Project #01

Design and Implementation of High-Availability Enterprise Network Architecture using Cisco Packet Tracer

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1. Introduction

1.1 Project Overview

In the modern digital era, a robust and scalable network infrastructure is the backbone of any successful enterprise. This project focuses on designing and implementing a comprehensive network solution for a multi-branch organization. The organization consists of a Head Office located in Colombo, a regional branch in Kandy, and a remote branch in Galle. The design aims to simulate a real-world enterprise environment, ensuring seamless connectivity, high availability, and security across all locations.

1.2 Problem Statement

As organizations grow, they face challenges such as network downtime, security vulnerabilities, and inefficient data traffic management. A single point of failure at Head Office could disrupt operations for the entire company. Therefore, the primary challenge addressed in this project is designing a network that eliminates single points of failure while maintaining strict logical separation between departments (HR, Admin, Sales) to ensure data security.

1.3 Project Objectives

The main objective of this simulation is to demonstrate the practical application of advanced networking concepts. The specific objectives are as follows:

- **To Implement High Availability (HA):** Deploying HSRP (Hot Standby Router Protocol) at the Head Office to ensure 100% network uptime in case of router failure.
- **To Ensure Traffic Isolation:** Utilizing VLANs (Virtual Local Area Networks) to segregate traffic between IT, Sales, and HR departments for enhanced security.

- **To Enable Dynamic Routing:** Configuring OSPF (Open Shortest Path First) to facilitate efficient and automatic route updates between Colombo, Kandy, and Galle branches.
- **To Centralize Management:** implementing a DHCP Server with IP Helper addresses to automate IP allocation across the entire WAN.
- **To Integrate Wireless Connectivity:** Deploying a secure Wireless LAN (WLAN) in the Kandy branch for mobile users.

1.4 Scope and Tools Used

The scope of this project covers the end-to-end design, configuration, and verification of the enterprise network. The simulation is conducted using **Cisco Packet Tracer Version 8.2**, utilizing industry-standard devices such as Cisco 2911 Integrated Services Routers and Cisco 2960 Switches.

Network Diagram

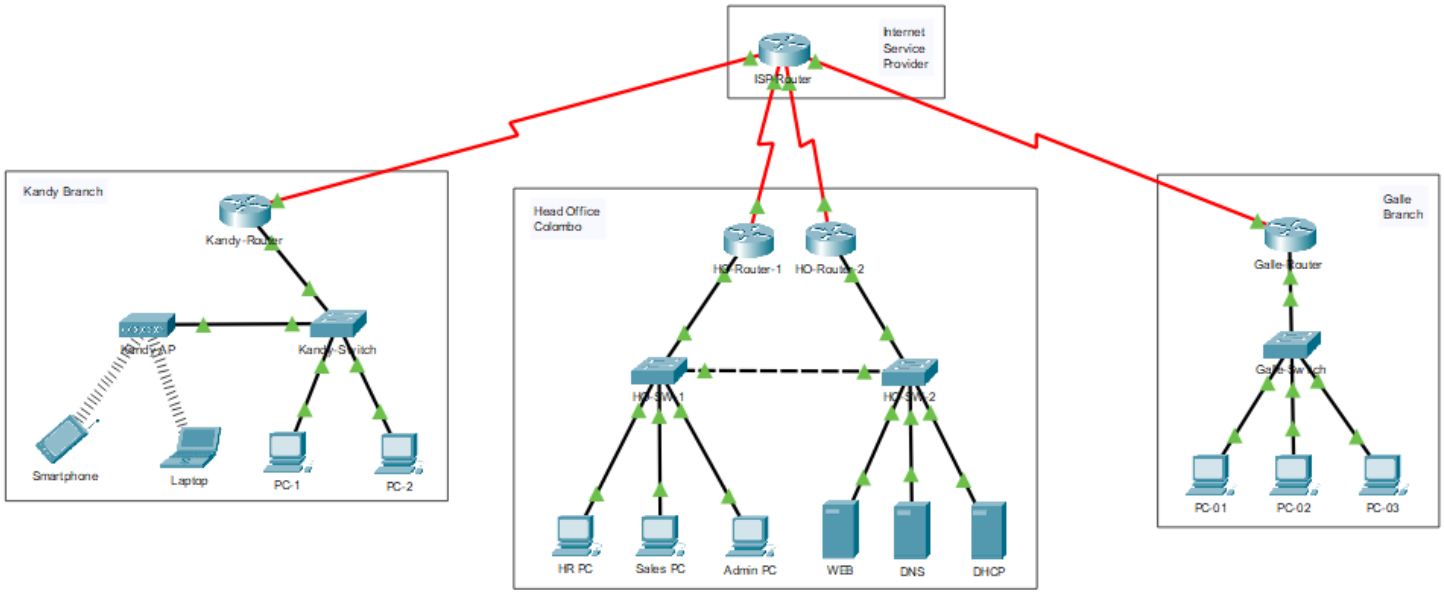

Figure 1: Enterprise Network Topology Diagram

2. Network Topology and Design

2.1 High-Level Network Architecture

The network architecture is designed based on the "Hub-and-Spoke" model, where the Colombo Head Office serves as the central hub, and the Kandy/Galle branches act as spokes connected via a simulated ISP cloud. This design ensures centralized management while allowing branch autonomy.

2.2 Design Justification

The topology has been engineered to address specific business requirements:

- **Redundant Core Layer (HQ):** The Head Office utilizes dual Cisco 2911 routers and dual switches. This redundancy ensures that if one device fails, the network automatically switches to the backup path using HSRP, preventing business disruption.
- **Hybrid Connectivity (Kandy Branch):** The Kandy branch demonstrates a modern hybrid office environment, supporting both wired workstations and wireless mobile devices via a secure Access Point.
- **Remote Connectivity (Galle Branch):** The Galle branch represents a remote site connected via a WAN link, simulating a typical branch office setup.
- **Traffic Segmentation:** The design avoids a "flat network" by using VLANs. This ensures that sensitive HR and Admin data is logically separated from general Sales traffic.

2.3 Hardware Specification

The following industry-standard Cisco devices were selected for the simulation:

Device Type	Model	Qty.	Role
Router	Cisco 2911 ISR	5	Gateway and WAN connectivity
Switch	Cisco 2960-24TT	4	Layer 2 Access Switching and VLAN handling
Access Point	Linksys WRT300N	1	Wireless connectivity for Kandy Branch
Servers	Generic PT Server	3	Hosting DHCP, DNS, and Web Services

3. IP Addressing Strategy

3.1 Addressing Scheme Overview

The IP addressing plan follows a hierarchical structure designed for scalability and ease of management. The Head Office utilizes the private **Class A (10.0.0.0/8)** range to accommodate a large number of hosts and future expansion. The branch offices are assigned **Class C (192.168.x.x)** addresses, which are standard for smaller networks.

3.2 Subnet Allocation

To conserve IP addresses on Point-to-Point WAN links, a **Prefix Length of /30 (255.255.255.252)** is used, providing exactly two usable IP addresses per link.

Table 1: WAN Connectivity

Connection	Interface	Network Address	Subnet mask	IP Address (Side A)	IP Address (Side B)
ISP -> HO_R1	Serial 0/0/0	200.1.1.0	/30	ISP: 200.1.1.1	HO_R1: 200.1.1.2
ISP -> HO_R2	Serial 0/0/1	200.1.1.4	/30	ISP: 200.1.1.5	HO_R2: 200.1.1.6
ISP -> Kandy	Serial 0/1/0	200.1.1.8	/30	ISP: 200.1.1.9	Kandy: 200.1.1.10
ISP -> Galle	Serial 0/1/1	200.1.1.12	/30	ISP: 200.1.1.13	Galle: 200.1.1.14

Table 2: Head Office LAN & VLAN Infrastructure (Colombo)

VLAN ID	VLAN Name	Network Address	Subnet Mask	Virtual Gateway IP (HSRP VIP)	Router 1 Physical IP	Router 2 Physical IP
10	IT_Dept	10.1.10.0	/24	10.1.10.254	10.1.10.1	10.1.10.2
20	Sales_Dept	10.1.20.0	/24	10.1.20.254	10.1.20.1	10.1.20.2
30	HR_Dept	10.1.30.0	/24	10.1.30.254	10.1.30.1	10.1.30.2
50	Servers	10.1.50.0	/24	10.1.50.254	10.1.50.1	10.1.50.2

Table 3: Branch Office LANs

Branch	Network Address	Subnet Mask	Default Gateway	DHCP Pool Range	Wireless SSID
Kandy	192.168.10.0	/24	192.168.10.1	.10 to .253	Kandy_WiFi
Galle	192.168.20.0	/24	192.168.20.1	.10 to .253	-

Table 4: Server Farm Allocation (Head Office - VLAN 50)

Server	IP Address	Subnet Mask	Default Gateway	Function
DHCP	10.1.50.10	/24	10.1.50.254	Assigns IPs to all branches
DNS	10.1.50.11	/24	10.1.50.254	Domain Name Resolution
WEB	10.1.50.12	/24	10.1.50.254	Corporate Intranet Website

4. Implementation and Configuration

4.1 VLAN and Trunking Configuration (Layer 2)

VLANs were implemented on the Head Office switches to logically separate departments. Trunk ports were configured using IEEE 802.1Q encapsulation to carry traffic from multiple VLANs to the router.

Configurations on Head Office Switch 1

```
! Creating VLANs
vlan 10
 name IT_Dept
vlan 20
 name Sales_Dept

! Configuring Access Ports
interface FastEthernet0/1
 switchport mode access
 switchport access vlan 10

! Configuring Trunk Ports
interface GigabitEthernet0/1
 switchport mode trunk
```

```
HO-SW-1#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/4, Fa0/5, Fa0/6, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24
10   IT_Dept                          active    Fa0/1
20   Sales_Dept                       active    Fa0/2
30   HR_Dept                          active    Fa0/3
50   Servers                          active
1002 fddi-default                     active
```

Figure 2: VLAN Verification on Head Office Switch 1

4.2 High Availability with HSRP (Layer 3)

To eliminate the single point of failure at the Head Office gateway, **Hot Standby Router Protocol (HSRP)** was configured. HO-Router-1 is set as the Active router with a higher priority (110), while HO-Router-2 acts as the Standby router.

Configurations on Head Office Router 1

```
interface GigabitEthernet0/0.10
 encapsulation dot1q 10
 ip address 10.1.10.1 255.255.255.0
 standby 10 ip 10.1.10.254
 standby 10 priority 110
 standby 10 preempt
```

```
HO-Router-1>enable
HO-Router-1#show standby brief
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Gig         10   110 P Active   local           10.1.10.2       10.1.10.254
Gig         20   110 P Active   local           10.1.20.2       10.1.20.254
Gig         30   110 P Active   local           10.1.30.2       10.1.30.254
Gig         50   110 P Active   local           10.1.50.2       10.1.50.254
```

Figure 3: HSRP Verification on Head Office Router 1

```
HO-Router-2>en
HO-Router-2#show standby brief
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Gig         10   100   Standby  10.1.10.1       local           10.1.10.254
Gig         20   100   Standby  10.1.20.1       local           10.1.20.254
Gig         30   100   Standby  10.1.30.1       local           10.1.30.254
Gig         50   100   Standby  10.1.50.1       local           10.1.50.254
```

Figure 4: HSRP Verification on Head Office Router 2

4.3 Routing Configuration (OSPF)

Inter-branch connectivity was achieved using OSPF Process ID 1. Network statements were added to advertise both LAN subnets and WAN links into Area 0 (Backbone Area).

Configurations on Kandy Router

```
router ospf 1
 network 192.168.10.0 0.0.0.255 area 0
 network 200.1.1.8 0.0.0.3 area 0
```

```
Kandy-Router>en
Kandy-Router#show ip route
Codes: L - local, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/24 is subnetted, 4 subnets
O       10.1.10.0/24 [110/129] via 200.1.1.9, 00:46:46, Serial0/0/0
O       10.1.20.0/24 [110/129] via 200.1.1.9, 00:46:46, Serial0/0/0
O       10.1.30.0/24 [110/129] via 200.1.1.9, 00:46:46, Serial0/0/0
O       10.1.50.0/24 [110/129] via 200.1.1.9, 00:46:46, Serial0/0/0
     192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0
L       192.168.10.1/32 is directly connected, GigabitEthernet0/0
O    192.168.20.0/24 [110/129] via 200.1.1.9, 00:46:46, Serial0/0/0
     200.1.1.0/24 is variably subnetted, 5 subnets, 2 masks
O       200.1.1.0/30 [110/128] via 200.1.1.9, 00:46:46, Serial0/0/0
O       200.1.1.4/30 [110/128] via 200.1.1.9, 00:46:46, Serial0/0/0
C       200.1.1.8/30 is directly connected, Serial0/0/0
L       200.1.1.10/32 is directly connected, Serial0/0/0
O       200.1.1.12/30 [110/128] via 200.1.1.9, 00:46:46, Serial0/0/0
```

Figure 5: OSPF Verification on Kandy Router2

4.4 DHCP & IP Helper Services

A centralized DHCP server located at the Head Office handles IP allocation for all branches. IP Helper-Address was configured on router interfaces to relay DHCP broadcast messages to the server across the WAN.

```
interface GigabitEthernet0/0.10
 ip helper-address 10.1.50.10
```

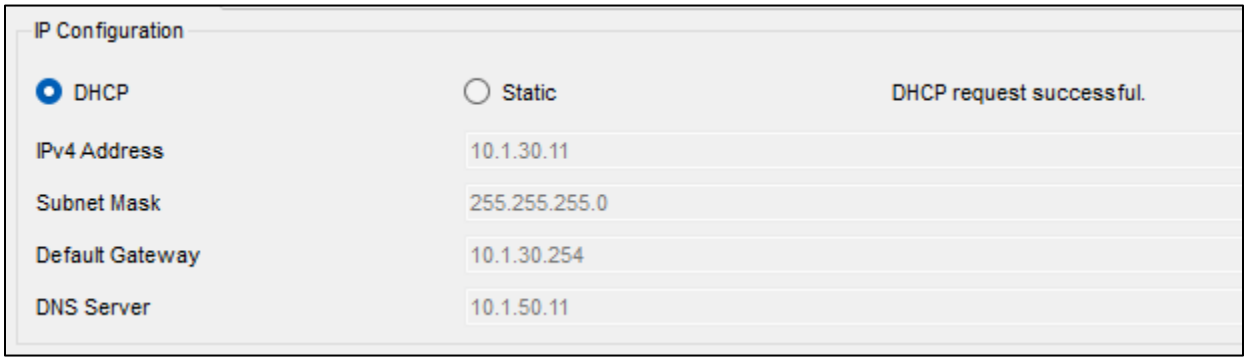

Figure 6: DHCP Verification on PC

5. Testing and Verification

5.1 Connectivity Test (Ping)

Successful ping response from a PC in Galle Branch (192.168.20.2) to the Head Office Web Server (10.1.50.12). This validates end-to-end connectivity across the WAN.

```
C:\>ping 10.1.50.12

Pinging 10.1.50.12 with 32 bytes of data:

Reply from 10.1.50.12: bytes=32 time=15ms TTL=125
Reply from 10.1.50.12: bytes=32 time=15ms TTL=125
Reply from 10.1.50.12: bytes=32 time=2ms TTL=125
Reply from 10.1.50.12: bytes=32 time=12ms TTL=125

Ping statistics for 10.1.50.12:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 2ms, Maximum = 15ms, Average = 11ms
```

Figure 7: Ping testing on PC at Galle Branch

5.2 Redundancy Test (HSRP)

When the link to HO-Router-1 was manually shut down, traffic automatically shifted to HO-Router-2 with minimal packet loss.

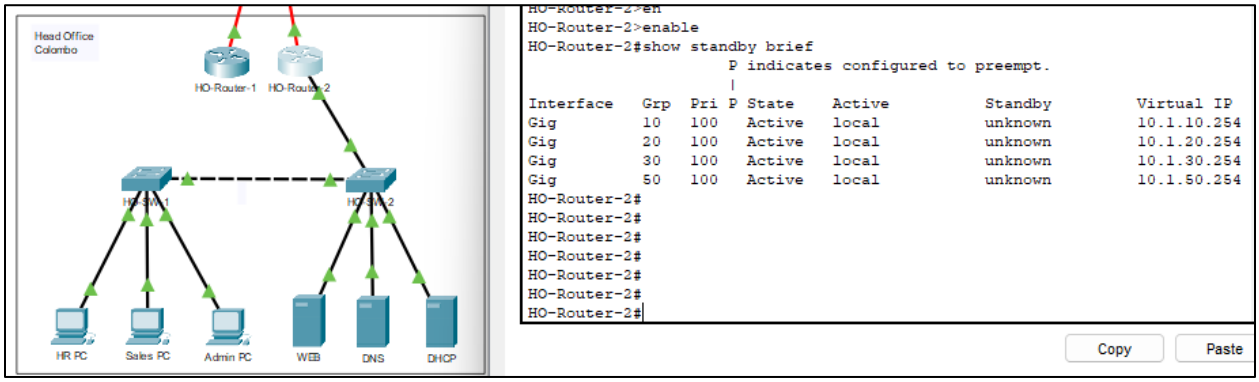

Figure 8: HSRP test on Head Office Router 2

5.3 Path Analysis (Trace Route)

A trace route from Kandy to Head Office shows the packet traversing through the ISP router, confirming proper routing path selection.

```
C:\>tracert 10.1.50.10

Tracing route to 10.1.50.10 over a maximum of 30 hops:

  1    31 ms     11 ms     11 ms     192.168.10.1
  2    16 ms     15 ms     11 ms     200.1.1.9
  3    19 ms     11 ms     13 ms     200.1.1.2
  4    8 ms      *         11 ms     10.1.50.10

Trace complete.
```

Figure 9: Trace Route from Kandy to Head Office

6. Conclusion

This project successfully demonstrated the design and implementation of a scalable, highly available enterprise network. By utilizing technologies such as VLANs for security, HSRP for redundancy, and OSPF for dynamic routing, the network ensures business continuity and efficient data flow. The simulation proves that the proposed architecture is suitable for deployment in a real-world multi-branch organization.