Computer Network

“Life is struggle” - Karl Marx

Outline

1. Fundamentals
    - History
    - Network Types
    - OSI Model
    - Protocols
2. Network Topology
3. Web
    - What happens when you type in a URL on a browser?
    - HTTP Routing

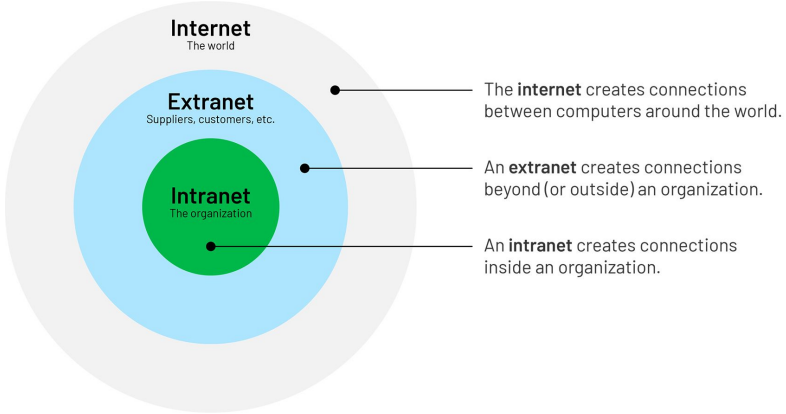
1. Fundamentals

1.1. History

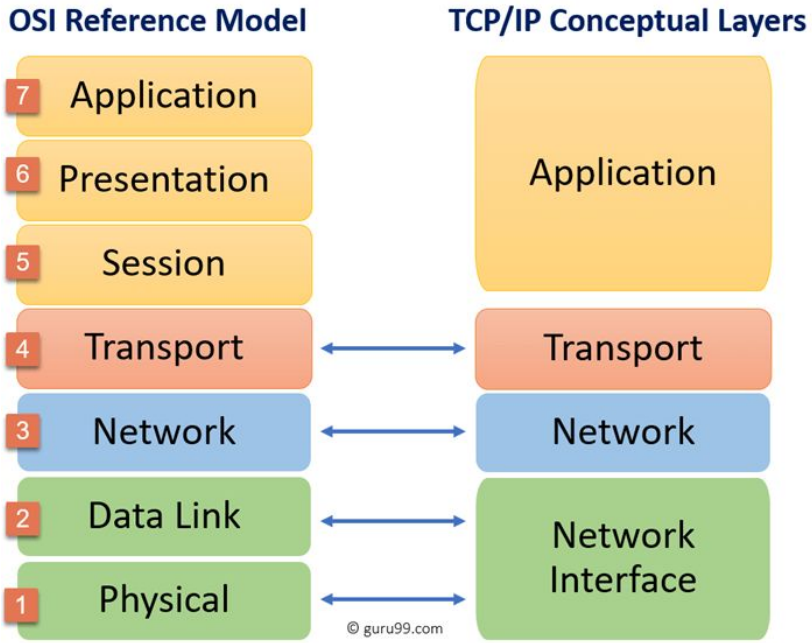
Year	Event
1961	Leonard Kleinrock proposed the earliest computer networks, which was the idea of ARPANET.
1969	On ARPANET, the first data transmission was sent by using it.
1973	Robert Metcalfe developed the **Ethernet**
1978	The **TCP/IP** protocol was developed and invented by Bob Kahn for networks
1981	**IPv4** was officially defined in RFC 791
1991	Tim Berners-Lee invented the World Wide Web (**WWW**)
1996	IPv6 was introduced
1997	Wi-Fi was introduced
2004	Tim O'Reilly and Dale Dougherty popularize the term of **Web 2.0**

1.2. Network Types

- **Intranet**
  - **Connections inside an organization**
  - Any services within an intranet are restricted
  - These services remain **private** and inaccessible from the Internet.
  - Example: network in a bank
- **Extranet**
  - Extends intranet
  - **Connects to partners, customers**, …
  - Example: a bank connects to a merchant partners via leased lines
- **Internet**
  - Services that are **publicly available** or computer outside of our own networks
  - Example: Gmail, Youtube, Facebook, …



1.3. OSI Model


OSI Reference Model
TCP/IP Conceptual Layers
7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link
1 Physical
Application
Transport
Network
Network Interface
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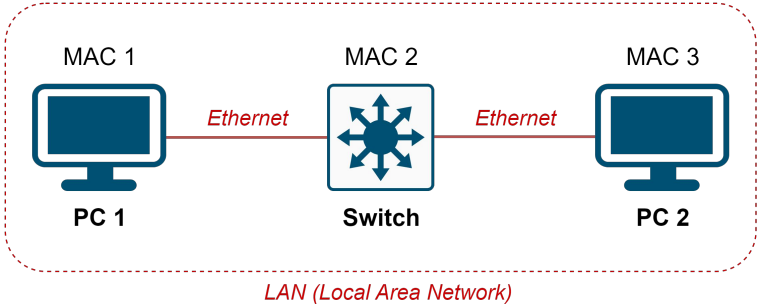
1.3. OSI Model

1. Physical Layer

- This layer converts data in the form of **digital bits into physical signals** (electrical, radio, or optical signals) to create the physical connection between devices.

2. Data Link Layer

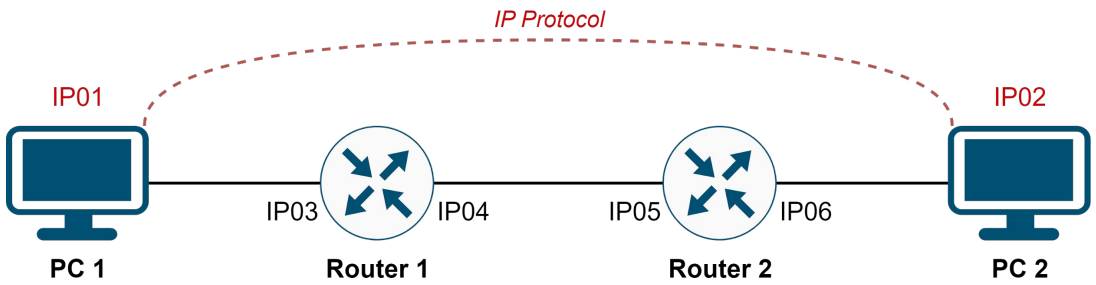
- Is responsible for the **host-to-host transfers on the same local network**
- Error detection and error correction
- Identification: **MAC** (Media Access Control) address
- Protocols: Ethernet, WiFi, PPP



1.3. OSI Model

3. Network Layer

- Transferring data flows from **a host on one network to a host on another network**
- **Unreliable**
  - Delivery of packets
  - In-order packets
  - Integrity of data
- Identification: **IP** Address
- Protocol: IP



1.4. OSI Model

4. Transport Layer

- **Transferring data between applications/processes**
- Providing **reliable data transfer** services to the upper layers
  - Flow Control
  - Segmentation
  - Error Control
- Identification: **Port**. There might be many processes receiving or transmitting data on an OS, so **Port number is needed to distinguish processes**.
- Protocols: **TCP, UDP**

1.3. OSI Model

5. Session Layer

- Sending and receiving data at the same time
- Establishing procedures for performing **checksum, suspending, restarting, and terminating a session**
- Identification: **Socket**

6. Presentation Layer

- **Converting data** into a format that applications can understand
- Encryption: **TLS/SSL**

7. Application Layer

- Providing application functions for users
- Protocols: **HTTP, FTP, DNS, SMTP, Telnet, …**

1.3. OSI Model

The data that the application need to transmit, might be very large, so it is difficult to transmit directly. What mechanism to handle this situation?

→ **Data packet must be divided into blocks**, so that even if there is a If a block is lost or corrupted, only that one block needs to be resent instead of the entire packet.

*Challenge: What identical information to establish a socket?

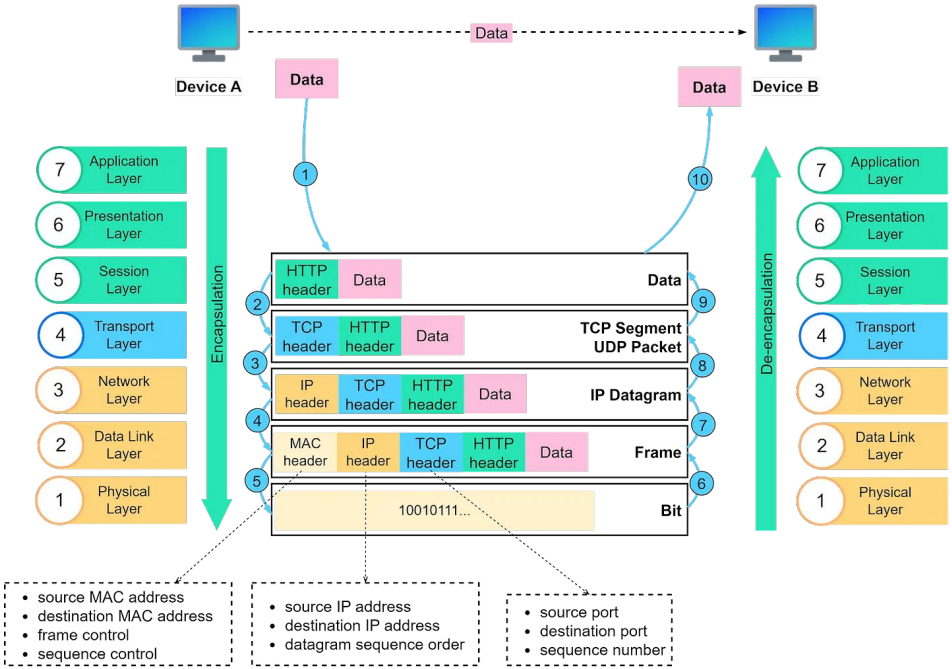
- **Source IP, Source Port**
- **Destination IP, Destination Port**
- **Transport Protocol: TCP / UDP**

1.3. OSI Model

Layer Number	Layer Name	Function Overview	Protocol(s)	Identification	Device	Data Unit
7	Application	Providing application functions for users	HTTP, FTP, DNS, SMTP, Telnet, …	User Identity	Computer	Data
6	Presentation	Converting data into a format that applications can understand; Encryption	TLS/SSL	CA Certs	Computer, Firewall	Data
5	Session	Establishing sessions		Socket	Firewall	Data
4	Transport	Transferring data between applications/processes reliably	TCP, UPD	Port	Firewall	Segment
3	Network	Transferring data from a host on one network to a host on another network	IP	IP	Router	Packet
2	Data Link	Host-to-host transfers on the same local network	Ethernet, WiFi, PPP	MAC	Switch, Hub	Frame
1	Physical	Creating the physical connection between devices		Cable Port, …	Cable, …	Bit

1.4. Encapsulation

- **Each layer adds its own protocol header**
- Each layer has its own data unit
- Maximum transmission unit (MTU) of Frame is 1500 B by default
- Trade off: MTU vs Throughput

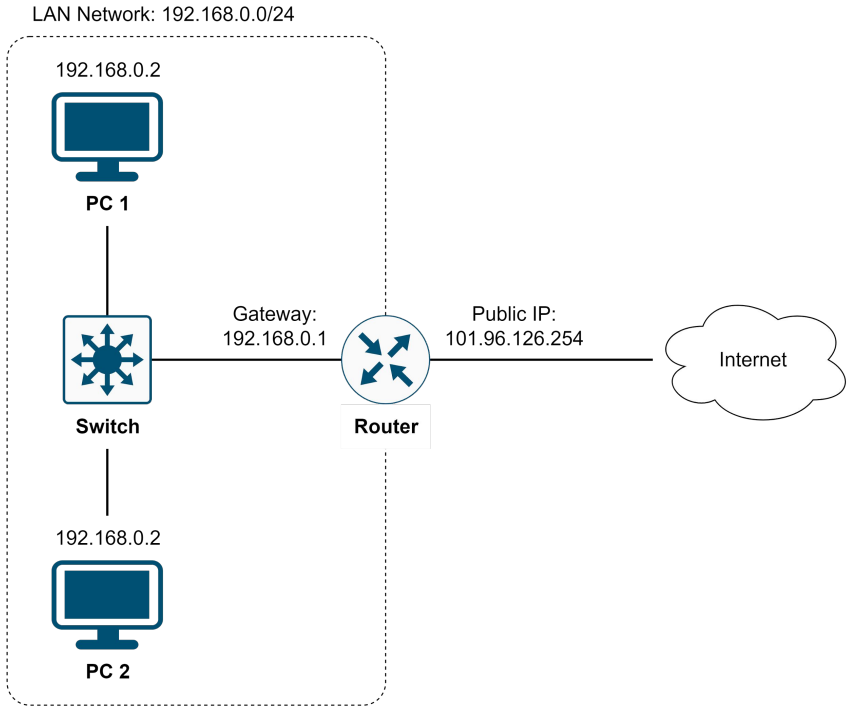


1.5. IP

- IP is responsible for communication between two devices **not connected directly**
  - Example: Lang Son – *train* → Noi Bai Airport – *aircraft* → HCM
- **IPv4: 32 bit**, 4 groups of 8 bits are separated by “.”
  - Example: 192.168.0.1
- ~ 4.3 billion IPv4 address
- IP address is assigned to network card, a host/device can have multiple IP addresses
  → Problem: **IPv4 exhausted**
- Solution:
  - **Multiple hosts use a IP address (private / public IP)**
  - **Extend the range of IP address (IPv6)**

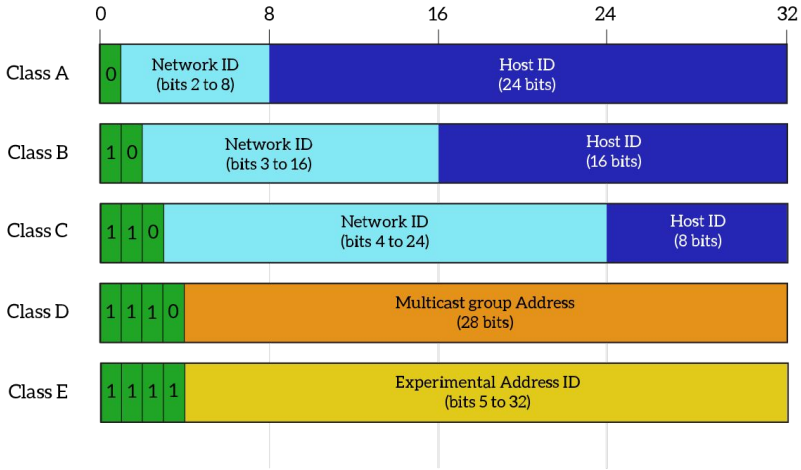
1.5.2. Public / Private IP

- **Public IP address**
  - It is **unique** on the global internet and can be used to **identify a device or network on the internet.**
  - Is managed by ISP (Internet Service Provider)
- **Private IP address**
  - Is used within a private network (LAN)
  - Not unique globally and **can be duplicated in different private networks.**
  - 192.168.x.x, 172.16.x.x to 172.31.x.x, and 10.x.x.x
- **NAT Overload** (PAT) rescues IPv4



1.5.3. IP Classes

- Class A, B, C are divided into 2 parts: network number and host number
  - Example: Network ID is a department, host ID is an employee
- Class D is often used for multicast
- Class E is a reserved classification that is not used temporarily



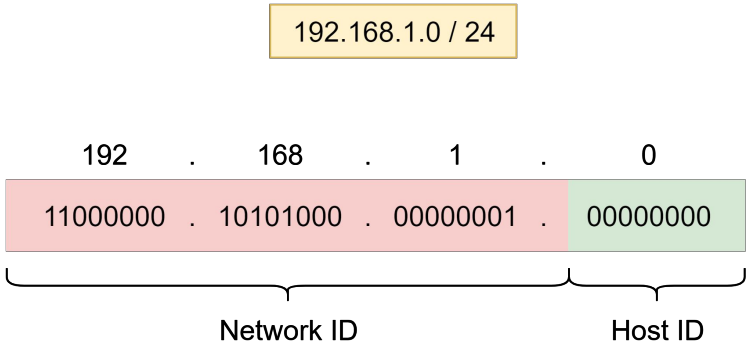
Disadvantages:

- Not flexible, not even distribution
  - Example: a B network can have ~ 65k host.
    On other hand, a C network can have 254 hosts only
- Difficile to manage

→ **Classless Inter-Domain Routing (CIDR)**

1.5.4. CIDR

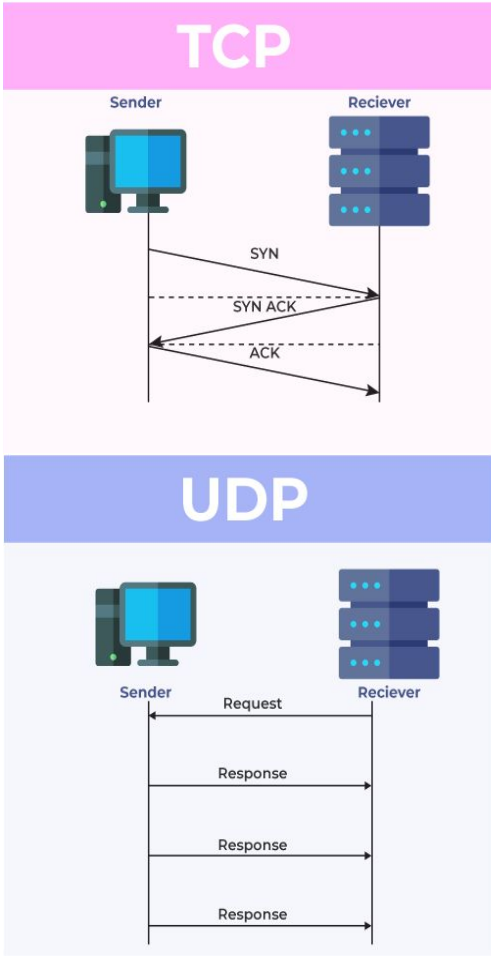
- 32-bit IP address is 2 parts:
  Network ID and Host ID
- **Prefix length means the first x bits belong to network ID**
- Number of available addresses for the network
  192.168.1.0/24
  = 2^(32-24) - 2
  = 2^8 - 2
  = 254 (hosts)
- Why subtract 2?
- **The first address for network ID**
- **The last address for broadcasting**
  - Broadcast packet is prevent from other networks by router



Network ID	192.168.1.0
Prefix Length	24
Subnet Mask	255.255.255.0
The First Available Address	192.168.1.1
The Last Available Address	192.168.1.254
The Broadcast Address	192.168.1.255

1.6. TCP vs UDP

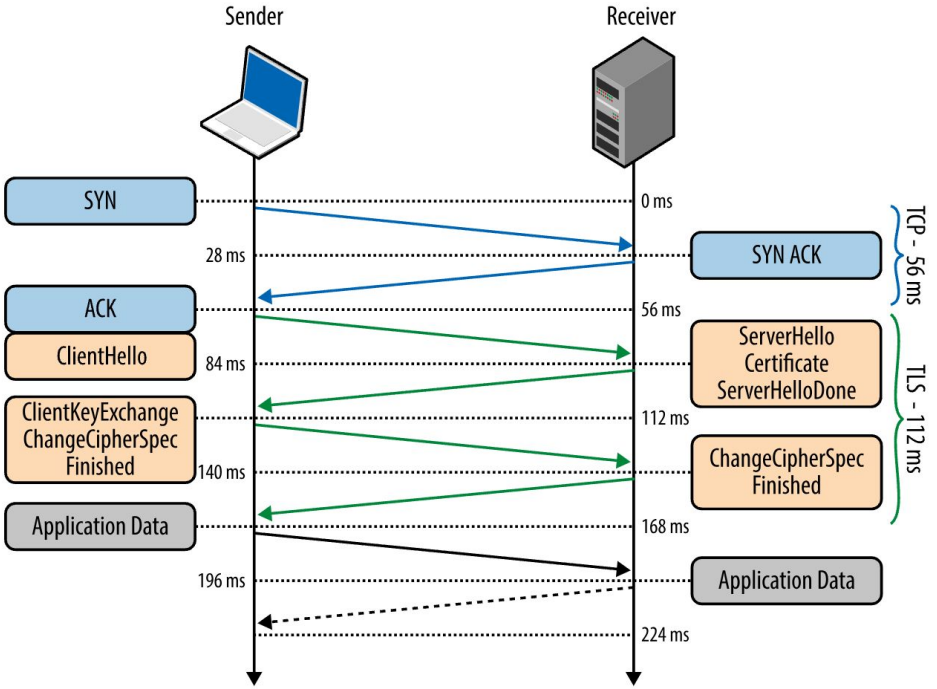
	TCP	UDP
Connection Type	**Connection-Oriented** Establishing a connection beforehand	**Connectionless** No establishing a connection beforehand
Error Checking	Robust: Flow Control, ACK	Basic: checksums
Retransmission	Yes	No
Sequence	Yes: Transmission Control	No
Header Length	20-60 B	8B
Broadcasting	No	Yes
Speed	**Slower**	**Faster**
Reliability	**Yes**	**No**
Application	Email, web, …	VoIP, video streaming, …



1.7. TLS/SSL Handshake

0. Create a TCP connection
1. Client says hello to server
2. **Server sends to client: SSL Certificate** (Public Key + Signature) + server random
3. Client verifies server's certificate
4. Client generate and encrypt a client random
5. Server decrypted message to get client random
6. The session key is generated based on server random + client random.

Transferred data is encrypted by session key as a **symmetric key**



1.7. TLS/SSL Handshake

- **Asymmetric encryption is more secure** than symmetric encryption.
- Client and server use **asymmetric encryption to change cipher**.
- Why do client and server use a session key **(symmetric key) to transfer data**?

→ **Symmetric encryption is less secure but cheaper and faster than asymmetric encryption.**

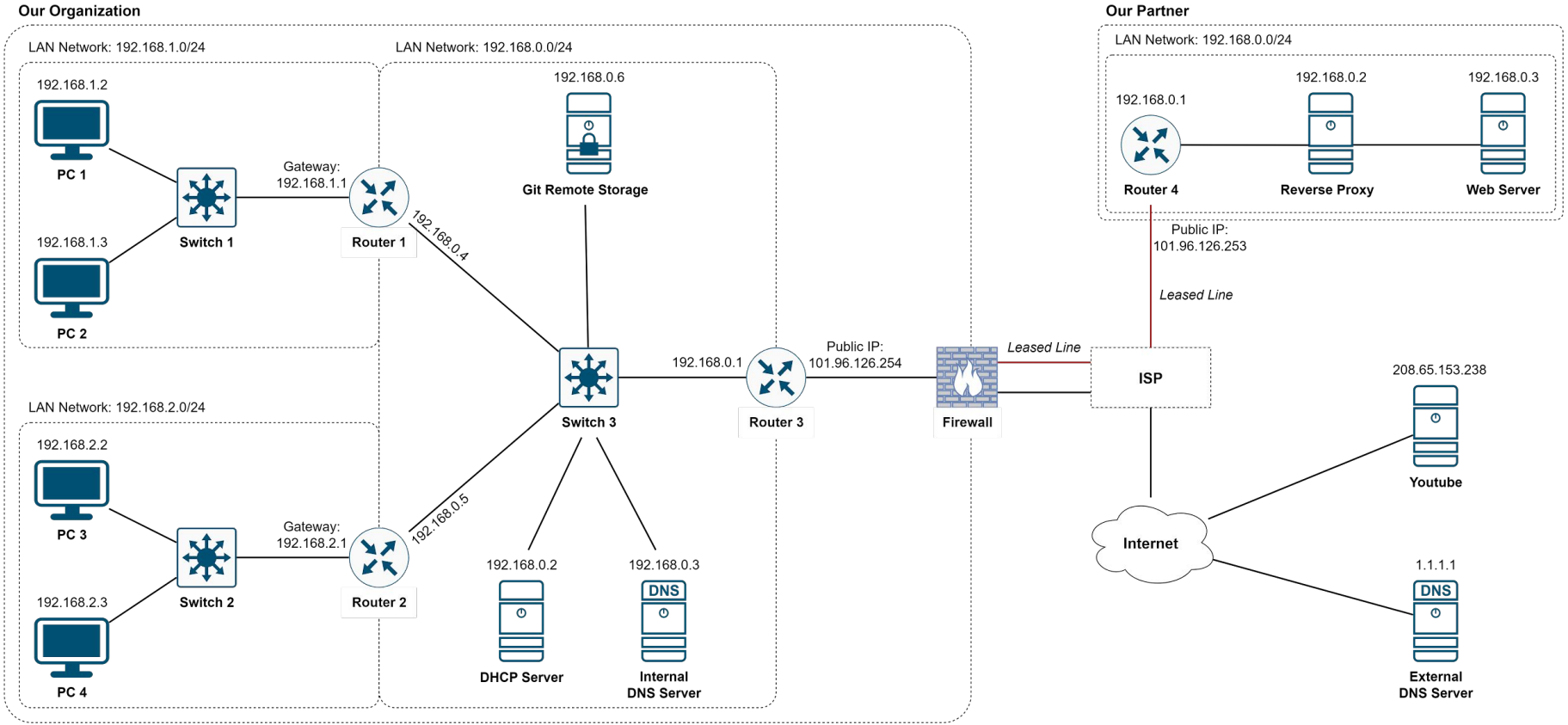
- To improve security, we can change symmetric key while transferring data

2. Network Topology

2.1. Network Services

- DHCP Servers
  - Automatically assigns and manages IP addresses and other network configuration settings to devices on a local network
- DNS server
  - Translate human-readable domain names into IP addresses
- Firewall
  - Monitor and filter incoming and outgoing network traffic based on an organization's previously established security policies.
- Proxy Server
  - An intermediary server act as a gateway, forwarding requests and responses between the user and the target server
- FTP Server

2.2. Network Topology



2.3. Network Topology At Home

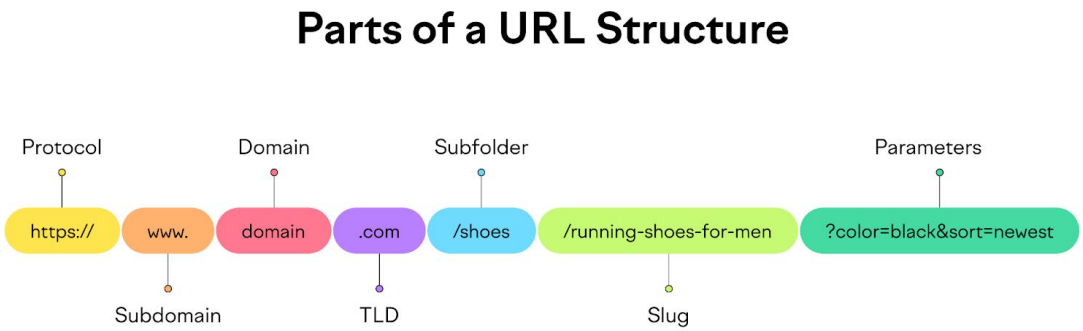
What are functions of the modem in your home network?

- Switch
- Wireless Access Point
- Router
- DHCP
- Firewall
- Web server

3. What happens when you type in a URL on a browser?

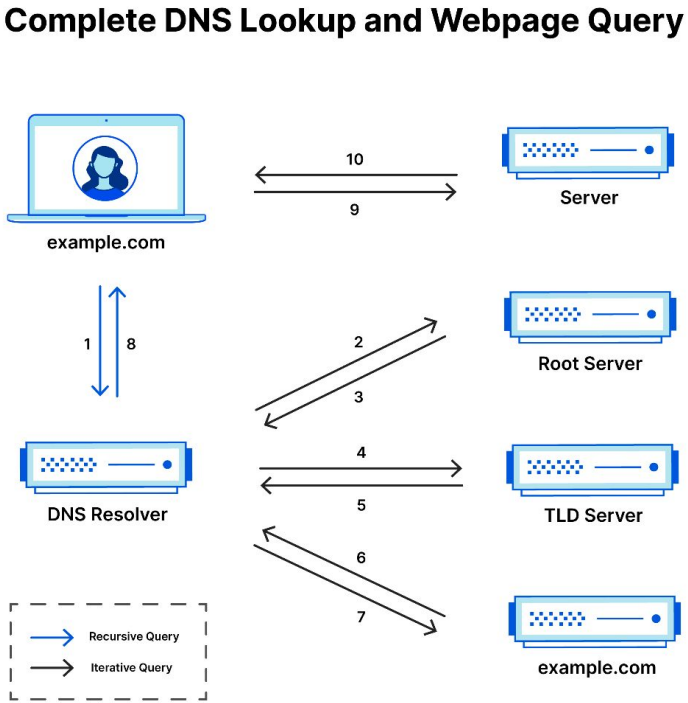
3.1. Browser parses URL

- Browser parses URL
- If path of the resource is missing → default file: index.html
- Browser makes a HTTP request



3.2. DNS Lookup

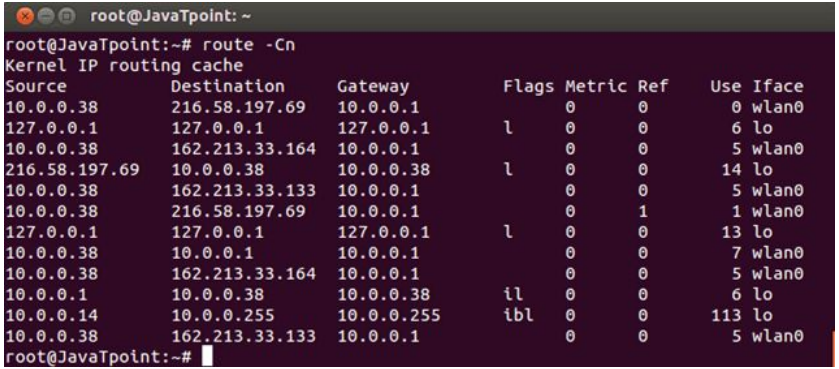
1. DNS Cache in browser
2. **Hosts file of OS**
3. DNS server / resolver:
    - 3.1. Root Server (.)
    - 3.2. Top Level Domain (TLD) Server (.com.)
    - 3.3. Authoritative Server (example.com.)



3.3. IP

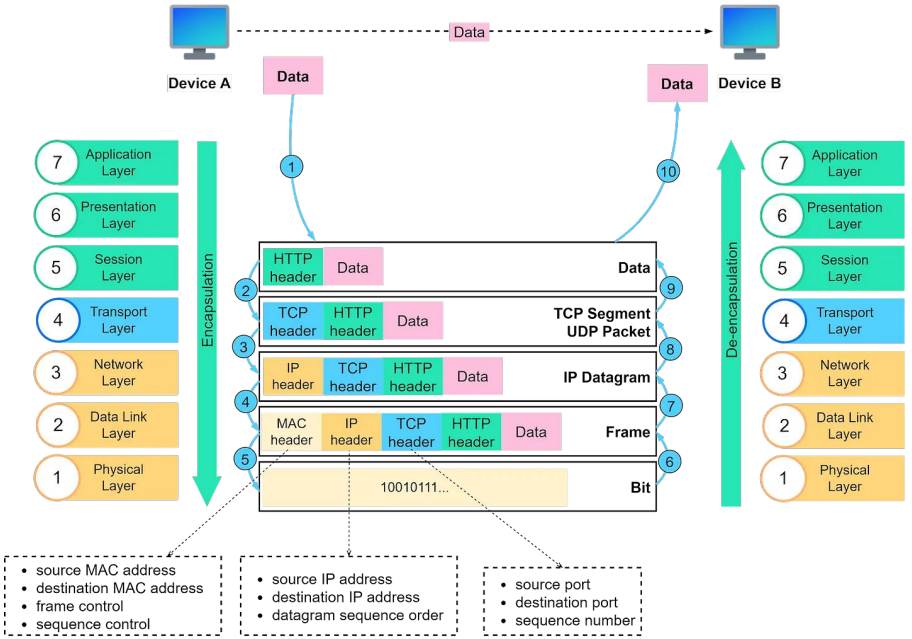
- Question:
  - Assuming that the client has multiple network cards.
  - Each network interface has a IP address.
  - Which IP should be selected as the source address? Which route should be selected?

- The routing table contains information that is used to determine the best possible path for data packets to travel across a network.
- Based on the routing table rules
- $ route -n



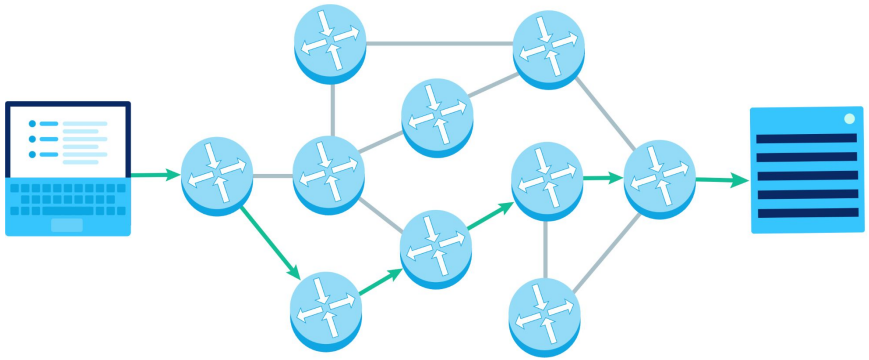
3.4. Protocol Stack

- In each layer, message add another headers.
- Data is split in unit length based on each layer.

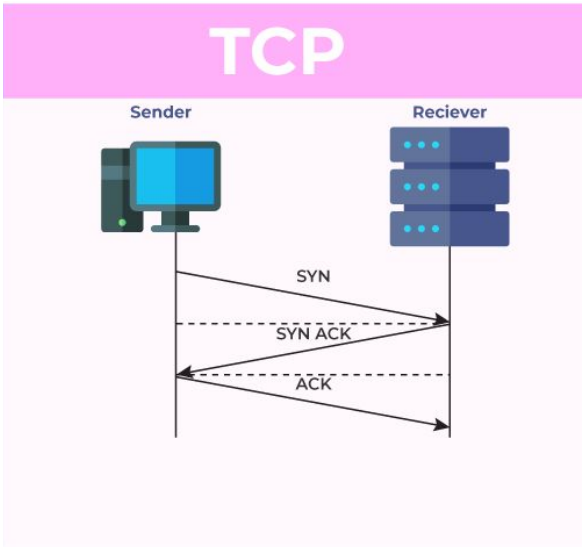


3.5. Routing

- Internet is a bunch of connected routers. And it contains many region.
- In a region, **each router know the way to reach others (based on routing table** generated by routing protocol).



3.6. Three Way Handshake



Recap

- Internet is a bunch of connected routers.
- TCP is reliable, establishing a connection/handshake beforehand
- Use hosts file to fake DNS lookup

Read More

- TCP retransmission, sliding window, **flow control, congestion control**
  - Batching package
- NAT
- IPv6
- TLS/SSL Handshake

References

- https://hpbn.co/transport-layer-security-tls/
- https://auth0.com/blog/the-tls-handshake-explained/

Homework

Take one of the two following:

Install Nginx and configure:

- Reversed Proxy (nginx) :80 → BE :3000
- gw-routing

Thank you 🙏