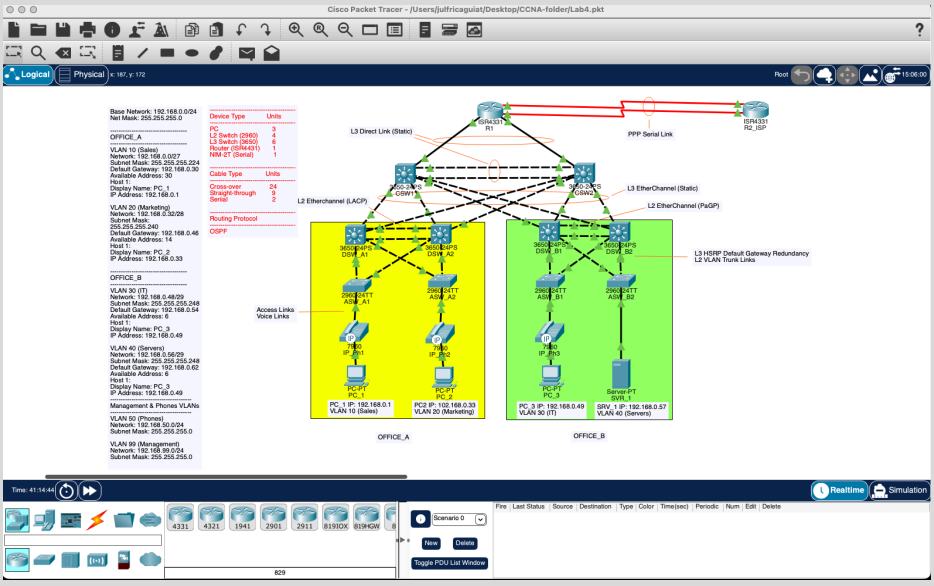
Lab 4: Implementing an Enterprise Campus Network with Redundancy, Dynamic Routing, and WAN Connectivity

This lab centers on designing and deploying an enterprise-grade campus network that follows industry best practices for scalability, resiliency, and structured growth. Using a hierarchical core–distribution–access architecture, the implementation incorporates **VLSM-based IP addressing** for efficient subnet allocation and **VTP** for centralized VLAN management. The network supports **voice VLANs** for IP telephony, a dedicated **management VLAN** for secure device administration, and native VLAN reassignment on trunk links to strengthen security. Link aggregation is achieved through multiple EtherChannel technologies, including **LACP, PAgP, and static Layer 2 and Layer 3 EtherChannels**, to increase bandwidth and provide path redundancy, while **Spanning Tree root alignment** ensures predictable Layer 2 traffic flow. **HSRP** is deployed at the distribution layer to deliver first-hop redundancy and maintain default gateway availability during failures. On the WAN edge, routers are connected via **PPP with CHAP authentication** to secure point-to-point communications, and **OSPF** is implemented across LAN and WAN segments to enable dynamic routing, rapid convergence, and default route advertisement. **NAT with PAT overload** is configured to translate private addresses into publicly routable IP space, allowing controlled internet access while preserving address resources. Collectively, this lab strengthens practical skills in enterprise network design, VLAN segmentation, high availability, dynamic routing, WAN technologies, and secure edge connectivity, closely reflecting modern production network environments.

Network Topology:



IMPLENTATION

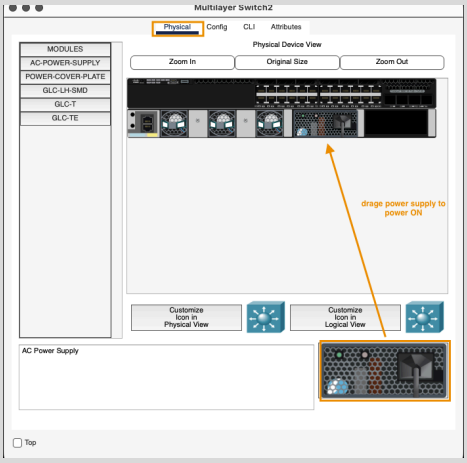
Note: The network is designed with both security and operational efficiency in mind, incorporating VLAN segmentation, controlled access, and clear physical/logical mappings:

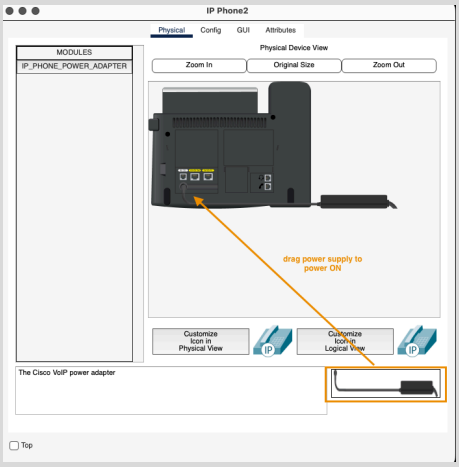
- VLAN 10 (Sales – OFFICE_A), VLAN 20 (Marketing – OFFICE_A), and VLAN 30 (IT – OFFICE_B) can access VLAN 40 (Servers – OFFICE_B) to ensure availability of shared server resources.
- VLAN 30 (IT – OFFICE_B) can access VLANs 10 (Sales) and 20 (Marketing) in OFFICE_A to support administrative and IT operations.
- VLANs 10 (Marketing – OFFICE_A) and 20 (Marketing – OFFICE_B) are restricted from accessing IT resources beyond their authorized scope, maintaining isolation of sensitive systems.
- This configuration enforces least privilege access, allowing required communications while preventing unauthorized cross-VLAN access.

Bill of Materials (BOM)

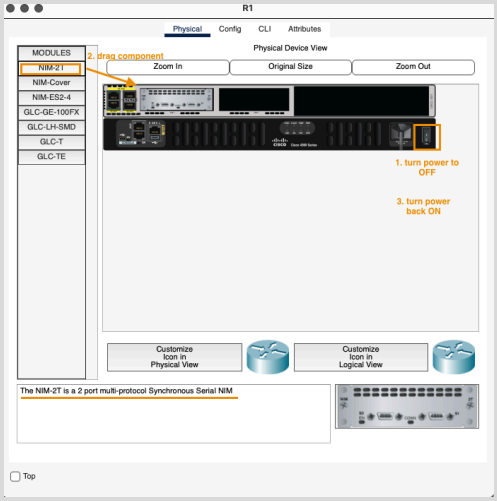
Category	Item	Units
Devices	PC	3
Devices	L2 Switch (Cisco 2960)	4
Devices	L3 Switch (Cisco 3650)	6
Devices	Router (Cisco ISR4431)	2 (Includes R2_ISP)
Devices	NIM-2T Serial Module	2 (Includes R2_ISP)
Cables	Cross-over Cable	24
Cables	Straight-through Cable	9
Cables	Serial Cable	2

Powering On Devices: Multi-Layer (L3) Switch & IP Phone





Adding NIM-2T Module to Router1 (R1) & Router2 (R2_ISP) for Serial PPP Connectivity



Network (VLAN) Addressing Plan: VLSM (Variable Length Subnet Mask) Based

Base Network

- Network: 192.168.0.0/24
- Subnet Mask: 255.255.255.0
- Design: VLSM for offices, management, and core EtherChannel links

End Device IP Assignment

VLAN	Name	Available Hosts	Host	IP Address	Subnet Mask	Default Gateway
10	Sales	30	PC_1	192.168.0.1	255.255.255.224 (/27)	192.168.0.30
20	Marketing	14	PC_2	192.168.0.33	255.255.255.240 (/28)	192.168.0.46
30	IT	6	PC_3	192.168.0.49	255.255.255.248 (/29)	192.168.0.54
40	Servers	6	DHCP	192.168.0.57	255.255.255.248 (/29)	192.168.0.62
40	Servers	6	DNS	192.168.0.58	255.255.255.248 (/29)	192.168.0.62

L3 Point-to-Point & Direct Connection IP Assignment

Link	Device A	IP A	Device B	IP B	Subnet	Type
DSW_A1 ↔ DSW_A2	DSW_A1 Po1	192.168.10.1	DSW_A2 Po1	192.168.10.2	/30	L2 LACP
DSW_B1 ↔ DSW_B2	DSW_B1 Po1	192.168.20.1	DSW_B2 Po1	192.168.20.2	/30	L2 PaGP
DSW_A1 ↔ CSW1	DSW_A1 Po10	192.168.10.5	CSW1 Po10	192.168.10.6	/30	L3 EtherChannel
DSW_A2 ↔ CSW1	DSW_A2 Po20	192.168.10.9	CSW1 Po20	192.168.10.10	/30	L3 EtherChannel
DSW_A1 ↔ CSW2	DSW_A1 Po11	192.168.10.13	CSW2 Po11	192.168.10.14	/30	L3 EtherChannel
DSW_A2 ↔ CSW2	DSW_A2 Po21	192.168.10.17	CSW2 Po21	192.168.10.18	/30	L3 EtherChannel
DSW_B1 ↔ CSW2	DSW_B1 Po30	192.168.20.5	CSW2 Po30	192.168.20.6	/30	L3 EtherChannel
DSW_B2 ↔ CSW2	DSW_B2 P40	192.168.20.9	CSW2 Po40	192.168.20.10	/30	L3 EtherChannel
DSW_B1 ↔ CSW1	DSW_B1 Po31	192.168.20.13	CSW1 Po31	192.168.20.14	/30	L3 EtherChannel
DSW_B2 ↔ CSW1	DSW_B2 Po41	192.168.20.17	CSW1 Po41	192.168.20.18	/30	L3 EtherChannel
CSW1 ↔ CSW2 (Primary)	CSW1 Gi1/0	192.168.30.1	CSW2 Gi1/0	192.168.30.2	/30	L3 P2P
CSW1 ↔ CSW2 (Backup)	CSW1 Gi1/1	192.168.30.5	CSW2 Gi1/1	192.168.30.6	/30	L3 P2P
CSW1 ↔ R1	CSW1 Gi0/0	192.168.30.9	R1 Gi0/0	192.168.30.10	/30	L3 Direct
CSW2 ↔ R1	CSW2 Gi0/1	192.168.30.13	R1 Gi0/1	192.168.30.14	/30	L3 Direct
R1 ↔ R2 (Primary ISP)	R1 S0/0/0	203.0.113.1	R2 S0/0/0	203.0.113.2	/30	Serial PPP
R1 ↔ R2 (Backup ISP)	R1 S0/0/1	203.0.113.5	R2 S0/0/1	203.0.113.6	/30	Serial PPP

SVI (Switch Virtual Interface) IP Assignment

VLAN ID	VLAN Name	Purpose	Subnet	Usable Host Range	Default Gateway
10	Sales	User data	192.168.0.0/27	192.168.0.1 – 192.168.0.30	192.168.0.30
20	Marketing	User data	192.168.0.32/28	192.168.0.33 – 192.168.0.46	192.168.0.46
30	IT	User data	192.168.0.48/29	192.168.0.49 – 192.168.0.54	192.168.0.54
40	Servers	Infrastructure (DHCP, DNS, etc.)	192.168.0.56/29	192.168.0.57 – 192.168.0.62	192.168.0.62
50	Phones	IP Phones / VoIP	192.168.0.64/29	192.168.0.65 – 192.168.0.70	192.168.0.70

Management Infrastructure IP Assignment (VLAN 99)

Device	Interface / SVI	IP Address	Notes / Role
CSW_A	VLAN 99	192.168.99.11	Core switch
CSW_B	VLAN 99	192.168.99.12	Core switch
DSW_A1	VLAN 99	192.168.99.3	Distribution switch (active/standby)
DSW_A2	VLAN 99	192.168.99.4	Distribution switch (active/standby)
DSW_B1	VLAN 99	192.168.99.23	Distribution switch (active/standby)
DSW_B2	VLAN 99	192.168.99.24	Distribution switch (active/standby)
ASW_A1	VLAN 99	192.168.99.1	Access switch
ASW_A2	VLAN 99	192.168.99.2	Access switch
ASW_B1	VLAN 99	192.168.99.21	Access switch
ASW_B2	VLAN 99	192.168.99.22	Access switch
R1 (Edge Router)	Loopback0	192.168.99.10	Management reachability
VLAN 99 Default Gateway	SVI on active DSW	192.168.99.254	HSRP VIP for management

Addressing Logic

OFFICE_A Switches
- .1 - .2 → Access (ASW_A1 & ASW_A2)
- .3 - .4 → Distribution (DSW_A1 & DSW_A2)

OFFICE_B Switches
- .21–.23 → Access (ASW_B1 & ASW_B2)
- .31–.34 → Distribution (DSW_B1 & DSW_B2)

Router & Core Switches
- .10 → Edge Router (R1)
- .11 - .12 → Core (CSW1 & CSW2)

HSRP VIP on active DSW
- .254 → Default gateway for VLAN 99

Network Connectivity and Configuration Reference : Cable to Port Connection

- Maps the physical and logical connectivity between all network devices.
- Identifies interface assignments, connection types, and cable methods for each link.
- Shows VLAN membership, IP addressing, and subnet usage for accurate traffic segmentation.
- Highlights redundancy, aggregation, and hierarchical network layering.
- Serves as a reference for configuration, lab implementation, and troubleshooting.

End Devices to IP Phone (Built-in) Switches

Device	Interface	Connected To		Cable / Mode / VLAN	IP Address
PC_1	Fa0	IP_Ph1	Fa	Straight-Through / Access / VLAN 10 - Sales	192.168.0.1/27
PC_2	Fa0	IP_Ph2	Fa	Straight-Through / Access / VLAN 20 - Marketing	192.168.0.32/28
PC_3	Fa0	IP_Ph3	Fa	Straight-Through / Access / VLAN 30 - IT	192.168.0.48/29
SVR_1	Fa0	ASW_B1	Fa0/1	Straight-Through / Access / VLAN 40 - Servers	192.168.0.56/29

IP Phone (Built-in) Switches to ASWs

Device	Interface	Connected To	Cable
IP_Ph1 (built-in Switch)	Fa	ASW_A1 Fa0/1	Straight-Through
IP_Ph2 (built-in Switch)	Fa	ASW_A2 Fa0/1	Straight-Through
IP_Ph3 (built-in Switch)	Fa	ASW_B1 Fa0/1	Straight-Through

Access Switches (ASWs) to DSWs (Trunk Links)

Device	Interface	Connected To	Cable / Type / Allowed VLANs & Native VLAN Assignment
ASW_A1	Gig0/1	DSW_A1 Gig1/0/1	Cross-Over / Trunk allowed VLAN 10, 20, 50, 99; Native VLAN 99
ASW_A1	Gig0/2	DSW_A2 Gig1/0/2	Cross-Over / Trunk allowed VLAN 10, 20, 50, 99; Native VLAN 99
ASW_A2	Gig0/1	DSW_A2 Gig1/0/1	Cross-Over / Trunk allowed VLAN 10, 20, 50, 99; Native VLAN 99
ASW_A2	Gig0/2	DSW_A1 Gig1/0/2	Cross-Over / Trunk allowed VLAN 10, 20, 50, 99; Native VLAN 99
ASW_B1	Gig0/1	DSW_B1 Gig1/0/1	Cross-Over / Trunk allowed VLAN 30, 40, 50, 99; Native VLAN 99
ASW_B1	Gig0/2	DSW_B2 Gig1/0/2	Cross-Over / Trunk allowed VLAN 30, 40, 50, 99; Native VLAN 99
ASW_B2	Gig0/1	DSW_B2 Gig1/0/1	Cross-Over / Trunk allowed VLAN 30, 40, 50, 99; Native VLAN 99
ASW_B2	Gig0/2	DSW_B2 Gig1/0/2	Cross-Over / Trunk allowed VLAN 30, 40, 50, 99; Native VLAN 99

Distribution Switches: DSWs to CSWs (Layer 3 EtherChannel Connections)

Device	Interface	Connected To		Cable \ Type	Subnet (P2P Connection)
DSW_A1	Gig1/0/5	CSW1	Gig1/0/5	Cross-Over \ Port-channel Po10 member	
DSW_A1	Po10	CSW1	Po10	Logical \ L3 EtherChannel (Static)	192.168.10.0/30
DSW_A1	Gig1/0/6	CSW2	Gig1/0/6	Cross-Over \ Port-channel Po11 member	
DSW_A1	Po11	CSW2	Po11	Logical \ L3 EtherChannel (Static)	192.168.10.4/30
DSW_A2	Gig1/0/7	CSW1	Gig1/0/7	Cross-Over \ Port-channel Po20 member	
DSW_A2	Po20	CSW1	Po20	Logical \ L3 EtherChannel (Static)	192.168.10.8/30
DSW_A2	Gig1/0/8	CSW1	Gig1/0/8	Cross-Over \ Port-channel Po21 member	

DSW_A2	Po21	CSW2	Po21	Logical \ L3 EtherChannel (Static)	192.168.10.12/30
DSW_B1	Gig1/0/5	CSW2	Gig1/0/5	Cross-Over \ Port-channel Po10 member	
DSW_B1	Po30	CSW2	Po30	Logical \ L3 EtherChannel (Static)	192.168.20.16/30
DSW_B1	Gig1/0/6	CSW1	Gig1/0/6	Cross-Over \ Port-channel Po11 member	
DSW_B1	Po31	CSW1	Po31	Logical \ L3 EtherChannel (Static)	192.168.20.20/30
DSW_B2	Gig1/0/7	CSW2	Gig1/0/7	Cross-Over \ Port-channel Po20 member	
DSW_B2	Po40	CSW2	Po40	Logical \ L3 EtherChannel (Static)	192.168.20.24/30
DSW_B2	Gig1/0/8	CSW1	Gig1/0/8	Cross-Over \ Port-channel Po21 member	
DSW_B2	Po41	CSW1	Po41	Logical \ L3 EtherChannel (Static)	192.168.20.28/30

Core Switches (CSWs) to R1

Device	Interface	Connected To	Cable / Type	Subnet (Direct Connection)
CSW1	Gig1/0/10	R1 Gi0/0/0	Straight-Through / L3 Direct (Static)	192.168.30.32/30
CSW2	Gig1/0/11	R1 Gi0/0/1	Straight-Through / L3 Direct (Static)	192.168.30.36/30

R1 (Enterprise Edge) to R2 (ISP)

Device	Interface	Connected To	Cable / Type	IP Address
R1	Serial0/0/0	R2 Serial0/0/0	Serial / L3 Direct (DCE)	203.0.113.1/30
R1	Serial0/0/1	R2 Serial0/0/1	Serial / L3 Direct (DCE)	203.0.113.5/30
R2	Serial0/0/0	R1 Serial0/0/0	Serial / L3 Direct (DTE)	203.0.113.2/30
R2	Serial0/0/1	R1 Serial0/0/1	Serial / L3 Direct (DTE)	203.0.113.6/30

Assign VLANs & Voice VLAN to Access Ports on ASWs

- Separates traffic types: Data (PCs) and voice (IP phones) are placed in different VLANs for security and QoS.
- Ensures proper tagging: Voice VLAN allows IP phones to tag traffic correctly while PCs use the data VLAN.
- Simplifies management: Each access port clearly knows which VLANs it carries, reducing misconfigurations.

ASW_A1 Configuration (OFFICE_A)

! Configure Access Switch

```
int f0/1
  sw access vlan 10
  sw voice vlan 50
  exit
```

ASW_A2 Configuration (OFFICE_A)

! Configure Access Switch

```
int f0/1
  sw access vlan 20
  sw voice vlan 50
  exit
```

ASW_B1 Configuration (OFFICE_B)

! Configure Access Switch

```
int f0/1
  sw access vlan 30
  sw voice vlan 50
  exit
```

ASW_B2 Configuration (OFFICE_B):

! Interface connected to SVR1

```
interface f0/1
  switchport mode access
  switchport access vlan 40       ! VLAN 40 – Servers
  no shutdown
  exit
```

Trunk Links (ASWs <-> DSWs & DSWs <-> DSWs) VLAN 99 (Mgmt) as Native VLAN on all trunk links

- Separates management traffic from user and voice VLANs, improving security and control.
- Ensures trunk negotiation and untagged traffic are handled consistently across switches.
- Simplifies network management, as all switches use the same native VLAN for infrastructure.

! ---------- OFFICE_A ----------

ASW_A1 Connected to DSWs

```
int range g0/1-2
  switchport mode trunk
  sw trunk native vlan 99
  switchport trunk allowed vlan 10,20,50,99
  switchport nonegotiate       ! Disable DTP
  exit
```

ASW_A2 Connected to DSWs

```
int range g0/1-2
  switchport mode trunk
  sw trunk native vlan 99
  switchport trunk allowed vlan 10,20,50,99
  switchport nonegotiate
  exit
```

DSW_A1 Connected to ASWs

```
int range g1/0/1-2
  switchport mode trunk
  sw trunk native vlan 99
  switchport trunk allowed vlan 10,20,50,99
  switchport nonegotiate
 exit
```

DSW_A2 Connected to ASWs

```
int range g1/0/1-2
  switchport mode trunk
  sw trunk native vlan 99
  switchport trunk allowed vlan 10,20,50,99
  switchport no negotiate
  exit
```

! ---------- OFFICE_B ----------

ASW_B1 Connected to DSWs

```
int range g0/1-2
  switchport mode trunk
  sw trunk native vlan 99
```

```
  switchport trunk allowed vlan 30,40,50,99
  switchport nonegotiate
  exit
```

ASW_B2 Connected to DSWs

```
int range g0/1-2
  switchport mode trunk
  sw trunk native vlan 99
  switchport trunk allowed vlan 30,40,50,99
  switchport nonegotiate
  exit
```

DSW_B1 Connected to ASWs

```
int range g1/0/1-2
  switchport mode trunk
  sw trunk native vlan 99
  switchport trunk allowed vlan 30,40,50,99
  switchport nonegotiate
  exit
```

DSW_B2 Connected to ASWs

```
int range g1/0/1-2
  sw trunk native vlan 99
  switchport mode trunk
  switchport trunk allowed vlan 30,40,50,99
  switchport nonegotiate
  exit
```

Complete Lab Trunk Port List

Device	Interface	Connected To	Type	Notes / Allowed VLANs
DSW_A1	G1/0/1	ASW_A1 G1/0/1	Trunk	Allow VLANs 10,20,50,99; Native VLAN 99
DSW_A1	G1/0/2	CSW_A G1/0/1	Trunk	Core uplink; Allow VLANs 10,20,50,99; Native VLAN 99
DSW_A2	G1/0/1	ASW_A2 G1/0/1	Trunk	Allow VLANs 10,20,50,99; Native VLAN 99
DSW_A2	G1/0/2	CSW_A G1/0/2	Trunk	Core uplink; Allow VLANs 10,20,50,99; Native VLAN 99
DSW_B1	G1/0/1	ASW_B1 G1/0/1	Trunk	Allow VLANs 30,40,50,99; Native VLAN 99
DSW_B1	G1/0/2	CSW_B G1/0/1	Trunk	Core uplink; Allow VLANs 30,40,50,99; Native VLAN 99
DSW_B2	G1/0/1	ASW_B2 G1/0/1	Trunk	Allow VLANs 30,40,50,99; Native VLAN 99
DSW_B2	G1/0/2	CSW_B G1/0/2	Trunk	Core uplink; Allow VLANs 30,40,50,99; Native VLAN 99
ASW_A1	G0/1	DSW_A1 G1/0/1	Trunk	Mirror of DSW_A1 trunk; Allow VLANs 10,20,50,99; Native VLAN 99
ASW_A1	G0/2	DSW_A2 G1/0/1	Trunk	Mirror of DSW_A2 trunk; Allow VLANs 10,20,50,99; Native VLAN 99
ASW_A2	G0/1	DSW_A1 G1/0/2	Trunk	Mirror of DSW_A1 trunk; Allow VLANs 10,20,50,99; Native VLAN 99
ASW_A2	G0/2	DSW_A2 G1/0/2	Trunk	Mirror of DSW_A2 trunk; Allow VLANs 10,20,50,99; Native VLAN 99
ASW_B1	G0/1	DSW_B1 G1/0/1	Trunk	Mirror of DSW_B1 trunk; Allow VLANs 30,40,50,99; Native VLAN 99
ASW_B1	G0/2	DSW_B2 G1/0/1	Trunk	Mirror of DSW_B2 trunk; Allow VLANs 30,40,50,99; Native VLAN 99
ASW_B2	G0/1	DSW_B1 G1/0/2	Trunk	Mirror of DSW_B1 trunk; Allow VLANs 30,40,50,99; Native VLAN 99
ASW_B2	G0/2	DSW_B2 G1/0/2	Trunk	Mirror of DSW_B2 trunk; Allow VLANs 30,40,50,99; Native VLAN 99

LACP (IEEE 802.3ad) Configuration – L2 Port-Channel Link Between DSW_A1 and DSW_A2

- Bundle parallel trunk links
- Use LACP (mode active)
- Configure Port-Channel as trunk
- active + active = forms faster
- active + passive = forms EtherChannel
- passive + passive = will NOT form an EtherChannel

on DSW_A1 (set to active):

```
! Configure physical interfaces for DSW channel
interface range gigabitEthernet1/0/3 - 4
  channel-group 1 mode active
  exit

! Configure Port-Channel interface for DSW channel
interface po1
  sw mode trunk
  sw trunk native vlan 99
  sw trunk allowed vlan 10,20,50,99
  sw noneg
  exit
```

on DSW1 (set to active or passive):

```
interface range gigabitEthernet1/0/3 - 4
  channel-group 1 mode active
  exit
interface po1
  sw mode trunk
  sw trunk native vlan 99
  sw trunk allowed vlan 10,20,50,99
  sw noneg
  exit
```

PaGP (Cisco Proprietary) – L2 Port-Channel Link Between DSW_B1 and DSW_B2

- Bundle parallel trunk links
- Use PAgP (desirable mode)
- desirable + desirable = forms faster (preferred in labs)
- desirable + auto = forms EtherChannel
- auto + auto = will NOT form an EtherChannel• Configure Port-Channel as a trunk

on DSW_B1 (set to desirable):

```
! Configure physical interfaces for DSW channel
interface range gigabitEthernet1/0/3 - 4
  channel-group 1 mode desirable
  no shutdown
  exit

! Configure Port-Channel interface
interface port-channel 1
  switchport mode trunk
  switchport trunk native vlan 99
  switchport trunk allowed vlan 30,40,50,99
  switchport noneg
  exit
```

on DSW_B2 (set to auto or desirable):

```
interface range gigabitEthernet1/0/3 - 4
  channel-group 1 mode desirable
  no shut
  exit
```

```
interface port-channel 1
switchport mode trunk
switchport trunk native vlan 99
switchport trunk allowed vlan 30,40,50,99
switchport noneg
exit
```

VTP VLAN Creation on DSWs & ASWs

- VTP propagates VLAN configuration across all switches in the same VTP domain.
- Reduces manual VLAN configuration on each switch, simplifying network management.
- Operates only on trunk links, not access ports.

! ---------- OFFICE_A ----------

on DSW_A2, ASW_A1, ASW_A2 (VTP Clients OFFICE_A)

! Configure vtp domain

```
vtp domain OfficeA
```

! Configure version

```
vtp version 2
```

! Configure Switch as VTP Clients

```
vtp mode client
```

on DSW_A1 (VTP server OFFICE_A: default)

! Configure domain

```
vtp domain OfficeA
```

! Configure version

```
vtp version 2
```

! Create VLANs (all created VLANs will be propagated to VTP clients)

```
vlan 10
  name Marketing
  exit
vlan 20
  name Sales
  exit
vlan 50
  name Phones
vlan 99
  name Management
  exit
```

! ---------- OFFICE_B ----------

on DSW_B2, ASW_B1, ASW_B2 (VTP Clients OFFICE_B)

```
vtp domain OfficeB
vtp version 2
vtp mode client
```

on DSW_B1 (VTP server OFFICE_B: default)

! Configure VTP domain

```
domain OfficeB
vtp version 2
```

! Create VLANs (all VLANs created will be propagated to VTP clients)

```
vlan 30
  name IT
  exit
```

```
vlan 40
  name Servers
  exit
vlan 50
  name Phones
  exit
vlan 99
  name Management
  exit
```

HSRP (Cisco Proprietary) & STP Root Priority Alignment – OFFICE_A & OFFICE_B

- Provides default gateway redundancy for hosts in a VLAN.
- Allows two or more routers/switches to share a single virtual IP address (VIP).
- Ensures high availability: if the active device fails, the standby device automatically takes over.

Note: HSRP uses priority values to determine the Active router. Higher = more preferred. Default is 100. Preemption is enabled with standby <group> preempt.

! ---------- OFFICE_A ----------

HSRP Design Rules:

- DSW_A1 = Active for VLAN 10 & VLAN 20
- DSW_A2 = Active for VLAN 50 & VLAN 99
- HSRP VIP = last usable IP in each subnet
- IP Routing enabled on both switches

DSW_A1 Configuration (Active for VLANs 10 & 20)

! Enable IP routing
```
ip routing
```

! VLAN 10 – Sales (192.168.0.0/27)
```
interface vlan 10
  ip address 192.168.0.29 255.255.255.224
  standby 10 ip 192.168.0.30
  standby 10 priority 110
  standby 10 preempt
  no shutdown
  exit
```

! VLAN 20 – Marketing (192.168.0.32/28)
```
interface vlan 20
  ip address 192.168.0.45 255.255.255.240
  standby 20 ip 192.168.0.46
  standby 20 priority 110
  standby 20 preempt
  no shutdown
  exit
```

! VLAN 50 – Phones (192.168.50.0/24)
```
interface vlan 50
  ip address 192.168.50.253 255.255.255.0
  standby 50 ip 192.168.50.254
  standby 50 priority 100
  no shutdown
  exit
```

! VLAN 99 – Management (192.168.99.0/24)
```
interface vlan 99
  ip address 192.168.99.3 255.255.255.0
  standby 99 ip 192.168.99.254
```

```
  standby 99 priority 100
  no shutdown
  exit
```

DSW_A2 Configuration (Active for VLANs 50 & 99)

! Enable IP routing

```
ip routing
```

! VLAN 10 – Sales (Standby)

```
interface vlan 10
  ip address 192.168.0.28 255.255.255.224
  standby 10 ip 192.168.0.30
  standby 10 priority 100
  no shutdown
  exit
```

! VLAN 20 – Marketing (Standby)

```
interface vlan 20
  ip address 192.168.0.44 255.255.255.240
  standby 20 ip 192.168.0.46
  standby 20 priority 100
  no shutdown
  exit
```

! VLAN 50 – Phones (Active)

```
interface vlan 50
  ip address 192.168.50.252 255.255.255.0
  standby 50 ip 192.168.50.254
  standby 50 priority 110
  standby 50 preempt
  no shutdown
  exit
```

! VLAN 99 – Management (Active)

```
interface vlan 99
  ip address 192.168.99.4 255.255.255.0
  standby 99 ip 192.168.99.254
  standby 99 priority 110
  standby 99 preempt
  no shutdown
  exit
```

STP Alignment on DSW_A1 (using Primary Root Designation)

!Align HSRP active with STP root for each VLAN:

```
spanning-tree vlan 10 root primary
spanning-tree vlan 20 root primary
```

STP Alignment on DSW_A2

```
spanning-tree vlan 50 root primary
spanning-tree vlan 99 root primary
```

! ---------- OFFICE_B ----------

HSRP Design Rules:

- DSW_B1 = Active for VLAN 30 & VLAN 40
- DSW_B2 = Active for VLAN 50 & VLAN 99
- HSRP VIP = last usable IP in each subnet
- IP Routing enabled on both switches

DSW_B1 Configuration (Active for VLANs 30 & 40)

```
! Enable IP routing
ip routing

! VLAN 30 – IT (192.168.0.48/29)
interface vlan 30
  ip address 192.168.0.53 255.255.255.248
  standby 30 ip 192.168.0.54
  standby 30 priority 110
  standby 30 preempt
  no shutdown
  exit
! VLAN 40 – Servers (192.168.0.56/29)
interface vlan 40
  ip address 192.168.0.61 255.255.255.248
  standby 40 ip 192.168.0.62
  standby 40 priority 110
  vrrp 40 preempt
  no shutdown
  exit

! VLAN 50 – Phones (192.168.50.0/24) - Backup
interface vlan 50
  ip address 192.168.50.251 255.255.255.0
  standby 50 ip 192.168.50.254
  standby 50 priority 100
  no shutdown
  exit

! VLAN 99 – Management (192.168.99.0/24) - Backup
interface vlan 99
  ip address 192.168.99.23 255.255.255.0
  standby 99 ip 192.168.99.254
  standby 99 priority 100
  no shutdown
  exit
```

DSW_A2 Configuration (Active for VLANs 50 & 99)

```
! Enable IP routing
ip routing

! VLAN 30 – IT (Standby)
interface vlan 30
  ip address 192.168.0.52 255.255.255.248
  standby 30 ip 192.168.0.54
  standby 30 priority 100
  standby 30 preempt
  no shutdown
  exit

! VLAN 40 – Servers (Standby)
interface vlan 40
  ip address 192.168.0.60 255.255.255.248
  standby 40 ip 192.168.0.62
  standby 40 priority 100
  standby 40 preempt
  no shutdown
  exit

! VLAN 50 – Phones (Master)
interface vlan 50
  ip address 192.168.50.250 255.255.255.0
```

```
  standby 50 ip 192.168.50.254
  standby 50 priority 110
  standby 50 preempt
  no shutdown
  exit
```

! VLAN 99 – Management (Master)

```
interface vlan 99
  ip address 192.168.99.24 255.255.255.0
  standby 99 ip 192.168.99.254
  standby 99 priority 110
  standby 99 preempt
  no shutdown
  exit
```

STP Alignment on DSW_B1 (using Lower Bridge Priority Assignment)

!Align HSRP active with STP root for each VLAN:

```
spanning-tree vlan 30 priority 4096   ! Active = STP Root
spanning-tree vlan 40 priority 4096   ! Active = STP Root
spanning-tree vlan 50 priority 8192   ! Standby = STP Backup
spanning-tree vlan 99 priority 8192   ! Standby = STP Backup
```

STP Alignment on DSW_B2

```
spanning-tree vlan 30 priority 8192   ! Standby = STP Backup
spanning-tree vlan 40 priority 8192   ! Standby = STP Backup
spanning-tree vlan 50 priority 4096   ! Active = STP Root
spanning-tree vlan 99 priority 4096   ! Active = STP Root
```

(NOT Supported in Packet Tracer) **VRRP (Open Standard) & STP Root Priority Alignment – OFFICE_B**

! ---------- OFFICE_B ----------

VRRP Design Rules (OFFICE_B)

- DSW_B1 = Master for VLAN 30 & VLAN 40
- DSW_B2 = Master for VLAN 50 & VLAN 99
- VRRP VIP = last usable IP in each subnet (same as HSRP VIP)
- IP routing enabled on both distribution switches

Note: VRRP uses priority values to determine the Master. Higher = more preferred. Default is 100. Preemption is enabled with vrrp <group> preempt.

DSW_B1 Configuration (Master for VLANs 30 & 40)

! Enable IP routing

```
ip routing
```

! VLAN 30 – IT (192.168.0.48/29)

```
interface vlan 30
  ip address 192.168.0.53 255.255.255.248
  vrrp 30 ip 192.168.0.54
  vrrp 30 priority 110
  vrrp 30 preempt
  no shutdown
  exit
```

! VLAN 40 – Servers (192.168.0.56/29)

```
interface vlan 40
  ip address 192.168.0.61 255.255.255.248
  vrrp 40 ip 192.168.0.62
  vrrp 40 priority 110
```

```
  vrrp 40 preempt
  no shutdown
  exit

! VLAN 50 – Phones (192.168.50.0/24) - Backup
interface vlan 50
  ip address 192.168.50.252 255.255.255.0
  vrrp 50 ip 192.168.50.254
  vrrp 50 priority 100
  no shutdown
  exit
! VLAN 99 – Management (192.168.99.0/24) - Backup
interface vlan 99
  ip address 192.168.99.252 255.255.255.0
  vrrp 99 ip 192.168.99.254
  vrrp 99 priority 100
  no shutdown
  exit
```

DSW_B2 Configuration (Master for VLANs 50 & 99)

```
! Enable IP routing
ip routing

! VLAN 30 – IT (Standby)
interface vlan 30
  ip address 192.168.0.52 255.255.255.248
  vrrp 30 ip 192.168.0.54
  vrrp 30 priority 100
  vrrp 30 preempt
  no shutdown
  exit

! VLAN 40 – Servers (Standby)
interface vlan 40
  ip address 192.168.0.60 255.255.255.248
  vrrp 40 ip 192.168.0.62
  vrrp 40 priority 100
  vrrp 40 preempt
  no shutdown
  exit

! VLAN 50 – Phones (Master)
interface vlan 50
  ip address 192.168.50.254 255.255.255.0
  vrrp 50 ip 192.168.50.254
  vrrp 50 priority 110
  vrrp 50 preempt
  no shutdown
  exit

! VLAN 99 – Management (Master)
interface vlan 99
  ip address 192.168.99.254 255.255.255.0
  vrrp 99 ip 192.168.99.254
  vrrp 99 priority 110
  vrrp 99 preempt
  no shutdown
  exit
```

STP Alignment on DSW_B1 (using Lower Bridge Priority Assignment)

!Align HSRP active with STP root for each VLAN:

```
spanning-tree vlan 30 priority 4096   ! VRRP Master = STP Root
spanning-tree vlan 40 priority 4096   ! VRRP Master = STP Root
spanning-tree vlan 50 priority 8192   ! VRRP Backup = STP Backup
spanning-tree vlan 99 priority 8192   ! VRRP Backup = STP Backup
```

STP Alignment on DSW_B2

```
spanning-tree vlan 30 priority 8192   ! VRRP Backup = STP Backup
spanning-tree vlan 40 priority 8192   ! VRRP Backup = STP Backup
spanning-tree vlan 50 priority 4096   ! VRRP Master = STP Root
spanning-tree vlan 99 priority 4096   ! VRRP Master = STP Root
```

Layer 3 Static EtherChannel Configuration (DSWs <-> CSWs)

- Dedicated L3 Links: Each core switch has a direct Layer 3 connection to the router (R1) to separate routing traffic from access and distribution layers.
- Point-to-Point Efficiency: Using /30 subnets for these links ensures minimal IP waste and simplifies routing.
- Redundancy: Two direct links (CSW1 ↔ R1 as primary, CSW2 ↔ R1 as backup) provide high availability and failover capability.
- OSPF Ready: These links can be advertised in a routing protocol like OSPF, ensuring dynamic routing between core and edge devices.

! ---------- OFFICE_A ----------

DSW_A1 & DSW_A2 ↔ CSW1

Link	Port-Channel	DSW IP	CSW1 IP	Subnet
DSW_A1 → CSW1	Po10	192.168.10.5	192.168.10.6	/30
CSW1 → DSW_A1	Po10	192.168.10.5	192.168.10.6	/30
DSW_A2 → CSW1	Po20	192.168.10.9	192.168.10.10	/30
CSW1 → DSW_A2	Po20	192.168.10.9	192.168.10.10	/30

DSW_A1 Configuration (to CSW1)

! Enable IP routing

```
ip routing
```

! Assign interface to Layer-3 EtherChannel

```
interface g1/0/5
 no switchport
 channel-group 10 mode on
 no shutdown
 exit
```

! Configure Port-Channel 10 as routed

```
interface port-channel10
 ip address 192.168.10.5 255.255.255.252
 no shutdown
 exit
```

CSW1 Configuration (to DSW_A1)

! DSW_A1 uplink

```
ip routing

interface g1/0/5
 no switchport
 channel-group 10 mode on
```

```
 no shutdown
 exit

interface port-channel10
 ip address 192.168.10.6 255.255.255.252
 no shutdown
 exit
```

DSW_A2 Configuration (to CSW1)

```
ip routing

interface g1/0/7
 no switchport
 channel-group 20 mode on
 no shutdown
 exit

interface port-channel20
 ip address 192.168.10.9 255.255.255.252
 no shutdown
 exit
```

CSW1 Configuration (to DSW_A2)

```
! DSW_A2 uplink
interface g1/0/7
 no switchport
 channel-group 20 mode on
 no shutdown
 exit
interface port-channel20
 ip address 192.168.10.10 255.255.255.252
 no shutdown
 exit
```

DSW_A1 & DSW_A2 ↔ CSW2

Link	Port-Channel	DSW IP	CSW2 IP	Subnet
DSW_A1 → CSW2	Po11	192.168.10.13	192.168.10.14	/30
CSW2 → DSW_A1	Po11	192.168.10.13	192.168.10.14	/30
DSW_A2 → CSW2	Po21	192.168.10.17	192.168.10.18	/30
CSW2 → DSW_A2	Po21	192.168.10.17	192.168.10.18	/30

DSW_A1 Configuration (to CSW2)

```
! Assign physical interface to Layer-3 EtherChannel
interface g1/0/6
 no switchport
 channel-group 11 mode on
 no shutdown
 exit

! Configure Port-Channel 11 as routed
interface port-channel11
 ip address 192.168.10.13 255.255.255.252
 no shutdown
 exit
```

CSW2 Configuration (to DSW_A1)

```
ip routing

interface g1/0/6
 no switchport
 channel-group 11 mode on
 no shutdown
 exit

interface port-channel11
 ip address 192.168.10.14 255.255.255.252
 no shutdown
 exit
```

DSW_A2 Configuration (to CSW2)

```
interface g1/0/8
 no switchport
 channel-group 21 mode on
 no shutdown
 exit

interface port-channel21
 ip address 192.168.10.17 255.255.255.252
 no shutdown
 exit
```

CSW2 Configuration (to DSW_A2)

```
interface g1/0/8
 no switchport
 channel-group 21 mode on
 no shutdown
 exit
interface port-channel21
 ip address 192.168.10.18 255.255.255.252
 no shutdown
 exit
```

! ---------- OFFICE_B ----------

DSW_B1 & DSW_B2 ↔ CSW2

Link	Port-Channel	DSW IP	CSW IP	Subnet
DSW_B1 → CSW2	Po10	192.168.20.5	192.168.20.6	/30
CSW2 → DSW_B1	Po10	192.168.20.5	192.168.20.6	/30
DSW_B2 → CSW2	Po20	192.168.20.9	192.168.20.10	/30
CSW2 → DSW_B2	Po20	192.168.20.9	192.168.20.10	/30

DSW_B1 Configuration (to CSW2)

```
ip routing

interface g1/0/5
 no switchport
 channel-group 30 mode on
 no shutdown
 exit

interface port-channel30
 ip address 192.168.20.5 255.255.255.252
 no shutdown
```

```
 exit
```

CSW2 Configuration (to DSW_B1)

```
interface g1/0/5
 channel-group 30 mode on
 no shutdown
 exit
interface port-channel30
 no switchport
 ip address 192.168.20.6 255.255.255.252
 no shutdown
 exit
```

DSW_B2 Configuration (to CSW2)

```
interface g1/0/7
 channel-group 40 mode on
 no shutdown
 exit

interface port-channel40
 no switchport
 ip address 192.168.20.9 255.255.255.252
 no shutdown
 exit
```

CSW2 Configuration (to DSW_B2)

```
interface g1/0/7
 channel-group 40 mode on
 no shutdown
 exit

interface port-channel40
 no switchport
 ip address 192.168.20.10 255.255.255.252
 no shutdown
 exit
```

DSW_B1 & DSW_B2 ↔ CSW2

Link	Port-Channel	DSW IP	CSW IP	Subnet
DSW_B1 → CSW1	Po30	192.168.20.13	192.168.20.14	/30
CSW1 → DSW_B1	Po30	192.168.20.13	192.168.20.14	/30
DSW_B2 → CSW1	Po40	192.168.20.17	192.168.20.18	/30
CSW1 → DSW_B2	Po40	192.168.20.17	192.168.20.18	/30

DSW_B1 Configuration (to CSW1)

```
interface g1/0/6
 channel-group 31 mode on
 no shutdown
 exit

interface port-channel31
 no switchport
 ip address 192.168.20.13 255.255.255.252
 no shutdown
 exit
```

CSW1 Configuration (to DSW_B1)

```
interface g1/0/6
 channel-group 31 mode on
```

```
 no shutdown
 exit

interface port-channel31
 no switchport
 ip address 192.168.20.14 255.255.255.252
 no shutdown
 exit
```

DSW_B2 Configuration (to CSW1)

```
interface g1/0/8
 channel-group 41 mode on
 no shutdown
 exit

interface port-channel41
 no switchport
 ip address 192.168.20.17 255.255.255.252
 no shutdown
 exit
```

CSW1 Configuration (to DSW_B2)

```
interface g1/0/8
 channel-group 41 mode on
 no shutdown
 exit

interface port-channel41
 no switchport
 ip address 192.168.20.18 255.255.255.252
 no shutdown
 exit
```

Core-to-Core Layer 3 Point-to-Point Links (CSW1 ↔ CSW2)

- Eliminates Layer 2 dependencies (STP, trunking, native VLAN concerns) by using pure Layer 3 routing between core switches.
- Provides deterministic redundancy: each point-to-point link is independently routed that can be used for dynamic protocols (OSPF) to select the optimal path and fail over automatically.
- Simplifies troubleshooting and scales better, as core links behave like routed WAN links rather than extended VLANs.

Link Role	CSW1 Interface	CSW1 IP	CSW2 Interface	CSW2 IP	Subnet	Routing
Primary	Gi1/0/1	192.168.30.1	Gi1/0/1	192.168.30.2	192.168.30.0/30	OSPF Area 0
Backup	Gi1/0/2	192.168.30.5	Gi1/0/2	192.168.30.6	192.168.30.4/30	OSPF Area 0

CSW1 Configuration (to CSW2)

```
! Enable IP routing
ip routing

! Configure first direct L3 link (Primary)
interface g1/0/1
  no switchport
  ip address 192.168.30.1 255.255.255.252
  description Core CSW1 -> CSW2 Primary
  no shutdown
  exit
```

! Configure second direct L3 link (Backup)
```
interface g1/0/2
  description Core CSW1 -> CSW2 Backup
  no switchport
  ip address 192.168.30.5 255.255.255.252
  no shutdown
  exit
```

CSW2 Configuration to (CSW1)

! Enable IP routing
```
ip routing
```

! Configure first direct L3 link (Primary)
```
interface g1/0/1
  description Core CSW2 -> CSW1 Primary
  no switchport
  ip address 192.168.30.2 255.255.255.252
  no shutdown
  exit
```

! Configure second direct L3 link (Backup)
```
interface g1/0/2
  description Core CSW2 -> CSW1 Backup
  no switchport
  ip address 192.168.30.6 255.255.255.252
  no shutdown
  exit
```

Core-to-Router Layer 3 Point-to-Point Links (CSW1 / CSW2 ↔ R1)

Link Role	CSW Interface	CSW IP	R1 Interface	R1 IP	Subnet	Routing
Primary	CSW1 Gi1/0/5	192.168.30.9	R1 Gi0/0/1	192.168.30.10	192.168.30.8/30	OSPF Area 0
Backup	CSW2 Gi1/0/5	192.168.30.13	R1 Gi0/0/2	192.168.30.14	192.168.30.12/30	OSPF Area 0

CSW1 → R1 (Primary Link)
```
ip routing

interface gi1/0/10
 description CSW1 -> R1 Primary
 no switchport
 ip address 192.168.30.9 255.255.255.252
 no shutdown
 exit
```

R1 → CSW1
```
ip routing

interface gi0/0/0
 description R1 -> CSW1 Primary
 ip address 192.168.30.10 255.255.255.252
 no shutdown
 exit
```

CSW2 → R1 (Backup Link)
```
conf t
ip routing

interface gi1/0/11
```

```
 description CSW2 -> R1 Backup
 no switchport
 ip address 192.168.30.13 255.255.255.252
 no shutdown
 exit
```

R1 → CSW2

```
ip routing

interface gi0/0/1
 description R1 -> CSW2 Backup
 ip address 192.168.30.14 255.255.255.252
 no shutdown
 exit
```

PPP w/ CHAP Authentication - R1 ↔ R2 Redundant L2 Serial Point-to-Point Links (DCE/DTE Roles)

- Redundant WAN links provide failover if the primary link goes down.
- DCE side (R1) provides the clock for both primary and backup serial links.
- HLDC provides framing and reliable data transmission over point-to-point serial links.

Link	R1 Interface	R1 IP	R2 Interface	R2 IP	Subnet	DCE/DTE
Primary	S0/0/0	203.0.113.1	S0/0/0	203.0.113.2	255.255.255.252	R1 = DCE
Backup	S0/0/1	203.0.113.5	S0/0/1	203.0.113.6	255.255.255.252	R1 = DCE

R1 Configuration (DCE)

! Create username & password for CHAP authentication: username must match the **neighbor's hostname**.

```
username R2_ISP password p@ss123              ! Use R2_ISP hostname and password

! Configure interface
interface s0/1/0
 encapsulation ppp
 ppp authentication chap
 ip address 203.0.113.1 255.255.255.252
 clock rate 64000
 no shutdown

interface s0/1/1
 encapsulation ppp
 ppp authentication chap
 ip address 203.0.113.5 255.255.255.252
 clock rate 64000
 no shutdown
```

R2 Configuration (DTE)

! Create username & password for CHAP authentication: username must match the **neighbor's hostname**.

```
username R1 password p@ss123                  ! Use R1 hostname and password

interface s0/1/0
 encapsulation ppp
 ppp authentication chap
 ip address 203.0.113.2 255.255.255.252
 no shutdown

interface s0/1/1
 encapsulation ppp
 ppp authentication chap
 ip address 203.0.113.6 255.255.255.252
 no shutdown
```

```
! Link 1 to be Primary Path
ip route 0.0.0.0 0.0.0.0 203.0.113.1              ! Link 1 (Primary)
ip route 0.0.0.0 0.0.0.0 203.0.113.5 5            ! Floating Static Route - AD set to 5 (Backup)
```

OSPF Implementation – Enterprise LAN & WAN & Default Route Advertisement

- Enables dynamic routing across all VLANs, distribution, and core switches.
- Uses network statements to include multiple subnets per device, simplifying configuration.
- Advertises internal LAN subnets and redundant WAN links to ensure reachability and failover.
- Propagates default route from the enterprise edge router to internal devices for Internet access.

R1 Configuration (Enterprise Edge / ISP Connection)

```
! Enable OSPF
router ospf 1
 router-id 1.1.1.1

! LAN links (to core switches)
network 192.168.30.8 0.0.0.255 area 0       ! R1 to CSW1 (Primary)
network 192.168.30.12 0.0.0.255 area 0     ! R1 to CSW1 (Backup)

! WAN links to ISP (primary & backup)
network 203.0.113.0 0.0.0.3 area 0          ! Primary WAN link
network 203.0.113.4 0.0.0.3 area 0          ! Backup WAN link

! Advertise default route to internal OSPF domain
ip route 0.0.0.0 0.0.0.0 203.0.113.2
ip route 0.0.0.0 0.0.0.0 203.0.113.6 120  ! Floating Static Route - AD set to 120 (Backup route)

router ospf 1
 default-information originate
```

CSW1 Configuration (Core Switch)

```
! Assign router ID
router ospf 1
 router-id 2.2.2.2

! All Port-Channels to DSWs
network 192.168.10.4 0.0.0.3 area 0         ! Po10 links to DSW_A1
network 192.168.10.8 0.0.0.3 area 0         ! Po20 links to DSW_A2
network 192.168.20.12 0.0.0.3 area 0        ! Po31 links to DSW_B1
network 192.168.20.16 0.0.0.3 area 0        ! Po41 links to DSW_B2

! Core to Core Links
network 192.168.30.0 0.0.0.3 area 0         ! CSW1 to CSW2 (Primary)
network 192.168.30.4 0.0.0.3 area 0         ! CSW2 to CSW1 (Backup)

! Link to R1
network 192.168.30.8 0.0.0.255 area 0       ! CSW1 to R1 (Primary)
```

CSW2 (Core Switch)

```
router ospf 1
 router-id 3.3.3.3

network 192.168.10.12 0.0.0.3 area 0        ! Po11 links to DSW_A1
network 192.168.10.16 0.0.0.3 area 0        ! Po21 links to DSW_A2
network 192.168.20.4 0.0.0.3 area 0         ! Po30 links to DSW_B1
network 192.168.20.8 0.0.0.3 area 0         ! Po40 links to DSW_B2
```

```
network 192.168.30.0 0.0.0.3 area 0        ! CSW2 to CSW1 (Primary)
network 192.168.30.4 0.0.0.3 area 0        ! CSW1 to CSW2 (backup)

network 192.168.30.12 0.0.0.255 area 0     ! CSW2 to R1 (Backup)
```

CSW1 to be the OSPF Primary Route

on CSW1

```
interface gi1/0/10
 ip ospf cost 10
```

on CSW2

```
interface gi1/0/5
 ip ospf cost 100
```

! ---------- OFFICE_A ----------

DSW_A1

```
router ospf 1
 router-id 4.4.4.4

! VLAN SVIs
network 192.168.0.0 0.0.0.31 area 0        ! VLAN 10 - Sales (192.168.0.0/27)
network 192.168.0.32 0.0.0.15 area 0       ! VLAN 20 - Marketing (192.168.0.32/28)
network 192.168.50.0 0.0.0.255 area 0      ! VLAN 50 - Phones
network 192.168.99.0 0.0.0.255 area 0      ! VLAN 99 - Management
! Port-Channels to CSWs
network 192.168.10.4 0.0.0.3 area 0        ! Po10 links to CSW1
network 192.168.10.12 0.0.0.3 area 0       ! Po11 links to CSW2
```

DSW_A2

```
router ospf 1
 router-id 5.5.5.5

network 192.168.0.0 0.0.0.31 area 0        ! VLAN 10
network 192.168.0.32 0.0.0.15 area 0       ! VLAN 20
network 192.168.50.0 0.0.0.255 area 0      ! VLAN 50
network 192.168.99.0 0.0.0.255 area 0      ! VLAN 99

! Port-Channels to CSWs
network 192.168.10.8 0.0.0.3 area 0        ! Po20 links to CSW1
network 192.168.10.16 0.0.0.3 area 0       ! Po21 links to CSW2
```

! ---------- OFFICE_B ----------

DSW_B1

```
router ospf 1
 router-id 6.6.6.6

network 192.168.0.48 0.0.0.7 area 0        ! VLAN 30 - IT (192.168.0.48/29)
network 192.168.0.56 0.0.0.7 area 0        ! VLAN 40 - Servers (192.168.0.56/29)
network 192.168.50.0 0.0.0.255 area 0      ! VLAN 50 - Phones
network 192.168.99.0 0.0.0.255 area 0      ! VLAN 99 - Management

! Port-Channels to CSWs
network 192.168.20.4 0.0.0.3 area 0        ! Po30 links to CSW2
network 192.168.20.12 0.0.0.3 area 0       ! Po31 links to CSW1
```

DSW_B2

```
router ospf 1
 router-id 7.7.7.7

network 192.168.0.48 0.0.0.7 area 0        ! VLAN 30
network 192.168.0.56 0.0.0.7 area 0        ! VLAN 40
network 192.168.50.0 0.0.0.255 area 0      ! VLAN 50
network 192.168.99.0 0.0.0.255 area 0      ! VLAN 99

! Port-Channels to CSWs
network 192.168.20.8 0.0.0.3 area 0        ! Po40 links to CSW2
network 192.168.20.16 0.0.0.3 area 0       ! Po41 links to CSW1
```

R1 NAT Configuration (IPv4 Internet Access)

- Allows internal IPv4 networks (LANs behind CSWs) to access external networks (simulated Internet).
- Translates private IP addresses to a public IP (or a single lab IP) for outbound traffic.
- Provides redundancy and ensures that internal hosts don't need public IPs.

Device	Interface	Role	IP Address / Subnet	Notes
R1	Gi0/0/1	NAT Inside	192.168.30.10/30	Connected to CSW1 (LAN, Office A/B via CSWs)
R1	Gi0/0/2	NAT Inside	192.168.30.14/30	Connected to CSW2 (LAN, Office B/A via CSWs)
R1	Gi0/1	NAT Outside	203.0.113.1/30	Connected to ISP (R2)

R1 (Edge Router)

```
! Configure inside interfaces (LAN-facing)
interface g0/0/0
ip nat inside
 no shutdown
 exit

interface g0/0/1
 ip nat inside
 no shutdown
 exit

! Configure outside interface (WAN-facing)
interface s0/1/0
 ip nat outside
 no shutdown
 exit

interface s0/1/1
 ip nat outside
 no shutdown
 exit

! Define ACL: the internal networks to be translated
access-list 1 permit 192.168.0.0 0.0.0.255        ! Permits all subnets (VLAN: 10, 20, 30, 40)
access-list 1 permit 192.168.50.0 0.0.0.255
access-list 1 permit 192.168.99.0 0.0.0.255

! Define NAT overload / PAT (1 public IP for multiple private IPs)
ip nat inside source list 1 interface s0/1/0 overload
ip nat inside source list 1 interface s0/1/1 overload
```

Access Control Lists (ACLs): Extended Named ACL

- Implemented extended ACLs to restrict unauthorized traffic between VLANs, enforcing least privilege access. Applied the ACL as close to the source as possible since it is an Extended ACL.
- ACLs applied inbound on source VLAN SVIs of Layer-3 switches to block Sales (VLAN 10) and Marketing (VLAN 20) from accessing IT resources (VLAN 30).
- Wildcard masks used to precisely define source and destination subnets, while permitting all other traffic.
- Deployed on redundant distribution switches to ensure consistent enforcement across all paths.

on DSWs

! Create extended ACL to block Sales & Marketing from reaching IT

```
ip access-list extended BLOCK_OUTGOING_TO_IT
  deny ip 192.168.0.0 0.0.0.31 192.168.0.48 0.0.0.7    ! Sales → IT
  deny ip 192.168.0.32 0.0.0.15 192.168.0.48 0.0.0.7   ! Marketing → IT
  permit ip any any                                    ! Allow all other traffic
```

! Apply ACL inbound on source VLAN SVIs for filtering before routing

```
interface vlan 10
  ip access-group BLOCK_OUTGOING_TO_IT  in
  exit
interface vlan 20
  ip access-group BLOCK_OUTGOING_TO_IT  in
  exit
```

Save Configuration on All Devices

! Save configurations

```
do write memory
```

Verification & Testing

VLAN & Access Port Configuration

Verify: Layer 2 segmentation is working.

Command	Purpose / What it Shows
show vlan brief	Confirms VLAN creation and port assignments.
show interfaces switchport	Verifies access VLAN and voice VLAN on ports.
show mac address-table	Confirms hosts are learning on the correct VLAN.

Voice VLAN

Verify: Phones and data traffic are separated.

Command	Purpose / What it Shows
show interfaces switchport	Displays the configured voice VLAN.
show running-config interface <port>	Confirms switchport voice vlan is applied.

Trunk Links + Native VLAN 99

Verify: VLAN 99 is native VLAN (untagged)

Command	Purpose / What it Shows
show interfaces trunk	Verifies trunking status and allowed VLANs.

show interfaces <int> switchport	Confirms trunk mode and native VLAN.
show running-config interface <int>	Validates switchport trunk native vlan 99.

VTP (VLAN Trunking Protocol)

Verify: Propagated VLANs in VTP clients

Command	Purpose / What it Shows
show vtp status	Displays domain name, mode, revision number.
show vtp counters	Shows VTP advertisements sent/received.
show vlan brief	Confirms VLAN propagation.

EtherChannel (LACP & PaGP)

Verify: Port-Channel status & protocol used

Command	Purpose / What it Shows
show etherchannel summary	**MOST IMPORTANT** — shows if bundle is up (P).
show etherchannel port-channel	Displays logical port details.
show interfaces port-channel <#>	Confirms Layer 2/3 status.
show etherchannel summary	Shows LACP or PAgP.
show pagp neighbor	Verifies PAgP adjacency.
show lacp neighbor	Verifies LACP adjacency.

Spanning Tree (Primary Root Alignment)

Verify: DSW_A1 should appear as Root Bridge

Command	Purpose / What it Shows
show spanning-tree vlan <id>	Displays root bridge and port roles.
show spanning-tree root	Quick root bridge summary.
show spanning-tree blockedports	Identifies blocked links.

HSRP (First Hop Redundancy)

Verify: One DSW → Active, Other DSW → Standby

Command	Purpose / What it Shows
show standby brief	**Best command** — shows Active/Standby routers.
show standby	Detailed HSRP timers and priorities.
show ip route	Confirms virtual gateway is used.

Layer 3 EtherChannel

Verify: Port-channel status

Command	Purpose / What it Shows
show etherchannel summary	Confirms routed port-channel is up.
show ip interface brief	Should show Port-channel with IP.
show running-config interface port-channel <#>	Confirms no switchport.

PPP with CHAP Authentication

Verify: LCP Open, Authentication successful

Command	Purpose / What it Shows
show interfaces serial <id>	Confirms encapsulation = PPP.
show ppp all	Displays PPP state.
debug ppp authentication	Real-time CHAP success/failure. *(Use carefully)*

OSPF (LAN & Default Route)

Verify: Neighbor adjacency

Command	Purpose
show ip ospf neighbor	**MOST IMPORTANT** — adjacency must be FULL.

OSPF Routes

Command	Purpose
show ip route ospf	Shows learned OSPF routes (O).
show ip protocols	Confirms OSPF process and networks.
show ip ospf interface brief	Quick OSPF interface check.

Default Route Advertisement: No neighbors = OSPF is NOT working.

Command	Purpose
show ip route	Should see O*E2 or O* default route.

NAT (PAT Overload + Failover Ready)

Verify: Translated global addresses. Note: Always generate traffic before checking.

Command	Purpose / What it Shows
show ip nat translations	Displays private → public mappings.
show ip nat statistics	Shows hits/misses.
show access-lists	Confirms internal networks are matched.
`show run	section nat`

Routing & Failover Validation

Test: Shut the primary link → confirm traffic still flows.

Command	Purpose / What it Shows
show ip route	Identifies active default route.
show track	Displays tracked interface state.
show ip sla statistics	Verifies reachability tests.

ACL Verification Commands

Command	Purpose / What It Shows
show access-lists	Displays all ACLs configured on the device, including **hit counts** for each rule.
show access-lists <ACL_NAME>	Shows details of a specific ACL (like BLOCK_OUTGOING_TO_IT) and the number of hits per line.
show ip interface	Displays which ACLs are applied inbound/outbound on each interface or SVI.

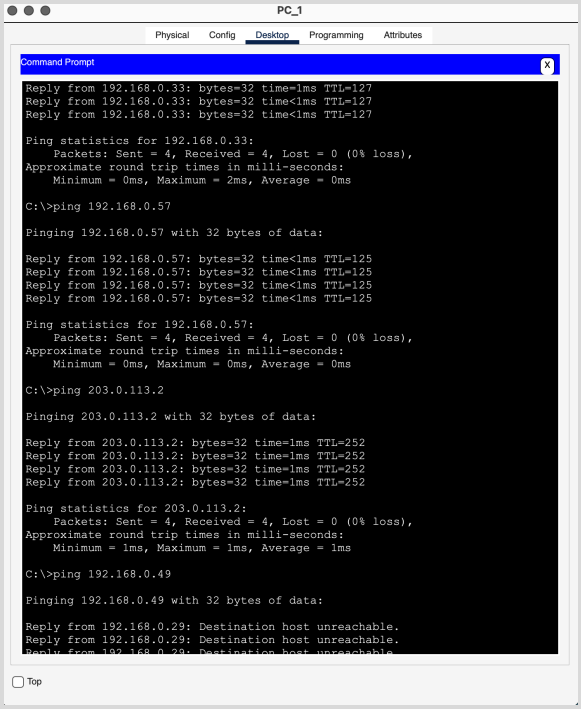
`show running-config	include access-group`	
ping <destination>	Tests connectivity to verify whether ACLs are **blocking or permitting traffic** as intended.
traceroute <destination>	Helps verify the path and whether ACLs are affecting traffic flow.
debug ip packet	(Optional) Shows real-time packet matches and drops for troubleshooting ACL behavior.

Successful Ping from PC_1 VLAN 10 : Sales

`ping 192.168.0.33`	PC_2 :	VLAN 20 - Marketing
`Ping 192.168.0.57`	SVR_1 :	VLAN 40 - Servers
`ping 203.0.113.2`	R2_ISP:	Internet

Unsuccessful Ping by Design (ACL Enforced):

`ping 192.168.0.49`	PC_3:	VLAN 30 - IT



Successful NAT Translation: