routing - facilitation of communication between networks

network layer (3rd layer)
- provides services to exchange the individual pieces of data over the network between identified end devices.

- backbone of the network

- receives segment of data or PDUs, network layer adds addressing and other information and send it to the next router along the best path or **route** to the destination network.

PDU – protocol data unit is a unit of information that is sent by a protocol at a particular osi layer

- **network layer protocol such as IP**, are rules and instructions that devices use to enable sharing of upper-layer information between hosts.

Addressing
- devices that have ip address are called **host**
- IP requires each sending and receiving device to have a unique IP address
- source IP address = sending host
- destination IP address = receiving host
- **IP header –** contains address information and other bits that identify PDU as network layer PDU

Encapsulation
- the process of adding information
- encapsulated PDU = **packet**

Routing
- process that routers perform to forward packets to the next path
- static and dynamic
- each route that a packet takes to reach to the destination is called a **hop**

Decapsulation
- the processo f removing encapsulation data at different layers
- network layer only decapsulates the IP Packets at the final destination after examining the destaintion address and determining that the journey is over

Network layer protocols
- IPv4, connectionless; best effort; media independent
- **maximum transmission unit (mtu)** deteremined by the data link layer, and requirement is passed to the network layer
- packets will undego **fragmentation** when MTU is reached

Packet Structure
- **IP source and destination address –** 32-bit binary value
- **time to live (ttl) –** 8-bit, describes the maximum hops before considered lost or undeliverable. This prevents internet from being cluttered with lost packets
- **different service field/type of service (ToS/DS field) –** 8 bits describes the level of througput priority a router should use in processing the packet. The way a router handles a packet from this data is known as **QoS / quality of service**
- **protocol –** upper layer protocol (tcp, udp, icmp) that will receive the packet when decapsulated and given to the transport layer
- **flag and fragment offset –** fragment offset and MF flag is used when fragmentation occurs for reconstruction of the packet; the fragment offset identifies the order for packet fragment.
- **version –** IPv4 or IPv6
- **header length –** tell router the length of the header, not always the same due to options field, length ng IP
- **identification –** sent by source to help reassemble any fragments
- **header checksum –** indicate the length of the header and is checked by each router. Checked by the router and if checksum is invalid, packet is dropped or corrupted.
- **total length –** minimum length is 20 bytes (header with no data) and maximum length 65, 535 bytes, IP header + data
- **options –** rarely used field that can provide special routing services

subnet / subnetwork
- dividing into groups from the large network

IP address
- **network address –** tells routers where to find the general network, 24 bits
- **host address –** use by the last router for delivery inside the network, 8 bits

Network Layer Protocols
→ **IP** – postal system, ensure that the data will be transmitted to the correct destination
IPv4 – 192.168.0.1, 32 bit address, kulang yung supply
IPv6 – hexadecimal format , 16^{32} ← ganto kadami yung sa IPv6

→ **Routing protocol**
- set of ruels by which routers dynamically share their routing information. Use along with the source and destination address to determine best path
- **static** – route information is manually configured on the router (e.g. default route)
- **dynamic –** routes automatically from other routes in the same network

→ **ICMP (internet control message protocol)**
- message protocol for the TCP/IP suite
- provide feedback about issues related to the processing of IP packets
- provides control and error messages and is used by the ping and traceroute
- usually a separate layer 3 of TCP/IP suite
– messenger, that will update host to the status of your package, one of the application is “ping”, and traceroute (nirerecord kung ilang routers na yung daanan ng data, from source to destination)
ICMP routing – suggest the best path or gateway
ICMP diagnostic – test the connectivity
ICMP error – if error, reply to host

→ **ARP (address resolution protocol)**
- determine the destination MAC address when it knows its IPv4 address
- resolve IPv4 addres to MAC address
- maintain ARP table of IPv4 to MAC address mappings
- show ip arp / arp -a
- maps the ip address to the mac address of the destination device, like phone book

public address
- designated for use in networks that are accessible on the internet

private address
- block of addresses used in networks that require limited or no internet access
- not be unique among outside networks, however, private networks still need unique IP address when connected in internet
- use by private organization, offline
- **class A** -10.0.0.0 – 10.255.255.255
- **class B –** 172.16.0.0 – 172.31.255.255
- **class C –** 192.168.0.0 – 192.168.255.255

Classful Adressing (what differs each network is the total number of network addresses and host addresses)

class A
- support extremely large networks with more than 16 million host addresses
- fewer network address, larger number of host addresses
- /8, 255.0.0.0
- 0-127
- 0XXX XXXX
- 2^{24} – 2 (no of host per network id)
- 2^{7} (no of networks)

class B
- moderate to large-size networks with more than 65 000 host
- /16. 255.255.0.0
- slight more efficient allocation addresses than class A
- 128-191
- 10XX XXXX
- 2^{16} – 2 (no of host per network id)
- 2^{14} (no of networks)

class C
- the most commonly available of the historic address classes
- support fo small networks with a maximum of 254 host
- /24, 255.255.255.0
- 192-223

- 110X XXXX
- $2^8 - 2$ (no of host per network id)
- 2^{21} (no of networks)

class D
- multicast
- 224-239
- 1110 XXXX

class E
- experimental
- 240-255
- 1111 XXXX

classless addressing
- address blocks appropriate ot the number of hosts are assigned to companies or organizations.

other information:
1. encapsulated transport layer PDU remains unchanged during the network layer processes
2. IPv4 address is composed of 32 bits
3. if a large network needs to be divided into smaller subnets, additional network codes can be created using some of the bits desingated for the host in a process called **subnetting –** use this to customize private network IPv4
4. To forward a packet, the router must know where to send it, information about this is available as routes in the routing table (destination network, next-hop and metric)
5. **network address translation (nat) –** changes the private space addresses in the IPv4 packet header to a public space address
6. **MAC address** – physical address, when the device is manufactured that device has mac address , permanent
7. **IP address** – network layer assigns the ip address, temporary; can only be obtain when connected to a network
8. **Router –** have input and output link
9. we need ip address for the data to be transmitted across the network. If in LAN we need the mac address to know where to send the data
10. Can have the same host address but different network address
11. first ip address – network address
12. last ip address – broadcast address (use to broadcast the message to LAN)
13. no need to configure the IP address, the IP address will be the network address
14. **subnet mask** identify which part is the network address and which is for host address
15. 127.0.0.0 reserved for loopback and IPC on the local host
16. 224.0.0.0 → 239.255.255.255 is reserved for multicast addresses

Subnetting
- we have a network and still divide into several networks that is called as **subnets / subnetwork**
- we have network and divide network into equal sides

Steps in subnetting:
1. identify what type of class
    class c table – subnet(1-256), host, subnet mask
    class b table – subnet(1-65536), host, subnet mask
2. check if the number of subnet that is appropriate for the number needed
3. now get the network id (pwede lang maglagay yung sa part ng host), subnet mask, host id range (pwede magamit ng mga host sa certain network), # of usable host, broadcast id

Remember:
1. if class C: add only the host to the end to get the next network id
2. if class B: 172.16.**0.0** + host = 01000000…, then divide into 8 bits, then covert to decimal (e.g. 64.0), broadcast id will have 255 at the end of Ip address

Other information:
1. 255.0.0.0 = 255 for network address and the rest are for host address
2. 192.168.4.0/24 = /24 subnet mask of the ip address means 255.255.255.0, from left to right there are 24 1s
3. host in class table tell the number of host per subnet
4. in # of usable host subtract 2 = reserve for broadcast id and network id

5. we can classify that an ip address is class b dahil sa /16 and also to the first bits in the address
6. other subnet mask:

/26 = 255.255.255.192
/27 = 255.255.255.224
/28 = 255.255.255.240
/29 = 255.255.255.248
/30 = 255.255.255.252

classless inter-domain routing (cidr)
- a set of internet protocol (IP) standards thati s used to create unique identifiers for networks and individual devices
- network id, host id range, broadcast id
- /24 - /30 = class c table
- /15 - /23 = class b table

subnetting the subnet
- classify a subnet by its subnet mask
- identify the subnet that's in a table, then multiply (e.g. 4 (subnet) * 4 (subnets to be assigned for departments), then follow what is done previously

fixed length subnet mask
- when we divide networks into several networks, each network will have the same number of host

variable length subnet mask
- more efficient and flexible, optimize number of host per network, more recommended to use

VLSM subnetting
1. arrange the number of host descending
2. pick the subnet for the largest network
3. repeat 2 until satisfied

/26 = 255.255.255.192
/27 = 255.255.255.224
/28 = 255.255.255.240
/29 = 255.255.255.248
/30 = 255.255.255.252