Lecture-9

1. OSI Recap (Layers 1–3)

Layer 1 – Physical

- Physical transmission of bits (1s an d 0s)
- Wired (e.g. Ethernet cables) and Wireless

Layer 2 – Data Link

- Transfers data between directly connected devices
- Uses **Ethernet frames** and **MAC addresses**
- Devices: **Switches**
- Uses **ARP** to map IP → MAC within a LAN

Layer 3 – Network

- Transfers packets **across networks**
- Uses **IP addresses** and routing
- Devices: **Routers**

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2. Switch vs Router

Switch (Layer 2)

- Handles Ethernet frames
- Works within a LAN
- Maintains MAC/ARP table
- Forwards frames based on MAC address

Router (Layer 3)

- Handles IP packets
- Connects multiple networks
- Maintains routing table
- Forwards packets based on destination IP

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3. Data Transmission

Within a LAN

- Application data → TCP/UDP → IP packet → Ethernet frame
- ARP resolves destination MAC address
- Switch forwards frame to target device

Across Networks

- Frame sent to **default gateway (router)**
- Router removes frame, keeps IP packet
- Routing table decides next hop
- Packet re-framed for next network
- Process repeats until destination LAN

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4. Network Layer (Internet Protocol – IP)

Main Functions

- Logical addressing (source & destination IP)
- Routing and packet forwarding
- Fragmentation and reassembly

Service Type

- **Connectionless (Datagram-based)**
  - Best-effort delivery
  - Packets may be lost or arrive out of order
- **Connection-Oriented (Virtual Circuits)**
  - Path established before data transfer
  - Ordered and reliable delivery (QoS)

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5. Internet Structure

- Internet is a collection of **Autonomous Systems (AS)**

- Each AS managed by one organisation
- Backbones use high-speed links
- Regional networks connect local LANs to backbones

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6. IP Datagrams

Datagram = self-contained packet

- Header + Payload

IPv4 Header

- Minimum size: **20 bytes + 20 optional bytes for extra features.**
- Includes:
    - Version
    - Header Length
    - Total Length
    - Identification
    - Flags
    - Fragment Offset
    - TTL (Time To Live)
    - Protocol (TCP/UDP)
    - Header Checksum
    - Source & Destination IP

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7. MTU & Fragmentation

MTU (Maximum Transmission Unit)

- Max packet size allowed by a Layer 2 network

Fragmentation

- Occurs if packet > MTU
- Each fragment has its own IP header
- Offset identifies fragment position

- M flag: 1 = more fragments, 0 = last fragment

8. IP Addressing

Concept

- IP Address = *location*
- MAC Address = *identity*

IPv4

- 32-bit address
- Written as dotted decimal (e.g. 192.168.1.1)
- Network ID + Host ID

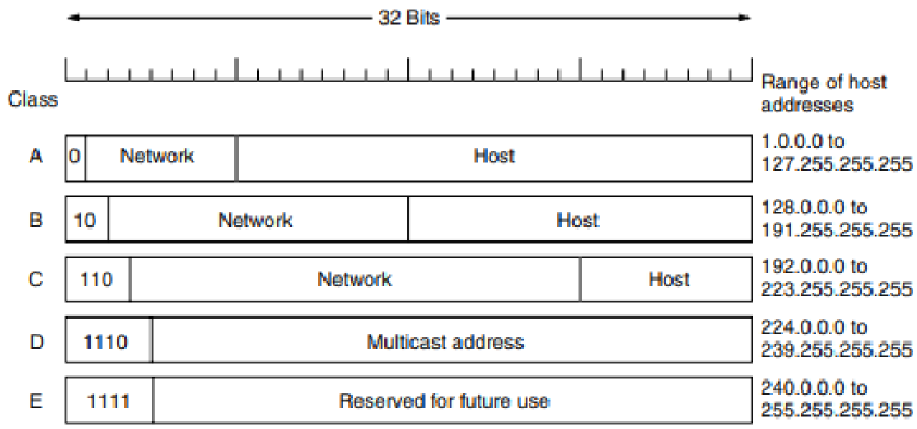

Figure 5-53. IP address formats.

IPv6

- 128-bit address
- Hexadecimal notation
- Designed to replace IPv4 exhaustion

9. Special IPv4 Addresses

- 0.0.0.0 → this host/network
- 255.255.255.255 → broadcast
- 127.0.0.1 → loopback (localhost)

Private IP Ranges

- 10.0.0.0/8
- 172.16.0.0/12
- 192.168.0.0/16

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10. CIDR (Classless Inter-Domain Routing)

- Replaces class-based addressing
- Format: **a.b.c.d /N**
  - N = number of network bits

Example

- 143.210.71.0/24 → 256 addresses
- Enables efficient IP allocation and subnetting

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11. Subnetting

Purpose

- Divide a network into smaller networks

Example: 192.168.1.0/24

- Total IPs = 256
- Can be split into multiple subnets based on requirements

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12. IPv4 Exhaustion & NAT

Problem

- Only ~4 billion IPv4 addresses

Solutions

- Dynamic IP allocation
- **NAT (Network Address Translation)**
  - Maps private IPs to one public IP
  - Uses port numbers to track sessions

- Allows many devices to share one public IP

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13. IPv6 Overview

Why IPv6?

- Massive address space (2^{128})
- Improved security & efficiency
- Better for mobile & real-time traffic

Current Use

- Dual-stack (IPv4 + IPv6)
- Gradual global adoption

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14. Routing Basics

- Routing selects best path for packets
- Routers use IP addresses and routing tables

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15. Routing Algorithms

Flooding

- Packet sent on all outgoing links
- Controlled with hop count & duplicate tracking

Shortest Path Routing

- Network modeled as a graph
- Edges have costs (delay, hop count, etc.)
- Uses **Dijkstra's Algorithm**

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16. Dijkstra's Algorithm (Key Idea)

- Finds shortest path from source to all nodes
- Steps:

1. Initialise distances
2. Visit nearest unvisited node
3. Update neighbour costs
4. Repeat until destination visited

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17. Dynamic Routing

- Adapts to network changes
- Routers share state information
- Considers congestion, delay, failures

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18. Hierarchical Routing

- Divides large networks into regions
- Routers store partial routing info
- Reduces routing table size
- Improves scalability

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19. Internet Routing

Within an AS

- Interior Gateway Protocols (IGP)
- Example: **OSPF** (uses Dijkstra)

Between ASes

- Exterior Gateway Protocols (EGP)
- **BGP (Border Gateway Protocol)**
- Policy-based global routing

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20. Key Takeaways

- Network Layer = IP + Routing
- Routers forward packets across networks

- IP is connectionless and best-effort
- CIDR, NAT, and IPv6 solve IPv4 limits
- Routing uses graph-based shortest