Network Recap & Some Network Attacks

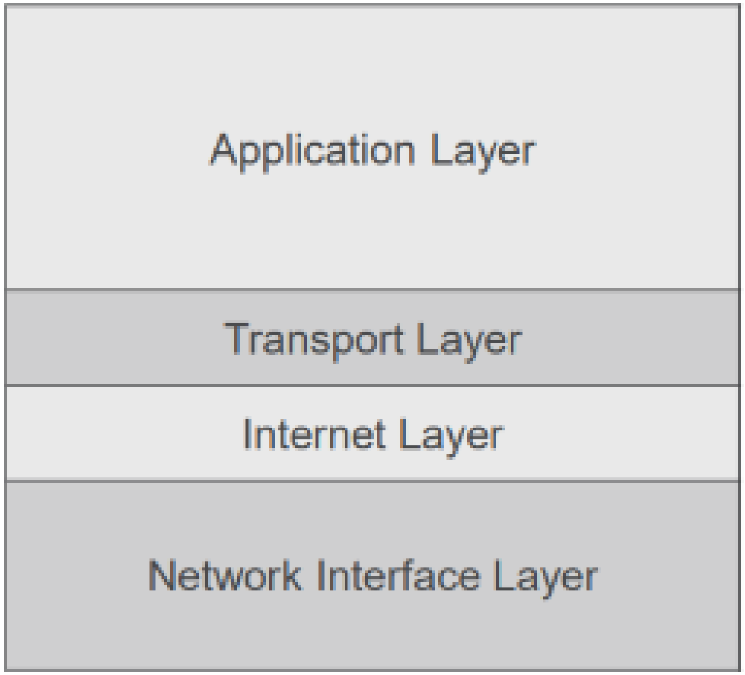
Tugberk Kocatekin
T.C. Istanbul Arel University

Spring 2023

TCP/IP

- Networking is the connection of two or more computers in order to share information and resources.
- Imagine there are two computers connected to each other by a single wire. This is enough to create a network.
- Remember the TCP/IP stack?

TCP/IP



Application Layer

Transport Layer

Internet Layer

Network Interface Layer

TCP/IP

Network Layer

- Takes a message and encapsulates it within a packet for transmission.

Internet Layer

- Responsible for routing packets from one device to another.

Transport Layer

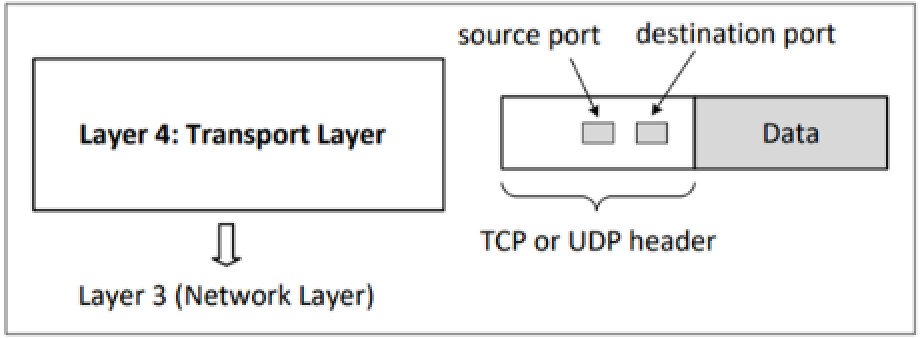
- Ensures the message is delivered. That means it ensures that the transmission is successful. It uses *packet numbering* for it. It also manages **congestion** in the network.

Application Layer

- User services that provide abstract functionality (FTP, HTTP, etc)

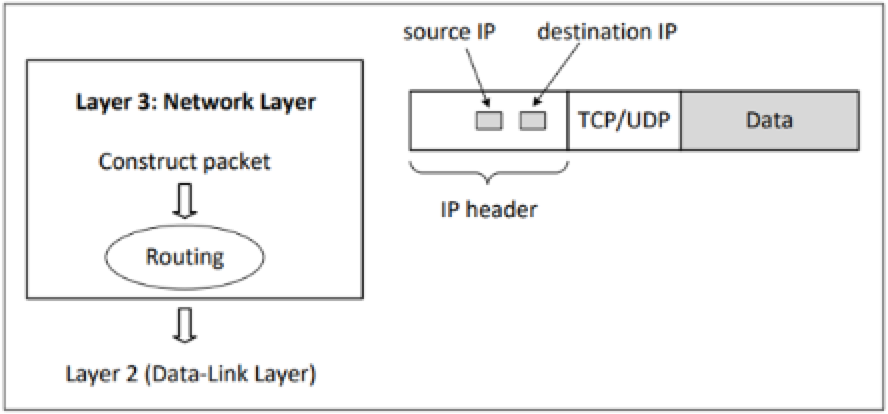
Layer 4 - Transport Layer

- Application Layer has the data and sends it down to Transport Layer. Here, depending on the communication protocol, Transport Layer adds a **header** to the data.
- It sends it to **network layer** after adding it.



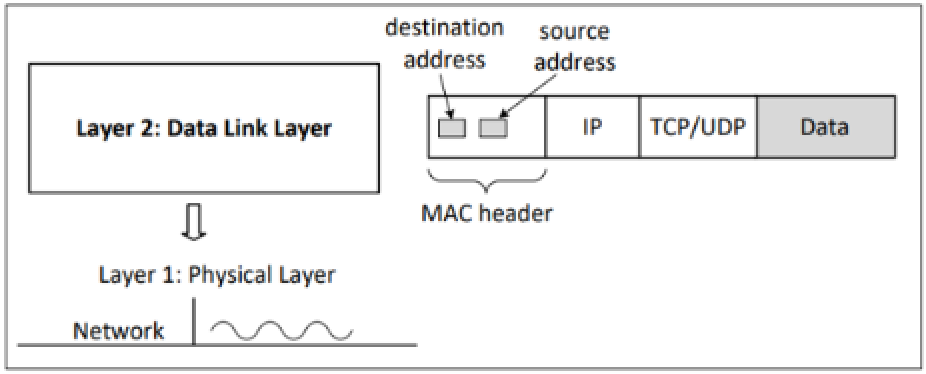
Layer 3 - Network Layer

- Network layer knows the **sender** and **receiver** IP address and adds that information to the package as the **IP Header**.
- Sends it to **Data Link Layer**.



Layer 2 - Data Link (MAC) Layer

- At this point, we have the **data**, **header** and **IP Header**. We are only missing the **MAC header** which consists of `destination address` and `source address`.
- After adding that, the package is given to the Physical layer and sent to the other side.



Protocols

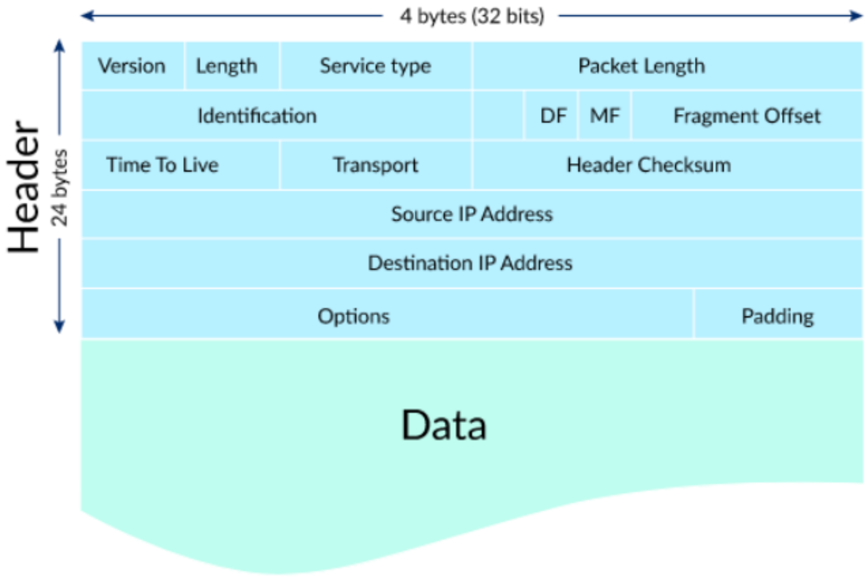
- In networks, there are protocols which are **rules** for clients and servers to follow such as:
  - Packet format
  - Packet ordering and timing
- There are protocol standards, **RFC** is one of them.
  - Request for Comments
- Some protocol examples;
  - TCP, UDP, ARP, HTTP, etc.

IP Address

- IP packet is also called a **datagram**.
- It has two main sections:
    - Header
    - Data section (payload)
- Header describes the packets.
- There are Private IP addresses which we use in our Local Area and Public IP address which is given to us by DHCP. (You can manually give IP address too.)
    - When you connect to the Internet, everyone in the local area have the same Public IP because they are using a single gateway to the Internet.
- Private are usually: 192.168.x.x and 10.0.x.x

Packets

- When you want to send information through the Internet, you use packets and send them by one or more packets.
- Size of packets are limited, that is why sometimes we divide a packet into multiple packets.
  - And sometimes a packet can be lost.



4 bytes (32 bits)

Header

24 bytes

Version | Length | Service type | Packet Length

Identification | DF | MF | Fragment Offset

Time To Live | Transport | Header Checksum

Source IP Address

Destination IP Address

Options | Padding

Data

Networking

- Let's say there are two houses **A** and **B**.
  - A wants to send a message. Since there are only two houses, it cannot send to anyone but B.
  - So, if A gives us a message, we know that the recipient is B.
- However, if there is another house **C**, now we need to know whether the recipient is B or C.
  - A must write the name of the **destination**.

UDP

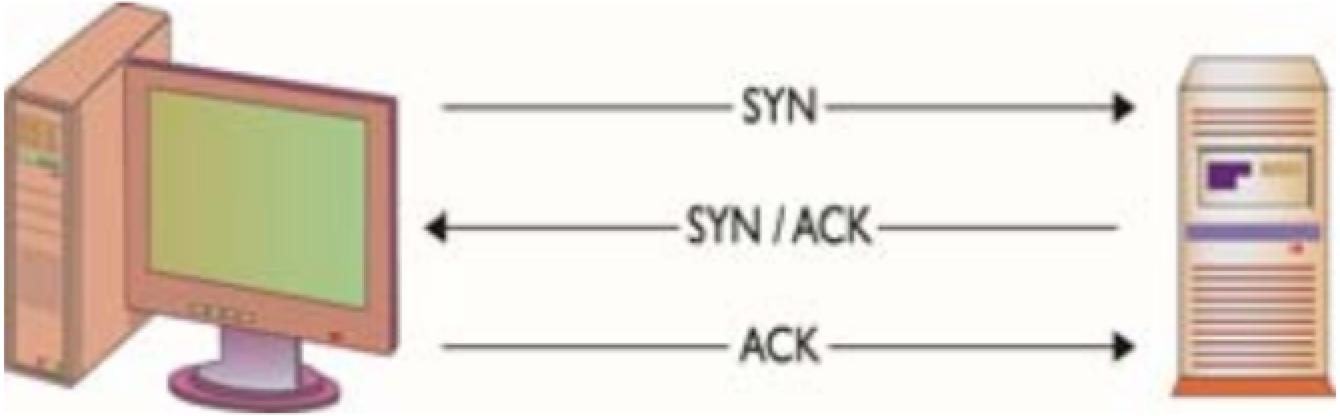
- User Datagram Protocol
- Connectionless protocol
  - It means that this protocol does not guarantee that your packets are going to be sent to/received by the **destination**.
- Unreliable
  - If a packet is lost, there is no re-transmission. So, no guarantee.
- Still, it is good for media streaming, gaming, VoIP, etc.
  - Why?

TCP

- Transmission Communication Protocol
- Connection oriented
  - It means that before sending data from *source* to *destination*, a connection is created between two parties.
- Reliable
  - Ensures that our packets are sent to the destination **in the order** we send them. Uses *sequence numbers* to do this.
  - Does re-transmission if the packets are lost.
  - Gives you information if data is received by the destination.
- It is good for web, SSH, etc. where you need **reliable** communication.

3-way handshake

- TCP is connection oriented and the connection is established by using this handshake method.



3-way handshake

SYN (Synchronize)

- Source sends a SYN packet to the destination. SYN packet has the **port** information that the source wants to connect and gives the initial packet sequence.
  - Remember that reliability is satisfied by using seq. numbers.

SYN/ACK

- Destination sends back SYN/ACK which means *I received your request* and also gives the destination's initial seq. number.

ACK

- Source sends back an ACK (*acknowledge*) to establish the connection.

TCP vs UDP

- **TCP**
  - Bob: I want to communicate with Alice.(SYN)
  - Alice: I am Alice. (SYN/ACK)
  - Bob: Hi Alice, I am Bob. (ACK)
- TCP is used where reliability is important.
- UDP is generally used for real-time stuff.

MAC Address

- MAC: Media Access Control
    - A unique identifier for every network adapter.
    - Also known as hardware address.
    - This is different for every adapter in the world.
        - However, we can spoof it.
- It is created by the *vendor* and wired into the network card. The form is in **AA:BB:CC:DD:EE:FF**.
- For example, our computers has multiple MAC address (at least 2). One is for WiFi and the other is for Ethernet. You can learn these addresses by typing `ipconfig /all` in Windows and `ifconfig -a` in Linux and Mac.
    - However, it is possible that you need to download some packages to see them.

Ports

- IP address is the **address** of the computer and ports are **doors**. They go together. Without specifying the port number, you cannot send anything to an IP address. **Why?**
  - Because they would not know how to enter the house!
- When we are connecting to a website, we are actually using the Port number 80.
  - There are 65536 ports.
  - We can also reach to other ports by using browsers. It is possible that the webserver is listening to another port.
    - `https://127.0.0.1:3000`
- Some ports are well known such as 80 (HTTP), 20-21 (FTP), etc.

DoS

- Attacker tries to consume the target's resources so that it cannot provide any service anymore.
- Denial of Service (DoS)
  - A computer floods a server with packets.
  - By flooding the server (TCP or UDP) it overloads the bandwidth.
  - Server becomes unreachable.

DDoS

- Distributed Denial of Service
  - Instead of **a** computer, now there are several computers sending packets to overwhelm the server.
  - *Mirai botnet* attacked to a **CDN server**. Since these are used for media, many websites could not work correctly.
- Both these attacks aims to make the server unavailable for **overwhelming** its traffic.
- These can even be done by `ping` commands!

DDoS and Botnets

- Botnets are usually used for DDoS. A program in your computer or **device** can be attacking websites.
    - Any device connected to a internet can be a *zombie*.
    - Those devices are used as **soldiers** and can be controlled from a remote place.
        - Command & Control Servers
- Also, it is possible that attackers are sending you a DDoS attack while trying another attack!

DDoS

- As we know, TCP is *connection oriented*.
  - In order to send something, you need to establish a connection.
    - 3-way Handshake
    - SYN Flood attack can make use of this.

SYN Flood attack

- A computer sends request with IP address of some other computer (let's say X) to the server.
- V sends a SYN/ACK back to X.
- Since X has nothing to do with the server, it discards SYN/ACK and leaves a half open connection at the server.
- When attacker does this with multiple computers and multiple IP addresses, there will be many open connections and this is going to exhaust resources at the Server.
    - Which leads to DoS.

DDoS

- There are two main types: Direct and Reflector
- Direct DDoS is previously mentioned.
- Reflector DDoS
  - This is more damaging and protects the attacker's identity better.

Homework

- Please read the homework in UZEM.
  - What is Reflector DDoS?
  - What can we do to secure ourselves from DDoS?

UDP Flood Attack

- When you send an UDP packet to a server for a specific port, two things happen:
  - Server checks if there is any program listening to that port
  - Responds you with ICMP(ping) if there is no such program.
- Therefore, for every request the server needs to go through each port and check whether a program is listening to it.
- Attackers also sends these requests by changing the IP address in the header so that the responds are not coming back to itself and exhaust attackers network.

DNS & DNS Flood Attackk

- DNS (Domain Name System)
  - These are *phonebooks* of the Internet. When you try to connect to a website by writing the name, it first checks the DNS server and gets the true name (IP address) of the computer.
- DNS is important and if you can attack DNS infrastructure, many people will be unable to use the Internet.
- By using high bandwidth connections of IoT devices such as IP cameras, DVR boxes etc. they can overwhelm the DNS servers of major providers. (Uses UDP)
  - When the number of requests are too much, DNS is spending a lot of time answering those and cannot answer our requests.
  - Usually done by *botnets* which took control of such IoT devices.

IP Spoofing

- When we are sending a packet, it has source and destination IP address written in the header.
- Here, we change the source IP address to some other address.
    - It is similar to sending a message with a **wrong** return IP address.
- When you attack a server with the same IP address, they are going to block you at some point.
    - You change the source IP address frequently so that they cannot block you.

Man in the Middle (MITM) Attacks

- A general term used to identify attacks when a network trafic is rerouted.
- Let's say A and B are communicating with each other and A is sending a message to B.
  - You (C), get in the middle and get all packets. You read them all, and relay that package to B.
  - No one knows you read the messages.
- It is a problem because now it's possible that you can relay **different** messages to B without breaking the connection.
- In networks, this can be done by using ARP spoofing.

ARP Spoofing

- Also called ARP cache poisoning, ARP poisoning etc.
- ARP is Address Resolution Protocol. It is used to resolve *Internet layer addresses* into *link layer* addresses.
- *Data link layer* uses MAC addresses to transmit data. Therefore, when you send a message from one host to another, a system must find the MAC address of the destination.
- First, the host looks at its **ARP table** if there is a MAC address for that IP address.
    - If not, it sends a *broadcast packet* to the network which is called an **ARP request**.
- Every device has an ARP table.

ARP Spoofing cont.

- Destination machine with the IP in the ARP request responsd with an *ARP Reply* which contains the MAC address for that IP address.
- When you learn this information, you write it into your *ARP table*.
- Be careful that this information is *broadcasted*. Computers which are not the host don't even reply to it.
  - However, the one who is that device responds.
- Instead of that device, we are going to respond to that request, stating that we are that machine (where we are not).

ARP Spoofing cont.

- Now, the computer is going to update the ARP table and now is going to send every packet to us, instead of the original destination.
- Since we know about the destination, now we can read that data and relay that data.
- This is a well known attack, especially in big networks. When the security was lacking in the previous years, this attack could be used to steal user credentials very easily.
  - If the packets are not encrypted, that means they can be read!
    - However, if they are encrypted, even if you do this attack you will be unable to read messages.

ARP defence

- **VPN** solves this problem because it is encrypted.
- **Using static ARP**: If you define a static ARP entry for an IP address, it is not going to send a request and will stop listening responses.
- There are also software to prevent ARP spoofing.

Hardware Firewalls

- When we are communicating via Internet, every packet goes through the Router.
  - Therefore it is also the first line of defence.
- This device assigns a private IP address to every computer in the local area network and uses *network address translation* to map these **private** addresses to a single public address.
- NAT also acts as a firewall by hiding the true addresses of attached equipment and controls which traffic reaches to each computer.
- Firewall restricts data transmission through most TCP and UDP ports. But it can be adjusted.

Software Firewalls

- Hardware firewalls protect the whole LAN, where software firewalls only protect those computers which it is installed to.
- They not only limit the incoming traffic but can also control the outgoing traffic.
- When a software in your computer is trying to send something through a port, it can block it and give you notification about the software.
- It is an important line of defence.
- You can change the settings of the firewall so that it can let software communicate through certain ports.

Packet Filter

- Inspects packets transferred between computers.
- Uses *control policies* to decide which data packets should be granted/denied request.
- Uses an *access control list (ACL)* containing *authorized* or *blocked* port numbers, IP addresses etc.
  - Even if you download a *keylogger* or *trojans* if the firewall works correctly, they are not going to be able to send information to the outside world.

Proxy Server

- Intermediary which acts as gateway between the user device and Internet.
- Set up via web filters or firewalls.
- It protects the user by hiding or masking the identity.
- It can aso be used as a repository to keep user's internet activity and website history.
    - It can get websites in cache to provide faster access.
- Sometimes companies use it to *block* connection to certain websites too.
    - And sometimes it is used to overcome blocking.
    - Opera VPN is essentially a proxy server.

IDS (Intrusion Detection Systems)

- These are devices or software application which monitors a network or systems for malicious activity.
- Firewalls allows traffic only from those who we let in.
  - What happens if they attack us?
- For that we use IDS. They monitor data and behavior, and report when they identify attacks.
- There are different kinds of IDS:
  - Signature-based, host-based, anomaly-based and network-based.

Signature-based IDS

- Uses known pattern matching to signify attack.
    - Byte sequences or instruction sequences used by malware.
- It is widely available and fairly fast.
- Easy to implement and update.
    - Cannot detect attacks if it doesn't know the signature/pattern.

Anomaly-based IDS

- Introduced to detect *unknown* attacks. There are a lot of malware being created and it is hard to know all - people don't update that much.
- Uses statistical model or machine learning engine to characterize normal usage behaviors.
    - If there is any difference from normal usage, it is seen as potential intrusions.
    - You train a model so that it can understand what *trustworthy activity* is.
- This can detect new attemps on unknown vulnerabilities.
    - Generally slow and more resource intensive compared to signature-based.
    - Greater complexity.
    - Higher percentage of *false positives*.

Network-based IDS

- Examine raw packets in the network passively and triggers alerts.
- Easy to deploy and difficult to evade.

Host-based ISD

- Runs on single host.
- Can analyze logs, file integrity and directories.
- More accurate compared to NIDS.
    - Deployment is expensive
    - Doesn't work when host get compromised.

IDS Placement

- Depends on the needs of the network.
- Behind the firewall
  - Common practice. Provides IDS with high visibility of traffic entering the network.
- Beyond the firewall
  - To defend against common attacks such as *port scans* and *nmap*.
  - Signature-based.
  - Useful because rather than showing *actual* breaches it will show *attempted* breaches.
  - Also decrease the amount of time taken to discover successful attacks.
- Within a firewall
  - To integrate sophisticated attacks.
- Within the actual network to reveal attacks or suspicious activity within the network.

Summary

- There are security vulnerabilities in TCP/IP because it assumes a lot of trust.
- There are several attacks on different layers:
  - IP attacks, ICMP attacks, Routing attacks, TCP attacks, App Layer attacks.
- IP addresses are filled by originating host. This makes IP spoofing possible.

Application

- `nc` netcat.
- Let's open up two shells. In one, we are going to listen to port 84 and from the other we are going to connect to it.
    - `nc -l 84` (root is needed for listening a port)
    - `nc localhost 84`
- We created a very simple chat between two computers.
    - You can also use this to send files.

      *Using `nc` like this creates a TCP connection. If you use `-u` flag, it becomes a UDP connection.

Sending a file

- In Server A, `nc -l -p 84 > log.txt`
- In B, `cat hello.txt | nc -w 5 localhost 84`
- Here, `-w` is for timeout. Otherwise it will stay on.
  - Now, in Server A we can read `log.txt` and will see the result of hello.txt
- Here, the contents are not encrypted so be careful.
- However, we can encrypt the file beforehand with `gpg` and send that file instead.
  - Or we can use `openssl` and use stdin.

Another example

- `sudo nc -l -p 94 | cat -`
- Client will send `echo "hello there" | nc -w 5 localhost 84`
    - It will output immediately.

Python Example

- We can so something similar by using Python programming language.
- There will be two examples here. One for `server` and the other for `client` .

```
#rec.py
#this is for the listening server
import socket

IP = "0.0.0.0"
PORT = 9090

sock  = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
sock.bind((IP, PORT))

while True:
    data, (ip, port) = sock.recvfrom(1024)
    print("Sender: {} and Port: {}".format(ip, port))
    print("Message: {}".format(data))
```

- We are listening with the other one. We can write several software as below to send information from other computers!

```python
#Sender - send.py
import socket

IP = "127.0.0.1"
PORT = 9090
data = b"hello world"

sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
sock.sendto(data, (IP, PORT))
```