UNIT IV · LESSON 07

Network Layer & Routing

IPv4 addressing · classes · subnetting · CIDR · NAT · IPv4/IPv6 headers · ICMP · DHCP · routing algorithms · RIP · OSPF · BGP

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32 BITS IPV4 ADDRESS

- Dotted decimal: 192.168.10.5 = 4 octets; **network part + host part**

Class	First bits	1st octet range	Default mask	Networks / hosts
A	0	1 – 126	/8 255.0.0.0	126 / 2^{24} – 2
B	10	128 – 191	/16 255.255.0.0	2^{14} / 65 534
C	110	192 – 223	/24 255.255.255.0	2^{21} / 254
D	1110	224 – 239	— multicast	
E	1111	240 – 255	— reserved	

- 127.x.x.x = **loopback**; 0.0.0.0 = this host; 255.255.255.255 = limited broadcast
- **Private ranges**: 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16; APIPA 169.254.0.0/16
- Hosts per network = $\mathbf{2^h - 2}$ (network & broadcast addresses excluded)

MASKS SUBNETTING

CIDR	Mask	Hosts	Block size
/24	255.255.255.0	254	256
/25	255.255.255.128	126	128
/26	255.255.255.192	62	64
/27	255.255.255.224	30	32
/28	255.255.255.240	14	16
/29	255.255.255.248	6	8
/30	255.255.255.252	2	4

- Network address = IP **AND** mask; broadcast = network with all host bits 1
- Subnets from borrowing s bits = 2^s

192.168.1.77/26 SUBNET EXAMPLE

- Mask 255.255.255.192, block 64 → subnets .0, .64, .128, .192
- 77 lies in **.64** subnet

Item	Value
Network address	192.168.1.64
First host	192.168.1.65
Last host	192.168.1.126
Broadcast	192.168.1.127
Usable hosts	62

20–60 BYTES IPV4 HEADER

Field	Bits	Note
Version	4	4
HLEN	4	header length in **4-byte words** (5 – 15)
Type of service / DSCP	8	QoS
Total length	16	max 65 535 bytes
Identification, flags (DF, MF), fragment offset	16 + 3 + 13	offset in **8-byte units**
TTL	8	decremented per hop; 0 → discard + ICMP
Protocol	8	1 ICMP, 6 TCP, 17 UDP
Header checksum	16	header only, recomputed each hop
Source / destination address	32 + 32	

CLASSLESS CIDR & SUPERNETTING

- Prefix notation a.b.c.d/n; route **aggregation** reduces routing tables
- Four /24s 200.1.0.0 – 200.1.3.0 → **200.1.0.0/22**
- **Longest-prefix match** decides the forwarding entry
- **VLSM**: different mask sizes within one network (allocate largest first)

ADDRESS SERVICES NAT & DHCP

- **NAT**: private ↔ public addresses at the router; **PAT/NAPT** uses port numbers (many hosts, one IP)
- **DHCP** (UDP 67 server / 68 client): **DORA** — Discover → Offer → Request → Acknowledge; lease time
- **ICMP**: error & control — echo request/reply (**ping**), destination unreachable, **time exceeded (traceroute)**, redirect, source quench
- **IGMP**: multicast group membership

20–60 BYTES IPV4 HEADER (CONTD.)

Field	Bits	Note
Options	0 – 40 B	

MTU FRAGMENTATION

- Packet larger than link **MTU** is split; reassembled only at the **destination**
- Data per fragment must be a multiple of 8 (except the last)

MTU FRAGMENTATION (CONTD.)

- 4000-byte datagram (20 B header, 3980 B data), MTU 1500 → data 1480, 1480, 1020; offsets **0, 185, 370**; MF = 1, 1, 0
- IPv6: no router fragmentation (source only, path-MTU discovery)

CLASSES ROUTING ALGORITHMS

Distance vector	Link state
share table with neighbours	flood link-state packets to **all** routers
Bellman–Ford	**Dijkstra** (SPF)
slow convergence, count-to-infinity	fast convergence
RIP	OSPF, IS-IS

- Count-to-infinity fixes: **split horizon**, poison reverse, hold-down timers, max hop count
- **Static** vs **dynamic**; **intra-domain (IGP)** vs **inter-domain (EGP)**
- Hierarchical routing, **flooding**, broadcast (reverse path forwarding), multicast (spanning trees)

128 BITS IPV6

- Written as 8 groups of 16-bit hex: 2001:0db8:0000:0000:0000:ff00:0042:8329 → **2001:db8::ff00:42:8329** (:: once)
- **Fixed 40-byte header**: version, traffic class, flow label, payload length, next header, hop limit, source, destination
- No header checksum, no broadcast (multicast, **anycast**), built-in IPsec support, autoconfiguration (SLAAC)
- Loopback ::1; link-local FE80::/10
- Transition: **dual stack**, **tunnelling** (6to4), **translation** (NAT64)

COMPARE ROUTING PROTOCOLS

Protocol	Type	Metric	Transport	Note
RIP	distance vector	hop count (max **15**, 16 = ∞)	UDP 520	updates every 30 s
OSPF	link state	cost (bandwidth)	IP proto 89	areas, backbone area 0
EIGRP	advanced DV (Cisco)	bandwidth + delay	IP proto 88	DUAL
BGP	path vector	AS path, policies	**TCP 179**	between autonomous systems

COMPARE ROUTING PROTOCOLS (CONTD.)

Protocol	Type	Metric	Transport	Note
IS-IS	link state	cost	L2 directly	ISPs

NETWORK CONGESTION & QOS

- Causes: buffer overflow at routers; control: **open loop** (prevention) / **closed loop** (feedback)
- **Leaky bucket**: smooths output to constant rate
- **Token bucket**: allows bursts; max burst time $S = C / (M - \rho)$ (C bucket size, M max rate, ρ token rate)
- Example C = 250 KB, M = 25 MB/s, ρ = 2 MB/s → S ≈ 250 / 23 000 s ≈ **10.9 ms**
- Choke packets, RED (random early detection), admission control, IntServ / DiffServ

TRAP EXAM TRAPS

- Usable hosts = $2^h - 2$, but subnets = 2^s (modern; no −2)
- Fragment offset is in 8-byte units, HLEN in 4-byte units
- Routers fragment IPv4 but **never** IPv6
- `::` may appear only once in an IPv6 address
- 127.0.0.1 is class A space but reserved for loopback

Q → A RAPID RECALL

Class of 172.16.5.4	B (private)
Hosts in a /27 subnet	30
Broadcast of 10.1.1.130/25	10.1.1.255
Address used for loopback	127.0.0.1
IPv4 header minimum	20 bytes
Field preventing infinite loops	TTL
DHCP message sequence	Discover, Offer, Request, Ack
Protocol used by ping	ICMP
RIP maximum hop count	15
Algorithm in OSPF	Dijkstra (shortest path first)
BGP runs over	TCP port 179
IPv6 address size	128 bits