

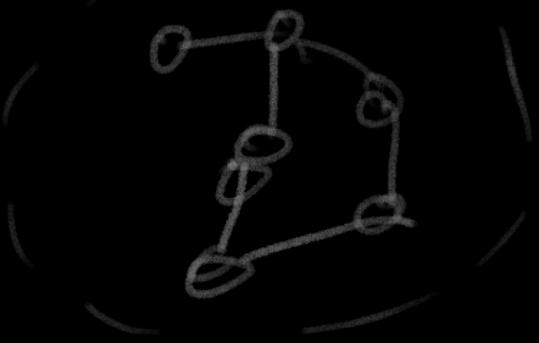
Computer Networking

Network - Comp Connected together

Internet - Collection of Comp networks



How it started?



ARPA - NET ^{(TCP)/(IP)} → MIT, Stanford, UCLA

In 1970 used to transfer UTAH

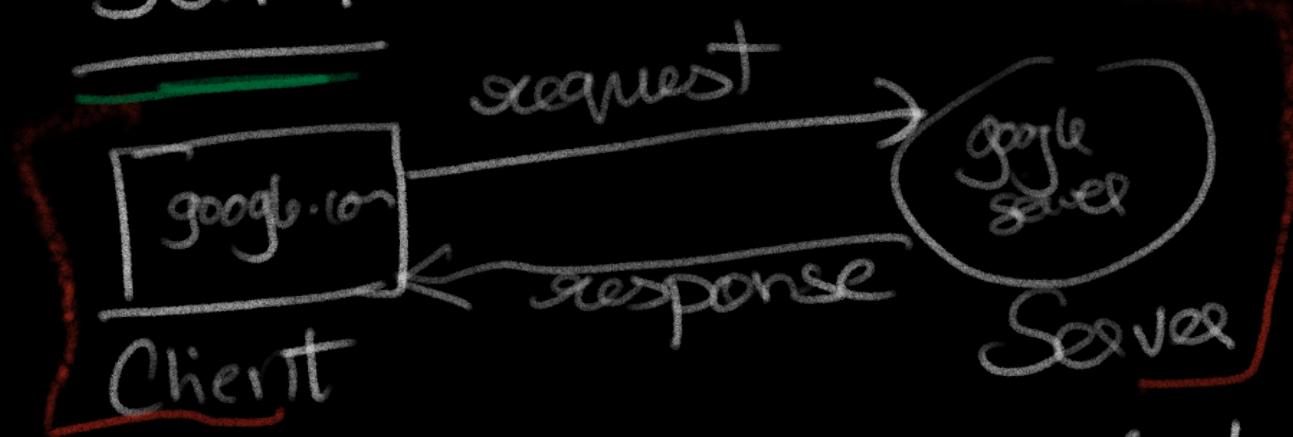
Later Comes wwww

Protocols (Rules)

→ Imp to have protocols . So, that we can communicate to the entire world.

Check later . RFC - Editor | Internet - Society

Server



→ Protocols are rules made by Internet Society.

Some of the Protocols :

TCP (Transmission Control Protocol)

→ It will ensure data will reach its destination without getting corrupted

(User datagram protocol)

→ UDP - not all data will be reached
ex: Video Conferencing

→ HTTP (Hyper Text Transfer Protocol)
Used by web Browsers

How data is transferred?

→ Since in Comp everything is 0, 1
it doesn't make sense to send
entire data once. You want
Send a large file it won't be
sent in 1 go if will come in
chunks.

Ex:- loading Webpage, Watch Movie

→ Data we will be getting will be
in packets

when you enter google.com how does it find which server to connect?

→ Basically, these computers & servers are identified by IP addresses. Think of it as phone book.

for example :

Peter

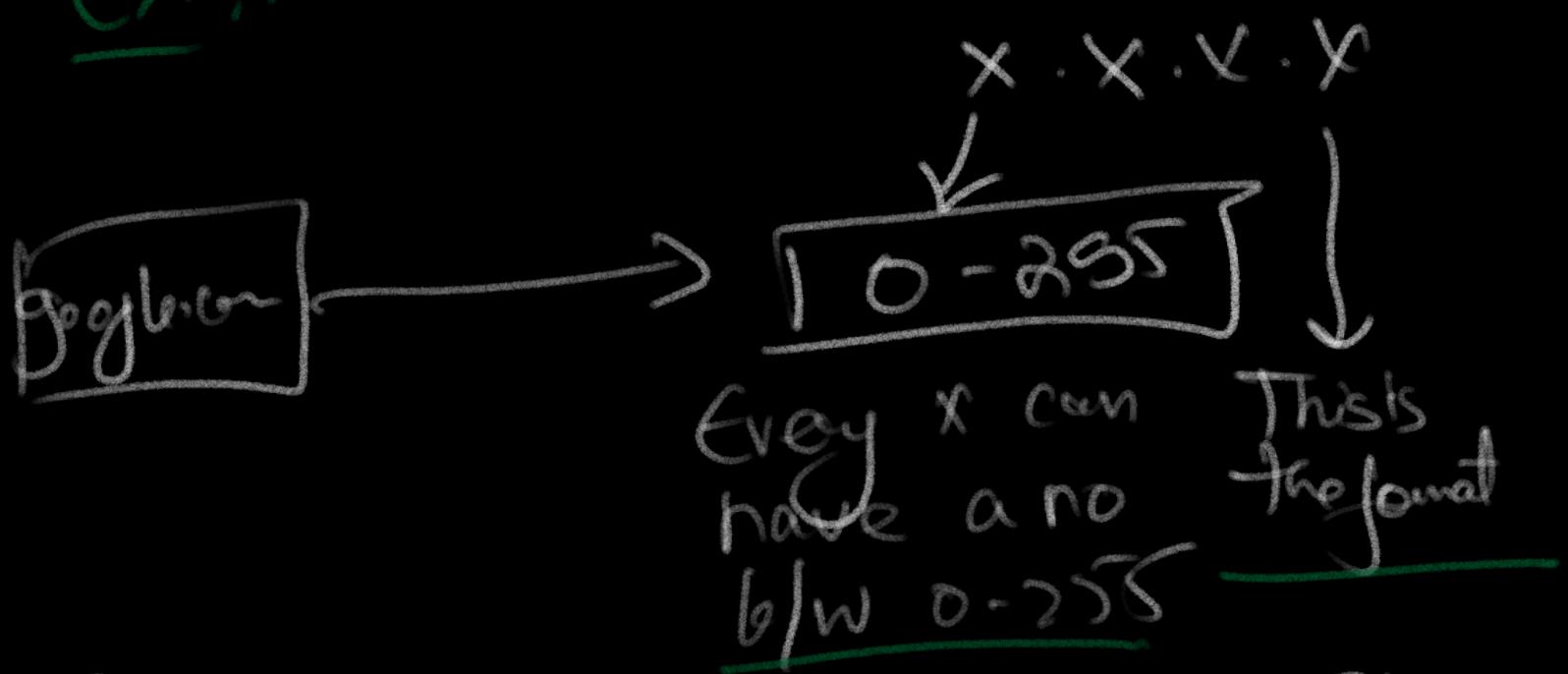


999999...

for example if you want to call peter & don't call peter it will directly call as the number is linked.

→ Every single device on Internet
that can talk to each other
has an I.P address.

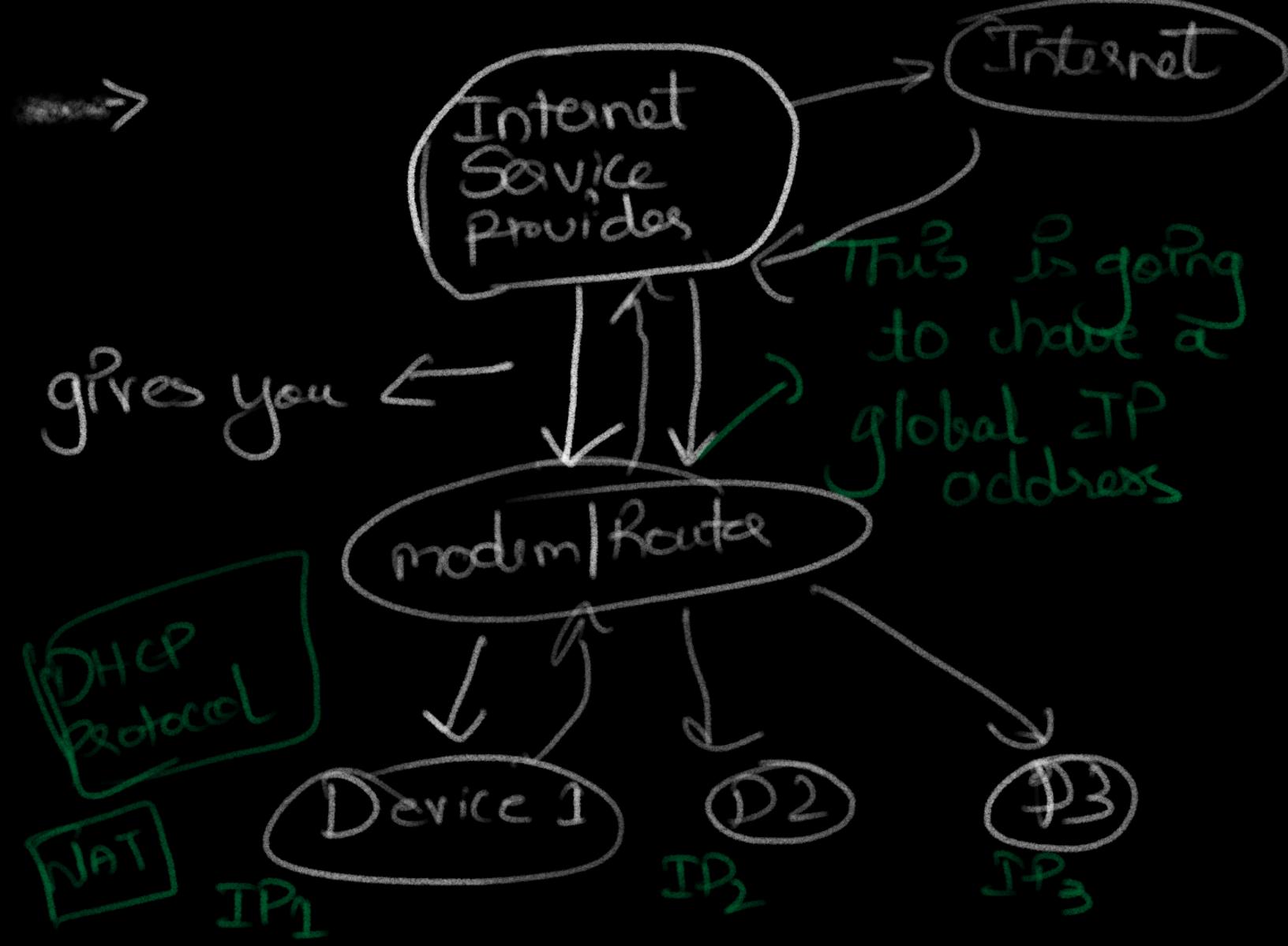
Ex:-



So, when click google.com it
will be resolved to a particular
IP address

To get the Ip address of your Internet
(or)

Use this command → **ipconfig**



The modem will assign each device a IP address known as Local IP address.

→ It does do it using DHCP
Dynamic Host Configuration Protocol
 It's also part of rules & regulations.

→ For example you make a request to google.com It will see the global IP address

from our above example if D1 & D2 make a request for google It will be seen 1 device making a request

→ You send a request to google.com your Isp will send " " " " & then it will return back the response.

→ Now, Modem | Router will decide who was the one who had the request. It does that using NAT

Network Access Translator (NAT)

- It says D1 has a connection
port open and A's requested
for this response

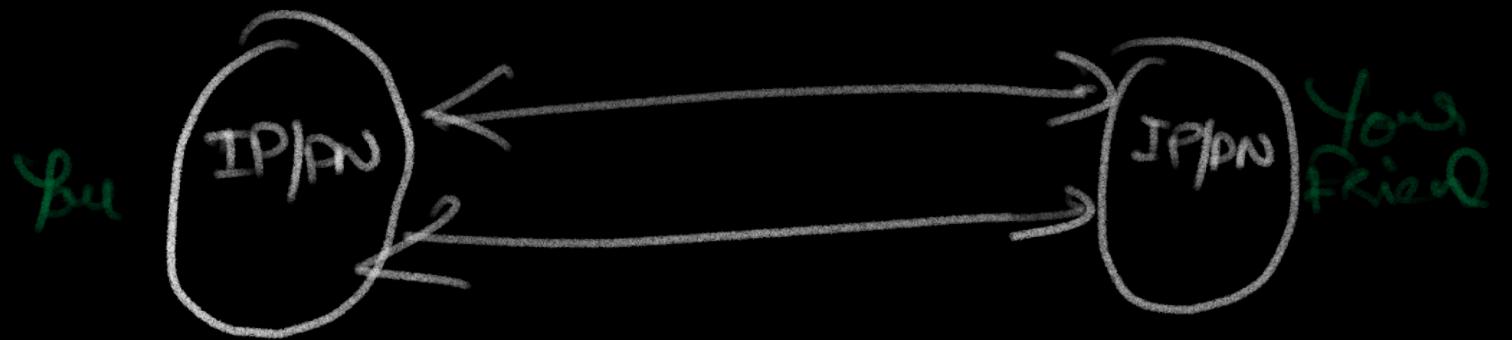
How do Modem/ Router figure out
which app made the request

We know that IP address decides
which device to send the data.

Since there are many applications
running the same device which
will have the same IP address.

It will send to the exact
app which made request using
Ports / Port Number

→ Let's say you talking to your friend
you & your friend will have IP address &
port number



IP address - will determine where comp located

Port Numbers - denoting which app you will be using to communicate

Ports

→ They are Basically 16-Bit numbers.

16-Bit means we can have 16 cells

1 each cell can contain 0 or 1

Total port numbers that are possible

are : $2^{16} \approx 65\text{K}$.

We know web pages are using HTTP protocol. All HTTP stuff will happen on Port 80 e.g. HTTP:80, MongoDB:27017

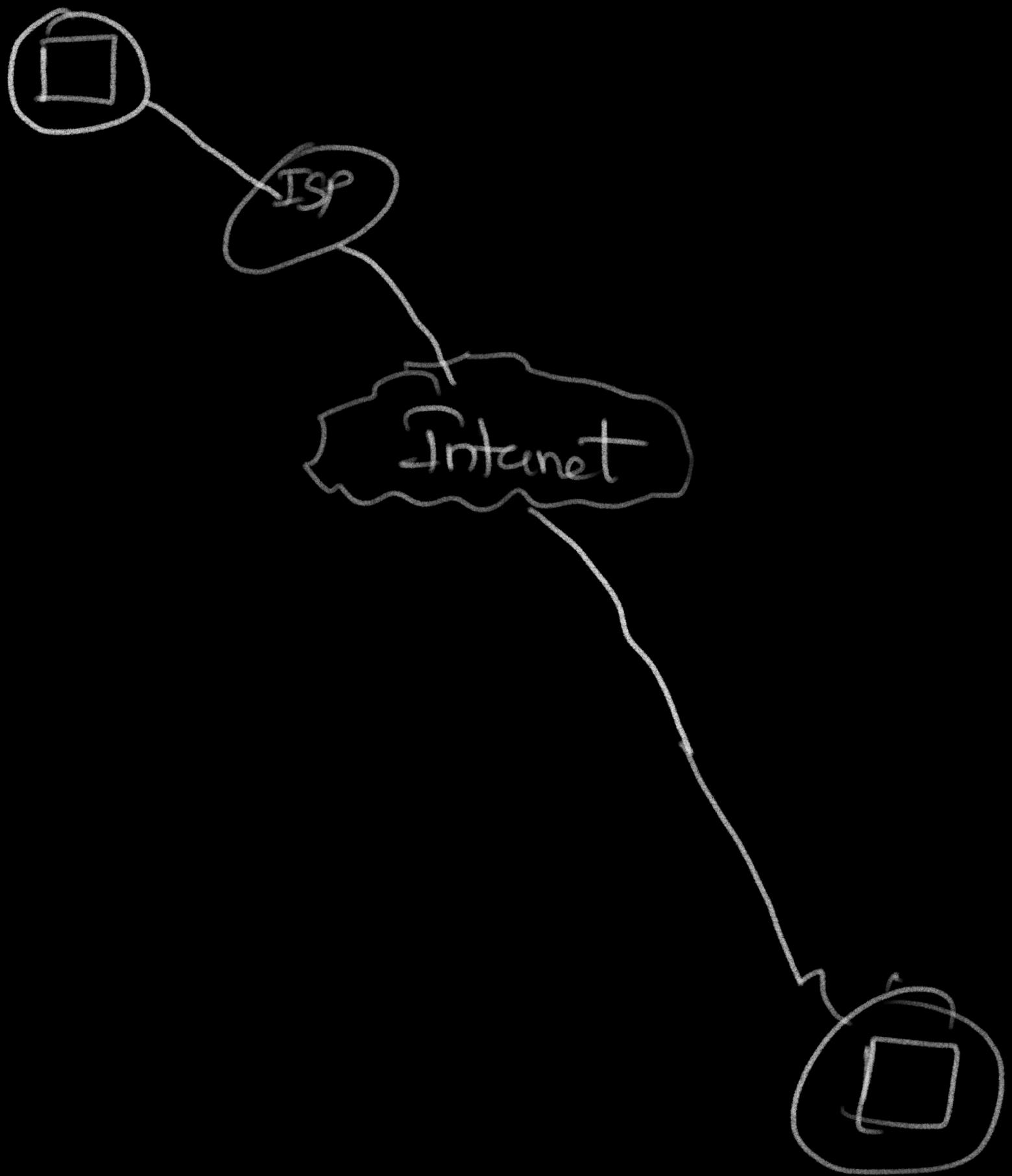
Ports from 0 - 1023 are reserved ports. It means for example you create an app & want to host on port number 80, you can't because it is reserved for http.

Ports: 0 - 1023 - Reserved

1024 - 49152 - Registered
but for
some
specific opps

HTTP:80
MongoDB: 27017
MySQL: 1433

The remaining ones we can use



Measuring Speed of Internet

1 NBps = 1 Megabit per Second

Mega means - [1 000 000] bits/sec

1 gbps = 10^9 bits/sec

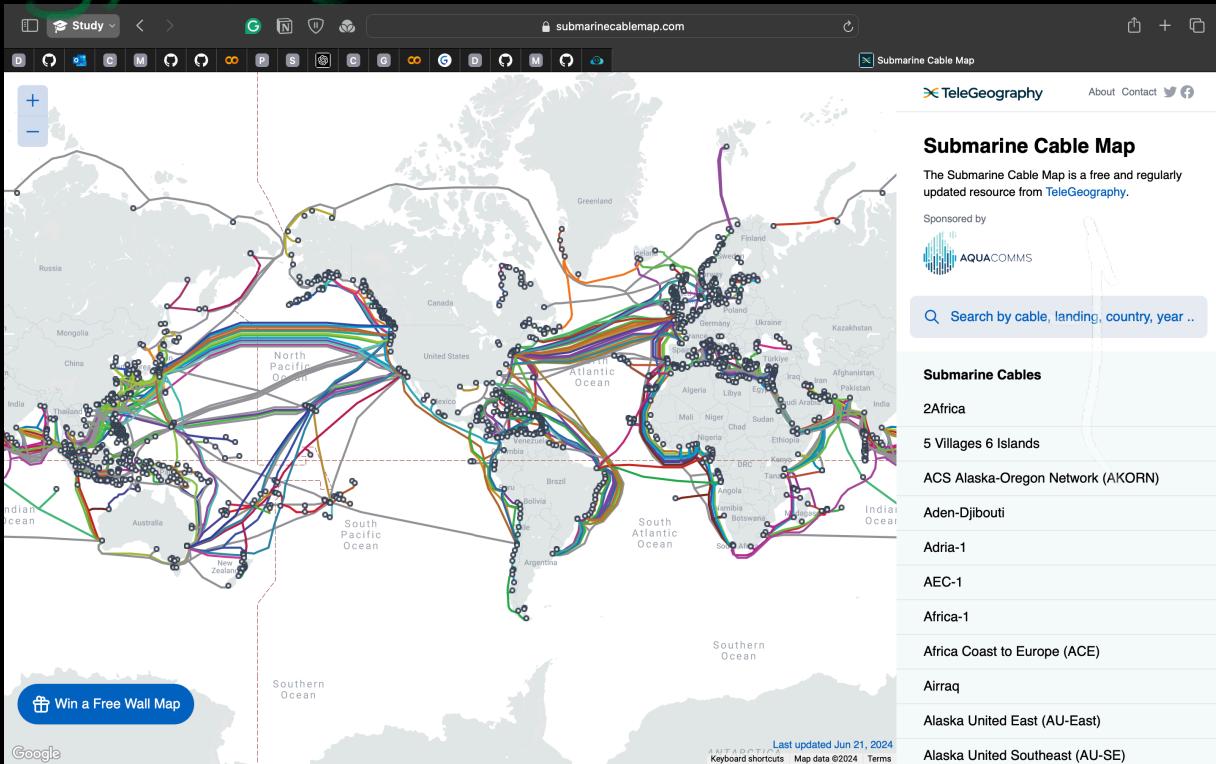
1 Kbps = 1000 bits/sec

You send data from 1 comp to
another — Upload

When someone sends data to
you & you download — Download

These are download & upload speeds
You can check fast.com, speedtest.ca

How Countries are Connected?



For example from Chennai we are connected Sri Lanka & Mumbai & are connected Dubai, Oman & Singapore.

→ One Big entity (Tata Maybe)
give to Small entities
they give to Internet Service Provider
& they give it to us this
how it works on large scale.

Physically: optical fibre cable, coaxial cable

Wireless: Bluetooth, WiFi, LTE, 5G

Using these cables \rightarrow way faster
than using via Satellites.

How Various things are Connected

Local Area Network (LAN): Small house/office
Ethernet, WiFi

Metropolitan Area Network (MAN) - Across the city

Wide Area Network (WAN): Across countries

using optical fibre cables.

③ Sonet - Synchronous optical networking ④ Frame - Relay

Internet is a collection of all the above 3 LAN, MAN, WAN.

A lot of LAN are connected to each other using MAN and they are connected using WAN

WAN

- ① Sonet - Carries data using optical fibres hence can cover larger distance.
- ② Frame Relay - A way to connect LAN to WAN.

Now what is a Modem / Router?

Modem is used to convert digital signal to analog signal & vice versa.

Ques: The digital data in your comp can be transferred to electronic signal so you can transfer it to other modem at the receiver side that will recover the digital data.

Router \rightarrow basically device that routes the data packets based on IP address.

Topologies \rightarrow How computers are connected

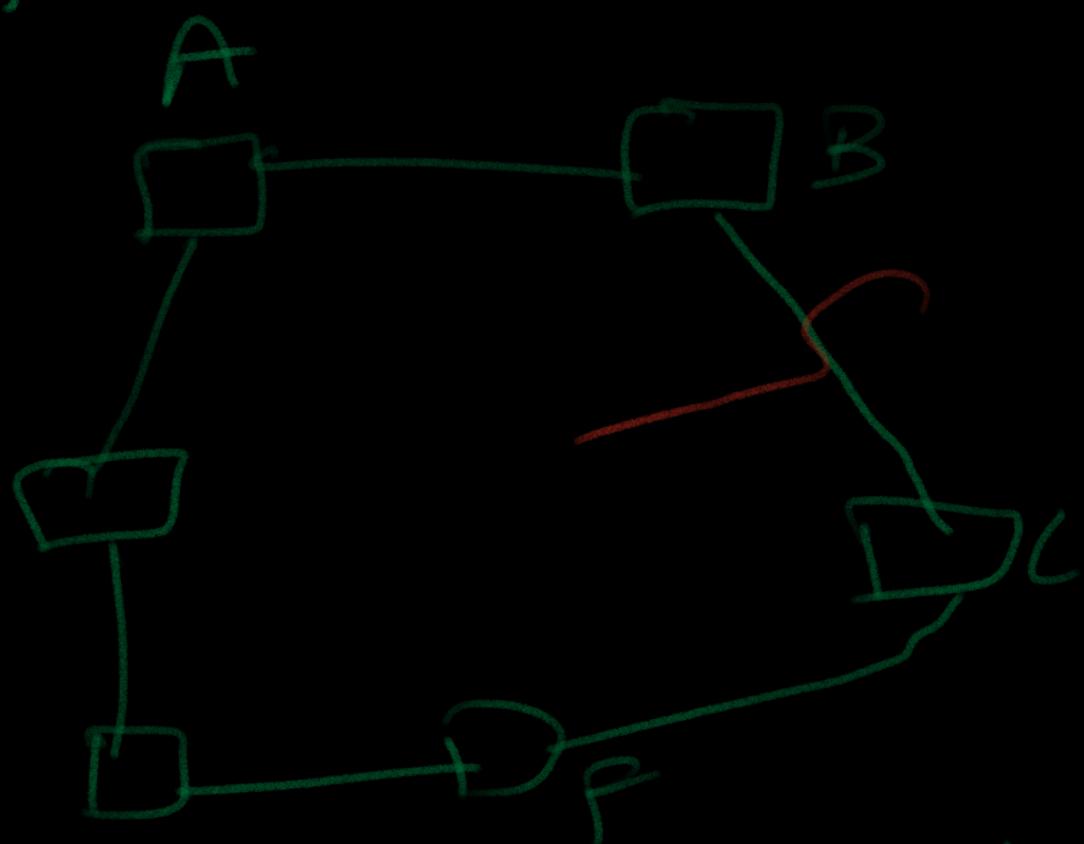
1. BUS \rightarrow Every system in bus topology is connected to one chord (or) one Back Bone



→ If this link gets broken the entire network is spoiled

→ Since everything is transmitted by this cable only 1 person can send data at particular time.

2. RRG

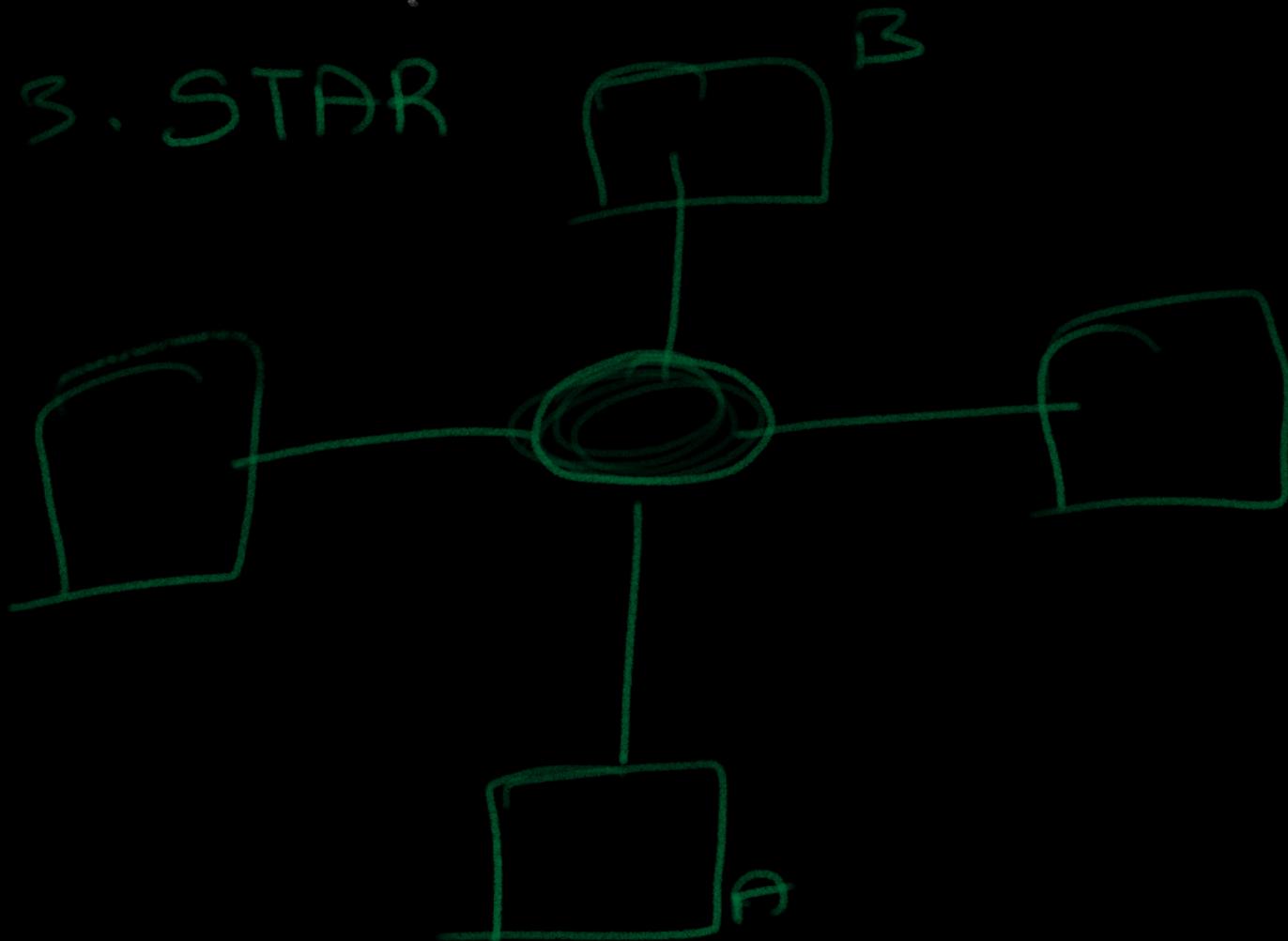


Here, every system communicates with one & other.

So, If I want from A - F it
Should go through B & C also

- If the cable breaks, you can't transfer data
- lot of unrequired calls being made for example you want to send from A to F it makes the call to B & C also

3. STAR



- There is 1 controlling Central device that is connected to all the devices. If want to send from Comp A to Comp B then it will communicate via central device.
- If Central device fails then Comp will go down.

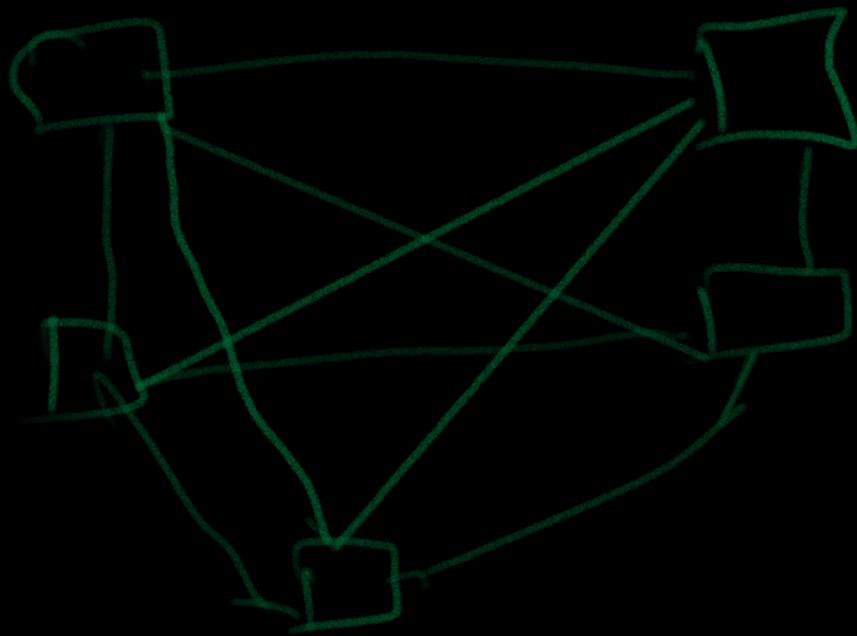
4. TREE (Bus - STAR)

Some star networks connected like a Bus. If



Has a bit more fault tolerance

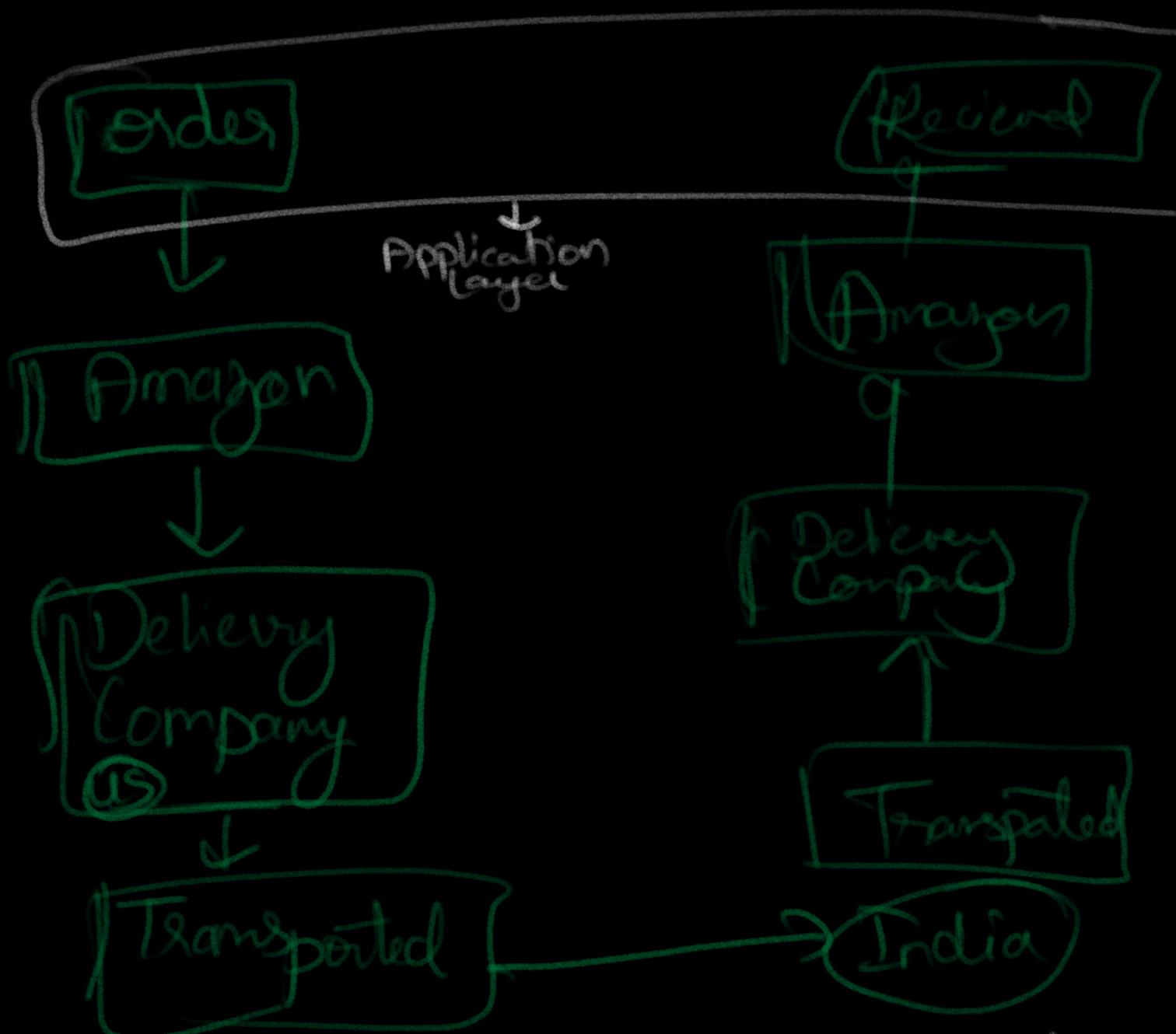
5. MESH - Every Single Comp is
Connected to every single Comp



- Expensive (so much wire used)
- Scalability (if you add Comp then you have to connect that with every Computer).

Structure of Network

Since, Internet is complex let's break down -



→ Basically you request a file video, it will take care prepare the data. It will give to transportation from it goes to server in your country & now it is received by.

How the Internet Works

OSI Model - Open System Interconnection Model

> It is developed to ensure a standard way how computers communicate with each other.

7 Layers: → Implemented in Software (APP)

Application

↓ You send a message

Presentation → It will take data & convert the data into Machine Representable Binary format known as Translation.

> From ASCII to EBCDIC . Before that data is transmitted it goes through encryption to make it readable to only the person that the data was sent to . Also provides Abstraction .

→ The data is also Compressed to send large files & reduce traffic

→ Encryption, Compression, Translation.

→ SSL protocol is used for encryption & decryption

↓
Session → It helps us setting up & managing connections & it enables sending & receiving data followed by termination of connected sessions.

→ Before a session is established it asks us for authentication like username & password & authorization takes place whether we have access to that file or not.

→ like how presentation layer assumes when we pass data to below layers it has to done similarly the session layer also assumes if it establish a session the data transportation will be done by transport layer.

↓
Transport - Basically, it will work the data transport from one end easily. It has its own protocol how data is transferred like UDP & TCP.

It does in 3 ways

Segmentation - data that is received from session layer will divided into small data units called segments.
→ Every segment will contain source destination port No & Sequence No.

Sequence No → helps to reassemble segments in correct order.

Flow Control - It controls amount of data that is being transported.

For example Server is sending at 40mbps & Client is receiving at 20mbps if not going to work it will say slow down.

Error Control → It adds checksum to every segment that says whether the data received by friend is good or not.

→ Connection Oriented Transmission
↳ TCP

→ Connection less , , , → UDP

→ UDP is faster , it doesn't provide feedback if data is lost .

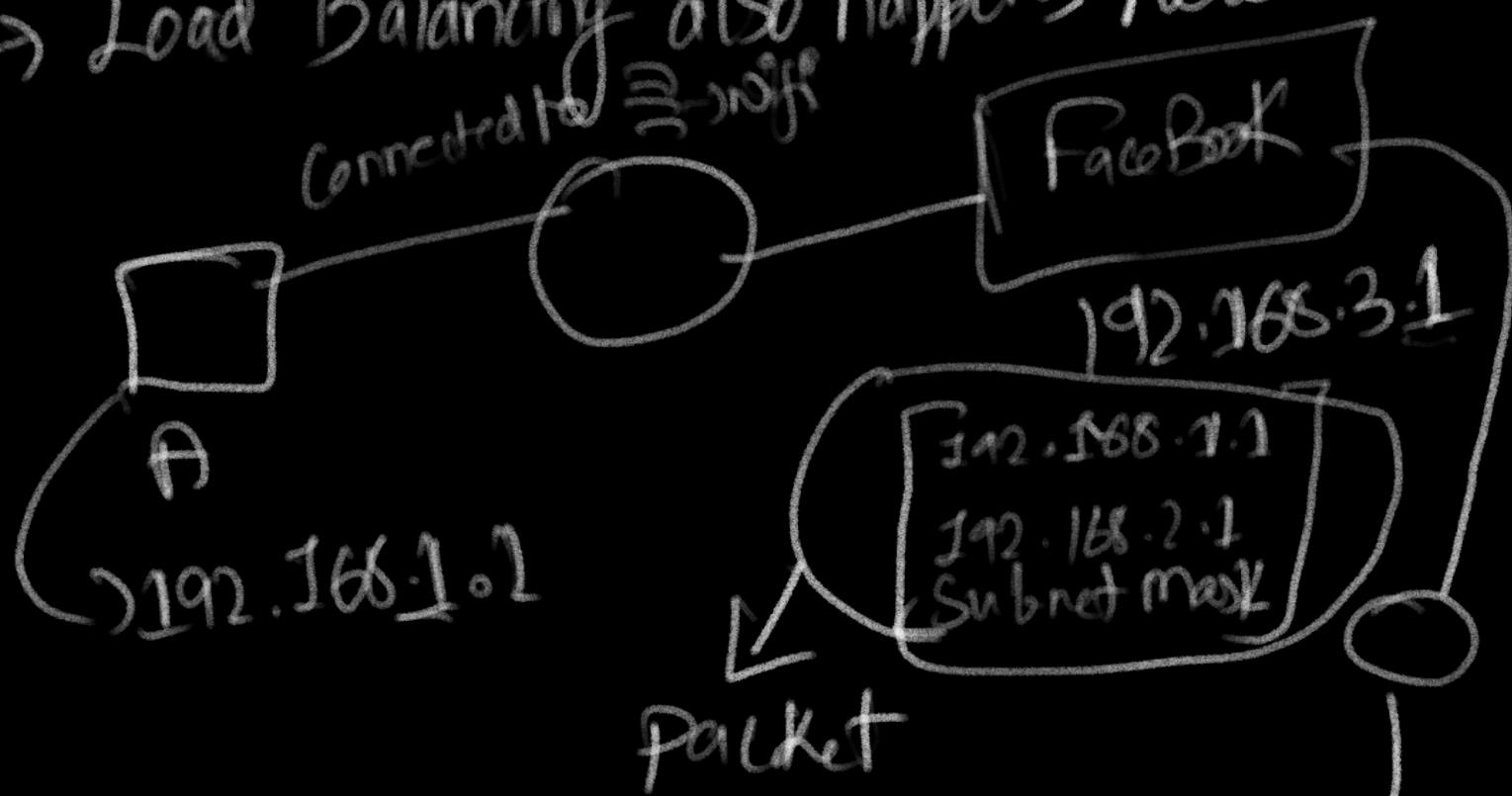
Network - It works for transmission of received data segments from one computer to another that is located in a different network .

→ IP addressing done in network layer
↳ logical addressing

→ This layer assigns the sender's & receiver's IP address to every segment and it forms an IP packet. So, that every data packet can reach correct destination

→ Also performs routing moving one data packet from SEC to destination.

→ Load Balancing also happens here



192.168.2.1 B

Data link - Allows to directly communicate to Computer & hosts.

→ Once it receive data packet from network, it will contain IP address of both sender & receiver. On the layer 2 types of addressing is performed.

1. Logical addressing - some as network Layer

2. Physical addressing - MAC Addresses

Here In This layer MAC Address of Sender & Receiver are attached to data packet to form a frame

Frame - A data unit of data link layer

MAC Address - 12 Digit Alpha Numeric of network interface of Computer

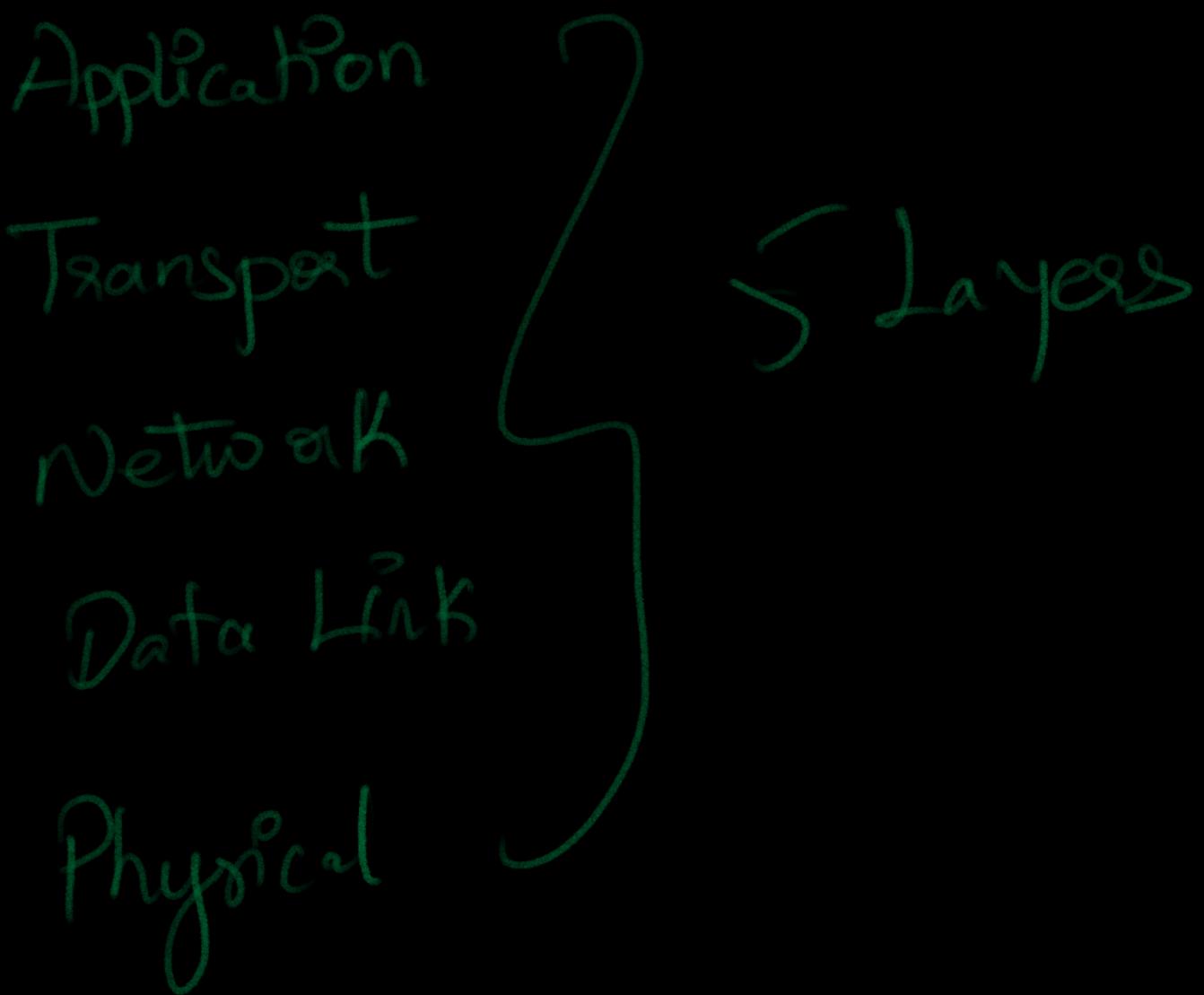
- Each Comp has more than 1 Mac address like Comp Bluetooth have another 1 Comp wifi has another 2 So on
- It allows all upper layers to access frames.
- It also controls data is placed / received using flags known as Media Access Control
- Adds Mac address to packet to make a frame & pushes the frame to layer 1

Physical

- It contains hardware.
- It transmits bits from electric signals

TCP | IP Model

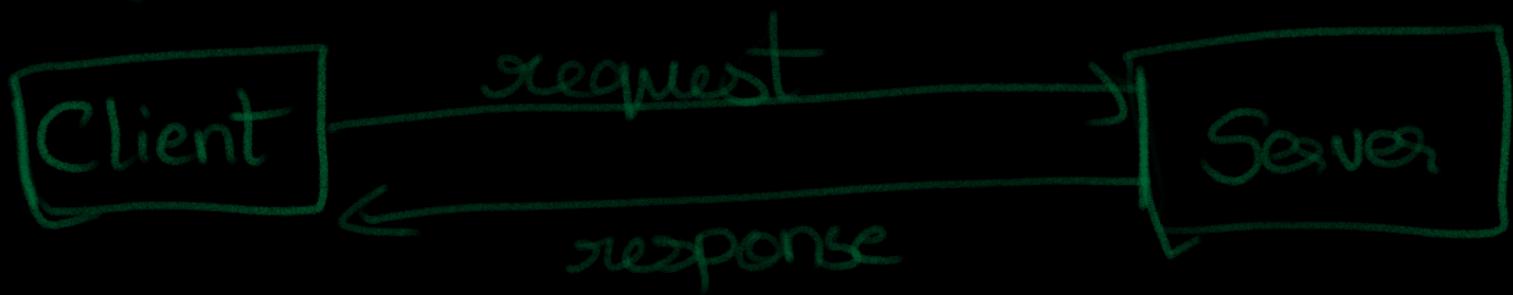
→ Another Model (Reduced to 5 layers)



1 Application Layer :

- Users interact with it.
- WhatsApp, browsers etc
- Where: on your device.
- Protocols

① Client Server Architecture



(Server is a system that controls the website you are hosting)

- The app has 2 parts client part & server part these are known as processes & they communicate with each other.
- Server should have stable IP address & high availability

→ Collection of Servers - Data Centre

```
base ~ (16.305s)
ping google.com
PING google.com (142.250.70.110): 56 data bytes
64 bytes from 142.250.70.110: icmp_seq=0 ttl=118 time=41.728 ms
64 bytes from 142.250.70.110: icmp_seq=1 ttl=118 time=41.650 ms
64 bytes from 142.250.70.110: icmp_seq=2 ttl=118 time=48.493 ms
64 bytes from 142.250.70.110: icmp_seq=3 ttl=118 time=41.887 ms
64 bytes from 142.250.70.110: icmp_seq=4 ttl=118 time=41.847 ms
64 bytes from 142.250.70.110: icmp_seq=5 ttl=118 time=48.181 ms
64 bytes from 142.250.70.110: icmp_seq=6 ttl=118 time=42.193 ms
64 bytes from 142.250.70.110: icmp_seq=7 ttl=118 time=48.558 ms
64 bytes from 142.250.70.110: icmp_seq=8 ttl=118 time=47.579 ms
64 bytes from 142.250.70.110: icmp_seq=9 ttl=118 time=44.465 ms
64 bytes from 142.250.70.110: icmp_seq=10 ttl=118 time=48.643 ms
64 bytes from 142.250.70.110: icmp_seq=11 ttl=118 time=48.204 ms
64 bytes from 142.250.70.110: icmp_seq=12 ttl=118 time=48.932 ms
64 bytes from 142.250.70.110: icmp_seq=13 ttl=118 time=45.670 ms
64 bytes from 142.250.70.110: icmp_seq=14 ttl=118 time=48.528 ms
64 bytes from 142.250.70.110: icmp_seq=15 ttl=118 time=48.039 ms
64 bytes from 142.250.70.110: icmp_seq=16 ttl=118 time=49.159 ms
^C
--- google.com ping statistics ---
17 packets transmitted, 17 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 41.650/46.103/49.159/2.961 ms
```

Command Ping
from terminal
as you can see
no packets lost
& every packet
is 64 bytes.

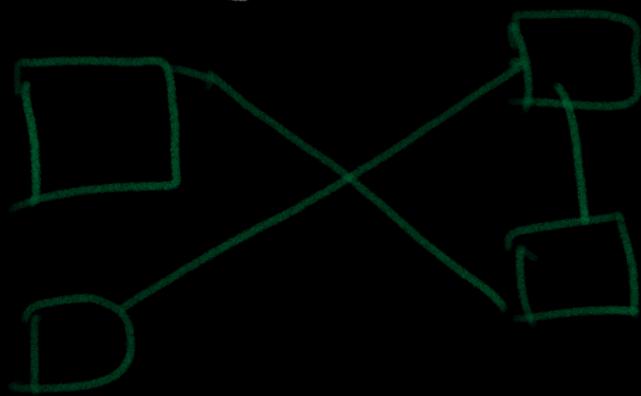
Here 142.250.70.110 is google's IP address.

Icmp-seq is the sequence no.

The ping measures the round trip time from message sent from originating host to destination & echoed back.

→ ② Peer to Peer (P2P) Architecture

Apps running on various devices communicate by getting connected with each other. In this case there isn't server (or) data centre
for ex:- In Colleges.



→ Easily Scalable

→ decentralized

→ Every Comp is client & Server

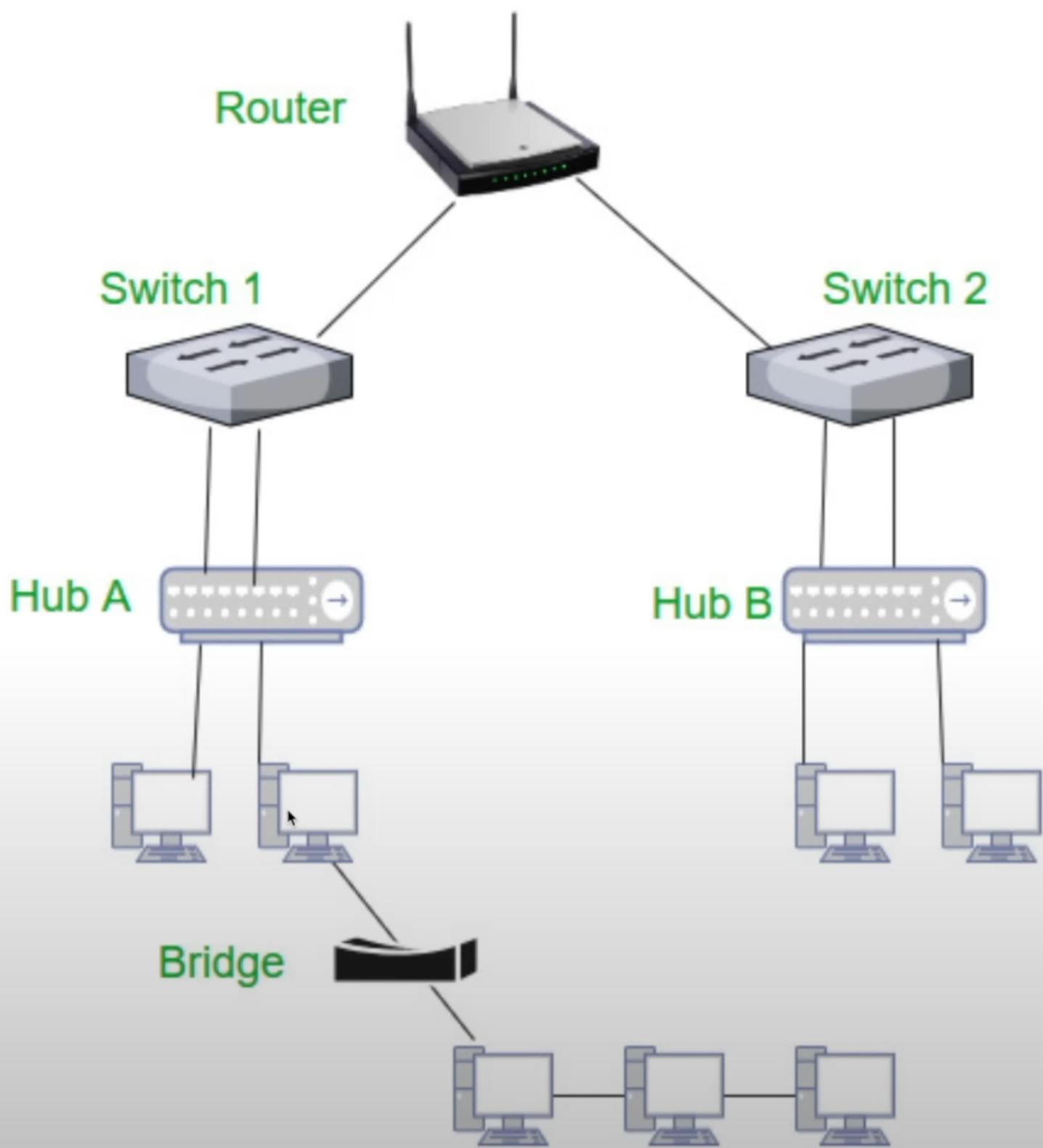
ex:- Bit-Torrent

→ Hybrid Also it's some P2P & Some Centralized DB.

Networking Devies

→

→ Link to get Endepth Info



Protocol

Web Protocols

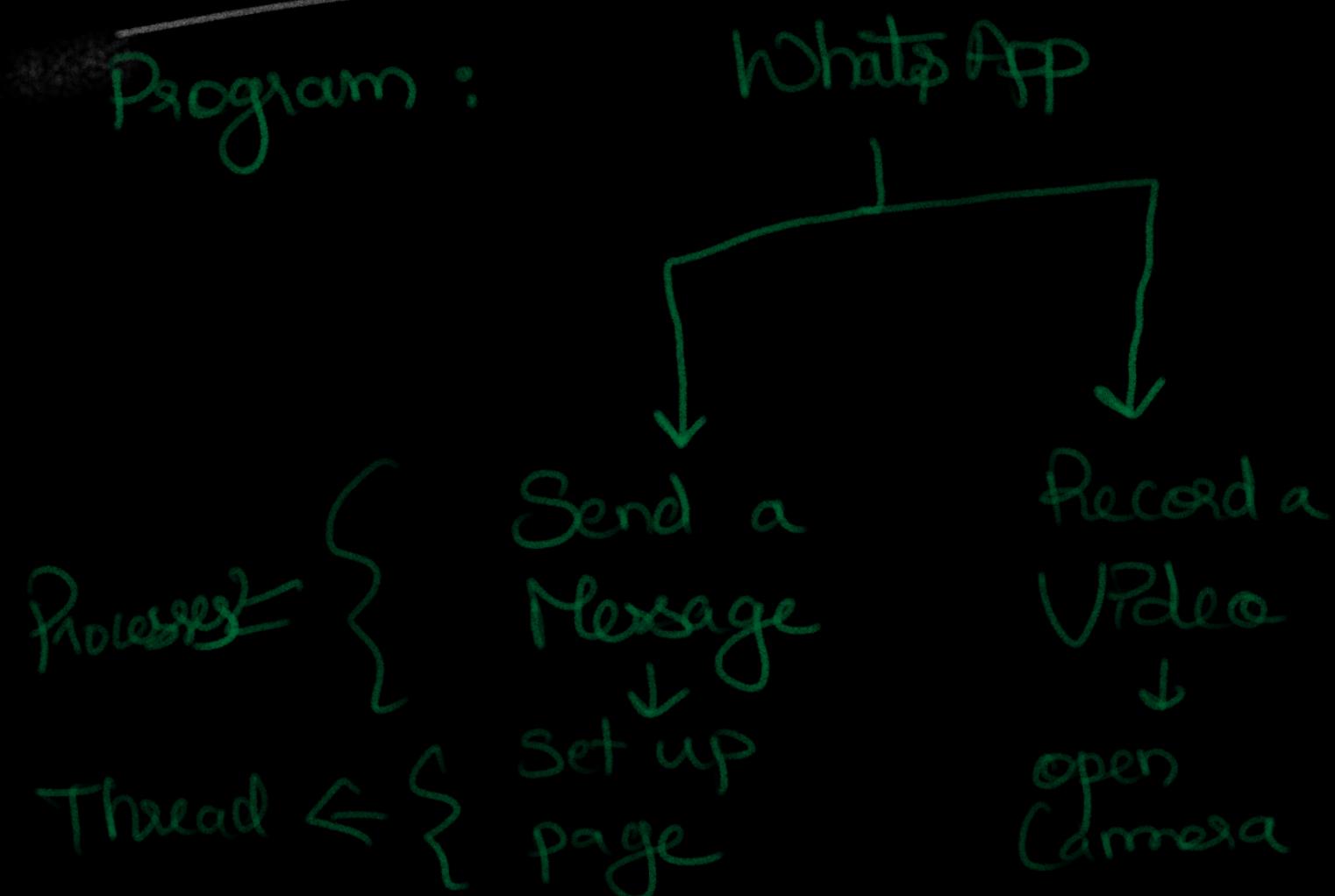
*TCP/IP :

- HTTP (hyper text transfer protocol)
- DHCP (Dynamic host config protocol)
- FTP (File transfer) (not being used anymore)
- SMTP (Simple mail transfer)
- POP3 & IMAP (To receive emails)
- SSH (Secure Shell protocol)
- VNC (Virtual Net Computing) (for graphical control)

* TELNET : Terminal Emulation

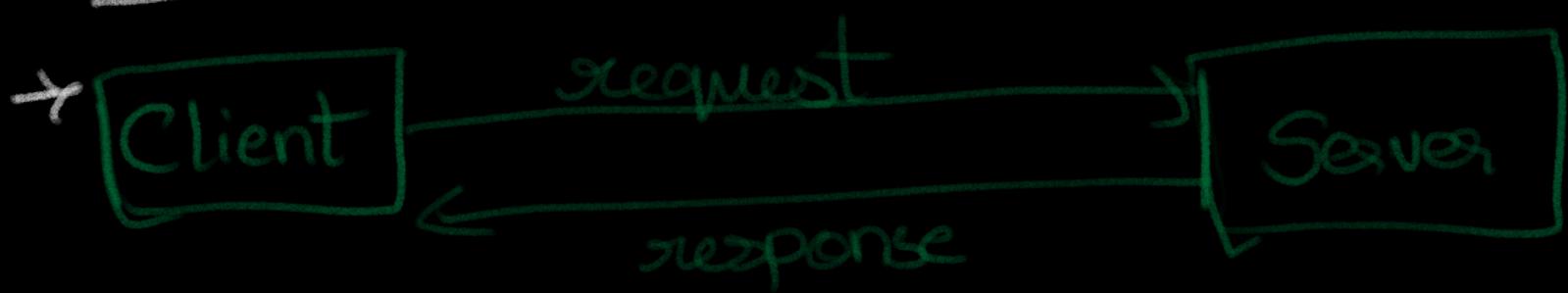
It enables remote host using a telnet client usually port 23.

* UDP: Stateless Connection
→ data may be lost like Video Conferencing.



- A program can have multiple processes.
- One process can have multiple running threads.
- Each thread is a lighter version of thread
- Thread does only one job unlike process.
- Sockets: Interface b/w process & Internet
- Ports → Ephemeral Ports → Internally it will assign random port no & work with it.
Basically to which window (or tab) to send to.

HTTP (Hyper text transfer Protocol)



→ It's a client server protocol & it tells us how you request this data from the server & it also tells us how server will send data back to a client.

→ It's an application layer protocol.
ex:- It has few methods
GET, POST, PUT, PATCH, DELETE.

→ HTTP uses TCP (Transmission Control Protocol) in its Transport layer

→ HTTP is Stateless protocol

→ Server will not store anything sent by Client by default.

→ protocol

→ URL

→ Link to the response.

→ We can also add arguments, for example

→ After ^o Argument

→ Above After question is argument video = video Pd

HTTP Methods: It's a method that tells server what to do.

1. GET Method

It means you are requesting the data.

2. POST Method

You are sending the data.

3. PUT Method

puts data at specific location

4. DELETE Method

Delete the data from Server.

Status Codes

When you send a req to server you need a way to know whether it was sent or not whatever for that the Status Code exists.

200 - Request Successful

404 - Couldn't find it

400 - Bad Request

500 - Internal Server Error

There are classes for these status

Code :-

1xx - Informational Category

2xx → Success Codes

3xx → Redirection

4xx → Client error

5xx → Server Error

Cookies :

→ HTTP is stateless as we know then
how do everytime you close Amazon

Add the Cart items 2 your account & still logged in the answer is Cookies

- It's a Unique string.
- It's stored on Client Browser.
- When you visit a website for a 1st time it will get a cookie
- whenever you make a request
After that in the request header
a cookie will be sent then server
will know this request is coming
from you & you sent a cookie
& it will check the DB & find
a state for that

→ In the response, you can see like below It has tag called Set-Cookie
It also has val, names & path
& also expiration date.

→ Some times cookies can be misused
to track the client's data

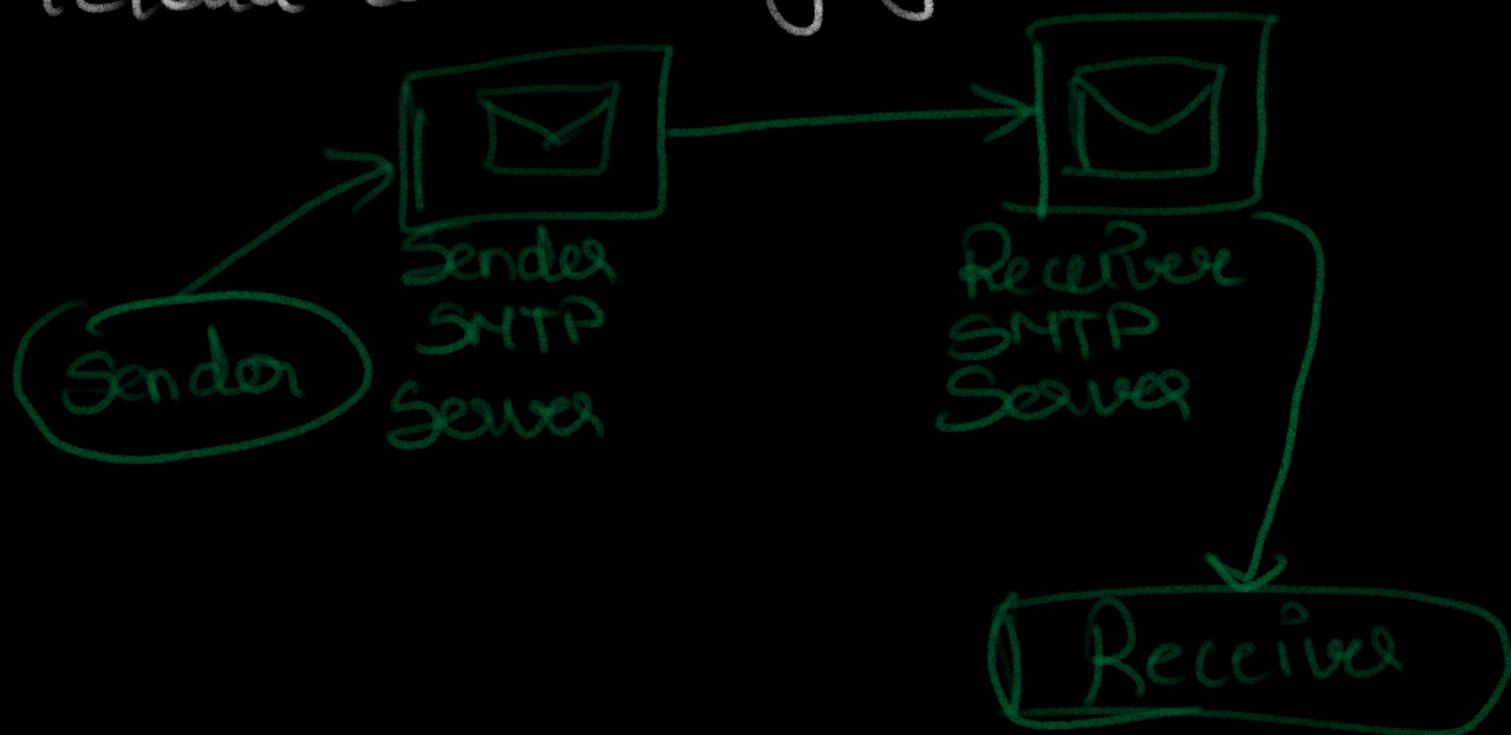
Third party Cookies

→ Cookies that are set for the URL's
you do not visit.

Face:- A website like youtube
has an add of faceBook that
way PD might use your cookies

How EMAIL Works

- for sending email SMTP is used & for receiving POP3 is used & this is at Application Layer
- Let's you are sending mail from `icloud.com` to `google.com`



- Internally it uses TCP.
- If both are using `gmail.service` then it directly handles it.

→ Using the Name Server lookup Command
you can find the name & IP addresses
of SMTP servers . Check Below

nslookup -type=mx gmail.com
↓
mail exchange

```
base ~ (0.124s)
nslookup -type=mx gmail.com
Server:      10.20.1.1
Address:     10.20.1.1#53

Non-authoritative answer:
gmail.com      mail exchanger = 5 gmail-smtp-in.l.google.com.
gmail.com      mail exchanger = 10 alt1.gmail-smtp-in.l.google.com.
gmail.com      mail exchanger = 20 alt2.gmail-smtp-in.l.google.com.
gmail.com      mail exchanger = 40 alt4.gmail-smtp-in.l.google.com.
gmail.com      mail exchanger = 30 alt3.gmail-smtp-in.l.google.com.
```

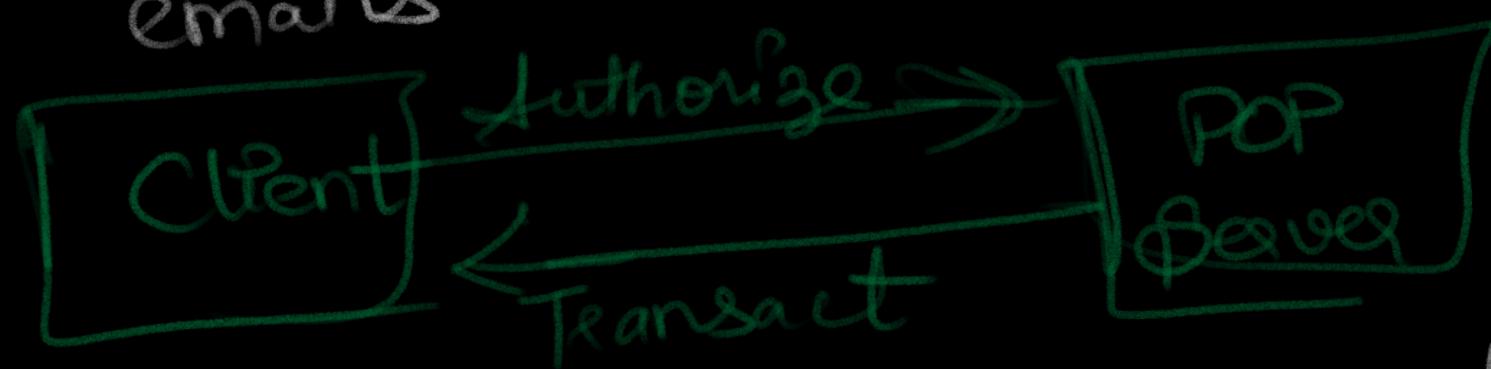
```
Authoritative answers can be found from:
.      nameserver = h.root-servers.net.
.      nameserver = b.root-servers.net.
.      nameserver = c.root-servers.net.
.      nameserver = a.root-servers.net.
.      nameserver = g.root-servers.net.
.      nameserver = j.root-servers.net.
.      nameserver = f.root-servers.net.
.      nameserver = k.root-servers.net.
.      nameserver = l.root-servers.net.
.      nameserver = d.root-servers.net.
.      nameserver = m.root-servers.net.
.      nameserver = e.root-servers.net.
.      nameserver = i.root-servers.net.
```

```
base ~ (0.191s)
nslookup -type=mx icloud.com
Server:      10.20.1.1
Address:     10.20.1.1#53

Non-authoritative answer:
icloud.com    mail exchanger = 10 mx02.mail.icloud.com.
icloud.com    mail exchanger = 10 mx01.mail.icloud.com.

Authoritative answers can be found from:
.      nameserver = g.root-servers.net.
.      nameserver = j.root-servers.net.
.      nameserver = f.root-servers.net.
.      nameserver = k.root-servers.net.
.      nameserver = l.root-servers.net.
.      nameserver = d.root-servers.net.
.      nameserver = m.root-servers.net.
.      nameserver = e.root-servers.net.
.      nameserver = i.root-servers.net.
.      nameserver = h.root-servers.net.
.      nameserver = b.root-servers.net.
.      nameserver = c.root-servers.net.
.      nameserver = a.root-servers.net.
```

- To download & receive Emails
lets look at POP (Post office Protocol)
- It uses port 110 & It does the authentication & then the client asks the Server for all the new emails



- After authorizing, You transact all the emails.
- Then you command the Server like to delete, Archive & So, on.

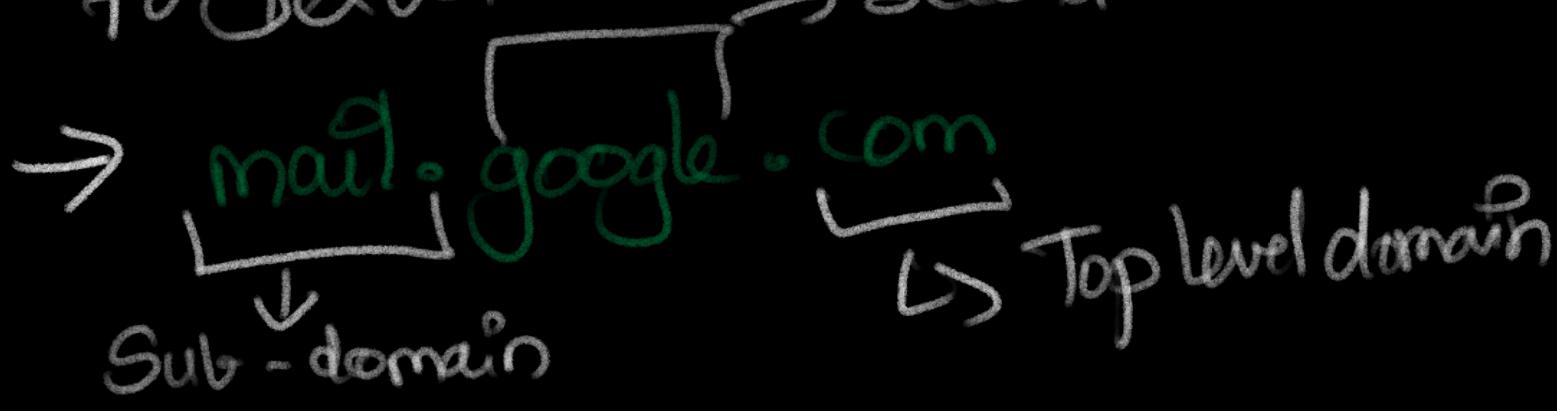
IMAP (Internet Message Access Protocol)

- It allows to view Email on Multiple devices.

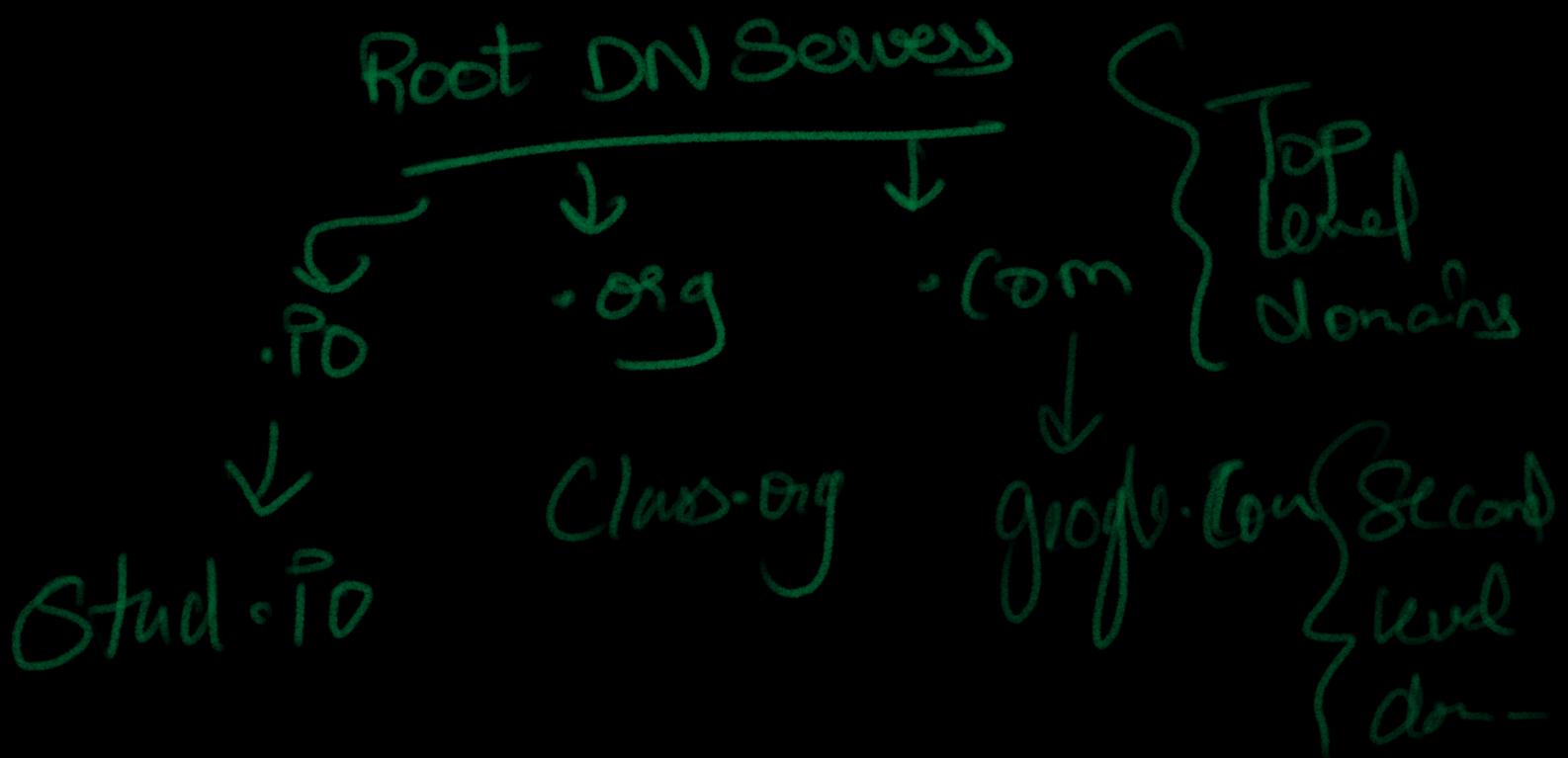
Ex:- If you delete an email in your phone it will be deleted in Mac & Ipad as well.

DNS - Domain Name System

- for example when you enter google.com it will use DNS to find the IP add of google.com
- part of App Layer.
- When clicked google.com http protocols uses DNS & convert the URL into IP add & then connect to server. → Second-level domain



- Sub-domain is a part of bigger domain
- Top level are known as Root DNS Servers



- Root DNS Servers are the first point of contact.

→ To check who is maintaining these servers

→ .com is for commercial, .edu for educational, .in, .us → country specific

the above are managed by this ICANN.

→ When you enter a new website, it will store the IP address in your local Cache/DNS. To make it not search again & again.



→ If not found in local system
It searches in local dns server.
↳ (ISP)

→ Checks own Computer or else local DNS Server (ISP). It checks through Root Server. If not there then sends to ISP & ISP sends to Top level domain which sends IP address to DNS.

```
base ~ (0.12s)
dig google.com

; <>> DiG 9.10.6 <>> google.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 51857
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 13, ADDITIONAL: 0

;; QUESTION SECTION:
;google.com.           IN      A

;; ANSWER SECTION:
google.com.        231    IN      A      142.250.183.142

;; AUTHORITY SECTION:
.          22083  IN      NS      j.root-servers.net.
.          22083  IN      NS      f.root-servers.net.
.          22083  IN      NS      k.root-servers.net.
.          22083  IN      NS      l.root-servers.net.
.          22083  IN      NS      d.root-servers.net.
.          22083  IN      NS      m.root-servers.net.
.          22083  IN      NS      e.root-servers.net.
.          22083  IN      NS      i.root-servers.net.
.          22083  IN      NS      h.root-servers.net.
.          22083  IN      NS      b.root-servers.net.
.          22083  IN      NS      c.root-servers.net.
.          22083  IN      NS      a.root-servers.net.
.          22083  IN      NS      g.root-servers.net.

;; Query time: 35 msec
;; SERVER: 10.20.1.1#53(10.20.1.1)
;; WHEN: Wed Jun 26 20:05:46 IST 2024
;; MSG SIZE  rcvd: 255
```

→ To check Messages received by
DNS sever you can the `ncat` command

→ This IP address is what is stored
In my local Cache -

\$ man dig - manpage of dig
dig - DNS lookup utility

2. Transport Layer

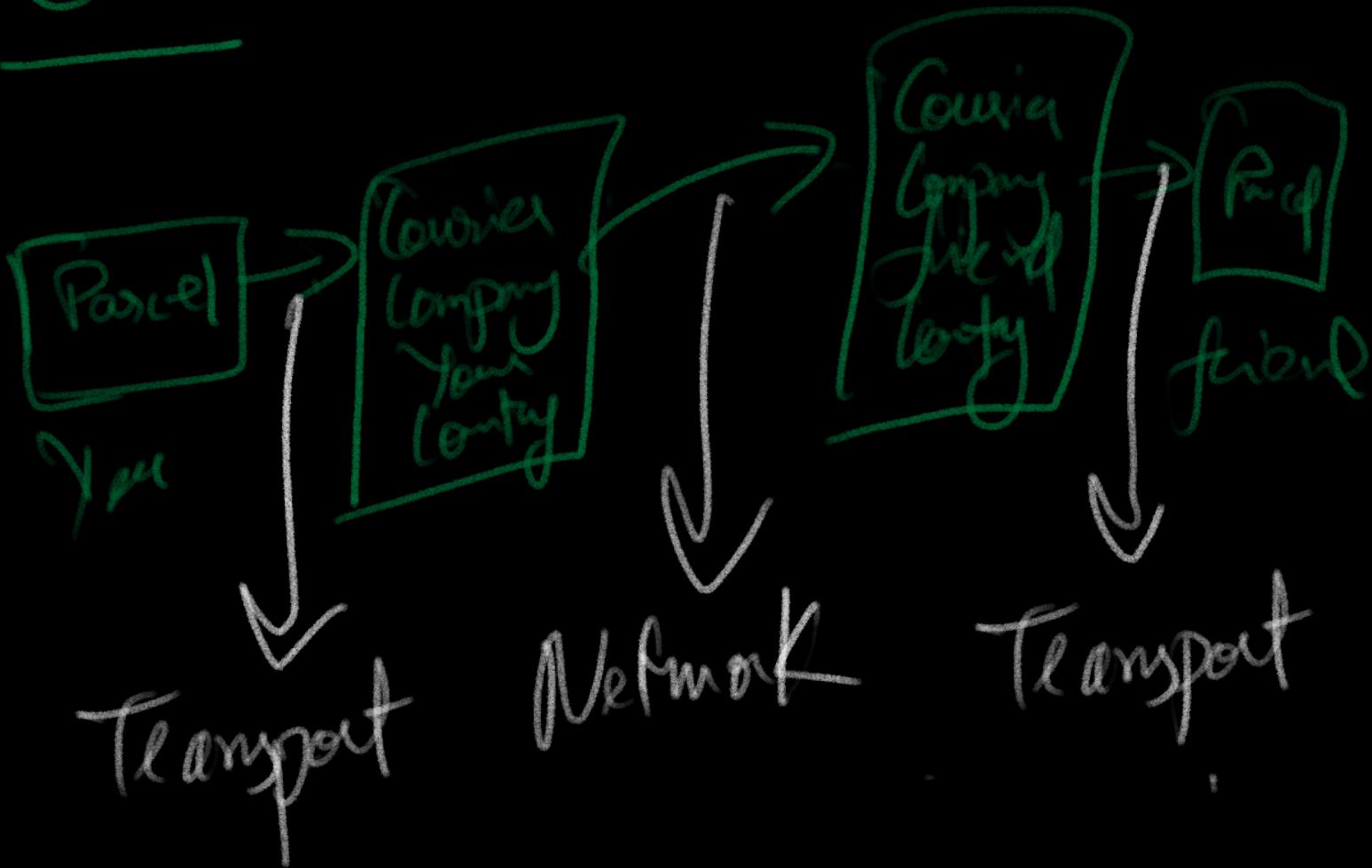


you write a message & send it to your friend.

→ The message transportation from one computer to other is done by Network Layer.

→ The Role of transport layer is to take information from the network layer & send to the correct application. This layer is in the device itself.

Ex:



→ from 1 device to another device
if uses Network Layer but within
each device for the app if
uses Transport Layer.

⇒ Transport 1 gives  Network K 1

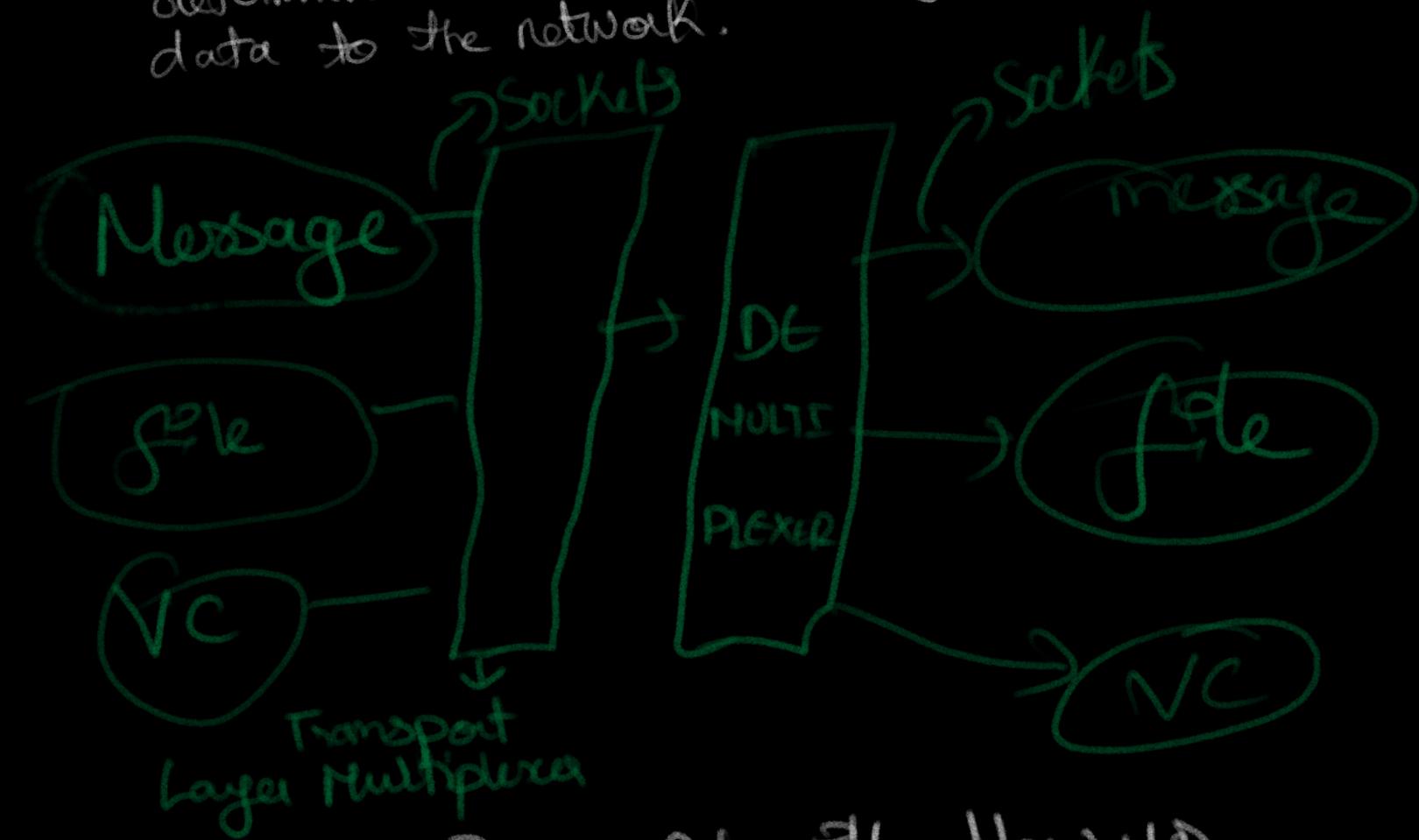
 Network K 2 gives  Transport

→ Transport layers have some
protocols

TCP - 100% of data can be
sent & in order.

UDP - Some data may not be
in order & some data packets
may be lost.

Let's figure out how one comp will determine to send these types of data to the network.



→ Multiplexing: It will allow up all these messages & things to a lot of destinations In above example 3 apps 3 destination just via 1 Medium

→ De Multiplexing: opp of Multiplexing It will pass it through apps

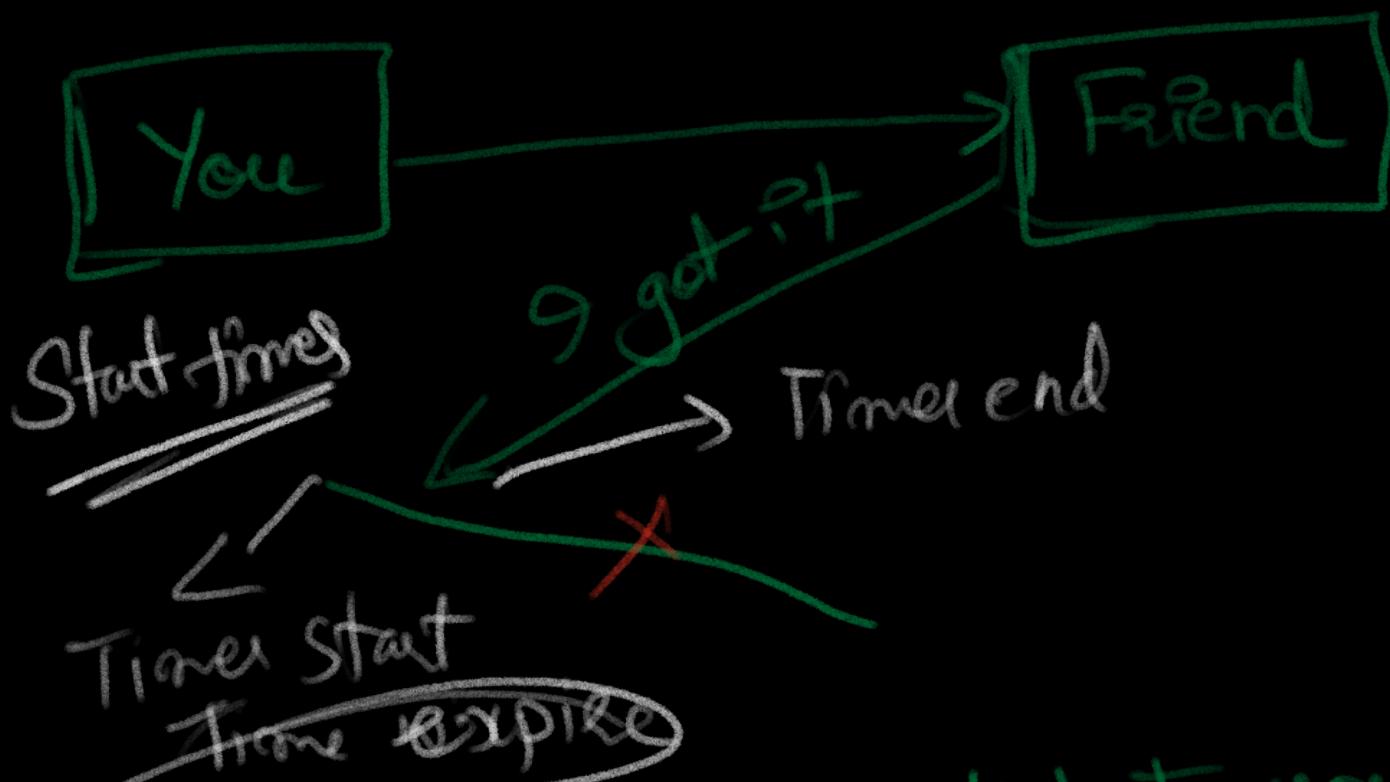
- Data travels in packets
- Transport layer will attach these socket port no., so we will know if A or B coming from & where to send the data.
- This layer also takes care of Congestion Control. (Traffic)
- Congestion Control algos built in TCP are used.

CheckSums

- checksum is a random number
- The diagram illustrates the process of attaching a checksum to data. On the left, a source node (represented by an oval) has two outgoing arrows. The top arrow is labeled "data" and the bottom arrow is labeled "Checksum". These arrows converge at a central point, indicated by a small circle with a dot. From this central point, a single arrow points to a destination node (represented by a circle). Below this path, the text "Checksum attached" is written. At the destination node, the data is received and stored in a box labeled "data" and "checksum".

- you send data to your friend using the data it will calculate a particular string val called checksum then friend get the data & since checksum is calculated using the data. The data will have a checksum associated with it. Checksum will be attached so, the checksum will be attached & when friend receives data, it will calculate using same Algo. → If Value is diff something is wrong if Value is same then it is correct.
- How Would I Know whether my data/packets are received to my friends?

Timers:

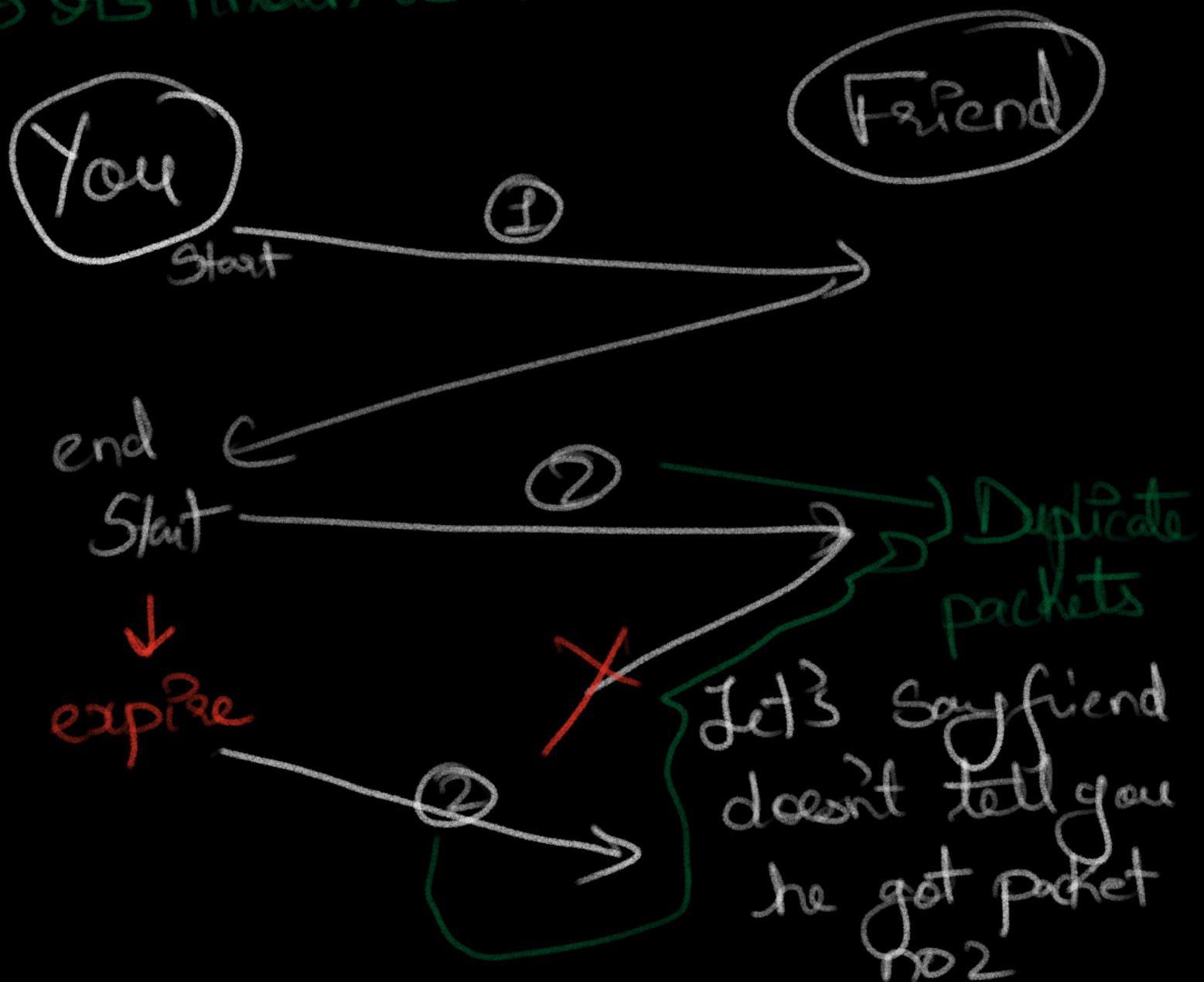


When you send a packet to your friend you will start a timer..

friend will say I got the packet now
you will know I got packet & Timer ends.

→ You sent another packet & In b/w only another packet is lost, when you send again timer will start again & since it's lost your friend won't be able to say he got the packet hence timer will expire.

- By Timer expiring, You will think the packet is not sent.
- It's known as Re-Transmission Timer



→ So, you have not received that & let's say timer will expire. Since I don't know whether they received

(a) net I will send packet no 0 again - Now the friend has 2 packets no 0 & a duplicate

→ We solve the above problem using Sequence Nos.

→ Every segment/packet will get a unique number.

USER DATAGRAM PROTOCOL (UDP)

- It's a transport layer protocol
- Data may (or) may not be delivered
- Data may change
- Data may not be in order.
- Connectionless protocol
- UDP uses checksums but won't do anything when the data is gone



$$\text{Total Size} = 2^{16} - 8$$

\approx 64 K Bytes

↳ Size of data you can send in 1 packet.

→ UDP is faster.

Use Cases

- Video-Conferencing
 - DNS also uses UDP
 - gaming also uses UDP
- of
UDP

```
base ~ (9.66s)
sudo tcpdump -c 5
Password:
tcpdump: data link type PKTAP
tcpdump: verbose output suppressed, use -v[v]... for full protocol decode
listening on pktap, link-type PKTAP (Apple DLT_PKTAP), snapshot length 524288 bytes
23:13:00.151515 IP 10.20.1.44.31013 > 10.20.1.1.domain: 17584+ A? www.youtube.com. (33)
23:13:00.151581 IP 10.20.1.44.18210 > 10.20.1.1.domain: 49937+ Type65? www.youtube.com. (33)
23:13:00.159895 ARP, Request who-has 10.20.1.44 tell 10.20.1.1, length 46
23:13:00.159924 ARP, Reply 10.20.1.44 is-at a0:78:17:a1:0e:1f (oui Unknown), length 28
23:13:00.163493 IP 10.20.1.1.domain > 10.20.1.44.18210: 49937 2/13/16 CNAME youtube-ui.l.google.com., Type65 (549)
5 packets captured
20 packets received by filter
0 packets dropped by kernel
```

Command above is to check all the data packets coming in & out of the computer. { -c 5 → only 5 packets }