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<u>**PROJECT REPORT**</u>

<u>**TITLE:**</u>

Enterprise Network Implementation with DTP, VTP, EtherChannel, STP, OSPF, NAT, and VPN using GNS3

1. ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my instructor and peers for their continuous support and guidance throughout this project. Special thanks to the open-source community of GNS3 for providing a robust platform that made this complex enterprise network simulation possible.

2. ABSTRACT

This project demonstrates the design and implementation of a secure, scalable, and redundant enterprise network using GNS3. It integrates advanced Layer 2 technologies like VTP, STP, and EtherChannel for local area network stability. Furthermore, it employs Layer 3 routing via OSPF and ensures secure remote connectivity through a Site-to-Site IPsec VPN tunnel, providing a comprehensive solution for modern business communication needs

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4. INTRODUCTION

In the modern digital era, enterprise networks require high availability, security, and efficient data routing. This project focuses on building such a network from scratch, simulating a Head Office (HQ) and a Branch Office connected via a secure VPN over an ISP backbone.

5. BACKGROUND / LITERATURE REVIEW

Traditional networks often face issues with scalability and manual configuration errors. Technologies like Virtual Trunking Protocol (VTP) and Dynamic Trunking Protocol (DTP) were developed to automate VLAN management. Redundancy protocols like Spanning Tree Protocol (STP) and EtherChannel ensure that the network remains operational even if a link fails.

6. PROBLEM STATEMENT

Many organizations struggle with maintaining consistent network policies across geographically dispersed offices while ensuring that internal traffic remains isolated via VLANs and external traffic remains encrypted over the public internet.

7. OBJECTIVES AND GOALS

- To implement a redundant Layer 2 topology using EtherChannel and STP.

- To automate VLAN propagation using VTP.

- To enable Inter-VLAN routing using the Router-on-a-Stick method.

- To establish secure Site-to-Site connectivity using IPsec VPN.

8. PROJECT SCOPE

The scope of this project includes the configuration of Core, Distribution, and Access switches, HQ and Branch routers, and an ISP cloud simulation in GNS3. It covers VLAN management, dynamic routing, NAT for internet access, and VPN for security.

9. WORKFLOW

1. **Topology Design:** Setting up nodes in GNS3.

2. **Layer 2 Setup:** Configuring VTP, STP, and Port-Channels.

3. **Layer 3 Setup:** Sub-interfaces for Inter-VLAN routing.

4. **Routing & WAN:** OSPF configuration and ISP integration.

5. **Security:** IPsec VPN Phase 1 and Phase 2 setup

10. OVERVIEW OF PROJECT

The project simulates a multi-departmental network (HR, IT, Sales, Finance) spread across two locations. It uses a hierarchical design to ensure that data flows efficiently between local users and securely between remote sites.

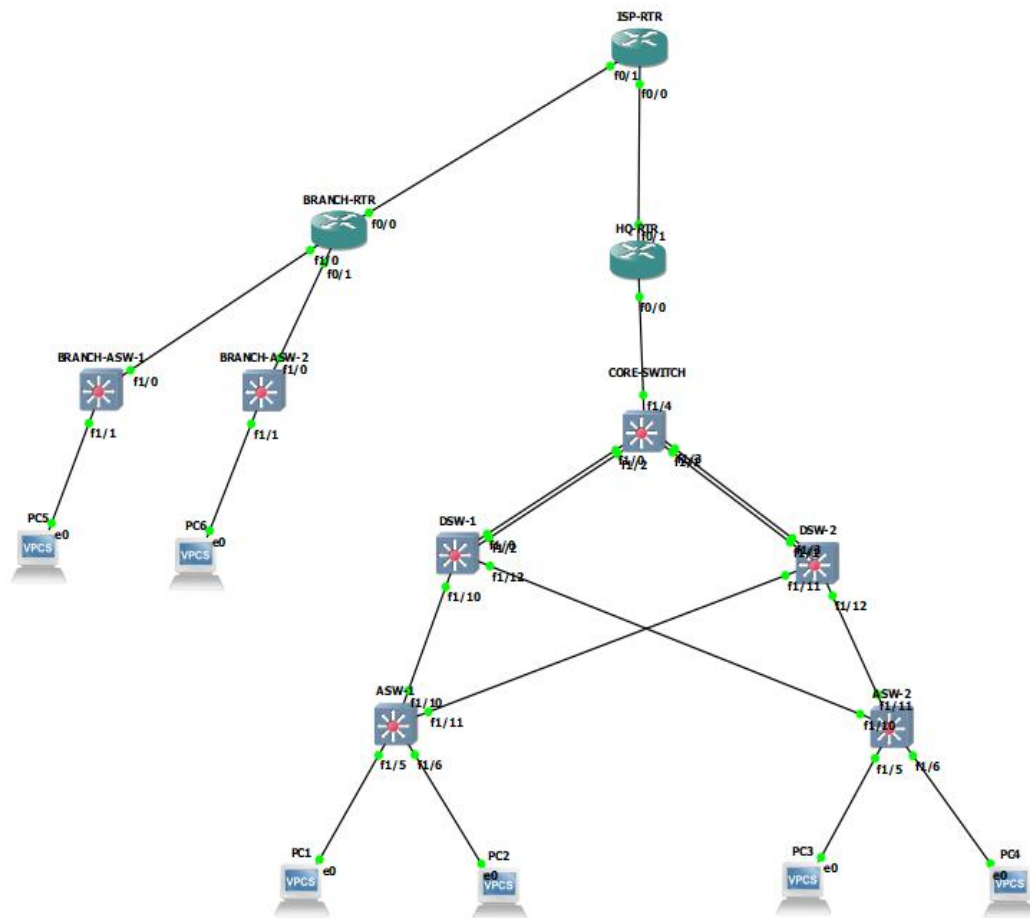## 11. TOOLS AND TECHNOLOGIES

- **Simulator:** GNS3 (Graphical Network Simulator-3)

- **IOS:** Cisco 3725 and 7200 series routers

- **L2 Technologies:** VTP, DTP, STP, EtherChannel

- **L3 Technologies:** OSPF, NAT, Router-on-a-Stick

- **Security:** IPsec VPN (IKEv1)

12. PROJECT FEATURES

- **Redundancy:** Link aggregation via EtherChannel.

- **Scalability:** Easy addition of VLANs via VTP.

- **Security:** AES encryption for inter-site traffic.

- **Efficiency:** Dynamic path selection using OSPF.

13.OUTPUT SCREENS (IMPLEMENTATION STEPS)

TOPOLOGY DESIGN:

Step 1: Layer 2 Core & Distribution Configuration

```
CORE-SWITCH#enable
CORE-SWITCH#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CORE-SWITCH(config)#vtp mode server
Device mode already VTP SERVER.
CORE-SWITCH(config)#vtp domain MY_ENTERPRISE
Changing VTP domain name from NULL to MY_ENTERPRISE
CORE-SWITCH(config)#vtp password cisco
Setting device VLAN database password to cisco
CORE-SWITCH(config)#vlan 10
CORE-SWITCH(config-vlan)#name HR
CORE-SWITCH(config-vlan)#vlan 20
CORE-SWITCH(config-vlan)#name IT
CORE-SWITCH(config-vlan)#vlan 99
CORE-SWITCH(config-vlan)#name Management
CORE-SWITCH(config-vlan)#exit
CORE-SWITCH(config)#end
CORE-SWITCH#sh
*Mar  1 00:02:35.383: %SYS-5-CONFIG_I: Configured from console by console
CORE-SWITCH#show vtp status
VTP Version                    : 2
Configuration Revision         : 3
Maximum VLANs supported locally : 36
Number of existing VLANs       : 8
VTP Operating Mode             : Server
VTP Domain Name                : MY_ENTERPRISE
VTP Pruning Mode               : Disabled
VTP V2 Mode                    : Disabled
VTP Traps Generation           : Disabled
MD5 digest                     : 0xBC 0xF8 0x98 0xBF 0xE8 0x42 0xDB 0x77
Configuration last modified by 0.0.0.0 at 3-1-02 00:02:18
Local updater ID is 0.0.0.0 (no valid interface found)
CORE-SWITCH#
CORE-SWITCH#
```

```
CORE-SWITCH#enable
CORE-SWITCH#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CORE-SWITCH(config)#interface range fal/2-3
                                          ^
% Invalid input detected at '^' marker.

CORE-SWITCH(config)#interface range fal/2 - 3
CORE-SWITCH(config-if-range)#switchport trunk encapsulation dotlq
CORE-SWITCH(config-if-range)#switchport mode trunk
CORE-SWITCH(config-if-range)#
*Mar  1 00:07:11.903: %DTP-5-TRUNKPORTON: Port Fal/2-3 has become dotlq trunk
CORE-SWITCH(config-if-range)#channel-group 1 mode desirable
                                               ^
% Invalid input detected at '^' marker.

CORE-SWITCH(config-if-range)#port-group 1 distribution
                                  ^
% Invalid input detected at '^' marker.

CORE-SWITCH(config-if-range)#channel-group 1 mode distribution
                                                  ^
% Invalid input detected at '^' marker.

CORE-SWITCH(config-if-range)#channel-group 1 mode on
Creating a port-channel interface Port-channel1
CORE-SWITCH(config-if-range)#
*Mar  1 00:10:48.831: %EC-5-BUNDLE: Interface Fal/2 joined port-channel Pol
*Mar  1 00:10:49.031: %EC-5-BUNDLE: Interface Fal/3 joined port-channel Pol
CORE-SWITCH(config-if-range)#
*Mar  1 00:10:51.591: %LINEPROTO-5-UPDOWN: Line protocol on Interface Port-chann
ell, changed state to up
CORE-SWITCH(config-if-range)#exit
CORE-SWITCH(config)#
```

```
CORE-SWITCH#enable
CORE-SWITCH#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CORE-SWITCH(config)#vlan 88
CORE-SWITCH(config-vlan)#exit
CORE-SWITCH(config)#no vlan 88
CORE-SWITCH(config)#end
CORE-SWITCH#
*Mar  1 00:00:53.259: %SYS-5-CONFIG_I: Configured from console by console
CORE-SWITCH#
CORE-SWITCH#show vtp status
VTP Version                    : 2
Configuration Revision         : 5
Maximum VLANs supported locally : 36
Number of existing VLANs       : 8
VTP Operating Mode             : Server
VTP Domain Name                : MY_ENTERPRISE
VTP Pruning Mode               : Disabled
VTP V2 Mode                    : Disabled
VTP Traps Generation           : Disabled
MD5 digest                     : 0x7F 0x81 0x39 0xAE 0x31 0x80 0x5D 0x75
Configuration last modified by 0.0.0.0 at 3-1-02 00:00:51
Local updater ID is 0.0.0.0 (no valid interface found)
CORE-SWITCH#
CORE-SWITCH#
*Mar  1 00:11:49.967: %SPANTREE-7-RECV_1Q_NON_TRUNK: Received 802.1Q BPDU on non
 trunk FastEthernet1/2 VLAN1.
*Mar  1 00:11:49.967: %SPANTREE-7-BLOCK_PORT_TYPE: Blocking FastEthernet1/2 on V
LAN1. Inconsistent port type.
CORE-SWITCH#
*Mar  1 00:12:04.971: %SPANTREE-2-UNBLOCK_CONSIST_PORT: Unblocking FastEthernet1
/2 on VLAN1. Port consistency restored.
CORE-SWITCH#dir flash
%Error opening flash:/flash (No such file or directory)
CORE-SWITCH#dir flash:
Directory of flash:/

    3  -rw-        780                  <no date>  vlan.dat

16777212 bytes total (16774620 bytes free)
CORE-SWITCH#
```

Description: The CORE-SW is configured as the VTP Server and the STP Root Bridge for the entire network. It maintains the master VLAN database (VLAN 10, 20, 30, and 40), ensuring consistent VLAN information across all downstream switches.

Step 2: Distribution Layer Setup (VTP Clients & EtherChannel)

```
DSW-1#
DSW-1#enable
DSW-1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
DSW-1(config)#interface fa1/0
DSW-1(config-if)#switchport trunk encapsulation dotlq
DSW-1(config-if)#switchport mode trunk
DSW-1(config-if)#
*Mar  1 01:37:01.111: %DTP-5-TRUNKPORTON: Port Fa1/0 has become dotlq trunk
DSW-1(config-if)#channel-group 1 mode on
DSW-1(config-if)#
*Mar  1 01:37:15.035: %EC-5-BUNDLE: Interface Fa1/0 joined port-channel Po1
DSW-1(config-if)#no shutdown
*Mar  1 01:37:18.055: %LINEPROTO-5-UPDOWN: Line protocol on Interface Port-channel1
, changed state to up
DSW-1(config-if)#no shutdown
DSW-1(config-if)#exit
DSW-1(config)#interface range fa1/2 - 3
DSW-1(config-if-range)#switchport trunk encapsulation dotlq
DSW-1(config-if-range)#switchport mode trunk
DSW-1(config-if-range)#chann
*Mar  1 01:38:05.971: %DTP-5-TRUNKPORTON: Port Fa1/2 has become dotlq trunk
DSW-1(config-if-range)#channel-group 1 mode on
DSW-1(config-if-range)#no s
*Mar  1 01:38:18.959: %EC-5-BUNDLE: Interface Fa1/2 joined port-channel Po1
DSW-1(config-if-range)#no shutdown
DSW-1(config-if-range)#exit
DSW-1(config)#end
DSW-1#sh
*Mar  1 01:38:31.867: %SYS-5-CONFIG_I: Configured from console by console
DSW-1#show etherchannel summary
Flags:  D - down         P - in port-channel
        I - stand-alone  s - suspended
        R - Layer3       S - Layer2
        U - in use
Group Port-channel  Ports
-----+------------+-------------------------------------------------------
1      Po1(SU)      Fa1/0(P)   Fa1/2(P)   Fa1/3(D)

DSW-1#enable
DSW-1#config t
```

```
DSW-1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
DSW-1(config)#interface fal/3
DSW-1(config-if)#switchport trunk encapsulation dotlq
DSW-1(config-if)#switchport mode trunk
DSW-1(config-if)#channel-group l mode on
DSW-1(config-if)#no shutdown
DSW-1(config-if)#exit
DSW-1(config)#end
DSW-1#
*Mar  1 01:39:49.115: %SYS-5-CONFIG_I: Configured from console by console
DSW-1#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        R - Layer3      S - Layer2
        U - in use
Group Port-channel  Ports
-----+------------+-----------------------------------------------------------
1     Po1(SU)      Fa1/0(P)   Fa1/2(P)   Fa1/3(D)


DSW-1#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa1/1, Fa1/3, Fa1/4, Fa1/5
                                                Fa1/6, Fa1/7, Fa1/8, Fa1/9
                                                Fa1/10, Fa1/11, Fa1/12, Fa1/13
                                                Fa1/14, Fa1/15
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
DSW-1#
DSW-1#enable
DSW-1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
DSW-1(config)#interface fal/3
DSW-1(config-if)#no channel-group l mode on
DSW-1(config-if)#shutdown
DSW-1(config-if)#exit
DSW-1(config)#end
*Mar  1 01:42:35.815: %LINK-5-CHANGED: Interface FastEthernet1/3, changed state to
administratively down
DSW-1(config)#end
DSW-1#
*Mar  1 01:42:37.107: %SYS-5-CONFIG_I: Configured from console by console
DSW-1#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        R - Layer3      S - Layer2
        U - in use
Group Port-channel  Ports
-----+------------+-----------------------------------------------------------
1     Po1(SU)      Fa1/0(P)   Fa1/2(P)

DSW-1#vtp password cisco
Password already set to cisco
DSW-1#end
```

```
DSW-1#enable
DSW-1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
DSW-1(config)#vtp mode transparent
Setting device to VTP TRANSPARENT mode.
DSW-1(config)#vlan 10
DSW-1(config-vlan)#name HR
DSW-1(config-vlan)#vlan 20
DSW-1(config-vlan)#name IT
DSW-1(config-vlan)#vlan 99
DSW-1(config-vlan)#name Management
DSW-1(config-vlan)#exit
DSW-1(config)#end
DSW-1#show
*Mar  1 01:55:51.935: %SYS-5-CONFIG_I: Configured from console by console
DSW-1#show interface trunk

Port        Mode            Encapsulation  Status        Native vlan
Po1         on              802.1q         trunking      1

Port      Vlans allowed on trunk
Po1       1-4094

Port      Vlans allowed and active in management domain
Po1       1,10,20,99

Port      Vlans in spanning tree forwarding state and not pruned
Po1       1,10
DSW-1#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- --------------------------------
1    default                          active    Fa1/1, Fa1/3, Fa1/4, Fa1/5
                                                Fa1/6, Fa1/7, Fa1/8, Fa1/9
                                                Fa1/10, Fa1/11, Fa1/12, Fa1/13
                                                Fa1/14, Fa1/15

10   HR                               active
20   IT                               active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
DSW-1#
DSW-1#
```

```
DSW-2#format flash:
Format operation may take a while. Continue? [confirm]
Format operation will destroy all data in "flash:".  Continue? [confirm]
Writing Monlib sectors....
Monlib write complete

Format: All system sectors written. OK...

Format: Total sectors in formatted partition: 32736
Format: Total bytes in formatted partition: 16760832
Format: Operation completed successfully.

Format of flash: complete
DSW-2#enable
DSW-2#config t
Enter configuration commands, one per line.  End with CNTL/Z.
DSW-2(config)#vtp mode transparent
Setting device to VTP TRANSPARENT mode.
DSW-2(config)#vlan 10
DSW-2(config-vlan)#name HR
DSW-2(config-vlan)#vlan 20
DSW-2(config-vlan)#name IT
DSW-2(config-vlan)#vlan 99
DSW-2(config-vlan)#name Management
DSW-2(config-vlan)#exit
DSW-2(config)#interface fa1/1
DSW-2(config-if)#switchport trunk encapsulation dot1q
DSW-2(config-if)#switchport mode trunk
DSW-2(config-if)#c
*Mar  1 00:04:51.659: %DTP-5-TRUNKPORTON: Port Fa1/1 has become dot1q trunk
DSW-2(config-if)#channel-group 1 mode on
Creating a port-channel interface Port-channel1
DSW-2(config-if)#
*Mar  1 00:05:05.855: %EC-5-BUNDLE: Interface Fa1/1 joined port-channel Po1
DSW-2(config-if)#no
*Mar  1 00:05:08.371: %LINEPROTO-5-UPDOWN: Line protocol on Interface Port-chann
el1, changed state to up
DSW-2(config-if)#no shutdown
DSW-2(config-if)#exit
DSW-2(config)#interface fa1/3
DSW-2(config-if)#switchport trunk encapsulation dot1q
DSW-2(config-if)#switchport mode trunk
DSW-2(config-if)#chann
*Mar  1 00:06:02.207: %DTP-5-TRUNKPORTON: Port Fa1/3 has become dot1q trunk
DSW-2(config-if)#channel-group 1 mode on
DSW-2(config-if)#
*Mar  1 00:06:11.155: %EC-5-BUNDLE: Interface Fa1/3 joined port-channel Po1
DSW-2(config-if)#no shutdown
DSW-2(config-if)#exit
DSW-2(config)#end
DSW-2#s
*Mar  1 00:06:26.783: %SYS-5-CONFIG_I: Configured from console by console
DSW-2#show ehterchannel summary
                 ^
% Invalid input detected at '^' marker.

DSW-2#show etherchannel summary
Flags:  D - down         P - in port-channel
        I - stand-alone  s - suspended
        R - Layer3       S - Layer2
        U - in use
Group Port-channel  Ports
```

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```
DSW-2#show etherchannel summary
Flags:  D - down         P - in port-channel
        I - stand-alone s - suspended
        R - Layer3       S - Layer2
        U - in use
Group Port-channel  Ports
-----+-----------+-------------------------------------------------------
1      Po1(SU)      Fa1/1(P)   Fa1/3(P)

DSW-2#show interface trunk

Port        Mode            Encapsulation  Status       Native vlan
Po1         on              802.1q         trunking     1

Port        Vlans allowed on trunk
Po1         1-4094

Port        Vlans allowed and active in management domain
Po1         1,10,20,99

Port        Vlans in spanning tree forwarding state and not pruned
Po1         1,10,20,99
```

Description: The CORE-SW acts as the VTP Server, managing the master VLAN database, while DSW-1 and DSW-2 are configured to sync these VLANs to ensure consistency.

```
CORE-SWITCH#enable
CORE-SWITCH#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CORE-SWITCH(config)#interface Fa1/4
CORE-SWITCH(config-if)#switchport mode trunk
CORE-SWITCH(config-if)#n
*Mar  1 00:00:49.871: %DTP-5-TRUNKPORTON: Port Fa1/4 has become dot1q trunk
CORE-SWITCH(config-if)#no shutdown
CORE-SWITCH(config-if)#exit
CORE-SWITCH(config)#show interface trunk
                      ^
% Invalid input detected at '^' marker.

CORE-SWITCH(config)#end
CORE-SWITCH#s
*Mar  1 00:01:16.583: %SYS-5-CONFIG_I: Configured from console by console
CORE-SWITCH#show interface trunk

Port        Mode            Encapsulation  Status       Native vlan
Fa1/4       on              802.1q         trunking     1

Port        Vlans allowed on trunk
Fa1/4       1-4094

Port        Vlans allowed and active in management domain
Fa1/4       1,10,20,99

Port        Vlans in spanning tree forwarding state and not pruned
Fa1/4       1,10,20,99
CORE-SWITCH#write memory
Building configuration...
[OK]
CORE-SWITCH#
```

Description: Distribution switches (DSW-1 and DSW-2) are configured to synchronize VLANs from the Core. An **EtherChannel (Port-Channel 1)** is established between them to provide link redundancy and increased bandwidth for inter-switch communication.

Step 3: Access Layer Configuration (ASW Switches)

```
ASW-1#enable
ASW-1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
ASW-1(config)#vtp mode transparent
Device mode already VTP TRANSPARENT.
ASW-1(config)#vlan 10
ASW-1(config-vlan)#name HR
ASW-1(config-vlan)#vlan 20
ASW-1(config-vlan)#name IT
ASW-1(config-vlan)#exit
ASW-1(config)#interface Fa1/5
ASW-1(config-if)#switchport mode access
ASW-1(config-if)#switchport access vlan 10
ASW-1(config-if)#no shutdown
ASW-1(config-if)#interface Fa1/6
ASW-1(config-if)#switchport mode access
ASW-1(config-if)#switchport access vlan 20
ASW-1(config-if)#no shutdown
ASW-1(config-if)#exit
ASW-1(config)#interface range Fa1/10 - 11
ASW-1(config-if-range)#switchport mode trunk
ASW-1(config-if-range)#no shutdown
ASW-1(config-if-range)#end
ASW-1#
*Mar  1 01:23:19.151: %SYS-5-CONFIG_I: Configured from console by console
ASW-1#write memory
Building configuration...
[OK]
ASW-1#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa1/0, Fa1/1, Fa1/2, Fa1/3
                                                Fa1/4, Fa1/7, Fa1/8, Fa1/9
                                                Fa1/12, Fa1/13, Fa1/14, Fa1/15
10   HR                               active    Fa1/5
20   IT                               active    Fa1/6
99   MGMT                             active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
ASW-1#show interfaces trunk

Port        Mode            Encapsulation Status        Native vlan
Fa1/10      on              802.1q        trunking      1
Fa1/11      on              802.1q        trunking      1

Port        Vlans allowed on trunk
Fa1/10      1-4094
Fa1/11      1-4094

Port        Vlans allowed and active in management domain
Fa1/10      1,10,20,99
Fa1/11      1,10,20,99

Port        Vlans in spanning tree forwarding state and not pruned
Fa1/10      1,10,20,99
Fa1/11      10,20,99
ASW-1#
```

```
Device mode already VTP TRANSPARENT.
ASW-2(config)#vlan 10
ASW-2(config-vlan)#name HR
ASW-2(config-vlan)#vlan 20
ASW-2(config-vlan)#name IT
ASW-2(config-vlan)#exit
ASW-2(config)#interface Fal/5
ASW-2(config-if)#switchport mode access
ASW-2(config-if)#switchport access vlan 10
ASW-2(config-if)#ni shutdown
                   ^
% Invalid input detected at '^' marker.

ASW-2(config-if)#no shutdown
ASW-2(config-if)#interface Fal/6
ASW-2(config-if)#switchport mode access
ASW-2(config-if)#switchport access vlan 20
ASW-2(config-if)#no shutdown
ASW-2(config-if)#end
ASW-2#
*Mar  1 00:08:28.251: %SYS-5-CONFIG_I: Configured from console by console
ASW-2#enable
ASW-2#config t
Enter configuration commands, one per line.  End with CNTL/Z.
ASW-2(config)#interface range Fal/11 - 12
ASW-2(config-if-range)#switchport mode trunk
ASW-2(config-if-range)#
*Mar  1 00:10:50.339: %DTP-5-TRUNKPORTON: Port Fal/11 has become dotlq trunk
ASW-2(config-if-range)#no shutdown
ASW-2(config-if-range)#end
ASW-2#
*Mar  1 00:11:04.587: %SYS-5-CONFIG_I: Configured from console by console
ASW-2#write memory
Building configuration...
[OK]
ASW-2#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fal/0, Fal/1, Fal/2, Fal/3
                                                Fal/4, Fal/7, Fal/8, Fal/9
                                                Fal/10, Fal/12, Fal/13, Fal/14
                                                Fal/15
10   HR                               active    Fal/5
20   IT                               active    Fal/6
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
ASW-2#show interfaces trunk

Port      Mode          Encapsulation Status        Native vlan
Fal/11    on            802.1q        trunking      1

Port      Vlans allowed on trunk
Fal/11    1-4094

Port      Vlans allowed and active in management domain
Fal/11    1,10,20

Port      Vlans in spanning tree forwarding state and not pruned
Fal/11    10,20
ASW-2#
```

Description: At the Access Layer, ports on ASW-1 and ASW-2 are assigned to their respective VLANs (HR, IT, Sales, and Finance). The show vlan brief output verifies that end-devices are connected to the correct logical broadcast domains.

Step 4: HQ Inter-VLAN Routing (Layer 3)

```
HQ-RTR#enable
HQ-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
HQ-RTR(config)#interface fa0/0
HQ-RTR(config-if)#no shutdown
HQ-RTR(config-if)#exit
HQ-RTR(config)#
*Mar  1 00:01:59.659: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state t
o up
*Mar  1 00:02:00.659: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to up
HQ-RTR(config)#interface fa0/0.10
HQ-RTR(config-subif)#encapsulation dotlq 10
HQ-RTR(config-subif)#ip add
*Mar  1 00:02:25.779: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state t
o up
HQ-RTR(config-subif)#ip address 192.168.10.1 255.255.255.0
HQ-RTR(config-subif)#interface fa0/0.20
HQ-RTR(config-subif)#encapsulation dotlq 20
HQ-RTR(config-subif)#ip address 192.168.20.1 255.255.255.0
HQ-RTR(config-subif)#interface fa0/0.99
HQ-RTR(config-subif)#encapsulation dotlq 99
HQ-RTR(config-subif)#ip address 192.168.99.1 255.255.255.0
HQ-RTR(config-subif)#end
HQ-RTR#
*Mar  1 00:04:59.655: %SYS-5-CONFIG_I: Configured from console by console
HQ-RTR#write memory
Building configuration...
[OK]
HQ-RTR#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.10.0/24 is directly connected, FastEthernet0/0.10
C    192.168.99.0/24 is directly connected, FastEthernet0/0.99
C    192.168.20.0/24 is directly connected, FastEthernet0/0.20
HQ-RTR#
```

```
HQ-RTR#show ip interface brief
Interface                   IP-Address      OK? Method Status              Prot
ocol
FastEthernet0/0             unassigned      YES unset  up                  up

FastEthernet0/0.10          192.168.10.1    YES manual up                  up

FastEthernet0/0.20          192.168.20.1    YES manual up                  up

FastEthernet0/0.99          192.168.99.1    YES manual up                  up
```

```
HQ-RTR#ping 192.168.10.10

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.10, timeout is 2 seconds:
!.!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 180/199/232 ms
HQ-RTR#ping 192.168.20.10

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.20.10, timeout is 2 seconds:
.!.!!
Success rate is 60 percent (3/5), round-trip min/avg/max = 16/126/208 ms
```

Description: Inter-VLAN routing is implemented on the HQ-RTR using the **Router-on-a-Stick** method. FastEthernet 0/0 is divided into sub-interfaces (Fa0/0.10 and Fa0/0.20) with IEEE 802.1Q encapsulation to route traffic between the HR and IT departments.

```
DSW-1#show interfaces trunk

Port         Mode              Encapsulation  Status         Native vlan
Fa1/10       on                802.1q         trunking       1
Fa1/12       on                802.1q         trunking       1
Po1          on                802.1q         trunking       1

Port        Vlans allowed on trunk
Fa1/10      1-4094
Fa1/12      1-4094
Po1         1-4094

Port        Vlans allowed and active in management domain
Fa1/10      1,10,20,99
Fa1/12      1,10,20,99
Po1         1,10,20,99

Port        Vlans in spanning tree forwarding state and not pruned
Fa1/10      1,10,20,99
Fa1/12      1,10,20,99
Po1         1,10,20,99
DSW-1#show etherchannel summary
Flags:  D - down         P - in port-channel
        I - stand-alone s - suspended
        R - Layer3       S - Layer2
        U - in use
Group Port-channel  Ports
-----+------------+-----------------------------------------------------------
1     Po1(SU)      Fa1/0(P)   Fa1/1(D)   Fa1/2(P)

DSW-1#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa1/1, Fa1/3, Fa1/4, Fa1/5
                                                Fa1/6, Fa1/7, Fa1/8, Fa1/9
                                                Fa1/11, Fa1/13, Fa1/14, Fa1/15

10   HR                               active
20   IT                               active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
DSW-1#
DSW-1#show interfaces Fa1/10 status

Port    Name               Status       Vlan      Duplex Speed Type
Fa1/10                     connected    trunk      a-full   a-100 10/100BaseTX
DSW-1#show interfaces Fa1/12 status

Port    Name               Status       Vlan      Duplex Speed Type
Fa1/12                     connected    trunk      a-full   a-100 10/100BaseTX
DSW-1#
DSW-1#
```

```
DSW-2#show interfaces trunk

Port       Mode            Encapsulation  Status       Native vlan
Fal/11     on              802.1q         trunking     1
Fal/12     on              802.1q         trunking     1
Po1        on              802.1q         trunking     1
Po2        on              802.1q         not-trunking  1

Port       Vlans allowed on trunk
Fal/11     1-4094
Fal/12     1-4094
Po1        1-4094
Po2        none

Port       Vlans allowed and active in management domain
Fal/11     1,10,20,99
Fal/12     1,10,20,99
Po1        1,10,20,99
Po2        none

Port       Vlans in spanning tree forwarding state and not pruned
Fal/11     1,10,20,99
Fal/12     1,10,20,99
Po1        1,10,20,99
Po2        none
DSW-2#show etherchannel summary
Flags:  D - down         P - in port-channel
        I - stand-alone s - suspended
        R - Layer3       S - Layer2
        U - in use
Group Port-channel  Ports
-----+------------+----------------------------------------------------------
1     Po1(SU)     Fal/1(P)   Fal/2(D)   Fal/3(P)
2     Po2(SD)

DSW-2#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fal/0, Fal/2, Fal/4, Fal/5
                                                Fal/6, Fal/7, Fal/8, Fal/9
                                                Fal/10, Fal/13, Fal/14, Fal/15
10   HR                               active
20   IT                               active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

Step 5: HQ End-Device & Connectivity Verification

```
PC1> ip 192.168.10.10 255.255.255.0
Checking for duplicate address...
PC1 : 192.168.10.10 255.255.255.0

PC1> ip 192.168.10.10 255.255.255.0 192.168.10.1
Checking for duplicate address...
PC1 : 192.168.10.10 255.255.255.0 gateway 192.168.10.1

PC1> save
Saving startup configuration to startup.vpc
.  done

PC1> show ip

NAME          : PC1[1]
IP/MASK       : 192.168.10.10/24
GATEWAY       : 192.168.10.1
DNS           :
MAC           : 00:50:79:66:68:00
LPORT         : 20078
RHOST:PORT    : 127.0.0.1:20079
MTU           : 1500
```

```
PC2> ip 192.168.20.10 255.255.255.0 192.168.20.1
Checking for duplicate address...
PC2 : 192.168.20.10 255.255.255.0 gateway 192.168.20.1

PC2> save
Saving startup configuration to startup.vpc
.  done

PC2> show ip

NAME          : PC2[1]
IP/MASK       : 192.168.20.10/24
GATEWAY       : 192.168.20.1
DNS           :
MAC           : 00:50:79:66:68:01
LPORT         : 20080
RHOST:PORT    : 127.0.0.1:20081
MTU           : 1500
```

```
PC3> ip 192.168.10.11 255.255.255.0 192.168.10.1
Checking for duplicate address...
PC3 : 192.168.10.11 255.255.255.0 gateway 192.168.10.1

PC3> save
Saving startup configuration to startup.vpc
.  done

PC3> show ip

NAME          : PC3[1]
IP/MASK       : 192.168.10.11/24
GATEWAY       : 192.168.10.1
DNS           :
MAC           : 00:50:79:66:68:02
LPORT         : 20082
RHOST:PORT    : 127.0.0.1:20083
MTU           : 1500
```

```
PC4> ip 192.168.20.11 255.255.255.0 192.168.20.1
Checking for duplicate address...
PC4 : 192.168.20.11 255.255.255.0 gateway 192.168.20.1

PC4> save
Saving startup configuration to startup.vpc
.  done

PC4> show ip

NAME          : PC4[1]
IP/MASK       : 192.168.20.11/24
GATEWAY       : 192.168.20.1
DNS           :
MAC           : 00:50:79:66:68:03
LPORT         : 20084
RHOST:PORT    : 127.0.0.1:20085
MTU           : 1500
```

```
PC1> ping 192.168.10.1

84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=996.281 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=119.964 ms
192.168.10.1 icmp_seq=3 timeout
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=50.793 ms
192.168.10.1 icmp_seq=5 timeout
```

```
PC2> ping 192.168.20.1

84 bytes from 192.168.20.1 icmp_seq=1 ttl=255 time=167.728 ms
84 bytes from 192.168.20.1 icmp_seq=2 ttl=255 time=54.171 ms
192.168.20.1 icmp_seq=3 timeout
84 bytes from 192.168.20.1 icmp_seq=4 ttl=255 time=72.990 ms
84 bytes from 192.168.20.1 icmp_seq=5 ttl=255 time=82.856 ms
```

Step 6: Branch Office Setup (Routing & PCs)

```
BRANCH-ASW-1#enable
BRANCH-ASW-1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
BRANCH-ASW-1(config)#vlan 30
BRANCH-ASW-1(config-vlan)#name sales
BRANCH-ASW-1(config-vlan)#exit
BRANCH-ASW-1(config)#interface Fa1/0
BRANCH-ASW-1(config-if)#switchport mode trunk
BRANCH-ASW-1(config-if)#n
*Mar  1 00:02:57.447: %DTP-5-TRUNKPORTON: Port Fa1/0 has become dotlq trunk
BRANCH-ASW-1(config-if)#no shutdown
BRANCH-ASW-1(config-if)#exit
BRANCH-ASW-1(config)#interface Fa0/1
BRANCH-ASW-1(config-if)#switchport mode access
                         ^
% Invalid input detected at '^' marker.

BRANCH-ASW-1(config-if)#interface Fa1/1
BRANCH-ASW-1(config-if)#switchport mode access
BRANCH-ASW-1(config-if)#swithport access vlan 30
                         ^
% Invalid input detected at '^' marker.

BRANCH-ASW-1(config-if)#switchport access vlan 30
BRANCH-ASW-1(config-if)#no shutdown
BRANCH-ASW-1(config-if)#exit
BRANCH-ASW-1(config)#end
BRANCH-ASW-1#
*Mar  1 00:05:27.047: %SYS-5-CONFIG_I: Configured from console by console
BRANCH-ASW-1#write memory
Building configuration...
[OK]
```

```
BRANCH-ASW-1#show vlan-switch brief

VLAN Name                             Status     Ports
---- -------------------------------- ---------- --------------------------------
1    default                          active     Fa1/2, Fa1/3, Fa1/4, Fa1/5
                                                 Fa1/6, Fa1/7, Fa1/8, Fa1/9
                                                 Fa1/10, Fa1/11, Fa1/12, Fa1/13
                                                 Fa1/14, Fa1/15
30   sales                            active     Fa1/1
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
BRANCH-ASW-1#
```

```
BRANCH-ASW-2#enable
BRANCH-ASW-2#vlan database
% Warning: It is recommended to configure VLAN from config mode,
  as VLAN database mode is being deprecated. Please consult user
  documentation for configuring VTP/VLAN in config mode.

BRANCH-ASW-2(vlan)#vtp transparent
Setting device to VTP TRANSPARENT mode.
BRANCH-ASW-2(vlan)#vlan 40 name finance
VLAN 40 modified:
    Name: finance
BRANCH-ASW-2(vlan)#apply
APPLY completed.
BRANCH-ASW-2(vlan)#exit
APPLY completed.
Exiting....
BRANCH-ASW-2#config t
Enter configuration commands, one per line.  End with CNTL/Z.
BRANCH-ASW-2(config)#interface Fa1/1
BRANCH-ASW-2(config-if)#switchport mode access
BRANCH-ASW-2(config-if)#switchport access vlan 40
BRANCH-ASW-2(config-if)#no shutdown
```

```
BRANCH-ASW-2#show vlan-switch brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa1/2, Fa1/3, Fa1/4, Fa1/5
                                                Fa1/6, Fa1/7, Fa1/8, Fa1/9
                                                Fa1/10, Fa1/11, Fa1/12, Fa1/13
                                                Fa1/14, Fa1/15
40   finance                          active    Fa1/1
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
BRANCH-ASW-2#
```

```
BRANCH-RTR#enable
BRANCH-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
BRANCH-RTR(config)#interface Fa0/1.30
BRANCH-RTR(config-subif)#no ip address
BRANCH-RTR(config-subif)#exit
BRANCH-RTR(config)#interface Fa0/1
BRANCH-RTR(config-if)#shutdown
BRANCH-RTR(config-if)#exit
BRANCH-RTR(config)#
*Mar  1 01:06:39.967: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state
to administratively down
*Mar  1 01:06:40.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/1, changed state to down
BRANCH-RTR(config)#interface Fa1/0
BRANCH-RTR(config-if)#no shutdown
BRANCH-RTR(config-if)#exit
BRANCH-RTR(config)#interface Fa1/0.30
BRANCH-RTR(config-subif)#encapsulation dot1q 30
BRANCH-RTR(config-subif)#ip address 192.168.30.1 255.255.255.0
BRANCH-RTR(config-subif)#no shutdown
BRANCH-RTR(config-subif)#exit
```

```
BRANCH-RTR#enable
BRANCH-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
BRANCH-RTR(config)#interface Fa1/0.40
BRANCH-RTR(config-subif)#encapsulation dotlq 40
BRANCH-RTR(config-subif)#ip address 192.168.40.1 255.255.255.0
BRANCH-RTR(config-subif)#no shutdown
BRANCH-RTR(config-subif)#end
BRANCH-RTR#en
*Mar  1 01:29:28.083: %SYS-5-CONFIG_I: Configured from console by console
BRANCH-RTR#enable
BRANCH-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
BRANCH-RTR(config)#interface Fa1/0.40
BRANCH-RTR(config-subif)#no ip address
BRANCH-RTR(config-subif)#shutdown
BRANCH-RTR(config-subif)#exit
BRANCH-RTR(config)#interface Fa0/1
BRANCH-RTR(config-if)#no shutdown
BRANCH-RTR(config-if)#exit
BRANCH-RTR(config)#
*Mar  1 01:30:13.407: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state t
o up
*Mar  1 01:30:14.407: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/1, changed state to up
BRANCH-RTR(config)#interface Fa0/1.40
BRANCH-RTR(config-subif)#encapsulation dotlq 40
BRANCH-RTR(config-subif)#ip address 192.168.40.1 255.255.255.0
BRANCH-RTR(config-subif)#no shutdown
BRANCH-RTR(config-subif)#exit
BRANCH-RTR(config)#show ip interface brief
                        ^
% Invalid input detected at '^' marker.

BRANCH-RTR(config)#end
BRANCH-RTR#sh
*Mar  1 01:37:34.975: %SYS-5-CONFIG_I: Configured from console by console
BRANCH-RTR#show ip interface brief
Interface               IP-Address      OK? Method Status                Prot
ocol
FastEthernet0/0         10.10.10.2      YES manual up                    up

FastEthernet0/1         unassigned      YES NVRAM  up                    up

FastEthernet0/1.30      unassigned      YES manual up                    up

FastEthernet0/1.40      192.168.40.1    YES manual up                    up

FastEthernet1/0         unassigned      YES NVRAM  up                    up

FastEthernet1/0.30      192.168.30.1    YES manual up                    up

FastEthernet1/0.40      unassigned      YES manual administratively down down
```

```
PC5> ip 192.168.30.10 255.255.255.0 192.168.30.1
Checking for duplicate address...
PC5 : 192.168.30.10 255.255.255.0 gateway 192.168.30.1

PC5> save
Saving startup configuration to startup.vpc
.  done

PC5> show ip

NAME         : PC5[1]
IP/MASK      : 192.168.30.10/24
GATEWAY      : 192.168.30.1
DNS          :
MAC          : 00:50:79:66:68:04
LPORT        : 20097
RHOST:PORT   : 127.0.0.1:20098
MTU          : 1500
```

```
PC6> ip 192.168.40.10 255.255.255.0 192.168.40.1
Checking for duplicate address...
PC1 : 192.168.40.10 255.255.255.0 gateway 192.168.40.1

PC6> save
Saving startup configuration to startup.vpc
.  done

PC6> show ip

NAME         : PC6[1]
IP/MASK      : 192.168.40.10/24
GATEWAY      : 192.168.40.1
DNS          :
MAC          : 00:50:79:66:68:00
LPORT        : 10001
RHOST:PORT   : 127.0.0.1:10002
MTU:         : 1500
```

```
PC5> ping 192.168.30.1

84 bytes from 192.168.30.1 icmp_seq=1 ttl=255 time=98.934 ms
84 bytes from 192.168.30.1 icmp_seq=2 ttl=255 time=24.348 ms
84 bytes from 192.168.30.1 icmp_seq=3 ttl=255 time=11.466 ms
84 bytes from 192.168.30.1 icmp_seq=4 ttl=255 time=23.931 ms
84 bytes from 192.168.30.1 icmp_seq=5 ttl=255 time=35.875 ms
```

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```
PC6> ping 192.168.40.1
84 bytes from 192.168.40.1 icmp_seq=1 ttl=255 time=23.592 ms
84 bytes from 192.168.40.1 icmp_seq=2 ttl=255 time=24.229 ms
84 bytes from 192.168.40.1 icmp_seq=3 ttl=255 time=18.284 ms
84 bytes from 192.168.40.1 icmp_seq=4 ttl=255 time=18.317 ms
84 bytes from 192.168.40.1 icmp_seq=5 ttl=255 time=18.776 ms
```

Description: The BRANCH-RTR is configured with sub-interfaces for VLAN 30 (Sales) and VLAN 40 (Finance). Verification includes assigning static IPs to Branch PCs and performing successful local pings to ensure internal routing is functional.

Step 7: WAN Connectivity & Dynamic Routing (OSPF)

```
ISP-RTR#enable
ISP-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
ISP-RTR(config)#hostname ISP-RTR
ISP-RTR(config)#interface FastEthernet 0/0
ISP-RTR(config-if)#description Link_to_HQ
ISP-RTR(config-if)#ip address 10.10.10.1 255.255.255.252
ISP-RTR(config-if)#no shutdown
ISP-RTR(config-if)#
*Mar  1 00:04:18.419: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/0, sourced by c206.0a21.0001
ISP-RTR(config-if)#exit
*Mar  1 00:04:19.947: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state t
o up
*Mar  1 00:04:20.947: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to up
ISP-RTR(config-if)#exit
ISP-RTR(config)#interface Fa0/1
ISP-RTR(config-if)#description
*Mar  1 00:04:48.447: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/0, sourced by c206.0a21.0001
ISP-RTR(config-if)#description Link_to_Branch
ISP-RTR(config-if)#ip address 20.2
*Mar  1 00:05:18.907: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/0, sourced by c206.0a21.0001
ISP-RTR(config-if)#ip address 20.20.20.1 255.255.255.252
ISP-RTR(config-if)#no shutdow
*Mar  1 00:05:49.459: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/0, sourced by c206.0a21.0001
ISP-RTR(config-if)#no shutdown
ISP-RTR(config-if)#exit
ISP-RTR(config)#
*Mar  1 00:05:56.115: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state t
o up
*Mar  1 00:05:57.115: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/1, changed state to up
ISP-RTR(config)#
*Mar  1 00:06:19.835: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/0, sourced by c206.0a21.0001
ISP-RTR(config)#
*Mar  1 00:06:49.871: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/0, sourced by c206.0a21.0001
ISP-RTR(config)#end
ISP-RTR#
*Mar  1 00:13:07.887: %SYS-5-CONFIG_I: Configured from console by console
ISP-RTR#write memory
Building configuration...
[OK]
ISP-RTR#show ip interface brief
Interface              IP-Address      OK? Method Status                Prot
ocol
FastEthernet0/0        10.10.10.1      YES manual up                    up

FastEthernet0/1        20.20.20.1      YES manual up                    up

FastEthernet1/0        unassigned      YES unset  administratively down down

ISP-RTR#
```

```
HQ-RTR#enable
HQ-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
HQ-RTR(config)#interac
*Mar  1 01:17:50.403: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/1, sourced by c20a.0aba.0000
HQ-RTR(config)#interface Fa0/1
HQ-RTR(config-if)#ip
*Mar  1 01:18:20.607: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/1, sourced by c20a.0aba.0000
HQ-RTR(config-if)#ip address 10.10.10.2 255.255.255.252
*Mar  1 01:18:51.651: %IP-4-DUPADDR: Duplicate address 10.10.10.1 on FastEtherne
t0/1, sourced by c20a.0aba.0000
HQ-RTR(config-if)#ip address 10.10.10.2 255.255.255.252
HQ-RTR(config-if)#no shutdown
HQ-RTR(config-if)#exit
HQ-RTR(config)#ip route 0.0.0.0 0.0.0.0 10.10.10.1
HQ-RTR(config)#end
HQ-RTR#
*Mar  1 01:24:29.123: %SYS-5-CONFIG_I: Configured from console by console
HQ-RTR#write memory
Building configuration...
[OK]
HQ-RTR#ping 20.20.20.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 20.20.20.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 120/325/736 ms
HQ-RTR#
```

```
BRANCH-RTR#enable
BRANCH-RTR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
BRANCH-RTR(config)#interface Fa0/0
BRANCH-RTR(config-if)#ip address 20.20.20.2 255.255.255.252
BRANCH-RTR(config-if)#no shutdown
BRANCH-RTR(config-if)#exit
BRANCH-RTR(config)#ip route 0.0.0.0 0.0.0.0 20.20.20.1
BRANCH-RTR(config)#end
BRANCH-RTR#
*Mar  1 03:39:24.263: %SYS-5-CONFIG_I: Configured from console by console
BRANCH-RTR#write memory
Building configuration...
[OK]
BRANCH-RTR#ping 10.10.10.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.2, timeout is 2 seconds:
..!!!
Success rate is 60 percent (3/5), round-trip min/avg/max = 264/396/464 ms
BRANCH-RTR#ping 10.10.10.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 384/544/812 ms
BRANCH-RTR#
```

```
HQ-RTR#show ip ospf neighbor

Neighbor ID     Pri   State          Dead Time   Address        Interface
20.20.20.1       1    FULL/DR        00:00:34    10.10.10.1     FastEthernet0/
1
HQ-RTR#
```

```
BRANCH-RTR#show ip ospf neighbor

Neighbor ID     Pri   State          Dead Time   Address        Interface
20.20.20.1       1    FULL/DR        00:00:32    20.20.20.1     FastEthernet0/0
BRANCH-RTR#
```

```
ISP-RTR#show ip ospf neighbor

Neighbor ID     Pri   State          Dead Time   Address        Interface
2.2.2.2          1    FULL/BDR       00:00:39    20.20.20.2     FastEthernet0/
1
1.1.1.1          1    FULL/BDR       00:00:39    10.10.10.2     FastEthernet0/
0
ISP-RTR#
```

```
HQ-RTR#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.10.10.1 to network 0.0.0.0

O    192.168.30.0/24 [110/21] via 10.10.10.1, 01:15:26, FastEthernet0/1
     20.0.0.0/30 is subnetted, 1 subnets
O       20.20.20.0 [110/20] via 10.10.10.1, 01:15:26, FastEthernet0/1
C    192.168.10.0/24 is directly connected, FastEthernet0/0.10
O    192.168.40.0/24 [110/30] via 10.10.10.1, 01:15:26, FastEthernet0/1
C    192.168.99.0/24 is directly connected, FastEthernet0/0.99
C    192.168.20.0/24 is directly connected, FastEthernet0/0.20
     10.0.0.0/30 is subnetted, 1 subnets
C       10.10.10.0 is directly connected, FastEthernet0/1
S*   0.0.0.0/0 [1/0] via 10.10.10.1
```

```
BRANCH-RTR#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 20.20.20.1 to network 0.0.0.0

C    192.168.30.0/24 is directly connected, FastEthernet1/0.30
     20.0.0.0/30 is subnetted, 1 subnets
C       20.20.20.0 is directly connected, FastEthernet0/0
O    192.168.10.0/24 [110/30] via 20.20.20.1, 01:14:30, FastEthernet0/0
C    192.168.40.0/24 is directly connected, FastEthernet0/1.40
O    192.168.20.0/24 [110/30] via 20.20.20.1, 01:14:30, FastEthernet0/0
     10.0.0.0/30 is subnetted, 1 subnets
O       10.10.10.0 [110/20] via 20.20.20.1, 01:14:30, FastEthernet0/0
S*   0.0.0.0/0 [1/0] via 20.20.20.1
```

```
ISP-RTR#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

O    192.168.30.0/24 [110/11] via 20.20.20.2, 02:21:27, FastEthernet0/1
     20.0.0.0/30 is subnetted, 1 subnets
C       20.20.20.0 is directly connected, FastEthernet0/1
O    192.168.10.0/24 [110/20] via 10.10.10.2, 02:21:37, FastEthernet0/0
O    192.168.40.0/24 [110/20] via 20.20.20.2, 02:21:27, FastEthernet0/1
O    192.168.20.0/24 [110/20] via 10.10.10.2, 02:21:37, FastEthernet0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.10.10.0 is directly connected, FastEthernet0/0
ISP-RTR#
```

Description: OSPF is implemented as the dynamic routing protocol between the HQ, ISP, and Branch routers. The routing table (show ip route) displays "O" labeled routes, confirming that all network segments have established full reachability.

Step 8: Security - Site-to-Site VPN

VPN Phase 1 (ISAKMP):

```
HQ-RTR#show crypto isakmp sa
IPv4 Crypto ISAKMP SA
dst             src              state          conn-id slot status
 10.10.10.2      20.20.20.2      QM_IDLE          1002     0 ACTIVE
```

```
BRANCH-RTR#show crypto isakmp sa
IPv4 Crypto ISAKMP SA
dst             src              state          conn-id slot status
10.10.10.2      20.20.20.2       QM_IDLE          1002     0 ACTIVE

IPv6 Crypto ISAKMP SA
```

The show crypto isakmp sa command confirms the status is **QM_IDLE**, indicating a successful security handshake between HQ and Branch.

VPN Phase 2 (IPsec):

```
BRANCH-RTR#show crypto isakmp sa
IPv4 Crypto ISAKMP SA
dst             src             state           conn-id slot status
10.10.10.2      20.20.20.2      QM_IDLE            1002    0 ACTIVE

IPv6 Crypto ISAKMP SA

BRANCH-RTR#show crypto ipsec sa

interface: FastEthernet0/0
    Crypto map tag: MYMAP, local addr 20.20.20.2

   protected vrf: (none)
   local  ident (addr/mask/prot/port): (192.168.40.0/255.255.255.0/0/0)
   remote ident (addr/mask/prot/port): (192.168.20.0/255.255.255.0/0/0)
   current_peer 10.10.10.2 port 500
     PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 5, #recv errors 0

     local crypto endpt.: 20.20.20.2, remote crypto endpt.: 10.10.10.2
     path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/0
     current outbound spi: 0x0(0)

     inbound esp sas:

     inbound ah sas:

     inbound pcp sas:

     outbound esp sas:

     outbound ah sas:

     outbound pcp sas:

   protected vrf: (none)
   local  ident (addr/mask/prot/port): (192.168.30.0/255.255.255.0/0/0)
   remote ident (addr/mask/prot/port): (192.168.10.0/255.255.255.0/0/0)
   current_peer 10.10.10.2 port 500
     PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 0, #recv errors 0

     local crypto endpt.: 20.20.20.2, remote crypto endpt.: 10.10.10.2
     path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/0
 --More--
```

```
HQ-RTR#show crypto ipsec sa

interface: FastEthernet0/1
    Crypto map tag: MYMAP, local addr 10.10.10.2

   protected vrf: (none)
   local  ident (addr/mask/prot/port): (192.168.20.0/255.255.255.0/0/0)
   remote ident (addr/mask/prot/port): (192.168.40.0/255.255.255.0/0/0)
   current_peer 20.20.20.2 port 500
     PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 0, #recv errors 0

     local crypto endpt.: 10.10.10.2, remote crypto endpt.: 20.20.20.2
     path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/1
     current outbound spi: 0x0(0)

     inbound esp sas:

     inbound ah sas:

     inbound pcp sas:

     outbound esp sas:

     outbound ah sas:

     outbound pcp sas:

   protected vrf: (none)
   local  ident (addr/mask/prot/port): (192.168.10.0/255.255.255.0/0/0)
   remote ident (addr/mask/prot/port): (192.168.30.0/255.255.255.0/0/0)
   current_peer 20.20.20.2 port 500
     PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 0, #recv errors 0

     local crypto endpt.: 10.10.10.2, remote crypto endpt.: 20.20.20.2
     path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/1
  --More--
```

The show crypto ipsec sa output verifies that Phase 2 Security Associations (SAs) are **ACTIVE**, ensuring end-to-end data encryption.

Phase 3: VPN Session Status:

```
HQ-RTR#show crypto session
Crypto session current status

Interface: FastEthernet0/1
Session status: UP-IDLE
Peer: 20.20.20.2 port 500
  IKE SA: local 10.10.10.2/500 remote 20.20.20.2/500 Active
  IPSEC FLOW: permit ip 192.168.20.0/255.255.255.0 192.168.40.0/255.255.255.0
        Active SAs: 0, origin: crypto map
  IPSEC FLOW: permit ip 192.168.10.0/255.255.255.0 192.168.30.0/255.255.255.0
        Active SAs: 0, origin: crypto map

Interface: FastEthernet0/0.10
Session status: DOWN
Peer: 20.20.20.2 port 500
  IPSEC FLOW: permit ip 192.168.20.0/255.255.255.0 192.168.40.0/255.255.255.0
        Active SAs: 0, origin: crypto map
  IPSEC FLOW: permit ip 192.168.10.0/255.255.255.0 192.168.30.0/255.255.255.0
        Active SAs: 0, origin: crypto map

Interface: FastEthernet0/0.20
Session status: DOWN
Peer: 20.20.20.2 port 500
  IPSEC FLOW: permit ip 192.168.20.0/255.255.255.0 192.168.40.0/255.255.255.0
 --More--
*Mar  1 01:18:10.147: No peer struct to get peer description
*Mar  1 01:18:10.151: No peer struct to get peer description
*Mar  1 01:18:10.151: No peer struct to get peer description
*Mar  1 01:18:10.151: No peer struct to get peer description
*Mar  1 01:18:10.151: No peer struct to get peer description
 --More--
 --More--
```

```
BRANCH-RTR#show crypto session
Crypto session current status

Interface: FastEthernet0/0
Session status: UP-IDLE
Peer: 10.10.10.2 port 500
  IKE SA: local 20.20.20.2/500 remote 10.10.10.2/500 Active
  IPSEC FLOW: permit ip 192.168.40.0/255.255.255.0 192.168.20.0/255.255.255.0
        Active SAs: 0, origin: crypto map
  IPSEC FLOW: deny ip 192.168.30.0/255.255.255.0 192.168.10.0/255.255.255.0
        Active SAs: 0, origin: crypto map
  IPSEC FLOW: permit ip 192.168.30.0/255.255.255.0 192.168.10.0/255.255.255.0
        Active SAs: 0, origin: crypto map

Interface: FastEthernet0/1
Session status: DOWN
Peer: 10.10.10.2 port 500
  IPSEC FLOW: permit ip 192.168.40.0/255.255.255.0 192.168.20.0/255.255.255.0
        Active SAs: 0, origin: crypto map
  IPSEC FLOW: deny ip 192.168.30.0/255.255.255.0 192.168.10.0/255.255.255.0
        Active SAs: 0, origin: crypto map
  IPSEC FLOW: permit ip 192.168.30.0/255.255.255.0 192.168.10.0/255.255.255.0
        Active SAs: 0, origin: crypto map

 --More
*Mar  1 01:17:07.171: No peer struct to get peer description
*Mar  1 01:17:07.171: No peer struct to get peer description
*Mar  1 01:17:07.175: No peer struct to get peer description
*Mar  1 01:17:07.175: No peer struct to get peer description
*Mar  1 01:17:07.175: No peer struct to get peer description
*Mar  1 01:17:07.175: No peer struct to get peer description
*Mar  1 01:17:07.179: No peer struct to get peer description
*Mar  1 01:17:07.179: No peer struct to get peer description--
 --More--
```

The show crypto session command provides a summary confirming the tunnel status as **UP-IDLE**.

Phase 4: Site-to-Site Connectivity (Router-to-Router Ping)

```
HQ-RTR#ping 192.168.30.1 source 192.168.10.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.30.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.10.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/185/528 ms
```

```
BRANCH-RTR#ping 192.168.10.1 source 192.168.30.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.30.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/89/208 ms
```

Successful pings between the WAN interfaces of HQ and Branch routers confirm physical and logical connectivity through the ISP ROUTER.

14. NON-FUNCTIONAL REQUIREMENTS

- **Reliability:** High availability through redundant trunk links.

- **Maintainability:** Standardized IP addressing and documented VLAN IDs.

- **Security:** Encrypted communication for sensitive departmental data.

-

15. COURSE CONCEPTS IMPLEMENTED

- OSI Model Layers 2 and 3

- Network Security and Cryptography

- Routing Protocols (OSPF)

- Switching and VLAN Management

16. CONCLUSION

The project successfully met all its objectives. By combining Layer 2 redundancy with Layer 3 security protocols, a stable and secure enterprise environment was created. The successful VPN tunnel establishment ensures that data integrity is maintained across public networks.

17. REFERENCES (IEEE FORMAT)

[1] Cisco Systems, "Configuring IPsec Network Security," Cisco IOS Security Configuration Guide, 2023. [

2] GNS3 Documentation, "Simulating Complex Networks," [Online]. Available: docs.gns3.com.

[3] W. Stallings, "Cryptography and Network Security: Principles and Practice," 7th ed., Pearson, 2017.