle of a conversation between two endpoints.

This brings up an issue you need to keep in mind. If you are running spoofing attacks, it means at least one end of the conversation is potentially not getting to the appropriate endpoint. If everything doesn't look right, someone is going to start suspecting something. This means you need to make sure you are doing something to make the conversation whole. If someone gets suspicious that something is wrong, they may start looking for causes, which may mean you could be identified. Presumably, if you are running a spoofing attack, you don't want to be identified and caught. As always, you need to make sure you are using these powers for good and not for evil.

ARP Spoofing

The Address Resolution Protocol (ARP) has two stages. The first is the request, where a system knows an IP address but doesn't know the corresponding MAC address. It sends an ARP request asking for the system with the IP address to respond with its MAC address. The response is the system replying, indicating its MAC address to the requestor. There is nothing to authenticate that request, though. In theory, anyone could respond to that request with their MAC address to get the requesting system to send the message to the attacker's/spoofer's address. We could make it even easier by simply not waiting for the request to begin with and just sending the reply.

ARP Poisoning

You may also hear the term *ARP poisoning*, which means the same thing as ARP spoofing. You are poisoning the ARP cache on target systems with bad entries.

To be efficient, systems will take any ARP responses, even if they didn't ask, and cache the mapping. This keeps them from having to ask for the MAC address should they ever need it. This is a feature we can take advantage of. We could just send out ARP responses, mapping whatever IP address on the network we want to our MAC address. This would get all systems on the local network sending messages to us, as our address is in their ARP cache. The process of just sending out ARP responses without a corresponding ARP request is called *gratuitous ARP*, meaning it's an ARP message that wasn't asked for.

One of the problems we have is the length of time ARP entries are cached for. On Linux systems, the default cache length is 60 seconds. You can check it from an entry in the `/proc` pseudo file system, as you can see in the following code listing. You could also change the behavior by replacing the 60 with another value. On Windows systems, the cache time is different. Microsoft opted to follow RFC 4861, which applies to IPv6, for the IPv4 implementation. Starting with Windows Vista, Microsoft has a base time of 30,000 milliseconds, which is multiplied by a random value between .5 and 1.5 to get the cache duration. This means it's different from one system to another and also from one boot to another.

ARP Cache Duration on Linux

```
cat /proc/sys/net/ipv4/neigh/default/gc_stale_time
60
```

Because the cache can time out quickly, we have to keep sending out our gratuitous ARP responses. Obviously, this is something better done programmatically rather than manually. This is especially true since there is another problem. When we redirect messages to our system, we really need to forward them back out onto the network with the correct MAC address in the destination field. Otherwise, conversations don't happen. A TCP connection never completes because the SYN or the SYN/ACK never reaches the appropriate destination system. Instead, it is sent to our system where it dead-ends unless we do something. This requires turning on forwarding so the message we are hijacking can be forwarded back out the same interface to get to its intended destination.

There are a few programs that can be used to handle ARP spoofing. One of them, `arpspoof`, has been around for a long time now. It was written by Dug Song, who also wrote a program called `fragroute`, which is useful in its own way. Using `arpspoof`, we can inject ourselves in between two systems on the network. We can tell `arpspoof` which two IP addresses we want to pretend to be. It takes care of the rest for us. In the following code listing, you can see a run of `arpspoof` where I've selected the default gateway on my network to be the one I spoof. This means I get messages that are destined for the default gateway, so anything that's going off-net gets sent to the system running `arpspoof`. You'll see the gratuitous ARP responses being sent. They get sent out every few seconds to ensure that no ARP cache entries age out. On some Linux systems, such as Kali Linux, you will need to install `arpspoof` along with other sniffing tools in a package called `dsniff`.

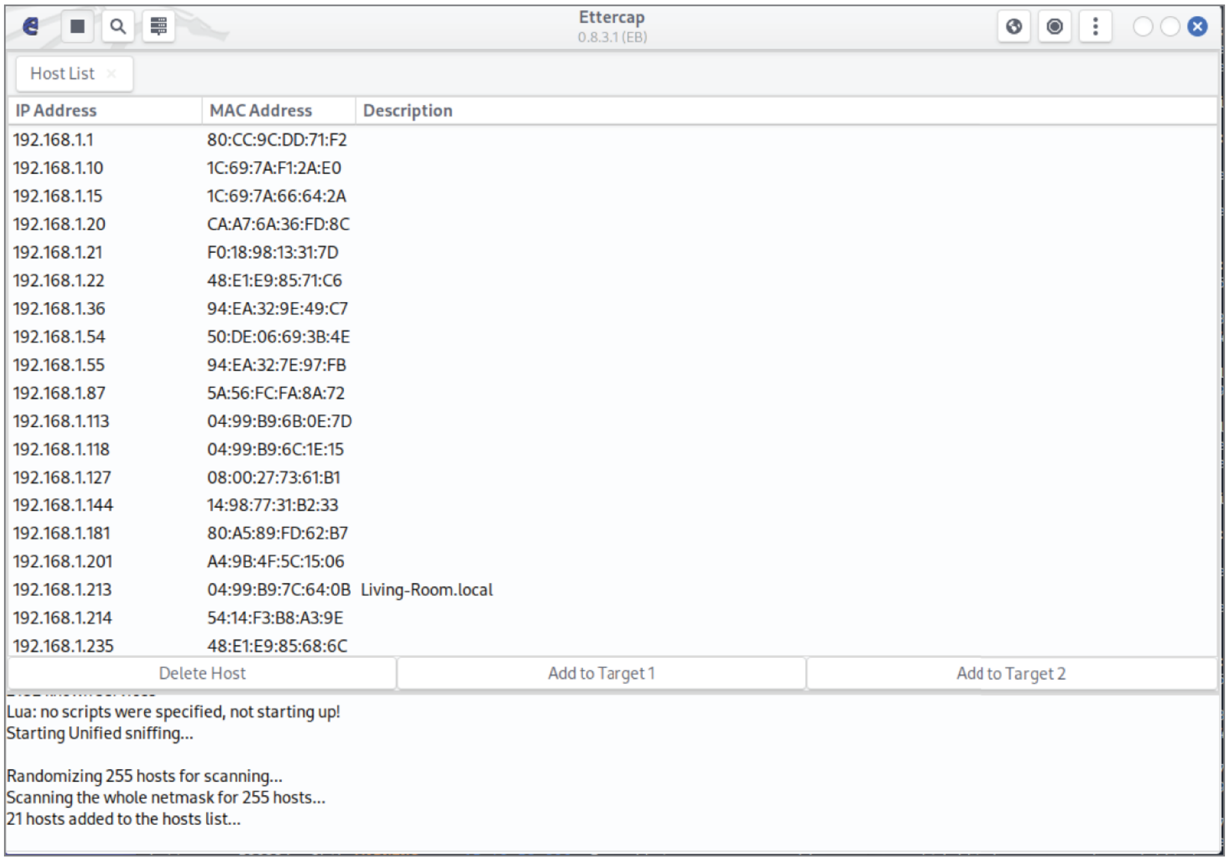
Using `arpspoof`

```
 kilroy@zaphod:~ $ sudo arpspoof -i eth0 -c both 192.168.86.1
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 0:1c:42:38:62:8e ff:ff:ff:ff:ff:ff 0806 42: arp reply
192.168.86.1 is-at 0:1c:42:38:62:8e
 ^CCleaning up and re-arping targets…
```

Instead of selecting a pair of hosts to sit between, I've essentially said I want to sit between the entire network and the default gateway. The problem with this approach is that only one side of the conversation will arrive at this system—the side that is destined for the default gateway. The response from outside the network won't show up at the system where `arpspoof` is running. This could be fixed by adding `-t` with a target IP address and then `-r` to indicate that reverse connections should be collected as well. Then, both of the systems specified would be spoofed to go to the system where `arpspoof` is running.

Another tool we could use for ARP spoofing, which has multiple uses in fact, is Ettercap. Ettercap has two modes. One is a console-based mode. The other is a GUI-based mode. When you run Ettercap, you have to indicate which mode you want it to run in. In GUI mode, you can more easily select which hosts you want to target. Ettercap is a sniffer that can also run man-in-the-middle (MitM) attacks. When you run an ARP spoof attack, you need to know IP address to MAC address mappings, and you need to get Ettercap to check for hosts on the network. The first thing to do is to tell Ettercap you are going to do a Unified sniff if there is only one interface on the system Ettercap is running on, or a Bridged sniff if there are multiple interfaces. Once that's done, other menus show up.

Once it runs a scan of all the hosts, you can bring up a host list. You can see the host list in Ettercap in Figure 9.13. Once the host list is in place, you can select the hosts you want to target. Since ultimately we're talking about conversations, you can have two targets to place hosts into. This refers to two ends of the conversation. Let's say you wanted to listen to a conversation between two hosts on your network, like a client system and a local domain controller, so as to potentially grab credentials. You would put one of the systems in Target 1 and the other into Target 2.



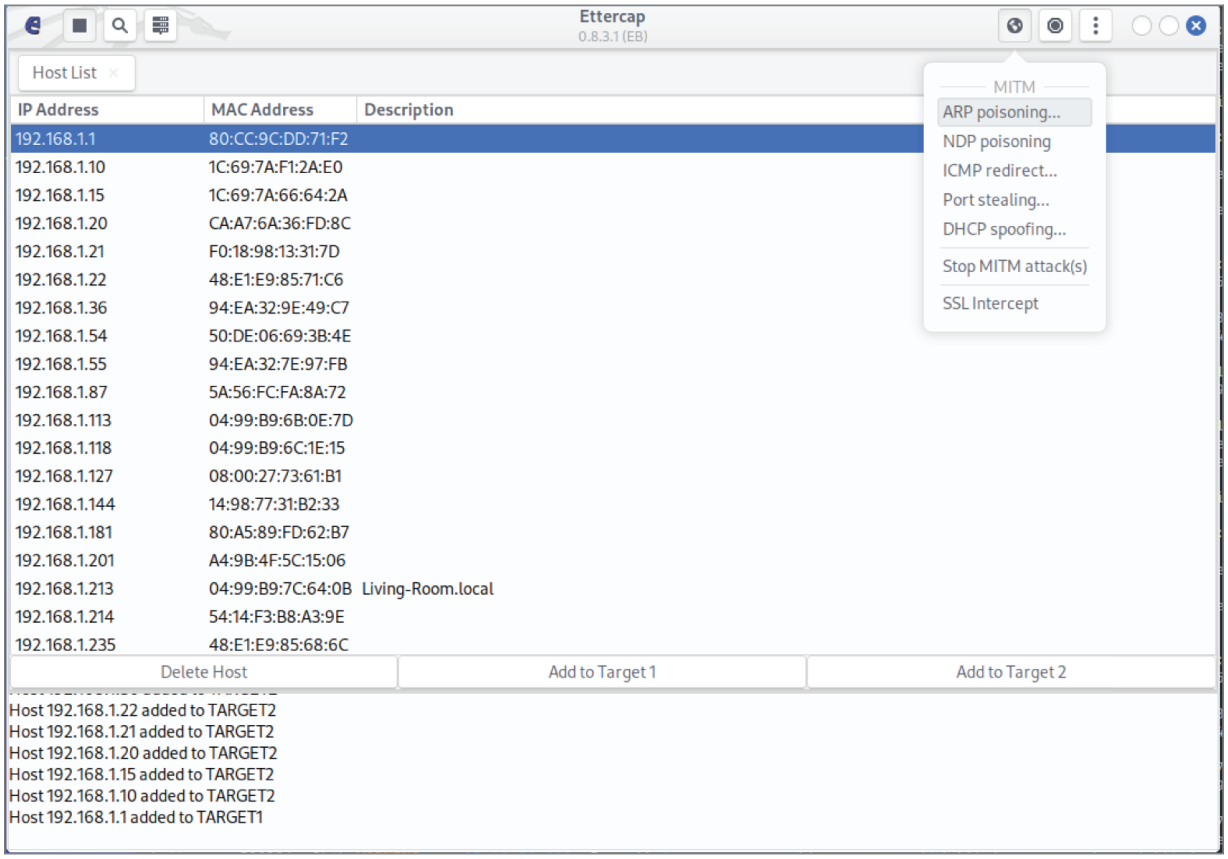
IP Address	MAC Address	Description
192.168.1.1	80:CC:9C:DD:71:F2	
192.168.1.10	1C:69:7A:F1:2A:E0	
192.168.1.15	1C:69:7A:66:64:2A	
192.168.1.20	CA:A7:6A:36:FD:8C	
192.168.1.21	F0:18:98:13:31:7D	
192.168.1.22	48:E1:E9:85:71:C6	
192.168.1.36	94:EA:32:9E:49:C7	
192.168.1.54	50:DE:06:69:3B:4E	
192.168.1.55	94:EA:32:7E:97:FB	
192.168.1.87	5A:56:FC:FA:8A:72	
192.168.1.113	04:99:B9:6B:0E:7D	
192.168.1.118	04:99:B9:6C:1E:15	
192.168.1.127	08:00:27:73:61:B1	
192.168.1.144	14:98:77:31:B2:33	
192.168.1.181	80:A5:89:FD:62:B7	
192.168.1.201	A4:9B:4F:5C:15:06	
192.168.1.213	04:99:B9:7C:64:0B	Living-Room.local
192.168.1.214	54:14:F3:B8:A3:9E	
192.168.1.235	48:E1:E9:85:68:6C	

```
Lua: no scripts were specified, not starting up!
Starting Unified sniffing...

Randomizing 255 hosts for scanning...
Scanning the whole netmask for 255 hosts...
21 hosts added to the hosts list...
```

FIGURE 9.13 Ettercap host list

Once the targets are selected, you can select ARP poisoning from the MitM menu, which is an icon that looks like a globe. Older versions of Ettercap had a more traditional menu, and you would use the MitM item in the menu bar on those versions. No matter which version you may be using, there are other options in that menu, which you can see in Figure 9.14. This time, we're going to just select ARP poisoning. That selection will bring up a dialog box asking if we want to sniff remote connections and also if we want to spoof one way. Make selections there and the spoofing starts.



IP Address	MAC Address	Description
192.168.1.1	80:CC:9C:DD:71:F2	
192.168.1.10	1C:69:7A:F1:2A:E0	
192.168.1.15	1C:69:7A:66:64:2A	
192.168.1.20	CA:A7:6A:36:FD:8C	
192.168.1.21	F0:18:98:13:31:7D	
192.168.1.22	48:E1:E9:85:71:C6	
192.168.1.36	94:EA:32:9E:49:C7	
192.168.1.54	50:DE:06:69:3B:4E	
192.168.1.55	94:EA:32:7E:97:FB	
192.168.1.87	5A:56:FC:FA:8A:72	
192.168.1.113	04:99:B9:6B:0E:7D	
192.168.1.118	04:99:B9:6C:1E:15	
192.168.1.127	08:00:27:73:61:B1	
192.168.1.144	14:98:77:31:B2:33	
192.168.1.181	80:A5:89:FD:62:B7	
192.168.1.201	A4:9B:4F:5C:15:06	
192.168.1.213	04:99:B9:7C:64:0B	Living-Room.local
192.168.1.214	54:14:F3:B8:A3:9E	
192.168.1.235	48:E1:E9:85:68:6C	

```
Host 192.168.1.22 added to TARGET2
Host 192.168.1.21 added to TARGET2
Host 192.168.1.20 added to TARGET2
Host 192.168.1.15 added to TARGET2
Host 192.168.1.10 added to TARGET2
Host 192.168.1.1 added to TARGET1
```

FIGURE 9.14 MitM Menu in Ettercap

Once the spoofing has started, you can do whatever you like with the traffic that is suddenly coming into your system. You can check easily enough to make sure the traffic is arriving by just capturing packets. What you see here are some packets going between 192.168.86.55 and 192.168.86.1. Neither of these IP addresses belongs to the system where Wireshark (and Ettercap) are running. This means the attack is working correctly. Rather than selecting a pair of targets, I selected only a single target. By default, with one target in Target 1 and nothing else explicitly selected, every other system on the network is in Target 2.

Once you are done capturing traffic off the network, you need to remember to stop the attack. Your tool may seed the network with the correct mappings, though in time the bad ARP cache entries will just time out. As noted earlier, on Linux systems, that would be within a minute. On Windows systems, it's even less. It's not absolutely required to restore the network to normal, but it would be polite to do so. You may cause issues on the network if you don't. It wouldn't be serious, but any disruption could end up causing issues.

DNS Spoofing

Another way to capture traffic is to use a technique called *DNS spoofing*. This is more targeted than an ARP spoof, however. ARP spoofing casts a very wide net, looking to capture every message being sent. With DNS spoofing, we aren't looking to capture traffic necessarily, in the sense of grabbing an existing conversation. Instead, we are looking to get a target to come to systems under our control for specific requests. We do this by intercepting DNS requests and providing responses to the requestor. Instead of providing legitimate responses, we're going to be using our own addresses. When one of our targets tries to visit a website that we are interested in getting information from, we redirect them to an IP address where we have our own website set up.

This is something we can use Ettercap for again. It is especially useful because it makes it so much easier to capture the DNS request. Unless we can capture the traffic somewhere, it's hard to make sure we are getting the DNS request so we can know how and when to respond to it. Unlike with ARP, we can't just send a spurious response to a system and have it cache the address. This is not to say that DNS information isn't cached. Just as with ARP, systems want to be as efficient as possible. DNS requests are time-consuming, so operating systems don't want to make them unless they are necessary. Where possible, operating systems will cache DNS mappings from hostname to IP address. That means we poison the cache once and have the system continue to send requests to the wrong address for potentially days.

Ettercap requires a configuration file in which you set up the DNS records you want to spoof. It will look just like a DNS zone file, where you provide the record name, the record type, and what it maps to. In the following code listing, you can see a sample of the DNS configuration file. In this case, the hostnames `www.foo.com` and `www.wubble.com` are both mapped to the same IP address. At that single IP address, since these are website hostnames, there should be a web server that is capable of serving requests for those hostnames. Additionally, there is a mapping for a mail exchanger record. This could be used if you want to intercept email to the domain indicated in the configuration file. The location of the file in the Linux distribution I'm working from is `/etc/ettercap/etter.dns`. There are a number of entries already in place there.

DNS Configuration for Ettercap

```
 #
#
 # Sample hosts file for dns_spoof plugin
#
 #
#
 www.foo.com        A    192.168.86.57
 www.wubble.com        A    192.168.86.57
 mail.foo.com            A    192.168.86.57

 foo.com            MX    192.168.86.57
```

Once DNS is in place, we need to go back to set up Ettercap to intercept traffic. This is the same process we did before. We need to sniff traffic so Ettercap can see the requests come in. We also need to use an ARP spoof attack to get traffic on the network to our system so we can see the DNS requests. Once you get to the stage of starting an ARP spoof, you can go to the Plugins menu and select Manage Plugins. From there, you can enable the DNS spoof plugin. This will automatically load the `etter.dns` file that was edited earlier.

NOTE In case it's not apparent, these attacks will work only on the local network because the addressing is by MAC address. This requires physical network connectivity for the interface being used to run the spoofing.

In the following listing, you will see the log that is written out in Ettercap from any request that has been captured. While the entries in the preceding code listing were added, none of the default entries in the file were removed. Microsoft's website is one of the hostnames that is being redirected. In that case, it's not being redirected to one of our local systems but instead to another system on the Internet altogether. Since we are using DNS here, the host doesn't have to be on the local network. DNS will respond with an IP address, and the requesting system will attempt to make a connection to that IP address. The only reason we need local access is to capture the requests. Once the requests have been captured and responded to, everything is layer 3 and above.

Ettercap DNS Spoof Log

```
 SEND L3 ERROR: 246 byte packet (0800:06) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 48 byte packet (0800:11) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 83 byte packet (0800:06) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 52 byte packet (0800:06) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 52 byte packet (0800:06) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 48 byte packet (0800:11) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 48 byte packet (0800:11) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 48 byte packet (0800:11) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 SEND L3 ERROR: 52 byte packet (0800:06) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
```

```
 )
 SEND L3 ERROR: 245 byte packet (0800:06) destined to
192.168.86.26 was not forwarded (libnet_write_raw_ipv4(): -1
bytes written (Network is unreachable)
 )
 DHCP: [192.168.86.1] ACK : 192.168.86.43 255.255.255.0 GW
192.168.86.1 DNS 192.168.86.1 "lan"
 dns_spoof: A [browser.pipe.aria.microsoft.com] spoofed to
[107.170.40.56]
```

The reason this works, even though the DNS request does go out to the legitimate DNS server and it responds, is because DNS is UDP, so there is no connection to be made. A UDP-based request goes out, and a UDP-based response comes back. A system may send out multiple requests, since they are UDP, and there is no guarantee the request will get to the DNS server. The first response that is received by the requesting system will be used. Since the Ettercap system is on the local network and there is a good chance the DNS server is not, the DNS response from the Ettercap system should be the first one back. Any subsequent responses to the requesting system will be ignored. By that point, the address configured in `etter.dns` has been sent back to the requesting system and populated the DNS cache on that system.

DHCP Starvation Attack

Another technique that can be used to acquire information from end users is something called the DHCP starvation attack. This attack works on IPv4 addresses that are dynamically provided to endpoints. This attack can end up having two outcomes, both malicious. In a DHCP starvation attack, as shown in a simple diagram in Figure 9.15, the attacker sends many DHCPDISCOVER messages to the DHCP server. These messages are sent to the broadcast address 255.255.255.255. The DHCP server responds with an offer to the client. In this case, the server will keep sending offers, reserving the IP address for that client, expecting an acknowledgment that never comes. At some point, the DHCP server runs out of IP addresses to provide to any legitimate endpoint. This would be a denial-of-service attack if it were left here. No endpoints would be able to get IP addresses from the legitimate DHCP server.

At this point, though, the attacker can create a new DHCP server. Keep in mind that DHCP works with broadcast addresses for new requests, so there is no need to pretend to be any specific IP address. In addition to IP addresses, a DHCP server can provide other IP configuration details, which may include a bogus DNS server, which could provide malicious addresses to requests to ensure users go to websites controlled by the attacker. Similarly, the attacker could provide a default gateway of a system on the local network they controlled. This would guarantee all traffic would be sent to this system so it could be observed before being sent on to the legitimate gateway. This does require some additional work to turn the device being controlled into what is effectively a router, but it is possible and would work much like the ARP spoofing attack.

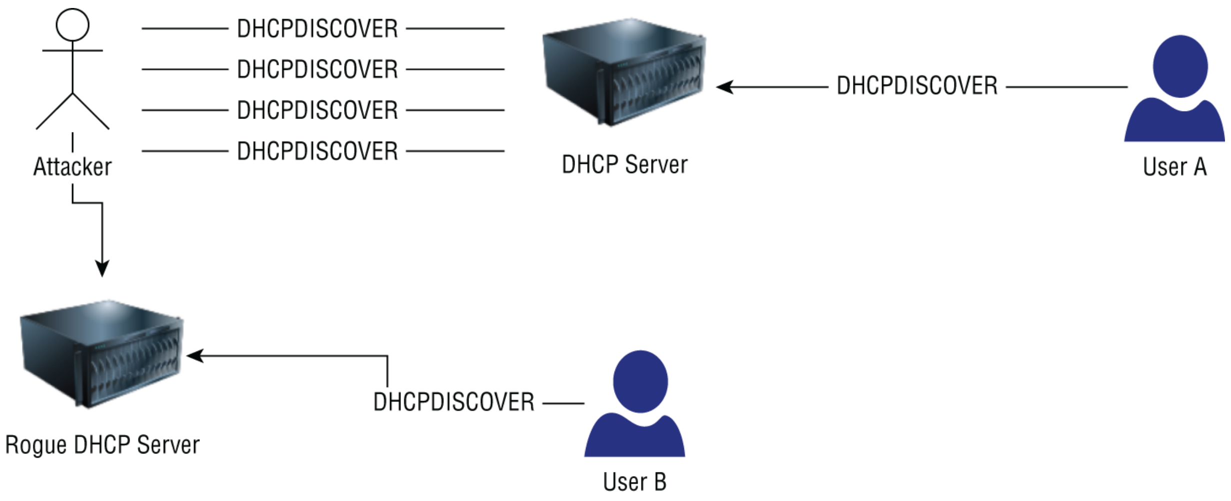


FIGURE 9.15 DHCP starvation attack

sslstrip

Encrypted messages are problematic when it comes to capturing traffic. Encryption is intended to be end to end, meaning there is no way to sit in the middle. Any mechanism to sit in the middle defeats the end-to-end expectation of most encryption schemes. Having said that, it is in our nature as ethical hackers to try to violate rules and break things. There are ways to try to break encrypted protocols. Of course, this was much easier when SSL was being used. SSL had multiple vulnerabilities over the different versions prior to TLS. Even when TLS was brought in to replace SSL because of SSL's vulnerabilities, the early versions of TLS had vulnerabilities that made it susceptible to having the encryption cracked.

The program `sslstrip` was developed to grab SSL messages and strip the encryption from them. This program was developed by Moxie Marlinspike in conjunction with a presentation he made at Black Hat in 2009. That was in the days when SSL was still prevalent, so there was a good chance it would work. Today, there is less of a likelihood of success because, ideally, system administrators on top of their game have removed older encryption mechanisms like SSL and TLS 1.0 and 1.1. If a server only supports TLS 1.2 and above, `sslstrip` won't work because the vulnerabilities that allowed it to work have been resolved. This is one reason it is not installed by default in distributions like Kali Linux.

You could use `sslstrip` as a stand-alone program. Essentially, `sslstrip` acts as a transparent proxy, sitting between the server and client. In doing that, it can change links from HTTPS to HTTP in some cases. It also uses other techniques to make it appear that the connection is encrypted when, in fact, it isn't. As a stand-alone, `sslstrip` makes use of `arpspoof`, which we looked at earlier. However, it is possible to run `sslstrip` as a plugin to Ettercap.

Just as we did with the DNS spoofing, `sslstrip` requires that we have an ARP spoof in place. We can do this with Ettercap, just as we did earlier. We would want to spoof the Internet gateway as we have before. We also need to sniff remote connections when we set up the ARP spoofing attack. `sslstrip` is a plugin to Ettercap, so it can be enabled just as the DNS spoofing plugin was enabled. This does require a configuration change in Ettercap before enabling the plugin. `sslstrip` needs to know what firewall command is being used so it can set up a redirect in the firewall. The following lines are commented in the `/etc/ettercap/etter.conf` file. They need to be uncommented if you are using `iptables`, which is more likely than `ipchains`, which is the other option.

[`/etc/ettercap/etter.conf`]

```
# if you use iptables:
redir_command_on = "iptables -t nat -A PREROUTING -i %iface -p
tcp --dport %port -j REDIRECT --to-port %rport"
redir_command_off = "iptables -t nat -D PREROUTING -i %iface -p
tcp --dport %port -j REDIRECT --to-port %rport"
```

Once that's done, the `sslstrip` plugin can be enabled. It will run the `iptables` command to start the redirect so the plugin can receive the messages. Here you can see the log that shows the start of `sslstrip` inside Ettercap.

Running `sslstrip` in Ettercap

```
 Host 192.168.86.1 added to TARGET1

 ARP poisoning victims:

  GROUP 1 : 192.168.86.1 18:D6:C7:7D:F4:8A

  GROUP 2 : ANY (all the hosts in the list)
 Activating sslstrip plugin…
 SSLStrip plugin: bind 443 on 59273
 SSLStrip Plugin version 1.1 is still under experimental mode.
Please reports any issues to the development team.
 DHCP: [192.168.86.1] ACK : 0.0.0.0 255.255.255.0 GW
192.168.86.1 DNS 192.168.86.1 "lan"
```

Once the `iptables` rule is in place, `sslstrip` should be capturing any HTTPS traffic. Again, though, this assumes that the HTTPS connection is using a version of SSL or TLS that is vulnerable to the stripping attack. If it isn't, you won't get any traffic.

Spoofing Detection

Network operators and security professionals need to be able to detect spoofing attacks. A good spoofing attack may not be detectable at the user level, which means you need to be able to detect them in the network. This may come from using a network intrusion detection system, but you still need to know how those detections would work. First, let's start with an ARP spoofing attack. As you saw, an ARP spoofing attack relies on the attacker sending out a lot of ARP responses. A user won't be able to see this happening, but any monitoring of the network would show up all of these gratuitous ARP messages on the network. This will give you the fact that the ARP spoofing is happening. It will also give you the MAC address of the spoofer.

Knowing a layer 2 address isn't going to tell you very much. After all, most people aren't going to be able to easily look at a 6-byte MAC address and know immediately what system it belongs to. First, you can take the first three bytes and look them up because the first three bytes are an organizationally unique identifier (OUI). Using an OUI lookup tool, such as the one available at `wireshark.org`, will give you the manufacturer of the network card the MAC address belongs to. As an example, the MAC address of a system on my network is 70:4d:7b:6d:52:6a. Performing an OUI lookup reveals that the manufacturer is ASUSTek. This is because the network interface is on a motherboard manufactured by ASUS.

The MAC address alone isn't sufficient, especially if all the computers on your network come from the same manufacturer. All you know is the manufacturer and a lot of companies will buy all their computer systems from a single manufacturer or even a couple of manufacturers. You may need to search your network for the MAC address. Your switches will always have a mapping of MAC address to port number. Once you have found which switch the MAC address is connected to, you can find the port and identify what system the port is connected to. It can take a little chasing, especially if the port doesn't directly connect to a system but instead an unmanaged port. At a minimum, you can chase the cable from the switch port or the jack the switch port connects to.

You may need to identify spoofing at the network layer, meaning spoofing the IP address. This may be especially true in the case of denial-of-service attacks. This should be handled by your router. Your router, if it's configured to do so, can perform something called *reverse path verification*. This is slightly less useful if you have only a single connection point on your router. Reverse path verification works by performing a lookup in the routing table. The router takes the source address from a packet and checks the routing table to determine which interface a response packet would go out on. If the interface the message comes in on is different, there is a chance the packet has been spoofed.

DNS spoofing may be harder to detect, especially if the attacker is using another mechanism to capture the outbound DNS request. If the IP address of the outbound message matches the address on the inbound message, you may be safe. If the two addresses don't match, you may be safe. Yes, that doesn't make a lot of sense. The problem with DNS is you may end up getting a response from a different address, depending on how the DNS server is configured. A better approach with DNS is to use local DNS servers and configure those DNS servers to use TCP rather than UDP. The three-way handshake of TCP will protect you from spoofing, or at least do a much better job of protecting you against spoofing than UDP does. You can also make sure your local DNS servers are configured to use DNS Security Extensions (DNSSEC). This will use cryptographic verification of servers you are communicating with.

DHCP starvation attacks can also be detected. If suddenly DHCP offers are coming from an unexpected IP address, it is likely there is malicious activity happening. This may be a result of a DHCP starvation attack, or it may simply be an attacker setting up a local DHCP server, since sometimes a device on the local network will proxy DHCP requests to a remote server. A local server would be able to respond faster. However, if you see a large number of `DHCPDISCOVER` requests happening, especially ones that are never accepted, it could be a strong indicator that there is a DHCP starvation attack happening.

Summary

Sniffing can be an important skill to have because of the many tactics that can rely on information that can be gathered from sniffing. *Sniffing* is another word for capturing packets, which is the process of gathering all messages that pass by the network interface, grabbing them at the Data Link layer, and passing all the messages up to an application that is capable of displaying the messages captured. While it's called packet capturing, it's really frames that are being grabbed since the data is being grabbed at the Data Link layer with the layer 2 headers intact. The protocol data unit (PDU) at layer 2 is a frame. The PDU at layer 3 is a packet. If the packet-capture software is discarding the layer 2 information, then it really is a packet capture.

There is a lot of software that can be used to capture packets across varied platforms. The program `tcpdump` has been around since the late 1980s and was standardized in the late 1990s. It is generally available across multiple operating systems, but especially Unix-like operating systems. On Windows, you can get a port of `tcpdump` called `windump`. The behavior is the same, but the source code is different in order to take into account the way Windows interacts with its network hardware. If you are looking for a program you can use with the same name across multiple platforms, you can use `tshark`. This is a command-line program that comes with the Wireshark package. It also has the advantage of giving you the capability of printing only the fields you indicate. Wireshark is a GUI-based program that can perform not only packet capture but also packet analysis.

There may be other programs and utilities you can use to analyze packet captures, but Wireshark has to be about the best you can get, especially for the money. It's freely available and packed with functionality. Wireshark knows about dozens if not hundreds of protocols. It does protocol decoding and can identify issues with protocols. It will call attention to those issues by coloring the frames in the packet capture and also coloring the lines in the protocol decode. Wireshark will provide expert information that you can look at all at once from the Analyze menu. There is also a Statistics menu that provides a number of different ways to look at the data. This includes a protocol hierarchy, showing how the protocols break down in the packet capture. You can also look at the packet capture from the perspective of endpoints. In the different statistics views, you can see packet and byte counts.

It can be challenging to get packets to the device where you are trying to capture them. One way to do this is to mirror ports on a switch. This is sometimes called port spanning because, as mentioned previously, Cisco calls the functionality SPAN. You may not have access to the switch, though. You can also perform spoofing attacks, such as ARP spoofing. ARP spoofing is when a system sends gratuitous ARP responses, which are then cached on other systems on the network. ARP spoofing can be used to get packets to your system for capture. However, you can also use ARP spoofing as a starting point to do DNS spoofing if what you really want to do is redirect requests to other IP addresses. You can also use ARP spoofing to redirect web requests to the `sslstrip` plugin. The program that does all this is Ettercap, though there are other programs that can do ARP spoofing.

DNS spoofing is also a possible way to redirect traffic to an attacker. This may be done by intercepting DNS requests and responding to them faster than the legitimate DNS server. In the case of DNS, first to answer wins, and sometimes DNS clients will accept answers even from IP addresses that don't originate the request because DNS servers may sometimes respond on a different IP address than the one the response came in on. DHCP starvation attacks are also ways to get traffic to malicious systems, since exhausting all IP addresses from a legitimate server would allow a rogue DHCP server to respond to users more easily. This could result in an attacker controlling not only IP addresses assigned to endpoints, but also provide rogue DNS servers or default gateway information.

Spoofing detection can be time-consuming. You may need to chase MAC addresses back through switch ports in order to find the system that owns that MAC address. When it comes to identifying spoofed IP addresses, you could use reverse path verification to check the routing table for the correct interface a message should come in on. This is more effective in larger networks where routers have multiple interfaces. In some cases, it's better to protect the network communication against spoofing attacks. This may be the case for spoofing attacks on DNS, for instance. Using local DNS servers, TCP, and DNSSEC can help protect DNS communications.

Review Questions

You can find the answers in the appendix.

1. Which hardware vendor uses the term *SPAN* on switches?
   - A. HP
   - B. 3COM
   - C. Cisco
   - D. Juniper
2. If you saw the following command line, what would you be capturing?

   ```
   tcpdump -i eth2 host 192.168.10.5
   ```

   - A. Traffic just from 192.168.10.5
   - B. Traffic to and from 192.168.10.5
   - C. Traffic just to 192.168.10.5

   D. All traffic other than from 192.168.10.5

3. In the following packet, what port is the source port?

```
20:45:55.272087 IP yazpistachio.lan.62882> loft.lan.afs3-
fileserver: Flags [P.], seq 915235445:915235528, ack
3437317287, win 2048, options [nop,nop,TS val 1310611430
ecr 1794010423], length 83
```

   A. 1310611430

   B. 272087

   C. 2048

   D. 62882

4. What is one downside to running a default `tcpdump` without any parameters?

   A. DNS requests

   B. Not enough information

   C. Sequence numbers don't show

   D. `tcpdump` not running without additional parameters

5. At which protocol layer does the Berkeley Packet Filter operate?

   A. Internetwork

   B. Transport

   C. Data Link

   D. Protocol

6. What do we call an ARP response without a corresponding ARP request?

   A. Is-at response

   B. Who-has ARP

   C. Gratuitous ARP

   D. IP response

7. Which functionality in Wireshark will provide you with percentages for every protocol in the packet capture, ordered by protocol layers?

   A. Conversations

   B. Endpoints

   C. Protocol hierarchy

   D. Statistics view

8. Which program would you use if you wanted to only print specific fields from the captured packet?

   A. `fielddump`

   B. `tcpdump`

   C. `wiredump`

   D. `tshark`

9. The following shows a time stamp. What does the time of this message reflect?

```
630    41.897644    192.168.86.210    239.255.255.250
SSDP    750    NOTIFY * HTTP/1.1    [ETHERNET FRAME CHECK
SEQUENCE INCORRECT]
```

   A. The time since 1970.

   B. The time of day.

   C. The time since packet start.

   D. There is no time in the summary.

10. What protocol is being used in the frame listed in this summary?

```
719    42.691135    157.240.19.26    192.168.86.26    TCP
1464    443 → 61618 [ACK] Seq=4361 Ack=1276 Win=31232
Len=1398 TSval=3725556941 TSecr=1266252437 [TCP segment of
a reassembled PDU]
```

   A. TLS

   B. UDP

    C. IP
    D. TCP
11. What program could be used to perform spoofing attacks and also supports plugins?
    A. `arpspoof`
    B. `fragroute`
    C. Ettercap
    D. `sslstrip`
12. What would you need to do before you could perform a DNS spoof attack using Ettercap?
    A. Set up a port span.
    B. Start up Wireshark.
    C. ARP spoof.
    D. Configure `sslstrip`.
13. Which command-line parameter would you use to disable name resolutions in `tcpdump`?
    A. `−n`
    B. `−i`
    C. `−r`
    D. `−x`
14. Why might you have more endpoints shown at layer 4 than at layer 2?
    A. Layer 4 multiplexes layer 2.
    B. Systems may initiate multiple connections to the same host.
    C. Ports are more numerous than MAC addresses.
    D. The IP addresses dictate the endpoints.
15. What would you use `sslstrip` for?
    A. Getting plaintext traffic

B. Removing all SSL requests

C. Converting SSL to TLS

D. Converting TLS to SSL

16. Why might you have problems with `sslstrip`?

    A. `sslstrip` is deprecated.

    B. `sslstrip` doesn't work with newer versions of TLS.

    C. `sslstrip` doesn't support TLS.

    D. `sslstrip` works only with Ettercap.

17. What does the following line mean?

```
Sequence number: 4361    (relative sequence number)
```

    A. The sequence number shown is not the real sequence number.

    B. The sequence number shown has not been incremented.

    C. The sequence number shown isn't long enough.

    D. The sequence number shown is the acknowledgment number.

18. What can you say about `[TCP Segment Len: 35]`, as provided by Wireshark?

    A. The window size has changed.

    B. Wireshark has inferred this information.

    C. Wireshark extracted this from one of the headers.

    D. Wireshark has additional detail below.

19. What problem does port spanning overcome?

    A. Switches don't support layer 3.

    B. Switches aggregate ports.

    C. Switches filter traffic.

    D. Switches are unreliable.

20. What is the `/etc/ettercap/etter.dns` file used for?

A. Enabling firewall rules for Ettercap

B. Configuring hostnames to IP addresses

C. Setting up mail for Ettercap

D. Disabling ARP spoofing in Ettercap

21. If you saw the following in your `ifconfig` output, what could you say is happening?

```
eth0:
flags=8963<UP,BROADCAST,SMART,RUNNING,PROMISC,SIMPLEX,MULTI
CAST> mtu 1500

options=50b<RXCSUM,TXCSUM,VLAN_HWTAGGING,AV,CHANNEL_IO>
             ether 14:98:77:31:b2:33
              inet6 fe80::10c6:713a:e86f:556d%en0 prefixlen
64 secured scopeid 0x7
             inet 192.168.1.144 netmask 0xffffff00
broadcast 192.168.1.255
               inet6 2601:18d:8b7f:e33a::52 prefixlen 64
dynamic
               inet6 fd23:5d5f:cd75:40d2:87:38bc:9448:3407
prefixlen 64 autoconf secured
             nd6 options=201<PERFORMNUD,DAD>
             media: autoselect (1000baseT <full-
duplex,flow-control,energy-efficient-ethernet>)
             status: active
```

A. ARP spoofing attack

B. ARP flooding attack

C. Network sniffing

D. Man-in-the-middle attack

22. Which of these would not be a result of a DHCP starvation attack for the victim?

A. Attacker getting a new IP address

B. Attacker setting default gateway

C. Attacker setting DNS server

D. Denial of service

23. If you suddenly saw a large number of DHCPDISCOVER packets on your network, what might you begin investigating?
    A. ARP spoofing
    B. Network sniffing
    C. DHCP starvation attack
    D. DNS poisoning
24. What network technology makes sniffing harder for attackers?
    A. Hubs
    B. DHCP
    C. Switches
    D. Mail servers
25. Your `sslstrip` session is not going well. What might you suspect?
    A. The sessions are all SSL v3.
    B. The sessions are all TLS v1.0.
    C. The sessions are all TLS v1.1.
    D. The sessions are all TLS v1.3.