Network Layer - Complete Study Notes

Overview

- **Position**: Third layer from bottom in OSI Model
- **Data Flow**: Takes data from Transport Layer → passes to Data Link Layer
- **Primary Function**: Handles communication between different networks

Key Responsibilities of Network Layer

1. Host-to-Host Delivery (Source-to-Destination Delivery)

Alternative Names:

- Host-to-Host delivery
- Source-to-Destination delivery
- Machine-to-Machine delivery

Example Scenario:

- **Network A** (Hub topology) and **Network B** (Bus topology)
- Machine A2 wants to communicate with Machine B2
- **Path**: A2 → R1 (Router 1) → R2 (Router 2) → B2

Key Points:

- No direct communication between machines in different networks
- Data Link Layer handles **node-to-node** delivery (A2 to R1)
- Network Layer handles **end-to-end** delivery (A2 to B2)

Implementation Method:

Uses Logical Addresses (IP Addresses)

IP Address Components:

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IP Address = Network ID + Host ID
```

- **Network ID**: Identifies which network to send the message
- **Host ID**: Identifies specific machine/server within that network

Process:

1. Source (A2) adds its IP address

2. Source adds destination IP address (B2)
3. Network Layer uses these addresses for routing decisions

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2. Routing

Definition:

Process of determining the best path for data packets from source to destination

Key Routing Protocols:

- **RIP** (Routing Information Protocol)
- **OSPF** (Open Shortest Path First)
- **Distance Vector Routing**
- **Link State Routing**

Why Protocols Are Important:

- Provide standardized set of instructions
- Ensure both source and destination follow same rules
- Enable fast, convenient, and efficient communication
- Prevent confusion from different custom protocols

Router Intelligence:

- Routers make independent routing decisions
- Each router determines the best path to destination
- Use routing algorithms to find shortest/optimal paths
- Example: R1 decides best path to reach B2, then R2 makes its own decision

Network Layer Devices:

Primary Devices:

- **Routers** (most important)
- **Switches**

Other Devices:

- Bridges
- Firewalls

Device Comparison:

- **Routers**: Have all 3 layers (Physical, Data Link, Network)
- **Bridges**: Only have 2 layers (Physical, Data Link)

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3. Fragmentation

Terminology:

- Network Layer uses **packets**
- Implements **packet switching**

When Fragmentation is Needed:

Scenario Example:

- Host sends large message to destination
- Message goes to R1 router
- Next router in path has limited buffer capacity
- Example: Ethernet (CSMA/CD) accepts maximum 1500 bytes
- If packet size > router capacity → Fragmentation required

Fragmentation Process:

1. Router receives large packet
2. Checks its buffer capacity and network limitations
3. Divides packet into smaller fragments
4. Each fragment sized according to network capacity
5. Forwards multiple smaller packets instead of one large packet

Why It's Important:

- Prevents packet loss due to size limitations
- Ensures compatibility across different network types
- Maintains data flow efficiency

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4. Congestion Control

Definition:

Managing network traffic to prevent network overload

Congestion Situation:

- Network filled to capacity with packets

- Multiple nodes sending unlimited packets simultaneously
- Network becomes saturated with messages
- Can cause packet loss and delays

Implementation:

Note: Primarily handled by Transport Layer, but Network Layer assists

Methods Used:

- **Leaky Bucket Method**
- **Token Bucket Method**

Protocols Used:

- **ICMP** (Internet Control Message Protocol)
- **IGMP** (Internet Group Management Protocol)

ICMP Functions:

- Router sends acknowledgment to source about message problems
- Sends speed reduction requests when source transmits too fast
- Helps maintain optimal network performance

Important Concepts Summary

Data Flow Path:

```
Source Machine (A2)
    ↓ (Data Link Layer - node to node)
Router R1
    ↓ (Network Layer - routing decision)
Router R2
    ↓ (Network Layer - routing decision)
Destination Machine (B2)
```

Key Technologies:

- **IP Addressing**: For host identification and routing
- **Packet Switching**: For efficient data transmission
- **Routing Algorithms**: For optimal path selection
- **Fragmentation**: For packet size management

Internet Context:

- Internet = Connection of different networks
- Routers connect multiple networks (not just 1-2)
- Each network can use different topologies
- Network Layer ensures interoperability

Layer Comparison:

- **Data Link Layer**: Node-to-node delivery (adjacent devices)
- **Network Layer**: Host-to-host delivery (across networks)
- **Transport Layer**: Process-to-process delivery (applications)

Key Takeaways

1. **Most Important Function**: Host-to-Host delivery using IP addresses
2. **Essential for Internet**: Enables communication across different networks
3. **Router Intelligence**: Routers make independent routing decisions
4. **Flexibility**: Handles different network types and sizes through fragmentation
5. **Efficiency**: Optimizes paths and manages congestion for better performance