

NETWORKING FUNDAMENTALS II





WORKFORCE DEVELOPMENT



COURSE STRUCTURE

Day 1: Networking Fundamentals I

Day 2: Networking Fundamentals II

Day 3: Networking in the Cloud Era

Day 4: Cloud Network Services & Connectivity

Day 5: Availability & Troubleshooting in the Cloud

AGENDA FOR DAY 2

1. Ethernet Switching Fundamentals
2. Inter-VLAN Routing & Design
3. Spanning Tree Protocol (STP)
4. EtherChannel & Link Aggregation
5. Routing Fundamentals
6. DHCP & NAT
7. Data Center Network Architecture and Operation



ETHERNET SWITCHING FUNDAMENTALS

CAM TABLE & L2 FORWARDING

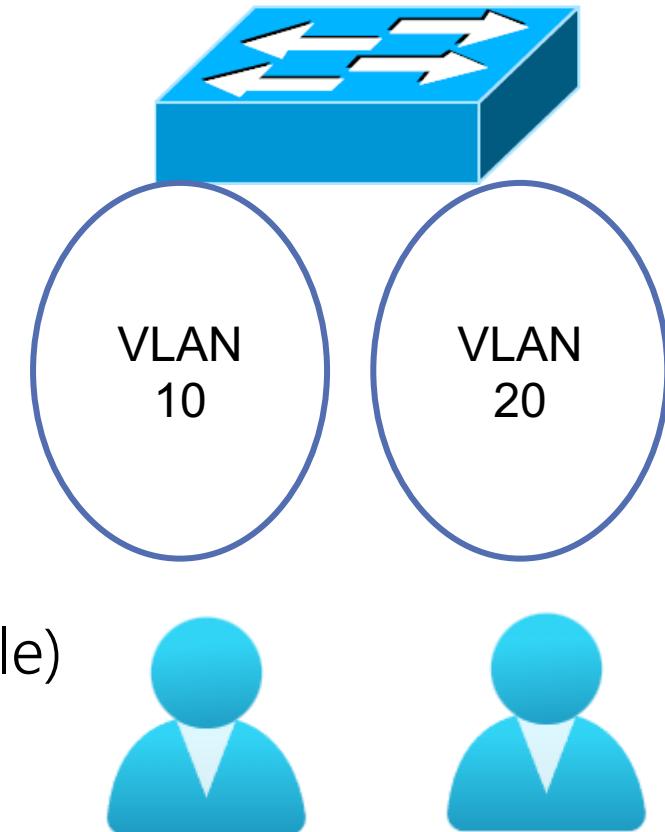
- Switches use a CAM (Content Addressable Memory) table
- Stores MAC addresses and corresponding ports
- Frame forwarding based on destination MAC
- Unknown destination → flooded out all ports except incoming
- Dynamic vs static MAC entries



Mac Address	Port	VLAN
0000.0000.1111	1	10
0000.0000.2222	2	10
0000.0000.3333	7	20

VLAN CONCEPT & BENEFITS

- VLAN = Virtual LAN; logical segmentation of a switch
- Separates broadcast domains
- Increases security and efficiency
- Simplifies management and policy enforcement
- VLANs identified by 12-bit VLAN ID (0–4095, 1–4094 usable)



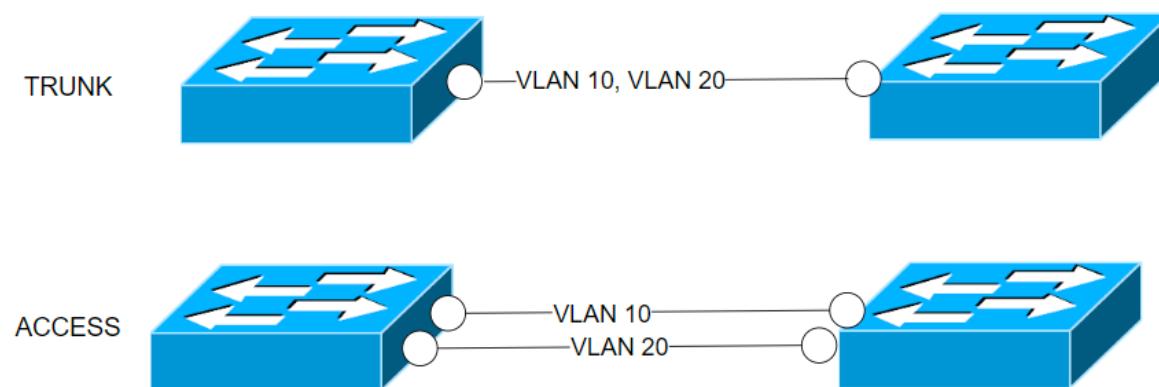
802.1Q TAGGING & NATIVE VLAN

- IEEE 802.1Q = VLAN tagging standard
- Adds 4-byte tag to Ethernet frame
- Contains VLAN ID and priority (CoS) bits
- Native VLAN = untagged traffic on trunk links
- Security best practice: avoid using VLAN 1 as native



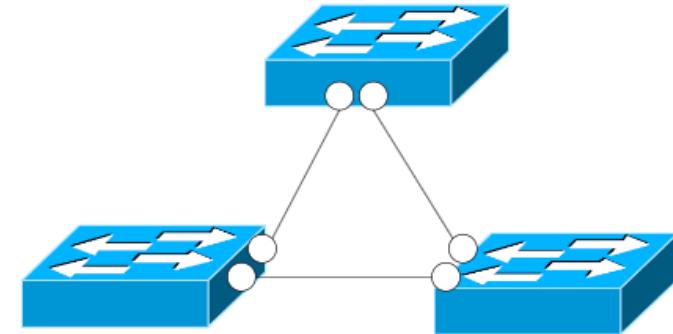
ACCESS VS TRUNK PORTS

- Access port: carries traffic for one VLAN
- Trunk port: carries multiple VLANs (tagged traffic)
- Dynamic Trunking Protocol (DTP) negotiates trunks (Cisco)
- Common commands: switchport mode access/trunk



MULTI-SWITCH VLAN PROPAGATION

- VLANs can span multiple switches via trunks
- VLAN database synchronized using VTP (Cisco)
- Transparent vs Server/Client modes
- Always verify VLAN consistency across switches



POP QUIZ:

What is the purpose of the CAM table in a network switch?

- A. To store routing information
- B. To store MAC addresses and associated ports
- C. To store IP-to-MAC mappings
- D. To filter broadcast traffic



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POP QUIZ:

What happens when a switch receives a frame with an unknown destination MAC address?

- A. It drops the frame
- B. It sends it to the default gateway
- C. It floods it out all ports except the incoming one
- D. It adds it to the CAM table



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POP QUIZ:

Which type of MAC entry in a switch is manually configured by an administrator?

- A. Dynamic
- B. Static
- C. Temporary
- D. Broadcast



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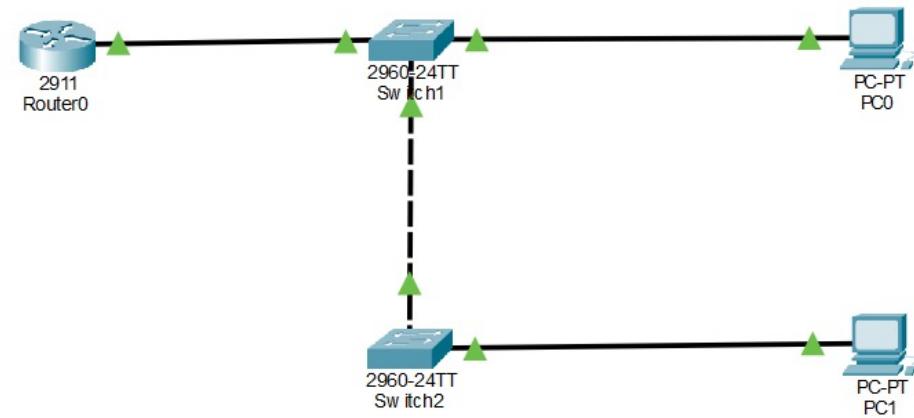
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INTER-VLAN ROUTING & DESIGN

INTER-VLAN ROUTING MODELS

- Router-on-a-Stick (ROAS)
- One physical link, subinterfaces per VLAN
- Layer 3 Switch (SVI-based)
- Inter-VLAN routing in hardware
- L3 switches = faster, scalable solution



STP BASICS: ROOT BRIDGE, PORT ROLES & STATES

- Spanning Tree Protocol prevents loops
- Elects Root Bridge (lowest Bridge ID)
- Port roles: Root, Designated, Alternate
- Port states: Blocking, Listening, Learning, Forwarding

STP ENHANCEMENTS: PORTFAST & BPDU GUARD

- PortFast: immediate forwarding on access ports
- BPDU (Bridge Protocol Data Unit) Guard: disables port if BPDU received
- Safety mechanism for access ports where you do not expect to receive a BPDU
- Enhancements improve stability and security

ETHERCHANNEL / LACP OVERVIEW

- Combines multiple physical links into one logical link
- Increases bandwidth and redundancy
- Protocols: PAgP (Cisco), LACP (802.3ad standard)
- Load balancing based on MAC/IP/Port

VERIFYING VLANS & TRUNKS

- show vlan brief – VLANs and ports
- show interfaces trunk – trunk status and allowed VLANs
- show interfaces switchport – mode and VLAN info

```
Switch#show vlan brief

VLAN Name          Status    Ports
---- --          -----  -----
 1  default        active   Fa0/2, Fa0/3, Fa0/4, Fa0/5
                           Fa0/6, Fa0/7, Fa0/8, Fa0/9
                           Fa0/10, Fa0/11, Fa0/12, Fa0/13
                           Fa0/14, Fa0/15, Fa0/16, Fa0/17
                           Fa0/18, Fa0/19, Fa0/20, Fa0/21
                           Fa0/22, Gig0/1, Gig0/2
                           Fa0/1
 10  HR            active
 20  FINANCE       active
 1002 fddi-default active
 1003 token-ring-default active
 1004 fddinet-default active
 1005 trnet-default active
```

VERIFYING STP STATE & ROOT ELECTION

- show spanning-tree – displays STP status
- Identify Root Bridge and port roles
- Check timers and priority values
- Common root election issue: unintentional root bridge

```
Switch#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority  32769
  Address    0001.6387.A8D3
  Cost       19
  Port       23 (FastEthernet0/23)
  Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID Priority  32769 (priority 32768 sys-id-ext 1)
  Address    0009.7C84.A89C
  Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec
  Aging Time 20

  Interface      Role Sts Cost      Prio.Nbr Type
  -----  -----
  Fa0/24        Desg FWD 19        128.24   P2p
  Fa0/23        Root FWD 19        128.23   P2p

VLAN0010
  Spanning tree enabled protocol ieee
  Root ID    Priority  32778
  Address    0001.6387.A8D3
  Cost       19
  Port       23 (FastEthernet0/23)
  Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID Priority  32778 (priority 32768 sys-id-ext 10)
```

VERIFYING ETHERCHANNEL (PAGP/LACP)

- show etherchannel summary
- show interfaces port-channel
- Verify protocol, mode, and member links
- Check load balancing algorithm

TROUBLESHOOTING VLAN MISMATCHES

- Check VLAN assignments on both sides
- Ensure trunk allowed VLANs match
- Review VTP mode/version consistency
- Use show cdp neighbor detail for mismatch hints

```
Switch#show cdp neighbor
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone
Device ID      Local Intrfce     Holdtme   Capability       Platform    Port ID
Router         Fas 0/24          159        R              C2900      Gig 0/0
Router         Fas 0/24          159        R              C2900      Gig 0/0.10
Router         Fas 0/24          159        R              C2900      Gig 0/0.20
Switch          Fas 0/23          159        S              2960       Fas 0/23
Switch#
```

TROUBLESHOOTING STP LOOPS

- Identify duplicated frames and MAC flapping
 - Use show mac address-table for flapping ports
 - Check BPDU Guard logs
- Verify redundant connections properly blocked

```
Switch#show mac address-table
      Mac Address Table
-----
Vlan   Mac Address        Type      Ports
---   -----
  1    0002.1701.3417    DYNAMIC   Fa0/23
  1    0090.21bc.7a01    DYNAMIC   Fa0/24
 10    0002.1701.3417    DYNAMIC   Fa0/23
 10    0090.21bc.7a01    DYNAMIC   Fa0/24
 20    0002.1701.3417    DYNAMIC   Fa0/23
 20    0090.21bc.7a01    DYNAMIC   Fa0/24
```

DESIGN TIPS: VLAN NUMBERING & NAMING

- Use structured VLAN numbering (Dept/Function/Location)
- Example: VLAN 10–19 = HR, 20–29 = Finance
- Use descriptive names
- Reserve high VLAN IDs for future expansion



MGMT VLAN & OUT-OF-BAND IDEAS

- Dedicated management VLAN for switches
- Prevents control traffic mixing with user data
- Optional out-of-band (OOB) network via console or mgmt port
- Restrict access with ACLs

DOCUMENTATION MUST-HAVES FOR L2

- VLAN numbering and naming plan
- Trunk and EtherChannel diagrams
- STP root bridge roles
- Management VLAN design
- Verification and troubleshooting checklist



POP QUIZ:

What is the main benefit of implementing VLANs in a network?

- A. Increases broadcast traffic
- B. Combines multiple networks into one
- C. Segments broadcast domains for security and efficiency
- D. Simplifies routing configuration



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POP QUIZ:

Which type of port carries traffic for multiple VLANs?

- A. Access port
- B. Trunk port
- C. Hybrid port
- D. Core port



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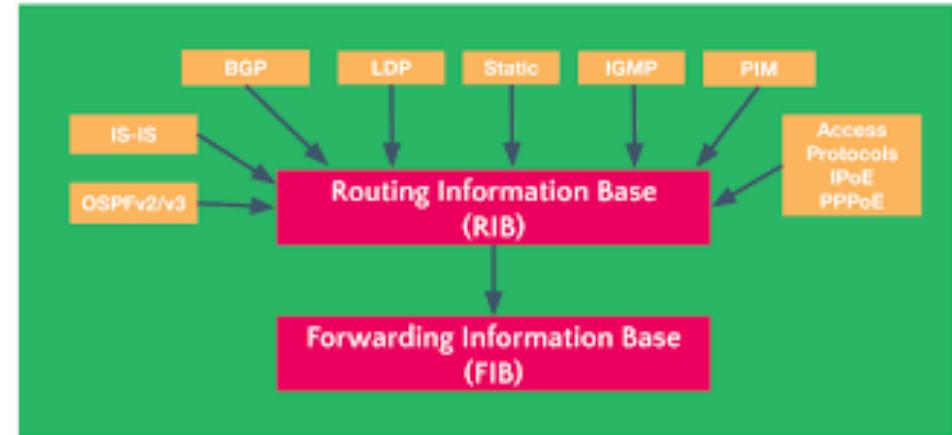
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ROUTING FUNDAMENTALS

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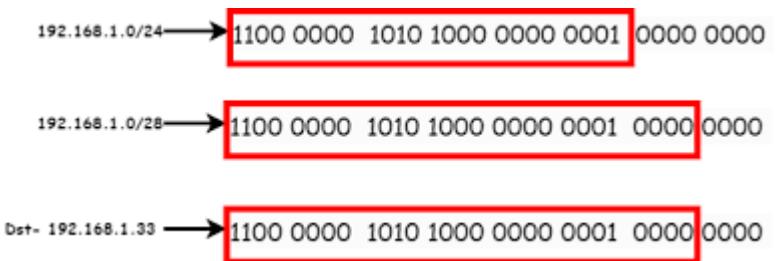
- RIB (Routing Information Base):
 - Stores all learned routes (static + dynamic)
- FIB (Forwarding Information Base):
 - Optimized routing table used for actual packet forwarding
- Relationship:
 - RIB → FIB (control plane → data plane)



LONGEST PREFIX MATCH

- Router selects the most specific route that matches the destination
- Example:

- 10.0.0.0/8 → broad
 - 10.0.1.0/24 → more specific → preferred
- Ensures efficient routing decisions



ADMINISTRATIVE DISTANCE & METRICS

- Administrative Distance (AD):
 - Trust level of a routing source
 - Direct = 0
 - Static = 1
 - EIGRP = 90
 - OSPF = 110
 - RIP = 120
- Metric:
 - Value used within a protocol to choose the best path

STATIC ROUTING – PROS & CONS

-  Advantages:
 - Simple to configure
 - Predictable paths
 - Secure (no routing updates)
-  Disadvantages:
 - No automatic failover
 - Manual updates required
 - Poor scalability

OSPF AREA 0 (SINGLE-AREA OVERVIEW)

- OSPF: Open Shortest Path First = Link-State Protocol
- Organizes network into areas
- Area 0 = Backbone (mandatory core area)
- Single-area OSPF: All routers share one LSDB

OSPF NEIGHBORS, DR & BDR

- OSPF routers form neighbor relationships via Hello packets
- On multi-access networks:
 - DR (Designated Router)
 - BDR (Backup DR)
 - Reduces LSA flooding on shared segments

OSPF COST & PATH CONTROL

- Cost = Reference Bandwidth / Interface Bandwidth
- Default reference = 100 Mbps
- Lower cost → preferred path
- Cost can be manually adjusted for path optimization

PASSIVE INTERFACE DESIGN

- Passive interface: Stops sending routing updates but still advertises its network
- Commonly used on LAN interfaces connected to end devices
- Increases security and reduces unnecessary routing traffic

POP QUIZ:

What is the relationship between RIB and FIB in routing?

- A. RIB is for control plane; FIB is for data plane forwarding
- B. RIB handles VLAN tagging
- C. FIB manages routing protocols
- D. They are identical tables



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POP QUIZ:

Which routing source has the lowest administrative distance?

- A. OSPF
- B. Static route
- C. RIP
- D. EIGRP



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- C. RIP
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POP QUIZ:

What rule determines which route is chosen when multiple matches exist?

- A. Longest prefix match
- B. Shortest prefix match
- C. Random selection
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DHCP & NAT

DHCP CONCEPTS

- Dynamic Host Configuration Protocol (DHCP):
- Automates IP address assignment
- Reduces manual configuration errors
- Provides additional configuration: subnet mask, gateway, DNS, etc.
- Operates on UDP ports 67 (server) and 68 (client)



DHCP SCOPES AND EXCLUSIONS

- DHCP Scope:
 - Range of IP addresses that a DHCP server can assign
 - Defines the subnet, default gateway, lease duration, and DNS servers
- Exclusions:
 - IP addresses not assigned automatically by DHCP
 - Used for devices that need static IPs (e.g., servers, printers, routers)

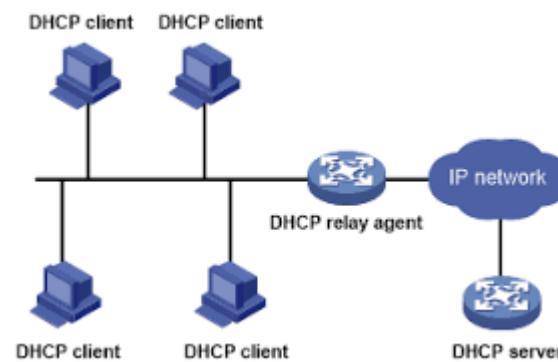
DHCP LEASE PROCESS (DORA)

- Discover – Client broadcasts to find a DHCP server.
- Offer – Server offers an available IP address.
- Request – Client requests the offered IP.
- Acknowledge – Server confirms and finalizes the lease.



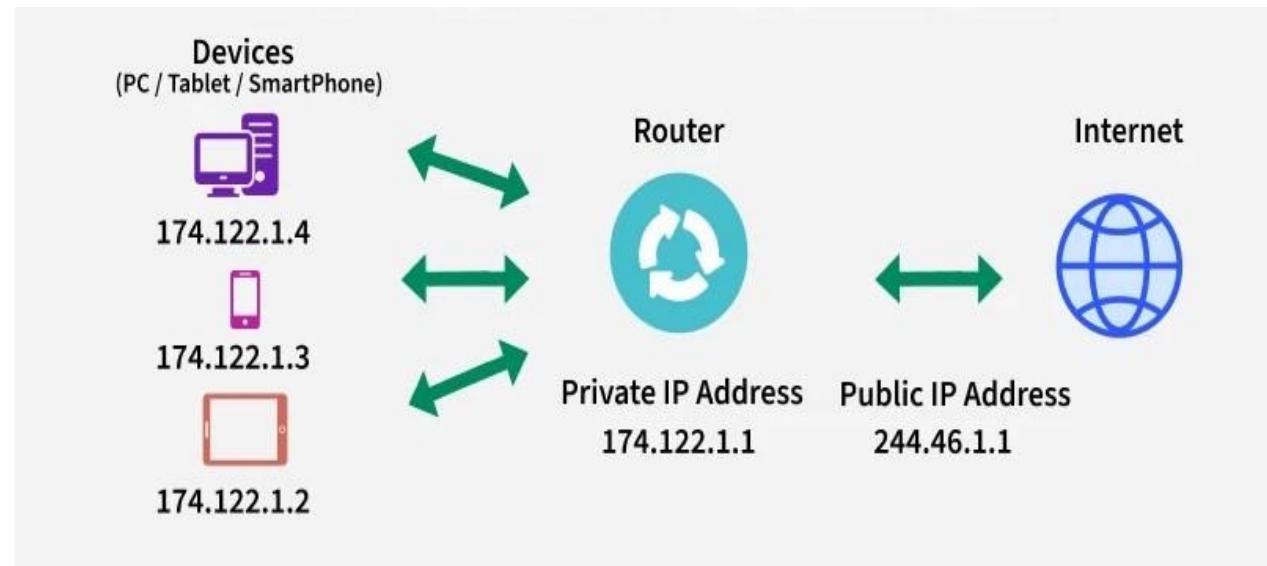
DHCP RELAY (IP HELPER-ADDRESS)

- Purpose:
 - DHCP messages are broadcasts — routers don't forward them by default.
 - DHCP Relay Agent (configured using ip helper-address) forwards requests to the DHCP server.



NAT OVERVIEW

- Network Address Translation
- Translates private IP addresses to public IPs
- Allows multiple internal devices to share limited public IP space
- Improves security by hiding internal network details



NAT TYPES

- Static NAT: One-to-one mapping between internal and external IPs
- Permanent translation manually configured
- Example:
 - ip nat inside source static 192.168.10.10 203.0.113.10
- Dynamic NAT: Many-to-many mapping using a pool of public IPs
- IPs are assigned from a pool when sessions are initiated
- Example:
 - ip nat pool PUBLIC_POOL 203.0.113.10 203.0.113.20 netmask 255.255.255.0
 - ip nat inside source list 1 pool PUBLIC_POOL
 - access-list 1 permit 192.168.10.0 0.0.0.255

NAT TYPES

- PAT (a.k.a. NAT Overload):
 - Many-to-one translation using port numbers
 - Multiple private IPs share a single public IP
 - Example:
 - ip nat inside source list 1 interface GigabitEthernet0/0/2

```
Router(config)#interface GigabitEthernet0/0/1
Router(config-if)#ip nat inside
Router(config-if)#exit
Router(config)#interface GigabitEthernet0/0/2
Router(config-if)#ip nat outside
Router(config-if)#exit
Router(config)#access-list 1 permit 10.0.0.4
Router(config)#access-list 1 permit 10.0.0.5
Router(config)#access-list 1 permit 10.0.0.6
Router(config)#ip nat inside source list 1 interface GigabitEthernet0/0/2
```

POP QUIZ:

Which UDP ports does DHCP use for communication?

- A. 80 and 443
- B. 67 and 68
- C. 110 and 143
- D. 22 and 23



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POP QUIZ:

What is the correct order of the DHCP lease process?

- A. Offer, Request, Acknowledge, Discover
- B. Discover, Offer, Request, Acknowledge
- C. Discover, Request, Offer, Acknowledge
- D. Request, Offer, Discover, Acknowledge



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What is the correct order of the DHCP lease process?

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- B. **Discover, Offer, Request, Acknowledge**
- C. Discover, Request, Offer, Acknowledge
- D. Request, Offer, Discover, Acknowledge



POP QUIZ:

What type of NAT allows multiple private IPs to share one public IP using port numbers?

- A. Static NAT
- B. Dynamic NAT
- C. PAT (NAT Overload)
- D. Reverse NAT



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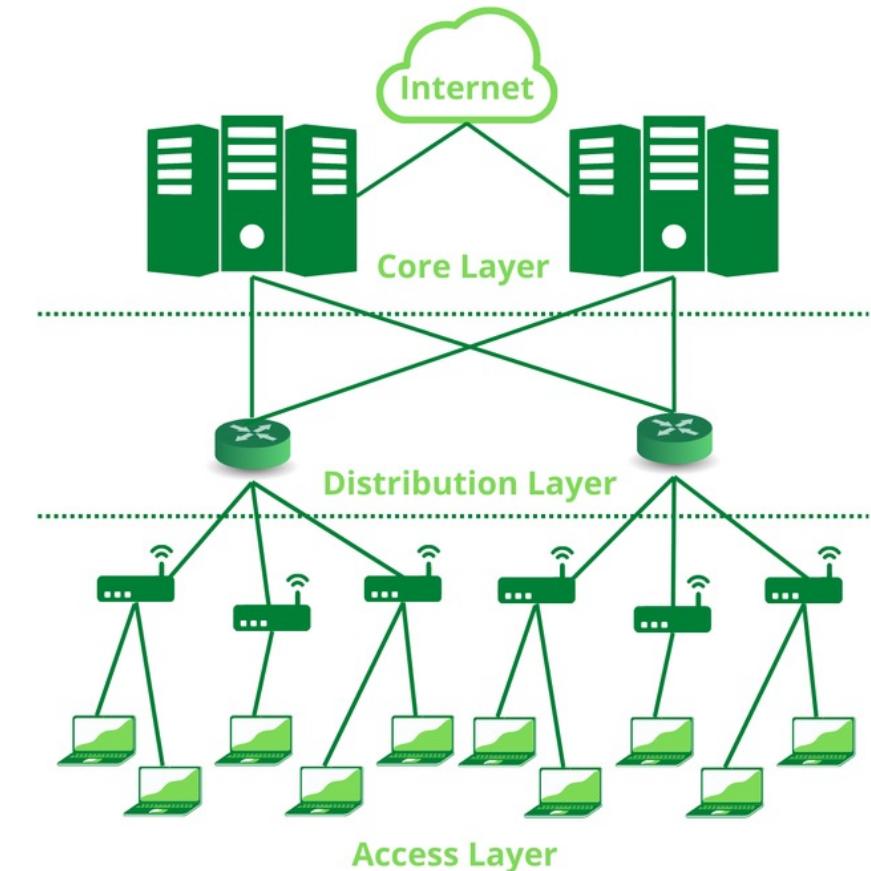
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DATA CENTER NETWORK ARCHITECTURE AND OPERATION

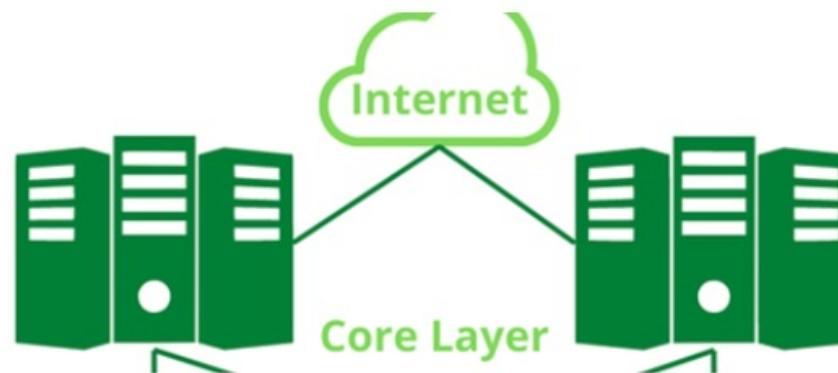
DATA CENTER NETWORK ARCHITECTURE OVERVIEW

- Hierarchical design provides scalability and performance
- Key layers:
 - Core Layer
 - Distribution Layer
 - Access / Edge Layer
 - Spine–Leaf Architecture (modern design)



CORE LAYER

- High-speed backbone of the network
- Provides fast, resilient connectivity between distribution switches
- Focus on throughput, redundancy, and minimal latency
- Typically no traffic filtering or packet manipulation



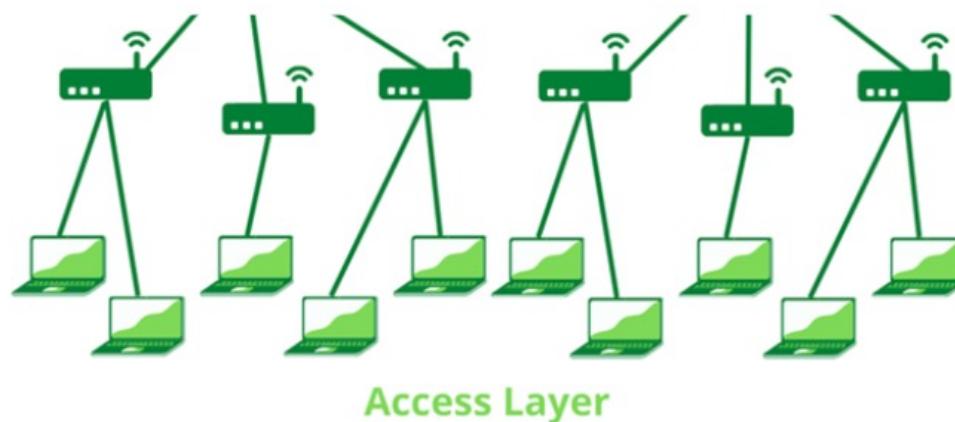
DISTRIBUTION LAYER

- Connects access (edge) layer to the core
- Enforces policy, security, and routing decisions
- Handles inter-VLAN routing, load balancing, and redundancy
- Often where first-hop redundancy protocols (HSRP/VRRP) operate



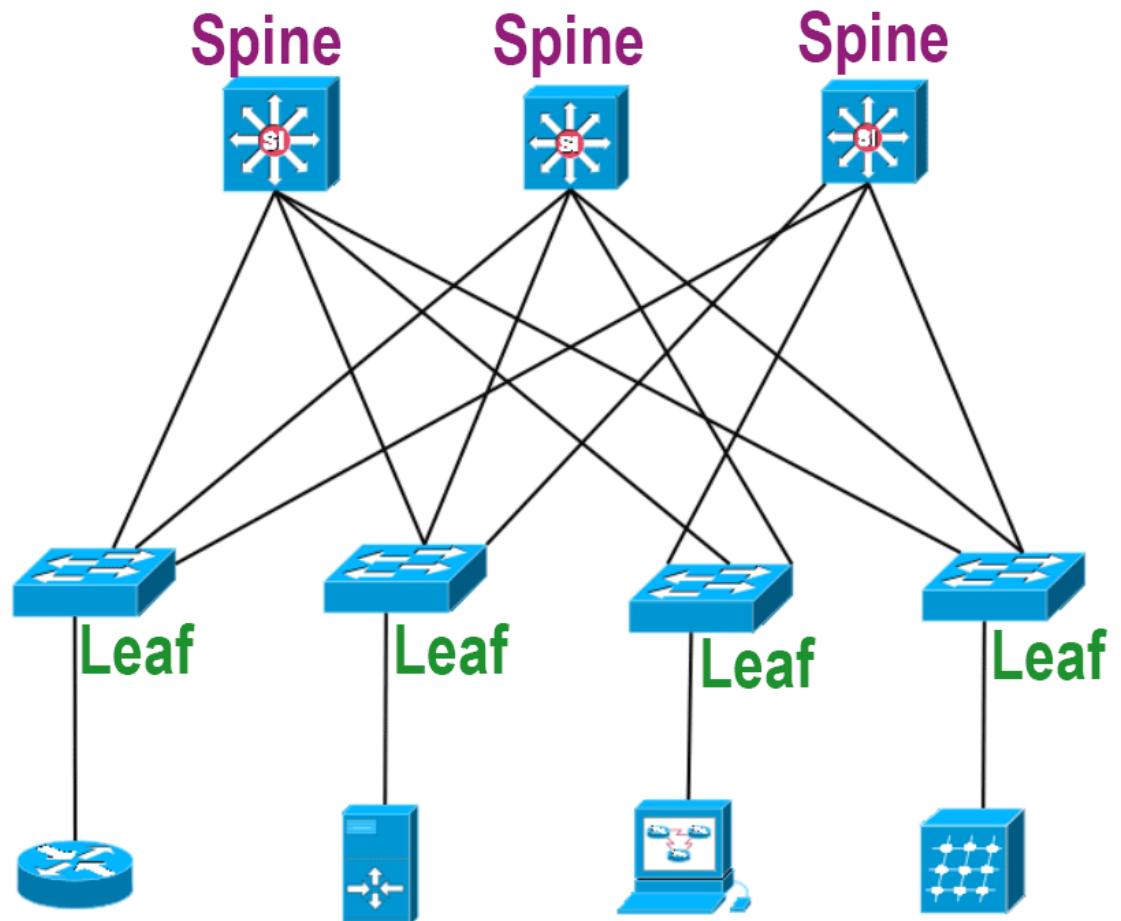
EDGE (ACCESS) LAYER

- Connects end devices, servers, and storage
- Provides port security, VLANs, QoS, and PoE
- L2 switching is common
- May use link aggregation for redundancy



SPINE–LEAF ARCHITECTURE

- Modern flat network design for data centers
- Spine switches: core backbone, high-speed, interconnect all leafs
- Leaf switches: connect to servers, storage, and other devices
- Every leaf connects to every spine — no single point of failure



DOCUMENTATION STANDARDS

- Accurate documentation = operational efficiency
- Includes:
- Network diagrams (logical & physical)
- IP address plans
- VLAN and subnet lists
- Routing & device configurations
- Change logs and version control
- Use centralized repositories (e.g., Git, CMDB, or wiki)



CHANGE & INCIDENT MANAGEMENT

- Change Management:
 - Assesses, approves, and schedules network changes
 - Uses Change Advisory Board (CAB) review
 - Tracks impact, risk, and rollback plans
- Incident Management:
 - Detects and resolves unplanned disruptions
 - Uses ticketing, priority levels, and post-incident review (PIR)
 - Goal: Stability + Continuous Improvement

POP QUIZ:

What is the main role of the core layer in a hierarchical network?

- A. Enforce access policies
- B. Provide high-speed, resilient backbone connectivity
- C. Manage VLAN assignments
- D. Handle DHCP requests



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POP QUIZ:

Which data center architecture eliminates single points of failure?

- A. Three-tier design
- B. Mesh topology
- C. Spine-Leaf architecture
- D. Star topology



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POP QUIZ:

At which layer are security and routing policies typically enforced?

- A. Core layer
- B. Access layer
- C. Distribution layer
- D. Spine layer



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POP QUIZ:

What is the main goal of Change Management in Network context?

- A. To troubleshoot network loops
- B. To approve and schedule controlled network modifications
- C. To monitor link aggregation status
- D. To configure routing protocols



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LAB 01: VLANS AND TRUNKING

- Goal: Segment network traffic using VLANs.
- Steps:
 - Create multiple VLANs on switches.
 - Configure access ports for end devices.
 - Set up trunk links between switches.
 - Verify VLAN isolation and trunk operation.

LAB 02: INTER-VLAN ROUTING

- Goal: Enable communication between VLANs.
- Steps:
 - Configure router-on-a-stick topology.
 - Create VLAN sub-interfaces on router.
 - Test inter-VLAN routing functionality.
 - Troubleshoot VLAN connectivity issues.

LAB 03: STP AND ETHERCHANNEL

- Goal: Implement redundancy and load balancing.
- Steps:
 - Configure Spanning Tree Protocol.
 - Create EtherChannel link aggregation.
 - Test failover scenarios.
 - Monitor STP topology changes