Week5: Internet Layer

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Internet Layer Overview

The Internet Layer is a crucial component of the TCP/IP protocol suite that handles addressing and routing of data packets across networks.

- **Core Concepts:**
  - **IP Addressing:** Logical addressing for devices across networks.
  - **Routing:** Determining the path for data packets.
  - **Packetization:** Encapsulating Transport Layer segments into IP Datagrams.
  - **Fragmentation & Reassembly:** Handling large packets.
  - **ICMP Errors:** Error reporting via Internet Control Message Protocol.

Key Functions:

- **Data Plane:** Handles packet forwarding.
- **Control Plane:** Manages routing and path determination.

IP Addressing:

- **IPv4 Structure:** 32-bit addresses split into 4 octets.
- **Classes:** A, B, C, D (Multicast), E (Experimental).
- **Private Addresses:** Used in NAT (e.g., 10.0.0.0/8).
- **CIDR:** Classless Inter-Domain Routing for flexible subnetting.

Key Functions of Internet Layer

- Logical addressing of devices using IP addresses
- Routing packets between networks
- Packet fragmentation and reassembly
- Error reporting and diagnostics

Internet Protocol (IP)

IP is the primary protocol operating at this layer, responsible for:

- Providing unique addressing for devices
- Defining packet structure and addressing methods
- Supporting both IPv4 and IPv6 addressing schemes

Private IP

all devices in local network have 32-bit addresses in a “private” IP address space (10/8, 172.16/12, 192.168/16 prefixes) that can only be used in local network

Private IPs

- Example addresses:
- **Class A**: 10.0.0.1 (private).
- **Class B**: 172.16.0.1 (private).
- **Class C**: 192.168.1.1 (private).

IPv4 Addressing

IPv4 uses 32-bit addresses divided into four octets (e.g., 192.168.1.1)

- Supports approximately 4.3 billion unique addresses
- Uses subnet masks for network segmentation
- Includes private address ranges (10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16)

Understanding IPv4 Addresses

- **32-bit Structure:** Split into 4 octets (e.g., 192.168.1.1).
- **Dotted-Decimal Notation:** Conversion from binary (e.g., 11000000.10101000.00000001.00000001 → 192.168.1.1).
- **Total Address Space:** 4.3 billion addresses (2^{32}).

- Class A (0.0.0.0–127.255.255.255):
  Large networks (16M hosts). Default mask: /8.
- Class B (128.0.0.0–191.255.255.255):
  Medium networks (65k hosts). Default mask: /16.
- Class C (192.0.0.0–223.255.255.255):
  Small networks (254 hosts). Default mask: /24.
- Class D (Multicast): 224.0.0.0–239.255.255.255.
- Class E (Experimental): 240.0.0.0–255.255.255.255.

IPv6 Addressing

IPv6 was developed to address IPv4 limitations:

- Uses 128-bit addresses
- Provides approximately 3.4 × 10^38 unique addresses
- Written in hexadecimal format (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334)
- Improved security features with IPSec integration

Internet Control Message Protocol (ICMP)

ICMP is used for network diagnostics and error reporting:

- Ping (Echo Request/Reply)
- Traceroute functionality
- Destination unreachable messages
- Time exceeded messages

Address Resolution Protocol (ARP)

ARP maps IP addresses to MAC addresses:

- Maintains ARP cache for quick lookups
- Broadcasts ARP requests to find unknown MAC addresses
- Handles address resolution within local networks

Routing Concepts

Key routing principles and mechanisms:

- Static vs. Dynamic routing
- Routing tables and their maintenance
- Route selection and metrics
- Common routing protocols (RIP, OSPF, BGP)

Packet Fragmentation

Process of breaking large packets into smaller ones:

- Maximum Transmission Unit (MTU) considerations
- Fragment offset and identification
- Reassembly at destination

Quality of Service (QoS)

Internet Layer QoS mechanisms:

- Differentiated Services (DiffServ)
- Traffic prioritization
- Congestion control

Security Considerations

Security aspects at the Internet Layer:

- IP spoofing prevention
- ICMP attack mitigation
- IPSec protocols and implementation
- Access Control Lists (ACLs)

Troubleshooting Tools

Common tools for Internet Layer diagnostics:

- ping - Testing connectivity
- traceroute/tracert - Path tracing
- ipconfig/ifconfig - Interface configuration
- nslookup - DNS queries

DHCP and Address Management:

- **DHCP Process:** Dynamic allocation of IP addresses. Dynamic Host Confirguration Protocol.
- **Benefits:** Address reuse, support for mobile users, and additional configuration (e.g., DNS server).

NAT and Subnets:

- **NAT:** Allows multiple devices to share a single public IP address.

- **Subnets:** Logical subdivisions of an IP network.

Routing and Forwarding:

- **Routing:** Determines the best path for data.
- **Forwarding:** Moves packets based on routing decisions.
- **Static vs. Dynamic Routing:** Static is manual and secure; dynamic adapts to network changes.

Routing Protocols:

- **RIP:** Distance-vector protocol with a hop limit.
- **OSPF:** Link-state protocol using Dijkstra's algorithm.
- **BGP:** Path-vector protocol for Internet backbone routing.

Advanced Routing Concepts:

- **Distance Vector Routing:** Uses hop count for path determination.
- **Dijkstra's Algorithm:** Finds shortest paths in a network.

IPv6 and Network Evolution:

- **Motivation:** Address space exhaustion in IPv4.
- **Features:** 128-bit addresses, no checksum, no fragmentation.
- **Transition:** Tunneling IPv6 within IPv4 for compatibility.

This summary encapsulates the key points and concepts covered in the document related to the Internet Layer and its associated topics.

IP addresses: how to get one?

Q: how does *network* get subnet part of IP address?

A: gets allocated portion of its provider ISP's address space

ISP's block	11001000 00010111 00010000 00000000	200.23.16.0/20

ISP can then allocate out its address space in 8 blocks:

Organization 0	11001000 00010111 00010000 00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010 00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100 00000000	200.23.20.0/23
...	.....	....
Organization 7	11001000 00010111 00011110 00000000	200.23.30.0/23