Introduction to Security
Networking and Packets

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Learning Objectives

- By the end of this week, you will be able to:
  1. Dissect packet captures (PCAPs), network traffic
  2. Perform network reconnaissance and port scanning
  3. Understand the methods of conducting a distributed denial of service attack (DDoS)

Why Cover Networking and Network Security First?

- The "Connectivity" issue (recall Gary McGraw’s “Trinity of Trouble”)
- Where the "cool stuff" happens
- Critical to understanding the cyber attribution problem

What is the Cyber Attribution Problem?

- **Attribution** - "the action of regarding something as being caused by a person or thing."
- How do you attribute an act of war in traditional warfare?
  - Uniform of attackers
  - Types of weapons attackers used
  - Direction of strike
  - List goes on…
- What is cyber attribution like? See https://twitter.com/thegrugq/status/706545282645757952
  - So why is that?

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What is Networking?

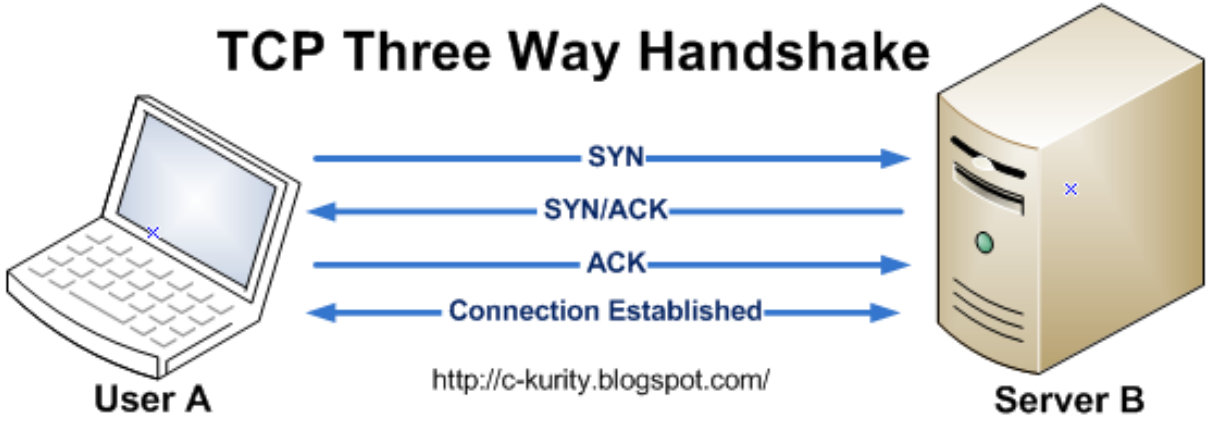
- Two or more computers talking to each other
- Basic definitions:
  - **Client** - A program running on your computer
    - Web browser - a client application that displays web pages (e.g., Chrome, Firefox, Microsoft Internet Explorer, Safari, Opera, lynx)
  - **Server** - A computer running web server software on a remote computer; delivers information to other clients
    - Example: Apache HTTP Server
  - **Internet** – The world's largest computer network
  - **World Wide Web (or the "web")** - A collection of web sites, pages, and content around the world
  - **Localhost** - home; this computer
  - **Socket** - an endpoint instance defined by an IP address and a port in the context of either a particular TCP connection or the listening state.
  - **Port** - a virtualization identifier defining a service endpoint (as distinct from a service instance endpoint aka session identifier); a number
    - Reference: https://stackoverflow.com/questions/152457/what-is-the-difference-between-a-port-and-a-socket

Abridged Analogy Describing How Two Computers Talk to Each Other

Telephone Conversation Between Two People	Conversation Between Two Computers
Telephone number	**IP address**. We will use IPv4 format extensively where an IP address is in octal format xxx.xxx.xxx.xxx where xxx is a number between 0-255 inclusive.
Telephone extension number	**Port number** - denotes a service provided by a computer. https://www.iana.org/assignments/service-names-port-numbers/service-names-port-numbers.xhtml
Telephone lines	Ethernet cables
Telephone book, "Yellow Pages"	Domain Name Systems (DNS)

Abridged Analogy Describing How Two Computers Talk to Each Other (continued)

- The "three-way handshake" - method used by *TCP* set up a *TCP/IP* connection over an *Internet Protocol (IP)* based network
  - **IMPORTANT: note the TCP flags SYN, SYN/ACK, and ACK as they will come up again**
- References:
  - http://www.inetdaemon.com/tutorials/internet/tcp/3-way_handshake.shtml



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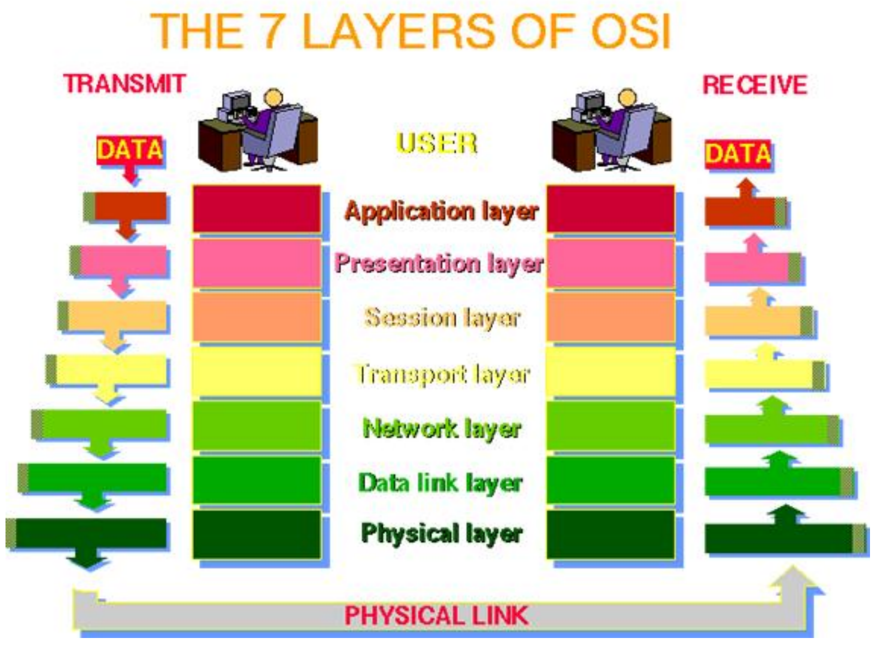
How Two Computers Talk to Each Other

- The OSI model
  - OSI - Open Systems Interconnection
  - Provides standards that allow hardware to focus on one particular aspect of communication that applies to them and ignore others



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The Seven Layers of the OSI Model

1. **Physical** - Lowest level, the bit level; primary role is communicating raw bit streams over physical medium (e.g., Ethernet cable and card, "wires")
2. **Data link** - Transferring data between two points connected by a physical layer; provides high level functions such as error correction and flow control (e.g., ARP, Ethernet)
3. **Network** – Middle ground; pass information between the lower and higher layers; provides addressing and routing (e.g., IP, ICMP) --delivery is NOT guaranteed
4. **Transport** - Provides transparent and reliable transfer of data between systems, including acknowledgement and segmentation (e.g., TCP, UDP)
5. **Session** - Establishes and maintains connections between network applications
6. **Presentation** - Allows for things like encryption and data compression (e.g., XML)
7. **Application** - The highest level interfaces, the services that you use on the Internet

Analogy to Understand the OSI Model via the US Postal Service

- **Physical** - The USPS' trucks, trains, and planes: this is how the letters actually get from point A to point B.
- **Data-link** - The envelope: you can't just put a handwritten letter in a mailbox and expect it to be sent somewhere.
- **Network** - The address: the USPS needs to know where to deliver the letter. This establishes a connection between two residences.
- **Transport** - Your name on the envelope: once it gets inside your house, it needs to be given to the correct person.
- **Session** - The standard letter format: this includes dating the letters, saying "dear so-and-so" and "yours truly.”
- **Presentation** - The body of the letter itself: let's make sure both parties are writing in English.
- **Application** - The collection of letters exchanged: the point of the previous six layers was to enable the pen pal relationship between two people.
- *We will focus on the Network, Transport, and Application layers extensively*
- Source: https://www.quora.com/Can-you-explain-OSI-layers-and-TCP-IP-in-laymans-terms

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Application Layer

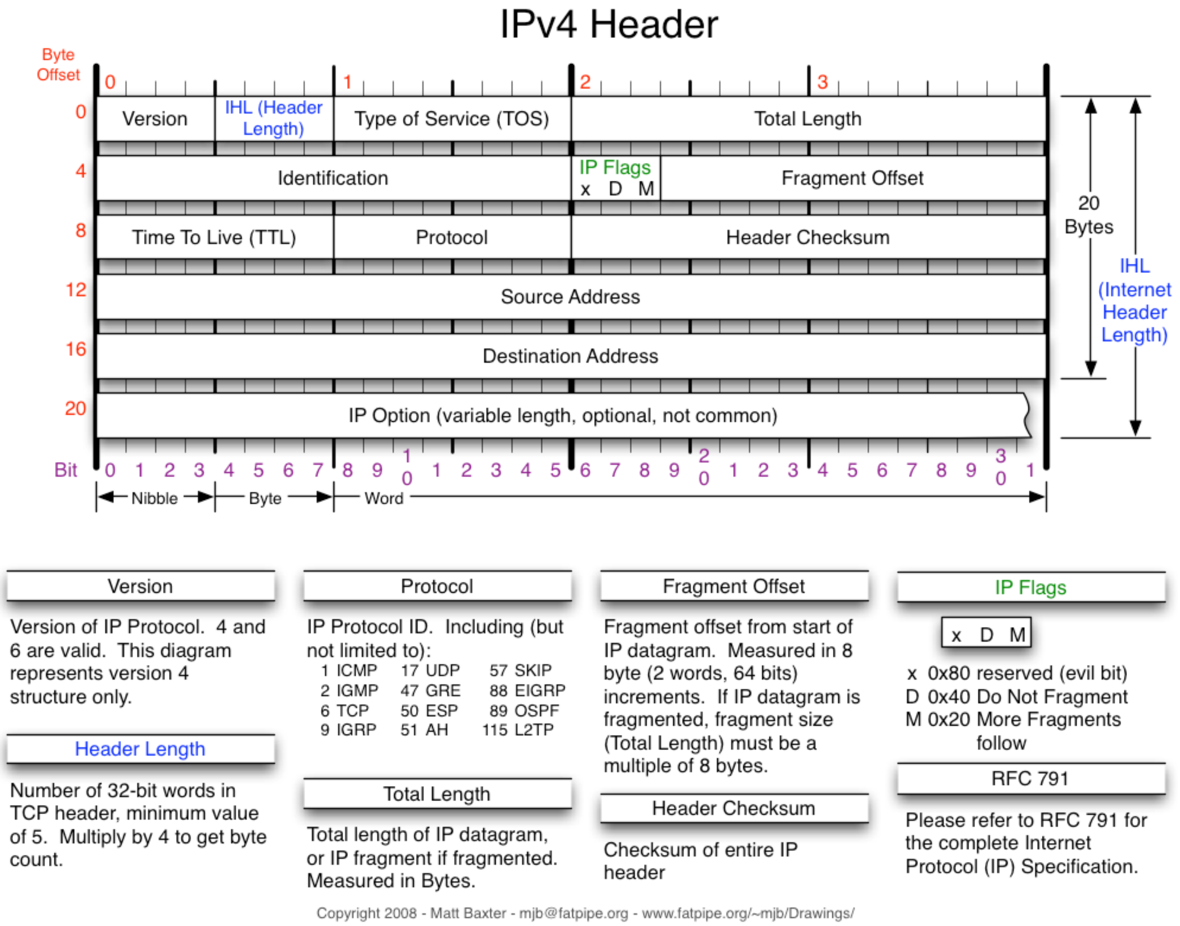
- The famous and insecure ones by default, data all unencrypted:
  - DNS – Domain Name Server (DNS)
    - Port 53
  - IMAP (Internet Message Access Protocol)
    - Email
    - Port 143
  - FTP (File Transfer Protocol)
    - File transfer
    - Port 21
  - HTTP (Hypertext Transfer Protocol)
    - The foundation of data communication for the World Wide Web
    - Port 80
  - Telnet
    - Protocol that allows you to connect to remote computers
    - Port 23
  - POP (Post Office Protocol)
    - Email
    - Port 110
    - Current version is 3 thus protocol is now known as POP3

Internet Protocol (IP)

- On the Network layer of OSI model
- Provides a connectionless, unreliable, best-effort datagram delivery service (delivery, integrity, ordering, non- duplication, and bandwidth is not guaranteed)
- RFC 791: http://www.ietf.org/rfc/rfc791.txt
  - RFC – Request For Comments, a publication from the Internet Engineering Task Force (IETF) and the Internet Society (ISOC), the principal technical development and standards-setting bodies for the Internet.

IP Header

- Source and reference: https://nmap.org/book/tcpip-ref.html



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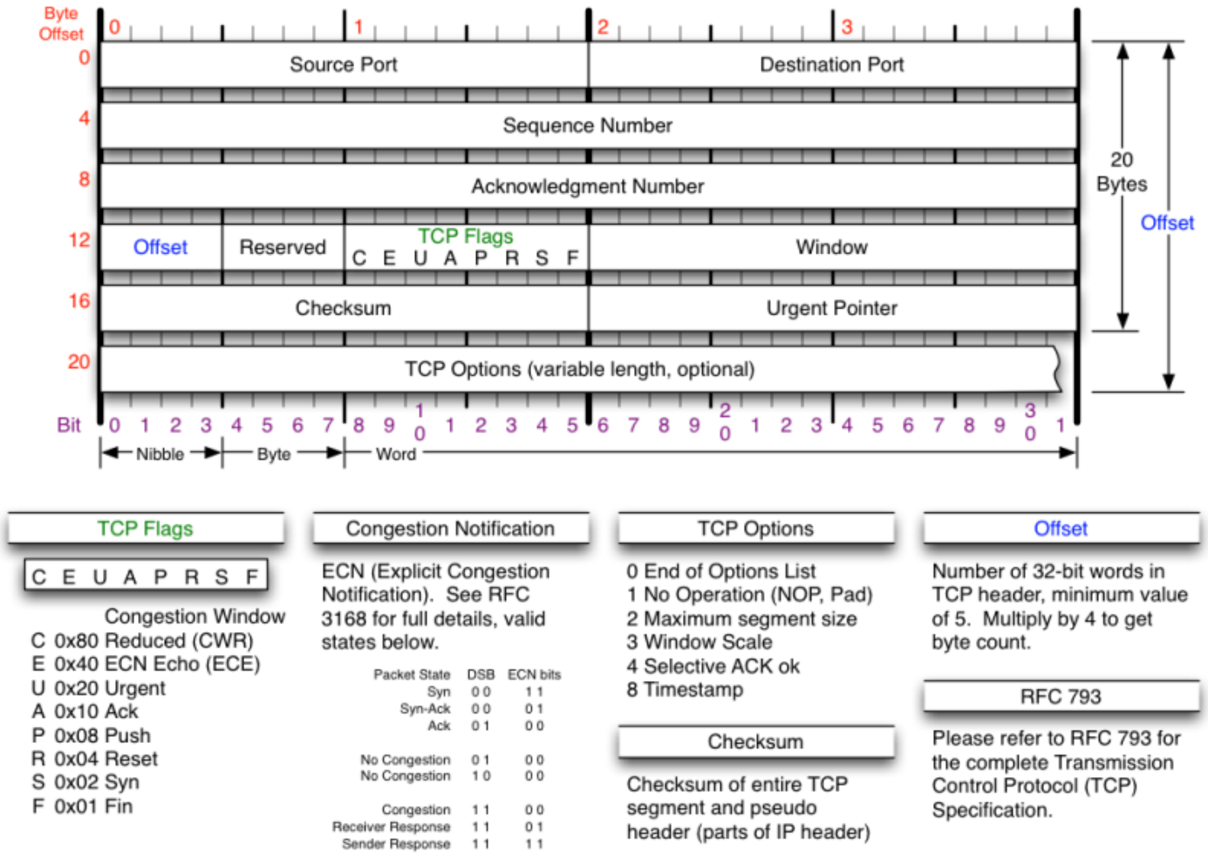
Transmission Control Protocol (TCP)

- Guarantees delivery of data in proper order thanks to IP protocol; thus, it is commonly known as TCP/IP
- Transparent, bidirectional, and reliable
- On the Transport layer of OSI model
- RFC 793: http://www.ietf.org/rfc/rfc793.txt

TCP Header

- Source and reference: https://nmap.org/book/tcpip-ref.html



Internet Control Message Protocol (ICMP)

- On Network layer of OSI model
- Testing and debugging protocol
- Used to determine whether a remote host is reachable
    - Thus generally speaking, ICMP is NOT used to exchange data between systems
- Other uses: inform about traffic overloads, obtain the network mask at boot time for diskless systems, synchronize clock
- Exchange control and error messages about the delivery of IP datagrams
    - Messages: Echo (request), Reply (response), Error
- RFC 792: http://www.ietf.org/rfc/rfc792.txt

Ping

- Utility to send `ICMP ECHO_REQUEST` packets to network hosts
  - More on what a packet is later
- Built in to almost all operating systems (e.g., Windows, Linux, Mac OS X)
- Documentation on Linux or Unix-based system: `man ping`
- Basic usage: `ping <host>`
  - Example: `ping google.com`
- What you cannot do with `ping`: check for open ports on a remote system

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User Datagram Protocol (UDP)

- On Transport layer of OSI model
- Relies on IP to provide a connectionless, unreliable, best-effort datagram delivery service.
- In other words, may be dropped before reaching targets a.k.a., fast
- Delivery, integrity, non-duplication, ordering, and bandwidth is not guaranteed
- Unlike TCP/IP, no handshaking!
- No sequence numbers
- Usage: DNS, streaming videos, video games
- RFC 768: https://www.ietf.org/rfc/rfc768.txt

Ethernet

- On Data Link layer of OSI model
- A network protocol that controls how data is transmitted over a local area network (LAN)
- Addressing: Media Access Control (MAC) address
  - A unique identifier assigned to network interfaces (e.g., your wireless network hardware card) for communications at the data link layer of a network segment
  - 48 bits in the format XX:XX:XX:XX:XX:XX
  - Example: 09:45:FA:07:22:23

Address Resolution Protocol (ARP)

- On Data Link layer of OSI model
- The idea of ARP: get Ethernet address of host with IP address (very much like delivering mail to an office building)
  - ARP request message, think of it this way: "Hey who has this IP? If it's you, please respond and tell me your MAC address”
  - ARP reply message, think of it this way: "This is my MAC address and I have this IP address”
- Host A wants to know the hardware address associated with IP address of host B
- A broadcasts a special message to all the hosts on the same physical link
- Host B answers with a message containing its own link-level address
- A keeps the answer in its cache (20 minutes)
- To optimize traffic, when A sends its request, A includes its own IP address
- The receiver of the ARP request will cache the requester mapping
- RFC 826: https://www.ietf.org/rfc/rfc826.txt
- Reference: https://www.homenethowto.com/switching/arp-mac-ip/
- Tools: `arp`

Domain Name Systems (DNS)

- Analogy: telephone book for the Internet; mapping of IP addresses to domain names and vice versa
- On Application layer of OSI model
- The name space is hierarchically divided in domains
- Each domain is managed by a name server
  - Servers are responsible for mapping names in a zone
- Root servers are associated with the top of the hierarchy and dispatch queries to the appropriate domains
- A server that cannot answer a query directly forwards the query up in the hierarchy.
- The results are maintained in a local cache for a limited time (which can range from minutes to days).
- Queries can be recursive
- DNS uses mostly UDP and sometimes TCP for long queries and zone transfers between servers (port 53)
- Associated RFCs: https://en.wikipedia.org/wiki/Domain_Name_System#RFC_documents
- References:
  - https://www.verisign.com/en_US/website-presence/online/how-dns-works/index.xhtml
  - https://dyn.com/blog/dns-why-its-important-how-it-works/
- Tools: `dig`, `host`, `nslookup`

So far…

- …you have learned about the OSI model
- …you have learned about the TCP three way handshake
- …you have seen headers, network protocols, etc.
- There is a lot going on here…
- ***How can you comprehend all this tangibly? How can one visualize what's going on?***
- Next steps: packets, PCAPs, and Wireshark

Packet

- **Packet** - unit of data
- A data stream (e.g., video, a web page) is comprised of many packets
- In general, a packet contains the following information:
  - Source and destination IP addresses (in IP layer)
  - Source and destination port number (in TCP layer)
  - MAC address (in Data Link layer)
  - Time To Live (TTL; in IP layer)
  - Payload
- Thus, a packet contains implementations of all the protocol layers (including TCP, IP, application, data link)
  - Encapsulation model
  - Think of an onion

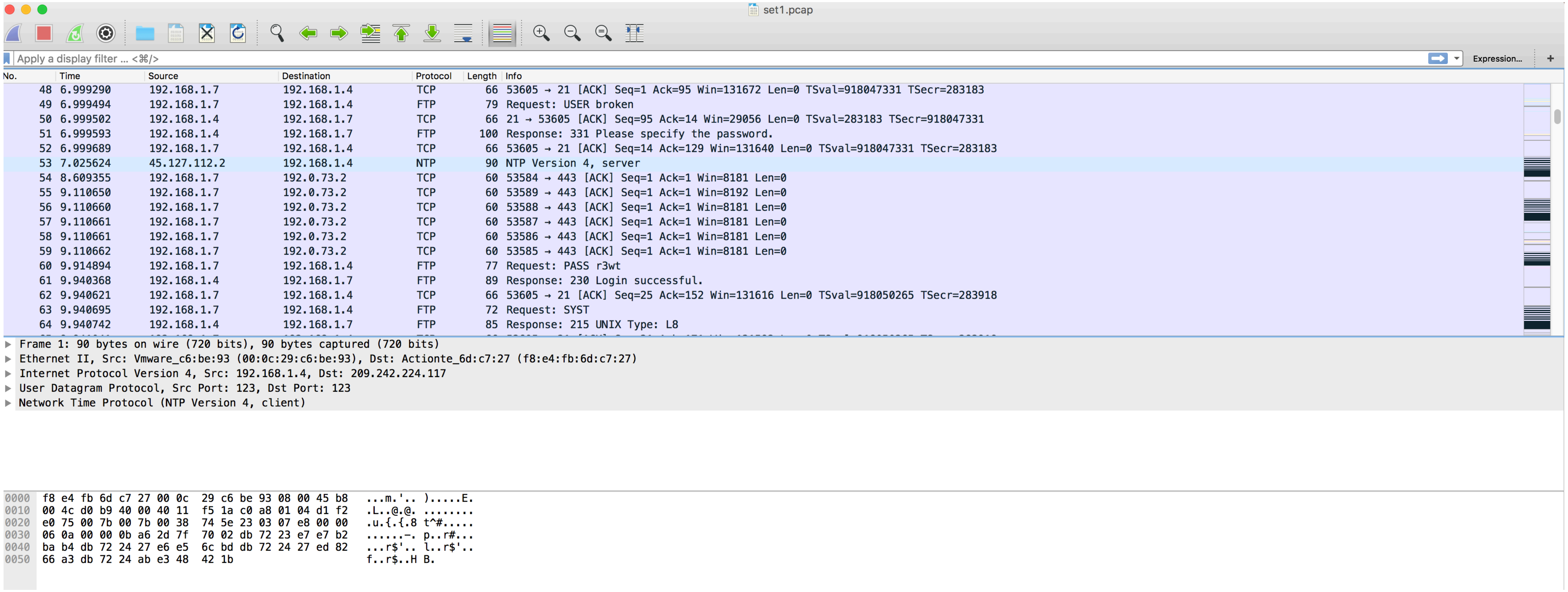
A .pcap File

- The common file extension for packet captures and is commonly used in many applications such as Wireshark, ettercap, tcpdump
- A 100 MB PCAP file contains tens of thousands of packets

Tool: Wireshark

- Graphical and extensive packet analyzer
- One of the most important tools in the field
- Very similar to `tcpdump`
- Open source and free
- Features include filtering, reconstructing conversations, reconstructing files based on packets
- https://www.wireshark.org/

Wireshark (continued)



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Tool: tshark

- Dumps and analyzes network traffic
- Command-line-based Wireshark
- Installed with Wireshark
- The manual: `man tshark`
- Example, list the hosts in a PCAP file:
  - `tshark -r file.pcap -q -z hosts,ipv4`

Tool: tshark (continued)

```
$ tshark -r set3.pcap -q -z hosts,ipv4
# TShark hosts output
#
# Host data gathered from set3.pcap

50.22.4.220     api.south.kontagent.net
17.172.224.47   apple.com
199.59.148.20   api.twitter.com
52.10.76.66     external-nginx-api.prod.us-west2.twitch.tv
23.21.212.107   data-collector-linkedin-prod-1143471378.us-east-1.elb.amazonaws
68.67.129.117   ib.anycast.adnxs.com
54.235.163.76   elb051356-548148482.us-east-1.elb.amazonaws.com
17.167.193.235  gsp36-ssl.ls-apple.com.akadns.net
222.239.85.206  upload.inven.co.kr
17.172.232.166  4.courier-sandbox-push-apple.com.akadns.net
52.7.6.170      api.shopkeepapp.com
54.148.244.104  external-nginx-api.prod.us-west2.twitch.tv
58.251.139.219  imap.qq.com
17.172.232.190  4.courier-sandbox-push-apple.com.akadns.net
17.134.126.30   gsp-ssl.ls-apple.com.akadns.net
52.21.62.183    elb-ad-01-659338009.us-east-1.elb.amazonaws.com
108.168.211.132 api.south.kontagent.net
169.46.12.66    api.south.kontagent.net
108.168.211.135 api.south.kontagent.net
169.46.12.69    api.south.kontagent.net
199.59.149.230  twitter.com
54.183.107.128  aerios.cyngn.com
169.46.12.72    api.south.kontagent.net
104.25.56.25    cdn.inspectlet.com
```

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Tool: tcpdump

- A packet analyzer that runs via command line
- To run: `sudo tcpdump -i <INTERFACE>`
- The manual: `man tcpdump`
- Cheat sheet via SANS Institute: https://www.sans.org/security-resources/tcpip.pdf
- Example: reading a PCAP file
  - `tcpdump -r file.pcap`
- Example: splitting a PCAP file into smaller ones (e.g., 10 MB)
  - `tcpdump -r old_file.pcap -w new_files -C 10`

Lab: Packet Sleuth

The Next Time: Attacking Networks

- Sniffing
- Network reconnaissance
- Denial of Service (DoS)
- Impersonation (spoofing)
- Hijacking (information access, delivery tampering)