DESIGN AND IMPLEMENT A SCALABLE AND SECURE IPV6 NETWORK

PROJECT IN COMPUTER NETWORKING

OVERVIEW

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INTRODUCTION

Objective:

Design a scalable, secure, multi-branch network infrastructure using modern IPv6 protocols and advanced routing.

Key Features:

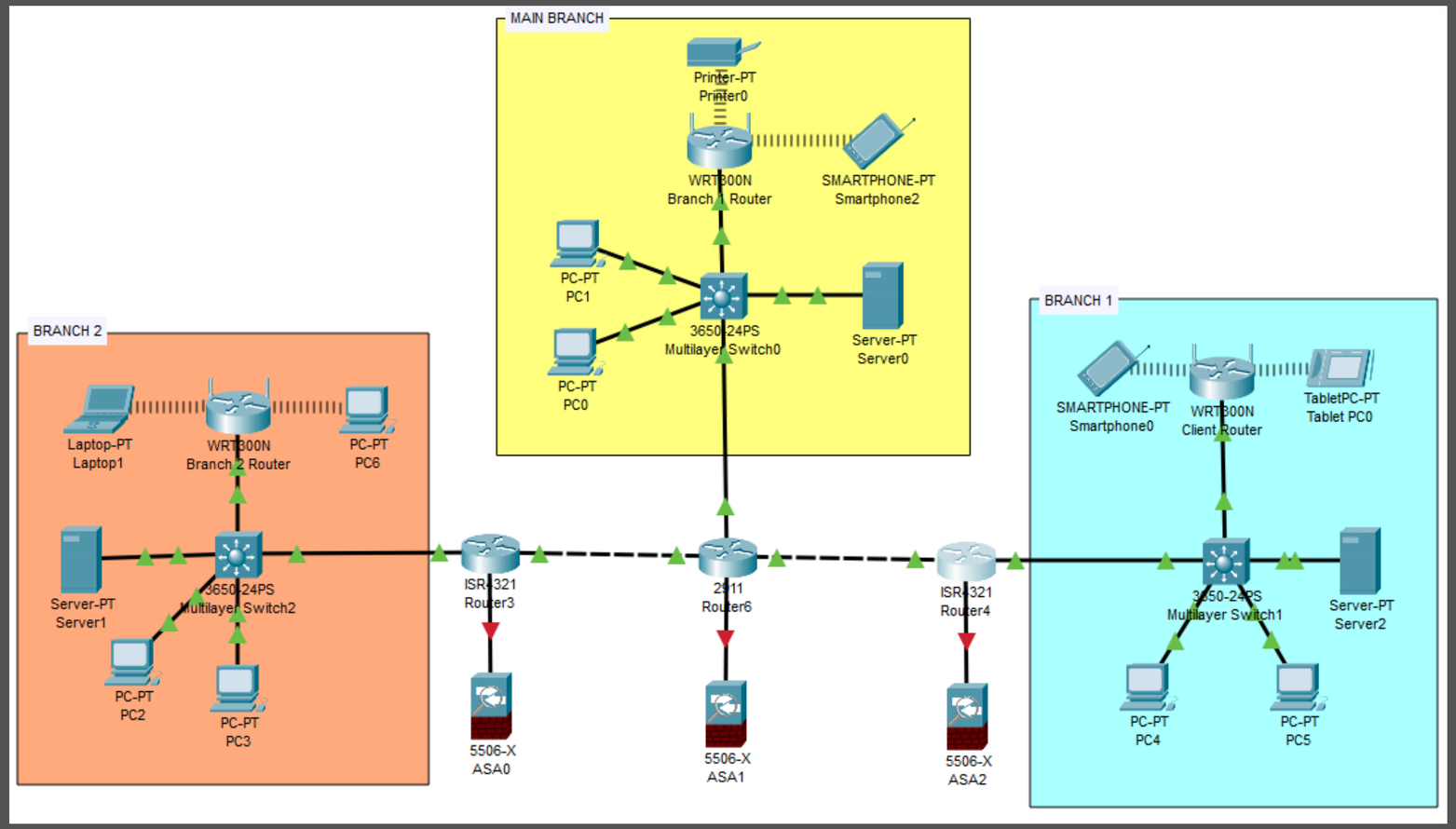
- **IPv6**: Enhanced address space and simplified address management.
- **Advanced Routing**: Using OSPFv3 and BGP for effective traffic management and scalability.
- **Wireless Integration**: Wi-Fi 6 and mesh networks for seamless wireless connectivity.
- **Security**: Branch-specific firewalls to protect against potential threats.

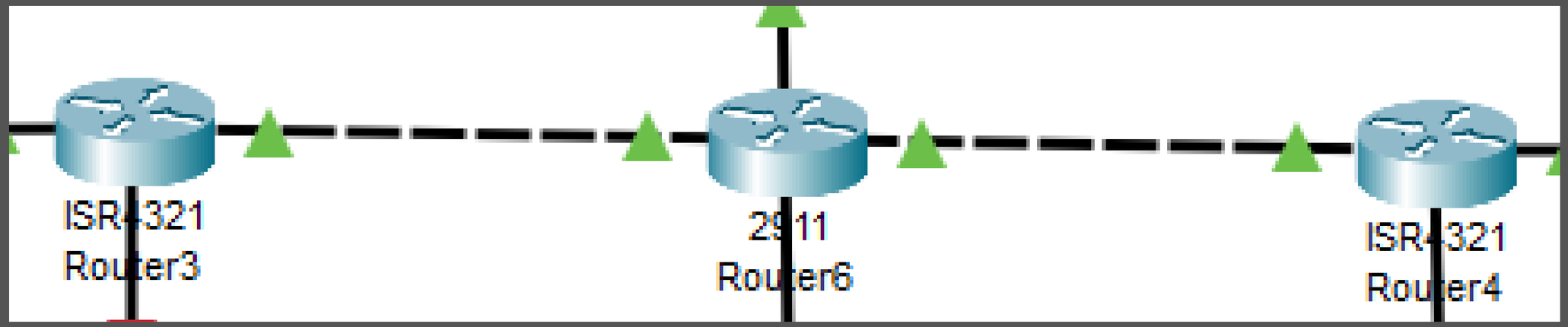
Significance: This project highlights the importance of adopting IPv6 and advanced protocols to meet the growing demands of today's interconnected world, ensuring future-ready and efficient network operations.

DESIGN OVERVIEW

Network Architecture

- Multi-branch setup with IPv6 for each network segment.
- Architecture Diagram: Visual representation of branches and network flow.



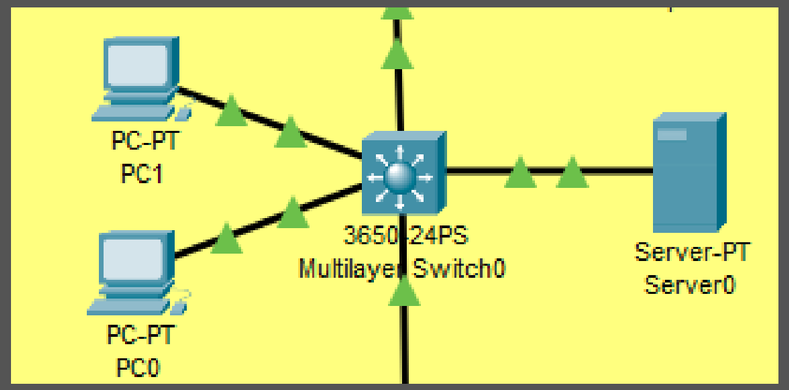


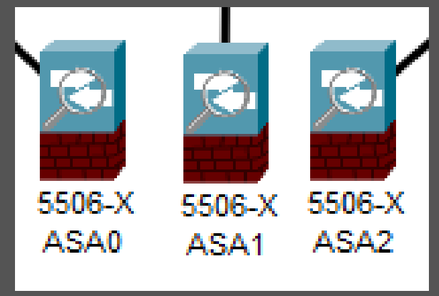
CORE LAYER

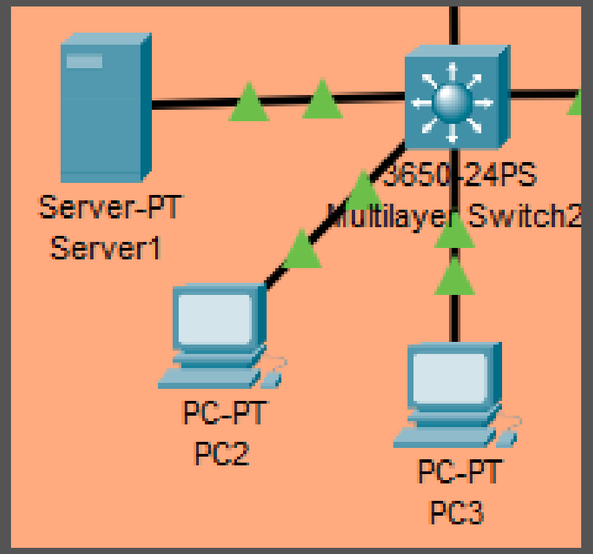
The core layer of the interconnected routers (ISR 321 Router3, 2911 Router6, and ISR 321 Router4) at the network architecture diagram. This layer forms the backbone of the network, providing high-speed and reliable connectivity between the main branch and branch offices, and ensuring efficient data transmission across the distribution and access layers.

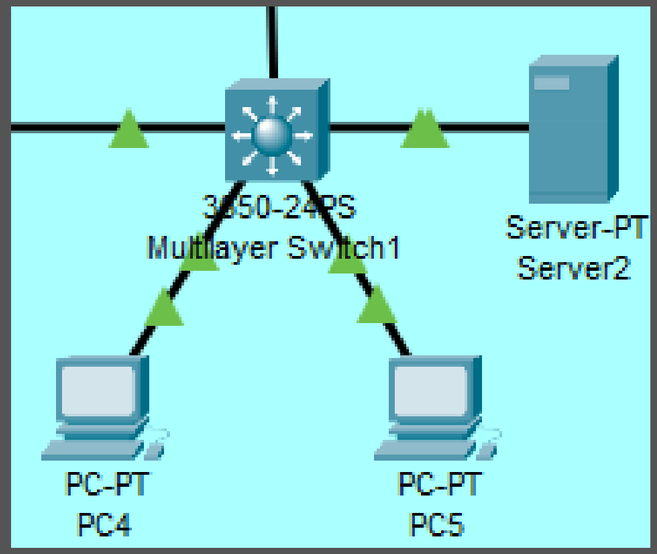
DISTRIBUTION LAYER

The distribution layer, consisting of ASA firewalls and multilayer switches, connects important routers to branches, handles routing, enforces security policies, and controls inter-VLAN traffic.



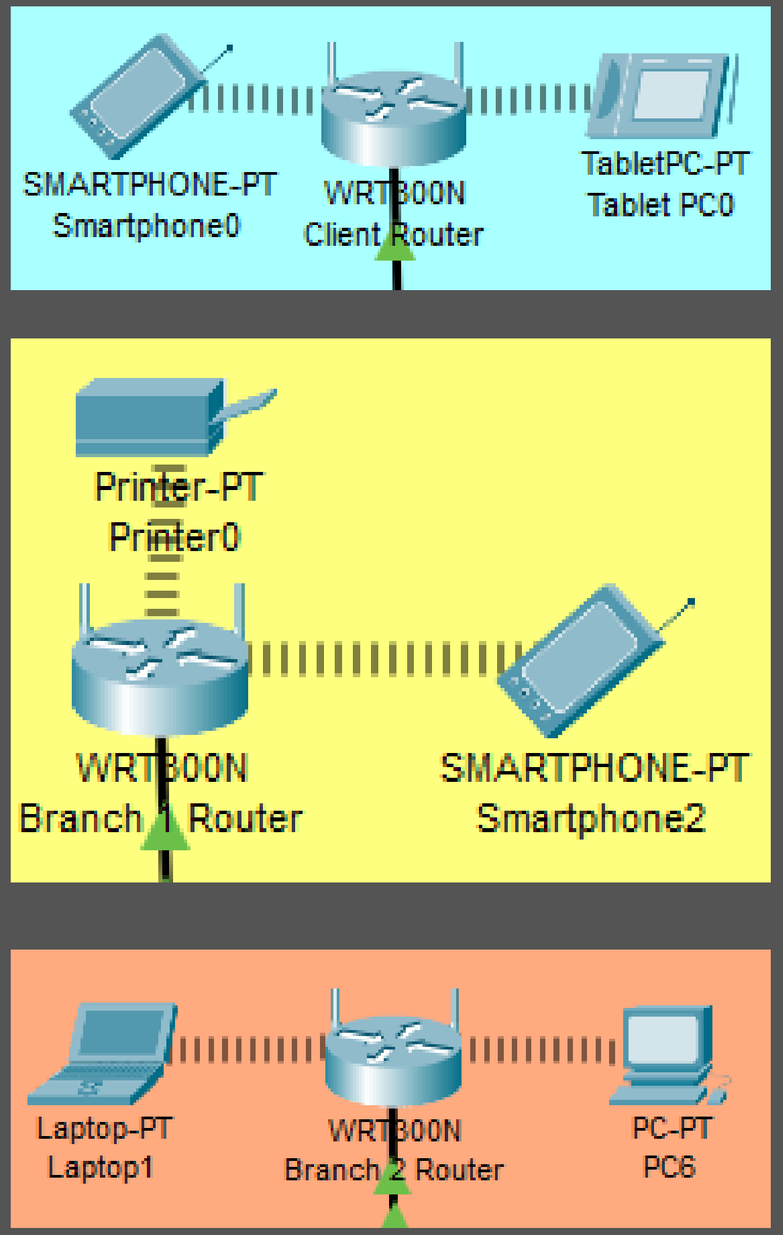






ACCESS LAYER

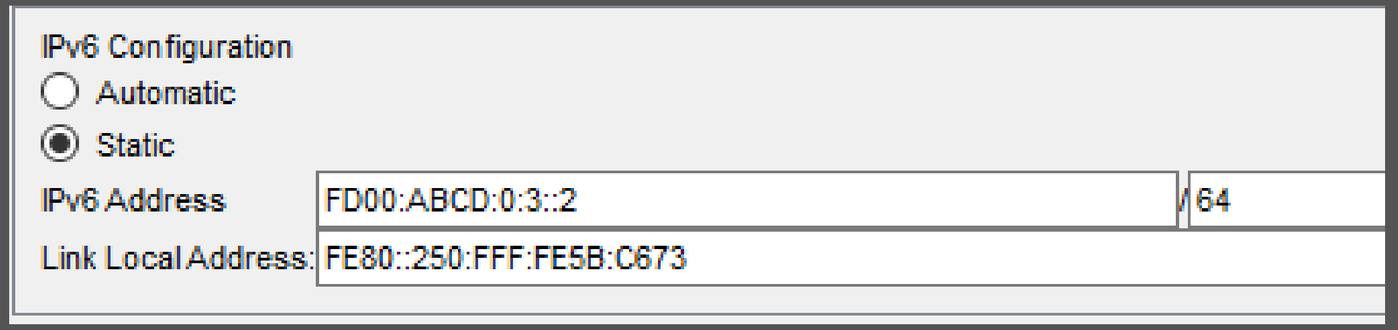
The access layer comprises three WRT300N routers, each referred to as a "Client Router," "Branch1 Router," and "Branch2 Router" that connect end-user devices to the network, facilitating communication across different segments.



IPv6 Addressing Scheme

- Each segment assigned a unique /64 subnet.
- Structure: FD00:ABCD:0:X::Y/64, where X is the subnet, Y is the device

```
Router>en
Router#show ipv6 interface brief
GigabitEthernet0/0/0       [up/up]
    FE80::201:42FF:FEEB:CE01
    FD00:ABCD:0:1::1
GigabitEthernet0/0/1       [up/up]
    FE80::201:42FF:FEEB:CE02
    FD00:ABCD:0:10::1
```



Routing Protocols

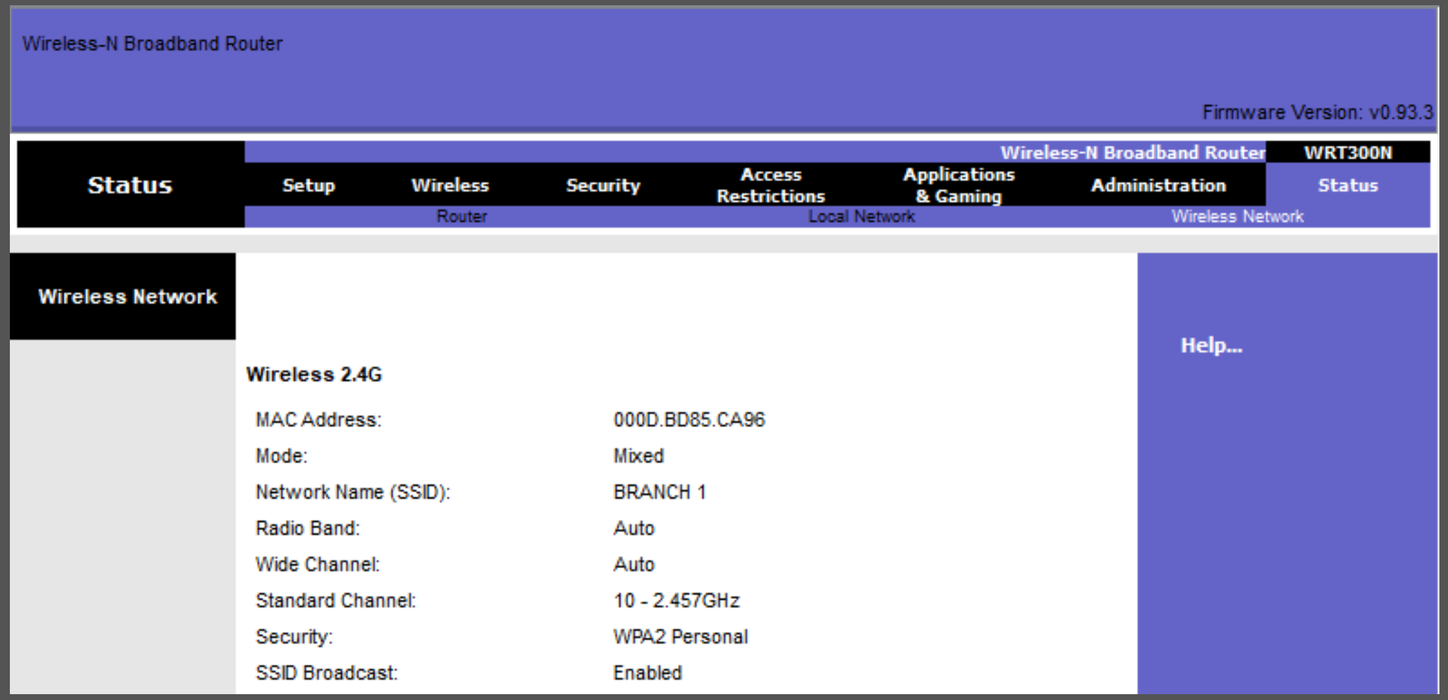
- OSPFv3: Enables dynamic routing within branches, supports IPv6.
- BGP: Manages inter-branch routing, scalable across dispersed networks.

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface g0/0/1
Router(config-if)#ipv6 address FD00:ABCD:0:10::1/64
Router(config-if)#ipv6 ospf 1 area 0
Router(config-if)#ex
Router(config)#ex
Router#
%SYS-5-CONFIG_I: Configured from console by console
wr me
Building configuration...
[OK]
Router#
02:26:14: %OSPFv3-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0/1 from
LOADING to FULL, Loading Done
```

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router bgp 65001
Router(config-router)#neighbor 192.168.1.2 remote-as 65002
Router(config-router)#network 192.168.1.0 mask 255.255.255.0
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#wr me
Building configuration...
[OK]
```

Wireless & Security Measures

- Wi-Fi 6 and mesh networks for robust wireless coverage.
- Branch-specific firewalls; IPsec for VPN security, AES-256 encryption for data integrity.




```
ciscoasa>en
Password:
ciscoasa#conf t
ciscoasa(config)#crypto ikev1 policy 10
ciscoasa(config-ikev1-policy)#authentication pre-share
ciscoasa(config-ikev1-policy)#encryption aes-256
ciscoasa(config-ikev1-policy)#hash sha
ciscoasa(config-ikev1-policy)#group 2
ciscoasa(config-ikev1-policy)#lifetime 86400
ciscoasa(config-ikev1-policy)#ex
ciscoasa(config)#ex
ciscoasa#wr me
Building configuration...
Cryptochecksum: 70c65aed 49e5515f 67bc6077 3c462a85

1171  bytes copied in 1.524 secs (768 bytes/sec)
[OK]
```

Implementation Plan

- Step-by-step configuration for routers, switches, and firewalls.
- Commands and configurations saved for setup consistency.

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface g0/0/0
%Invalid interface type and number
Router(config)#interface g0/0
Router(config-if)#ipv6 address FD00:ABCD:0:2::1/64
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to up

Router(config-if)#ex
Router(config)#interface g0/1
Router(config-if)#ipv6 address FD00:ABCD:0:10::2/64
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to up

Router(config-if)#ex
Router(config)#interface g0/2
Router(config-if)#ipv6 address FD00:ABCD:0:10::3/64
%GigabitEthernet0/2: Error: FD00:ABCD:0:10::/64 is overlapping with FD00:ABCD:0:10::/64 on GigabitEthernet0/1
Router(config-if)#ipv6 address FD00:ABCD:0:11::3/64
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/2, changed state to up

Router(config-if)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#wr me
Building configuration...
[OK]
```

Implementation Plan

- Step-by-step configuration for routers, switches, and firewalls.
- Commands and configurations saved for setup consistency.

```
Switch>en
Switch#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)#ipv6 unicast-routing
Switch(config)#interface Vlan1
Switch(config-if)#ipv6 address FD00:ABCD:0:1::1/64
Switch(config-if)#no shutdown

Switch(config-if)#
%LINK-5-CHANGED: Interface Vlan1, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to up

Switch(config-if)#end
Switch#
%SYS-5-CONFIG_I: Configured from console by console

Switch#wr me
Building configuration...
Compressed configuration from 7383 bytes to 3601 bytes[OK]
[OK]
```

IMPLEMENTATION DETAILS

IPv6 Addressing Scheme

- Each network segment uses a unique /64 IPv6 subnet: FD00:ABCD:0:X::Y/64
- X: Represents subnetting for organization.
- Y: Device-specific identifier within the subnet.

```
Router>en
Router#show ipv6 route
IPv6 Routing Table - 6 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
C   FD00:ABCD:0:1::/64 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   FD00:ABCD:0:1::1/128 [0/0]
     via GigabitEthernet0/0/0, receive
O   FD00:ABCD:0:2::/64 [110/2]
     via FE80::260:5CFF:FEA1:5902, GigabitEthernet0/0/1
C   FD00:ABCD:0:10::/64 [0/0]
     via GigabitEthernet0/0/1, directly connected
L   FD00:ABCD:0:10::1/128 [0/0]
     via GigabitEthernet0/0/1, receive
```

Figure 1.2. Showing ipv6 route

Router Configuration

- IPv6 Setup: Assign IPv6 addresses on router interfaces (e.g., FD00:ABCD:0:2::1/64).
- Activation: Use no shutdown command to enable interfaces, and write memory to save configurations.

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface g0/0/0
%Invalid interface type and number
Router(config)#interface g0/0
Router(config-if)#ipv6 address FD00:ABCD:0:2::1/64
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to up

Router(config-if)#ex
Router(config)#interface g0/1
Router(config-if)#ipv6 address FD00:ABCD:0:10::2/64
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to up

Router(config-if)#ex
Router(config)#interface g0/2
Router(config-if)#ipv6 address FD00:ABCD:0:10::3/64
%GigabitEthernet0/2: Error: FD00:ABCD:0:10::/64 is overlapping with FD00:ABCD:0:10::/64 on GigabitEthernet0/1
Router(config-if)#ipv6 address FD00:ABCD:0:11::3/64
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/2, changed state to up

Router(config-if)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#wr me
Building configuration...
[OK]
```

Figure 1. Router configuration

Switch Configuration

- IPv6 on VLAN1: Configure IPv6 with ipv6 unicast-routing and assign IPv6 addresses (e.g., FD00:ABCD:0:1::1/64 on VLAN1).
- Security: Enable and save configuration with no shutdown and write memory.

```
Switch>en
Switch#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)#ipv6 unicast-routing
Switch(config)#interface Vlan1
Switch(config-if)#ipv6 address FD00:ABCD:0:1::1/64
Switch(config-if)#no shutdown

Switch(config-if)#
%LINK-5-CHANGED: Interface Vlan1, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to up

Switch(config-if)#end
Switch#
%SYS-5-CONFIG_I: Configured from console by console

Switch#wr me
Building configuration...
Compressed configuration from 7383 bytes to 3601 bytes[OK]
[OK]
```

Figure 2. Switch configuration

Network Security Protocols

- IPSec Implementation: Utilizes Internet Key Exchange (IKEv1) and AES-256 encryption in firewalls.
- VPN Setup: Tunnels and crypto mappings are established in firewalls to support secure VPN traffic.

```
ciscoasa>en
Password:
ciscoasa#conf t
ciscoasa(config)#crypto ikev1 policy 10
ciscoasa(config-ikev1-policy)#authentication pre-share
ciscoasa(config-ikev1-policy)#encryption aes-256
ciscoasa(config-ikev1-policy)#hash sha
ciscoasa(config-ikev1-policy)#group 2
ciscoasa(config-ikev1-policy)#lifetime 86400
ciscoasa(config-ikev1-policy)#ex
ciscoasa(config)#ex
ciscoasa#wr me
Building configuration...
Cryptochecksum: 70c65aed 49e5515f 67bc6077 3c462a85

1171  bytes copied in 1.524 secs (768 bytes/sec)
[OK]
```

Figure 1. Internet Key Exchange (IKEv1) protocol and Encryption aes-256 in a Firewall for IPsec

```
ciscoasa>en
Password:
ciscoasa#conf
% Incomplete command.
ciscoasa#conf t
ciscoasa(config)#access-list VPN-Traffic extended permit ip 192.168.1.0 255.255.255.0
192.168.2.0 255.255.255.0
WARNING: <VPN-Traffic> found duplicate element
ciscoasa(config)#ex
ciscoasa#wr me
Building configuration...
Cryptochecksum: 70c65aed 49e5515f 67bc6077 3c462a85

1539  bytes copied in 2.586 secs (595 bytes/sec)
[OK]
ciscoasa#show access-list
access-list cached ACL log flows: total 0, denied 0 (deny-flow-max 4096) alert-interval
300
access-list VPN-Traffic; 1 elements; name hash: 0xc0019c65
access-list VPN-Traffic line 1 extended permit ip 192.168.1.0 255.255.255.0 192.168.2.0
255.255.255.0(hitcnt=0) 0x55b5a17b
```

Figure 3. VPN-Traffic in a Firewall for IPsec

```
ciscoasa>en
Password:
ciscoasa#conf t
ciscoasa(config)#tunnel-group 203.0.113.1 type ipsec-l2l
WARNING: L2L tunnel-groups that have names which are not an IP
address may only be used if the tunnel authentication
method is Digital Certificates and/or The peer is
configured to use Aggressive Mode
ciscoasa(config)#tunnel-group 203.0.113.1 ipsec-attributes
ciscoasa(config-tunnel-ipsec)#ikev1 pre-shared-key PSKey123
ciscoasa(config-tunnel-ipsec)#ex
ciscoasa(config)#ex
ciscoasa#wr me
Building configuration...
Cryptochecksum: 70c65aed 49e5515f 67bc6077 3c462a85

1295  bytes copied in 1.896 secs (683 bytes/sec)
[OK]
```

Figure 2. Tunnel in a Firewall for IPsec

Testing Procedures

- Validated network performance for latency, throughput, and connectivity.
- Troubleshooting conducted on detected issues to ensure optimal functionality.

```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping FD00:ABCD:0:3::3

Pinging FD00:ABCD:0:3::3 with 32 bytes of data:

Reply from FD00:ABCD:0:3::3: bytes=32 time<1ms TTL=128
Reply from FD00:ABCD:0:3::3: bytes=32 time<1ms TTL=128
Reply from FD00:ABCD:0:3::3: bytes=32 time<1ms TTL=128
Reply from FD00:ABCD:0:3::3: bytes=32 time=9ms TTL=128

Ping statistics for FD00:ABCD:0:3::3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 9ms, Average = 2ms
```

```
C:\>tracert FD00:ABCD:0:3::3

Tracing route to FD00:ABCD:0:3::3 over a maximum of 30 hops:

  1    0 ms      0 ms      0 ms      FD00:ABCD:0:3::3

Trace complete.
```

Figure 1. Pinging PC 2 of Branch 2 to PC 4 of Branch 1 and Tracert

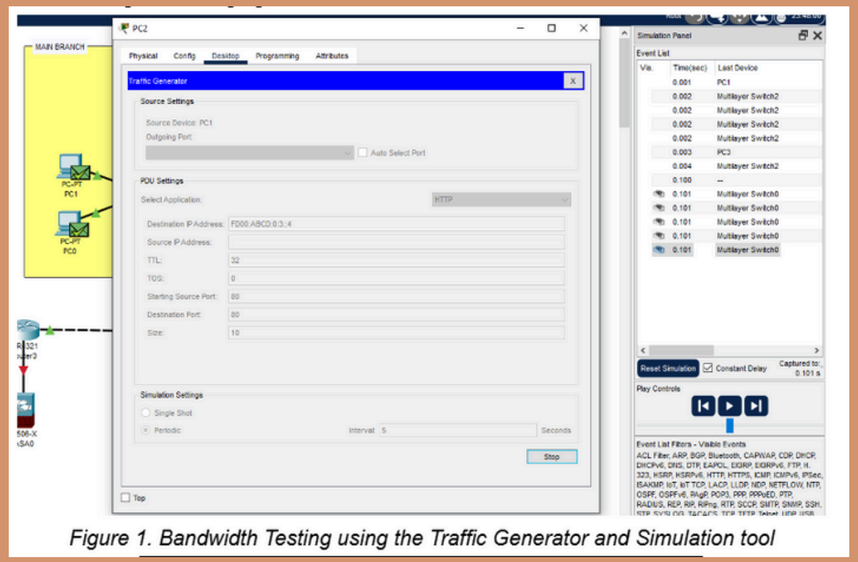


Figure 1. Bandwidth Testing using the Traffic Generator and Simulation tool

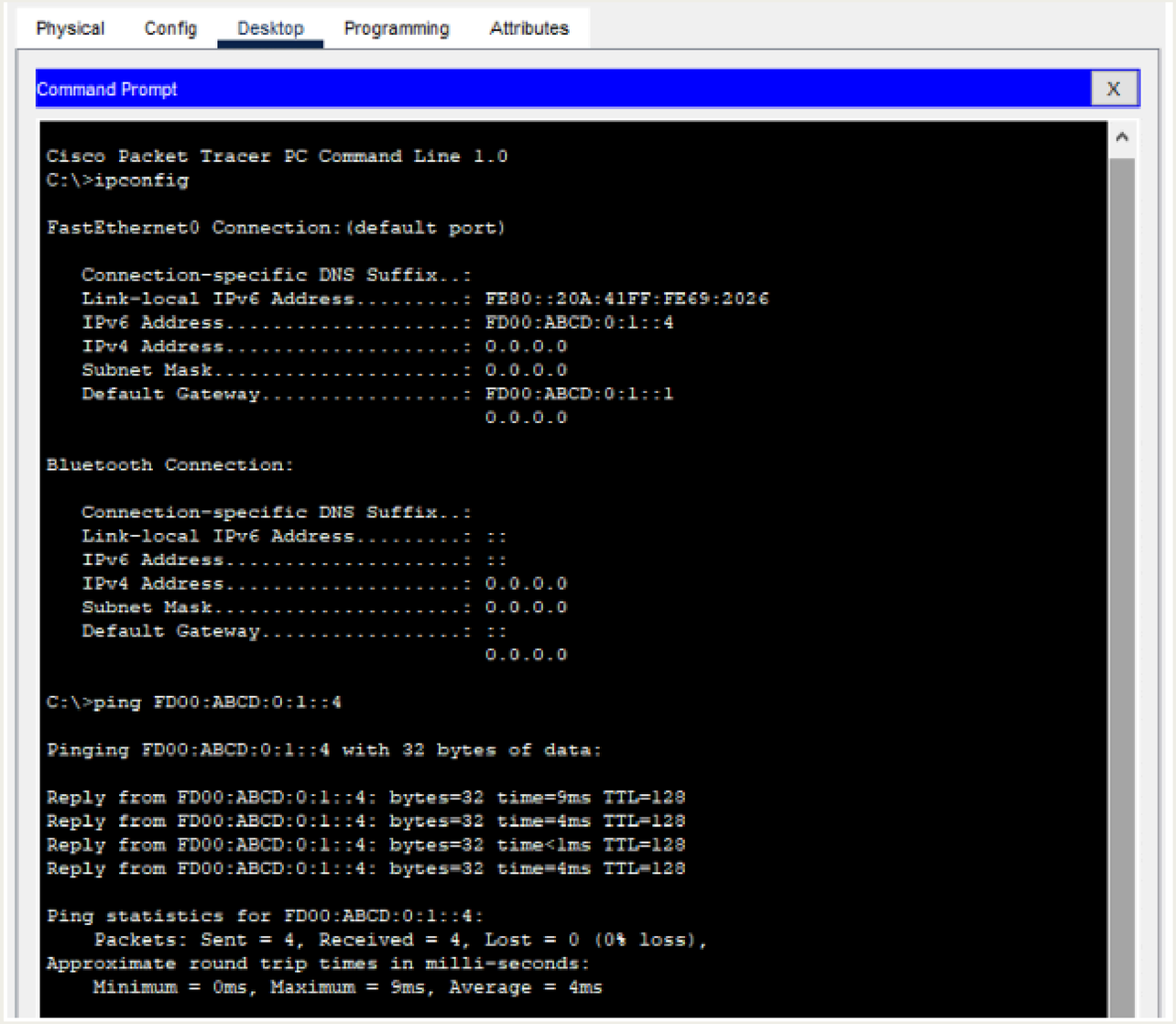
```
C:\>ping FD00:ABCD:0:2::2

Pinging FD00:ABCD:0:2::2 with 32 bytes of data:

Reply from FD00:ABCD:0:2::2: bytes=32 time=1ms TTL=128
Reply from FD00:ABCD:0:2::2: bytes=32 time<1ms TTL=128
Reply from FD00:ABCD:0:2::2: bytes=32 time<1ms TTL=128
Reply from FD00:ABCD:0:2::2: bytes=32 time<1ms TTL=128

Ping statistics for FD00:ABCD:0:2::2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

Figure 1. iPerf Client Testing

TESTING RESULTS

Ping Test

- Document the results of ping tests between IPv6-enabled devices to ensure connectivity.



Routing Table Verification:

- Show the routing table outputs from each router after the routing protocols are configured.

```
Router>en
Router#
Router#
07:24:26: %OSPFv3-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0/1 from LOADING
to FULL, Loading Done

Router#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0/0   192.168.2.1     YES manual up                    up
GigabitEthernet0/0/1   192.168.20.2    YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
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

     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.2.0/30 is directly connected, GigabitEthernet0/0/0
L       192.168.2.1/32 is directly connected, GigabitEthernet0/0/0
     192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.20.0/24 is directly connected, GigabitEthernet0/0/1
L       192.168.20.2/32 is directly connected, GigabitEthernet0/0/1
```

Router 4 Configuration

```
Router>en
Router#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0/0   192.168.3.1     YES manual up                    up
GigabitEthernet0/0/1   192.168.30.2    YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
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

     192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.3.0/30 is directly connected, GigabitEthernet0/0/0
L       192.168.3.1/32 is directly connected, GigabitEthernet0/0/0
     192.168.30.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.30.0/24 is directly connected, GigabitEthernet0/0/1
L       192.168.30.2/32 is directly connected, GigabitEthernet0/0/1
```

Router 3 Configuration

```
Router>en
Router#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0     192.168.1.1     YES manual up                    up
GigabitEthernet0/1     unassigned      YES unset  up                    up
GigabitEthernet0/2     unassigned      YES unset  up                    up
Vlan1                  unassigned      YES unset  administratively down down
Router#
07:22:36: %OSPFv3-5-ADJCHG: Process 1, Nbr 1.1.1.1 on GigabitEthernet0/0 from LOADING to
FULL, Loading Done

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

     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/30 is directly connected, GigabitEthernet0/0
L       192.168.1.1/32 is directly connected, GigabitEthernet0/0
```

Router 6 Configuration

BGP Status Check:

- Verify BGP peering and route propagation.

```
Router>en
Router#show ip bgp
BGP table version is 1, local router ID is 192.168.30.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path

Router#show ip bgp summary
BGP router identifier 192.168.30.2, local AS number 65001
BGP table version is 1, main routing table version 6
0 network entries using 0 bytes of memory
0 path entries using 0 bytes of memory
0/0 BGP path/bestpath attribute entries using 0 bytes of memory
0 BGP AS-PATH entries using 0 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
Bitfield cache entries: current 1 (at peak 1) using 32 bytes of memory
BGP using 32 total bytes of memory
BGP activity 0/0 prefixes, 0/0 paths, scan interval 60 secs

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.1.2     4 65002       0       0        1    0    0 32:10:51        4
```

CONCLUSION

The project successfully implemented a scalable network with IPv6, OSPFv3, and BGP, supporting a multi-branch organization. IPv6 expanded address space, OSPFv3 ensured fast convergence, and BGP enabled reliable inter-branch communication. Security measures, including firewalls, protected data integrity and privacy. Future enhancements could include advanced monitoring tools, IPS, and SDN for improved scalability, security, and adaptability to meet evolving organizational needs.

THANK YOU!