

**Purpose**

With growing networks, security and managing who can reach network resources is increasingly important. Virtual Routing & Forwarding (VRF) is a technology that can split a network in software, making devices be only able to recognize other specific devices in the network. This split made in software means that the hardware between separated networks can be shared, so new splits in the network can be added without needing new hardware or connections. VRF is commonly used to keep networks separate and confidential at points of intersection such as service providers networks.

**Background Information**

Virtual Routing & Forwarding (VRF) separates networks logically by creating separate routing tables for each instance. Routing tables are used by routers to figure out where to send the data. The routing table is like a GPS system that given a destination, will find the best path to reach it. By creating separate routing tables on a router, VRF can create new and separate path mappings for each VRF network. Networks that are on separate VRFs should not be able to reach each other because the routes exist separately, as if they are in a separate universe. This also means that given the same destination IP address, the router can have different paths because they are routing for separate VRFs. The power to use the same IP addresses to reach different locations makes VRF a strong choice for splitting a network without the need for changing IP addresses or adding routers.

In order to logically separate the network, sub interfaces must be configured for each network. Sub interfaces are a configuration of interfaces that allows a single interface to take on multiple IP address. Because the routers are sharing the same wires and connections yet need to support multiple networks, a single wire needs to create these software sub interfaces to distinguish between the separate VRFs. For routing purposes, the sub interfaces are treated as separate connections by the router. Even though the VRFs are routing using different sub interfaces, the same hardware wire is used to send data.

In terms of configuring sub interfaces, they must be configured with an 802.1q encapsulation number. This is for the local area network technology of VLANs where a local area network can be segmented into separate parts by labelling data packets by the VLAN number they are intended to be sent to. Although VRF technology does not interact with VLAN technology, sub interfaces still require a VLAN number for it to have an assigned IP address. VRF can be seen as a more software defined version of VLANs, but for a larger and wider network. Forwarding or assignment to a VRF is done for each interface or sub interface, meaning that a typical configuration would include a single interface split into multiple sub interfaces. Each sub interface would take on different VLAN numbers, IP addresses, and forward for a different VRF.

To route between the networks, dynamic routing protocols must be configured on a per-VRF basis. VRF separates networks in software by creating new routing tables for each VRF instance. As a result, a new dynamic routing protocol instance must be configured for each VRF’s separate routing tables. Since separate VRFs are invisible to each other, a device on one VRF will be unable to reach a device on another VRF because there will be no routes there.

**Lab Summary**

Four routers were connected in a line. On one end of the routers, two PC’s are connected to the edge router. On the other end, two loopback interfaces are used to simulate networks on that edge. All devices were configured using IPv4. The devices were evenly split into two separate VRFs, APPLE and FACEBOOK. Sub interfaces were used on the routers to use a single physical connection to represent two separate logical connections to each VRF. OSPF was used for both VRFs for routing.

**Lab Commands**

**Router (config) # ip vrf <VRF Name>**

Creates a VRF instance with the given VRF Name. Typical convention uses all caps to differentiate between user defined VRF names and lowercase Cisco IOS keywords.

**Router (config-subif) # encapsulation dot1q <VLAN Number>**

Configures the sub interface 802.1q encapsulation number. Used for routing between VLANs. In the case of VRF’s, a layer 3 protocol, the VLAN encapsulation number is not significant for inter-network routing. This command is used because it is required to configure an IP address on the sub interface.

**Router (config-subif) # ip vrf forwarding <VRF Name>**

Configures the sub interface to only forward for the specified VRF.

**Router (config-if) # ip vrf forwarding <VRF Name>**

Configures the interface to only forward for the specified VRF.

**Router (config) # router ospf <process-id> vrf <VRF Name>**

Creates an OSPF instance for the specified VRF.

**Router# show ip vrf**

Shows all the created VRFs on the router and all the interfaces that are forwarding for each VRF.

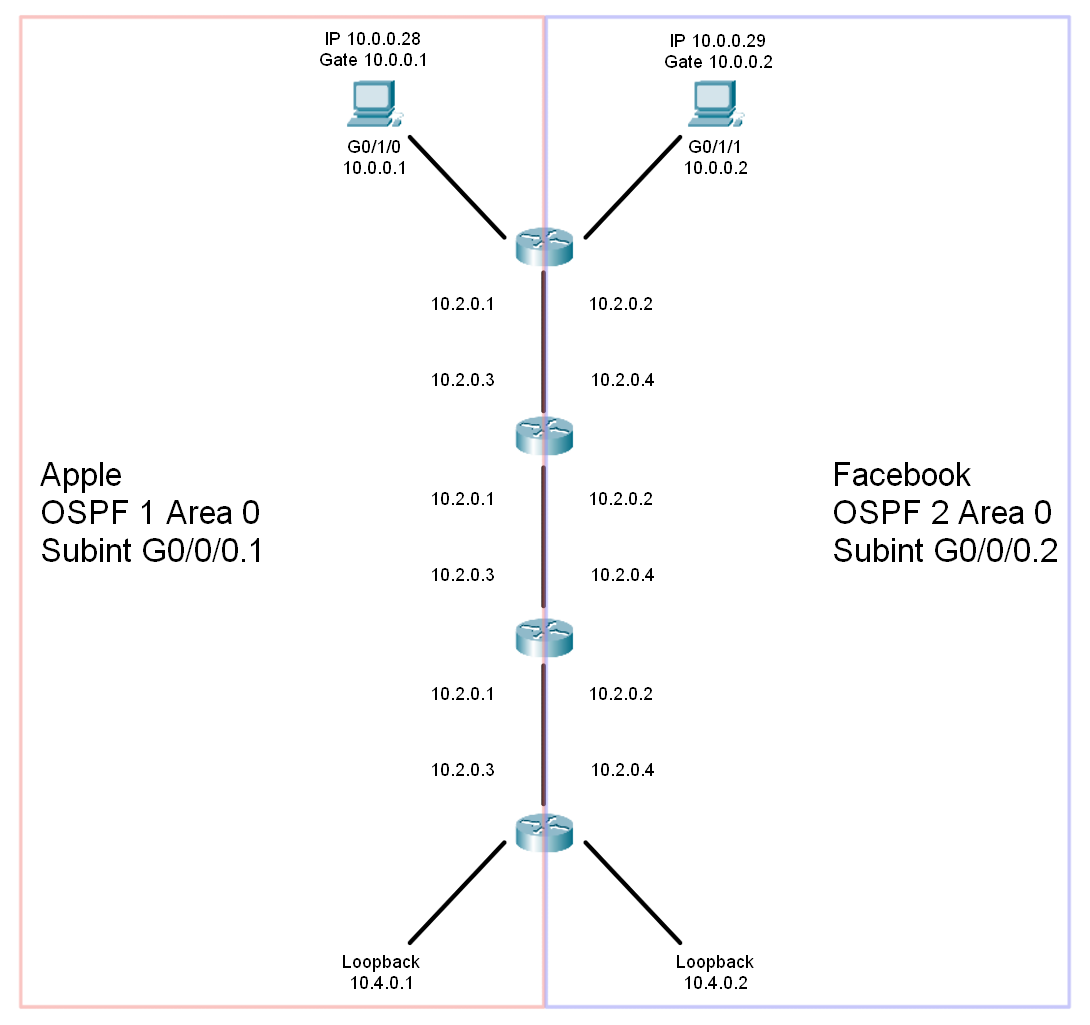
**Router# show ip route vrf <VRF Name>**

Shows the routing table for the specified VRF.

**Router# ping vrf <VRF Name>**

Test connectivity in the network within the network domain of the specified VRF.

**Network Diagram with IP’s**



|  |  |  |  |
| --- | --- | --- | --- |
| **Device Name** | Interface | IP Address | VRF |
| **R1** | G0/0/0.1 | 10.1.0.1/24 | APPLE |
|  | G0/0/0.2 | 10.1.0.2/24 | FACEBOOK |
|  | G0/1/0 | 10.0.0.1/24 | APPLE |
|  | G0/1/1 | 10.0.0.2/24 | FACEBOOK |
|  |  |  |  |
| **R2** | G0/0/0.1 | 10.1.0.3/24 | APPLE |
|  | G0/0/0.2 | 10.1.0.4/24 | FACEBOOK |
|  | G0/0/1.1 | 10.2.0.1/24 | APPLE |
|  | G0/0/1.2 | 10.2.0.2/24 | FACEBOOK |
|  |  |  |  |
| **R3** | G0/0/0.1 | 10.3.0.1/24 | APPLE |
|  | G0/0/0.2 | 10.3.0.2/24 | FACEBOOK |
|  | G0/0/1.1 | 10.2.0.3/24 | APPLE |
|  | G0/0/1.2 | 10.2.0.4/24 | FACEBOOK |
|  |  |  |  |
| **R4** | G0/0/0.1 | 10.3.0.3/24 | APPLE |
|  | G0/0/0.2 | 10.3.0.4/24 | FACEBOOK |
|  | Loopback0 | 10.4.0.1/24 | APPLE |
|  | Loopback1 | 10.4.0.2/24 | FACEBOOK |
|  |  |  |  |
| **PC1** |  | 10.0.0.28/24 | APPLE |
|  |  |  |  |
| **PC2** |  | 10.0.0.29/24 | FACEBOOK |

**Configurations**

**Router 1**

**R1#show running-config**

Current configuration : 4155 bytes

version 16.9

service timestamps debug datetime msec

service timestamps log datetime msec

platform qfp utilization monitor load 80

no platform punt-keepalive disable-kernel-core

hostname R1

boot-start-marker

boot system flash bootflash:isr4300-universalk9.16.09.08.SPA.bin

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ip vrf APPLE

ip vrf FACEBOOK

ip dhcp pool webuidhcp

login on-success log

subscriber templating

multilink bundle-name authenticated

crypto pki trustpoint TP-self-signed-3632327409

enrollment selfsigned

subject-name cn=IOS-Self-Signed-Certificate-3632327409

revocation-check none

rsakeypair TP-self-signed-3632327409

crypto pki certificate chain TP-self-signed-3632327409

certificate self-signed 01

30820330 30820218 A0030201 02020101 300D0609 2A864886 F70D0101 05050030

31312F30 2D060355 04031326 494F532D 53656C66 2D536967 6E65642D 43657274

69666963 6174652D 33363332 33323734 3039301E 170D3231 30393233 31383137

35335A17 0D333030 31303130 30303030 305A3031 312F302D 06035504 03132649

4F532D53 656C662D 5369676E 65642D43 65727469 66696361 74652D33 36333233

32373430 39308201 22300D06 092A8648 86F70D01 01010500 0382010F 00308201

0A028201 0100B261 9DFBA6B6 8D617464 7C90FCC7 D914F91B F0DF4ED7 9AFB8CE2

BF1F41AC DB949268 AF8CD9BE 16EAB58A FB679418 C789105C DB05CB67 9249A66C

B4538875 218832E8 5DA23BA9 0F7DDC35 93C41E6C 0CF872EC 1710D94A C40141C1

20E54B85 66DF49BD 93F48563 ECB6934A 4811F2C8 468950D1 031CAB0B DF6987B7

12B77176 24B19411 5D6BCE70 B5B590CC C87C3CA7 C55A90E3 B6EDD138 5C63C9F1

06462C2C 254BBA4F 307D9121 1E7A867B 6DE2D1DE 0A28083B 2CFC55B8 4F40192A

86551DA1 7281AA09 70BA719F 0810F085 897C7BF4 1EA0AC26 9977C614 C4CD4B1F

0EA1E92F ED0F86E3 6F330E3F 618DDBEF FA156AB1 2C435CEC 42B0CB03 6C00E24D

DE169FF2 29090203 010001A3 53305130 0F060355 1D130101 FF040530 030101FF

301F0603 551D2304 18301680 1461F090 CFE5BD03 762D6BEA 47FA40B1 B7B50D84

B3301D06 03551D0E 04160414 61F090CF E5BD0376 2D6BEA47 FA40B1B7 B50D84B3

300D0609 2A864886 F70D0101 05050003 82010100 7AA1BE0B 2C741D8F 13F9D863

11C880F0 643DE7BD D32247FD 8A2EA77A 5B8ECACA 138BDD75 BC36D296 83B3EA0B

95C3B925 56304C8F B143BC75 EAF50D76 05BBE797 E8332934 BAA0E845 D3210A85

451A52F8 3F76538E C575EBBC 664DC1DB 879816F1 E185EE64 074CE44B A2A144D3

E241B1E6 3E8F5931 3381B01E CB014313 DEDC5150 10A6476B 63776933 A334B1A9

F0223A98 176997A3 8F77DA19 86DEB18C E2016B13 692442EC 35D05474 DB4147F9

0EF0B077 7B9B80CF 58D0F081 DDA781E5 248FF007 681FC687 5763966C DB6DF225

5DBF2C1F 9CB22504 85D554EC 7A0F84E2 E53FFDEF 7A837C8B 1BBD531E 1B014549

3049C732 9B1BD2A8 51C365CD E565AFF9 A7A67504

quit

license udi pid ISR4321/K9 sn FLM240607Q1

no license smart enable

diagnostic bootup level minimal

spanning-tree extend system-id

redundancy

mode none

interface GigabitEthernet0/0/0

no ip address

negotiation auto

interface GigabitEthernet0/0/0.1

encapsulation dot1Q 1 native

ip vrf forwarding APPLE

ip address 10.1.0.1 255.255.255.0

ip ospf 1 area 0

interface GigabitEthernet0/0/0.2

encapsulation dot1Q 2

ip vrf forwarding FACEBOOK

ip address 10.1.0.2 255.255.255.0

ip ospf 2 area 0

interface GigabitEthernet0/0/1

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/1/0

ip vrf forwarding APPLE

ip address 10.0.0.1 255.255.255.0

ip ospf 1 area 0

negotiation auto

interface GigabitEthernet0/1/1

ip vrf forwarding FACEBOOK

ip address 10.0.0.2 255.255.255.0

ip ospf 2 area 0

negotiation auto

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

router ospf 1 vrf APPLE

router ospf 2 vrf FACEBOOK

ip forward-protocol nd

no ip http server

ip http authentication local

no ip http secure-server

ip tftp source-interface GigabitEthernet0

control-plane

line con 0

transport input none

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R1#show ip interface brief**

Interface IP-Address OK? Method Status Protocol

GigabitEthernet0/0/0 unassigned YES NVRAM up up

GigabitEthernet0/0/0.1 10.1.0.1 YES manual up up

GigabitEthernet0/0/0.2 10.1.0.2 YES manual up up

GigabitEthernet0/0/1 unassigned YES NVRAM administratively down down

GigabitEthernet0/1/0 10.0.0.1 YES manual up up

GigabitEthernet0/1/1 10.0.0.2 YES manual up up

GigabitEthernet0 unassigned YES NVRAM administratively down down

**R1#show ip vrf**

Name Default RD Interfaces

APPLE <not set> Gi0/0/0.1

Gi0/1/0

FACEBOOK <not set> Gi0/0/0.2

Gi0/1/1

Mgmt-intf <not set> Gi0

**R1#show ip route vrf APPLE**

Routing Table: APPLE

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

C 10.0.0.0/24 is directly connected, GigabitEthernet0/1/0

L 10.0.0.1/32 is directly connected, GigabitEthernet0/1/0

C 10.1.0.0/24 is directly connected, GigabitEthernet0/0/0.1

L 10.1.0.1/32 is directly connected, GigabitEthernet0/0/0.1

O 10.2.0.0/24 [110/2] via 10.1.0.3, 00:35:20, GigabitEthernet0/0/0.1

O 10.3.0.0/24 [110/3] via 10.1.0.3, 00:32:58, GigabitEthernet0/0/0.1

O 10.4.0.0/24 [110/4] via 10.1.0.3, 00:27:34, GigabitEthernet0/0/0.1

**R1#show ip route vrf FACEBOOK**

Routing Table: FACEBOOK

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

C 10.0.0.0/24 is directly connected, GigabitEthernet0/1/1

L 10.0.0.2/32 is directly connected, GigabitEthernet0/1/1

C 10.1.0.0/24 is directly connected, GigabitEthernet0/0/0.2

L 10.1.0.2/32 is directly connected, GigabitEthernet0/0/0.2

O 10.2.0.0/24 [110/2] via 10.1.0.4, 00:35:15, GigabitEthernet0/0/0.2

O 10.3.0.0/24 [110/3] via 10.1.0.4, 00:32:53, GigabitEthernet0/0/0.2

O 10.4.0.0/24 [110/4] via 10.1.0.4, 00:14:39, GigabitEthernet0/0/0.2

**Router 2**

**R2#show running-config**

Current configuration : 4174 bytes

version 16.9

service timestamps debug datetime msec

service timestamps log datetime msec

platform qfp utilization monitor load 80

no platform punt-keepalive disable-kernel-core

hostname R2

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ip vrf APPLE

ip vrf FACEBOOK

login on-success log

subscriber templating

multilink bundle-name authenticated

crypto pki trustpoint TP-self-signed-3458782570

enrollment selfsigned

subject-name cn=IOS-Self-Signed-Certificate-3458782570

revocation-check none

rsakeypair TP-self-signed-3458782570

crypto pki certificate chain TP-self-signed-3458782570

certificate self-signed 01

30820330 30820218 A0030201 02020101 300D0609 2A864886 F70D0101 05050030

31312F30 2D060355 04031326 494F532D 53656C66 2D536967 6E65642D 43657274

69666963 6174652D 33343538 37383235 3730301E 170D3232 30333130 31363431

34365A17 0D333030 31303130 30303030 305A3031 312F302D 06035504 03132649

4F532D53 656C662D 5369676E 65642D43 65727469 66696361 74652D33 34353837

38323537 30308201 22300D06 092A8648 86F70D01 01010500 0382010F 00308201

0A028201 0100F447 DA9A1B11 13ADE094 CD5C2616 EEF56697 ED6DD5B9 6FF892BC

D0D9F3A7 CCF10933 7C1D1019 B9940054 204FCB53 F993286A C3F8DFA8 A480A7D3

7D842D1A 12DA17C7 C6BEF63F 312B6A7D 220778D5 D8F312CD 8C7850DA 4A071198

5F2F154E CDEB3BBB 1DD0C94D C54B00E8 B2F7651B AF2403ED 0188B908 F345D367

FD24CC99 7C44A68D 72054CC8 71FFAAEC 51943CCB 5C956651 E90BDFF8 45F3CCE2

2B214947 EA250654 69E29508 7544A760 BDAA4C38 C49250AA C3CC6F2A 2EECC44F

4F6776BE 7D9A1B4C 99259ACC DCD92DE2 38FA0E42 48DB7F68 24DE3A46 A25A03FA

BE72A74F 1499BAFC CF313520 210EC70E 8B84151B 4C3C9C73 B1253FCF B6EE6340

F1B83415 912B0203 010001A3 53305130 0F060355 1D130101 FF040530 030101FF

301F0603 551D2304 18301680 14DFEEF8 4389DB46 808C71EF 916C1030 0E36F33C

21301D06 03551D0E 04160414 DFEEF843 89DB4680 8C71EF91 6C10300E 36F33C21

300D0609 2A864886 F70D0101 05050003 82010100 7DF43D46 C3DA5683 B4A18D6F

79F861BF F673DCD1 A917C79F F8102663 938DFED3 CD48640D 3DF4FEF6 8351B939

F05056BE D7E29419 6143F491 BAF24D38 7CEAD233 D5C1CBFD 0D5D3BE1 194E7CC3

80A045F4 1B5B0B69 6E1B71E8 59F0CC8C AF99AE13 3C1021E5 83267A30 9FE26BB2

43CECD27 EEF52891 23F0F71A 125A8007 AD35CA6F 4694878F 5B51D5DE EC04B2B8

1576BAE2 35DA97DE 02442050 DF79587B F998C5E8 DE4EB578 9E4046B9 C15223E7

71BC43C2 F46C3D64 9BBE214E E2BB79F2 3F4BA209 881EBE36 35D223A4 971C39C5

7202422C C2EEFA5A 5B283FE2 393D20D7 8700DD9C 782171A5 DF6646F4 0D077153

8B6FF8B8 9126B4A7 A20F98A5 6FD91B6F 0BE7E583

quit

license udi pid ISR4321/K9 sn FLM240800D6

no license smart enable

diagnostic bootup level minimal

spanning-tree extend system-id

redundancy

mode none

interface GigabitEthernet0/0/0

no ip address

negotiation auto

interface GigabitEthernet0/0/0.1

encapsulation dot1Q 1 native

ip vrf forwarding APPLE

ip address 10.1.0.3 255.255.255.0

ip ospf 1 area 0

interface GigabitEthernet0/0/0.2

encapsulation dot1Q 2

ip vrf forwarding FACEBOOK

ip address 10.1.0.4 255.255.255.0

ip ospf 2 area 0

interface GigabitEthernet0/0/1

no ip address

negotiation auto

interface GigabitEthernet0/0/1.1

encapsulation dot1Q 1 native

ip vrf forwarding APPLE

ip address 10.2.0.1 255.255.255.0

ip ospf 1 area 0

interface GigabitEthernet0/0/1.2

encapsulation dot1Q 2

ip vrf forwarding FACEBOOK

ip address 10.2.0.2 255.255.255.0

ip ospf 2 area 0

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

router ospf 1 vrf APPLE

router ospf 2 vrf FACEBOOK

ip forward-protocol nd

no ip http server

ip http authentication local

no ip http secure-server

ip tftp source-interface GigabitEthernet0

control-plane

line con 0

transport input none

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R2#show ip interface brief**

Interface IP-Address OK? Method Status Protocol

GigabitEthernet0/0/0 unassigned YES unset up up

GigabitEthernet0/0/0.1 10.1.0.3 YES manual up up

GigabitEthernet0/0/0.2 10.1.0.4 YES manual up up

GigabitEthernet0/0/1 unassigned YES unset up up

GigabitEthernet0/0/1.1 10.2.0.1 YES manual up up

GigabitEthernet0/0/1.2 10.2.0.2 YES manual up up

Serial0/1/0 unassigned YES unset administratively down down

Serial0/1/1 unassigned YES unset administratively down down

GigabitEthernet0 unassigned YES unset administratively down down

**R2#show ip vrf**

Name Default RD Interfaces

APPLE <not set> Gi0/0/0.1

Gi0/0/1.1

FACEBOOK <not set> Gi0/0/0.2

Gi0/0/1.2

Mgmt-intf <not set> Gi0

**R2#show ip route vrf APPLE**

Routing Table: APPLE

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O 10.0.0.0/24 [110/2] via 10.1.0.1, 00:23:37, GigabitEthernet0/0/0.1

C 10.1.0.0/24 is directly connected, GigabitEthernet0/0/0.1

L 10.1.0.3/32 is directly connected, GigabitEthernet0/0/0.1

C 10.2.0.0/24 is directly connected, GigabitEthernet0/0/1.1

L 10.2.0.1/32 is directly connected, GigabitEthernet0/0/1.1

O 10.3.0.0/24 [110/2] via 10.2.0.3, 00:35:43, GigabitEthernet0/0/1.1

O 10.4.0.0/24 [110/3] via 10.2.0.3, 00:30:20, GigabitEthernet0/0/1.1

**R2#show ip route vrf FACEBOOK**

Routing Table: FACEBOOK

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O 10.0.0.0/24 [110/2] via 10.1.0.2, 00:23:37, GigabitEthernet0/0/0.2

C 10.1.0.0/24 is directly connected, GigabitEthernet0/0/0.2

L 10.1.0.4/32 is directly connected, GigabitEthernet0/0/0.2

C 10.2.0.0/24 is directly connected, GigabitEthernet0/0/1.2

L 10.2.0.2/32 is directly connected, GigabitEthernet0/0/1.2

O 10.3.0.0/24 [110/2] via 10.2.0.4, 00:35:38, GigabitEthernet0/0/1.2

O 10.4.0.0/24 [110/3] via 10.2.0.4, 00:17:25, GigabitEthernet0/0/1.2

**Router 3**

**R3#show running-config**

Current configuration : 1931 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R3

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ip vrf APPLE

ip vrf FACEBOOK

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO21491LXF

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface GigabitEthernet0/0/0

no ip address

negotiation auto

interface GigabitEthernet0/0/0.1

encapsulation dot1Q 1 native

ip vrf forwarding APPLE

ip address 10.3.0.1 255.255.255.0

ip ospf 1 area 0

interface GigabitEthernet0/0/0.2

encapsulation dot1Q 2

ip vrf forwarding FACEBOOK

ip address 10.3.0.2 255.255.255.0

ip ospf 2 area 0

interface GigabitEthernet0/0/1

no ip address

negotiation auto

interface GigabitEthernet0/0/1.1

encapsulation dot1Q 1 native

ip vrf forwarding APPLE

ip address 10.2.0.3 255.255.255.0

ip ospf 1 area 0

interface GigabitEthernet0/0/1.2

encapsulation dot1Q 2

ip vrf forwarding FACEBOOK

ip address 10.2.0.4 255.255.255.0

ip ospf 2 area 0

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospf 1 vrf APPLE

router ospf 2 vrf FACEBOOK

ip forward-protocol nd

no ip http server

no ip http secure-server

ip tftp source-interface GigabitEthernet0

ip route 0.0.0.0 0.0.0.0 192.168.3.4

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R3#show ip interface brief**

Interface IP-Address OK? Method Status Protocol

GigabitEthernet0/0/0 unassigned YES manual up up

GigabitEthernet0/0/0.1 10.3.0.1 YES manual up up

GigabitEthernet0/0/0.2 10.3.0.2 YES manual up up

GigabitEthernet0/0/1 unassigned YES manual up up

GigabitEthernet0/0/1.1 10.2.0.3 YES manual up up

GigabitEthernet0/0/1.2 10.2.0.4 YES manual up up

Serial0/1/0 unassigned YES NVRAM administratively down down

Serial0/1/1 unassigned YES NVRAM administratively down down

GigabitEthernet0 unassigned YES NVRAM administratively down down

Vlan1 unassigned YES unset administratively down down

**R3#show ip vrf**

Name Default RD Interfaces

APPLE <not set> Gi0/0/0.1

Gi0/0/1.1

FACEBOOK <not set> Gi0/0/0.2

Gi0/0/1.2

Mgmt-intf <not set> Gi0

**R3#show ip route vrf APPLE**

Routing Table: APPLE

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O 10.0.0.0/24 [110/3] via 10.2.0.1, 00:27:21, GigabitEthernet0/0/1.1

O 10.1.0.0/24 [110/2] via 10.2.0.1, 00:39:23, GigabitEthernet0/0/1.1

C 10.2.0.0/24 is directly connected, GigabitEthernet0/0/1.1

L 10.2.0.3/32 is directly connected, GigabitEthernet0/0/1.1

C 10.3.0.0/24 is directly connected, GigabitEthernet0/0/0.1

L 10.3.0.1/32 is directly connected, GigabitEthernet0/0/0.1

O 10.4.0.0/24 [110/2] via 10.3.0.3, 00:34:04, GigabitEthernet0/0/0.1

**R3#show ip route vrf FACEBOOK**

Routing Table: FACEBOOK

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O 10.0.0.0/24 [110/3] via 10.2.0.2, 00:27:29, GigabitEthernet0/0/1.2

O 10.1.0.0/24 [110/2] via 10.2.0.2, 00:39:27, GigabitEthernet0/0/1.2

C 10.2.0.0/24 is directly connected, GigabitEthernet0/0/1.2

L 10.2.0.4/32 is directly connected, GigabitEthernet0/0/1.2

C 10.3.0.0/24 is directly connected, GigabitEthernet0/0/0.2

L 10.3.0.2/32 is directly connected, GigabitEthernet0/0/0.2

O 10.4.0.0/24 [110/2] via 10.3.0.4, 00:21:17, GigabitEthernet0/0/0.2

**Router 4**

**R4#show running-config**

Current configuration : 4247 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R4

boot-start-marker

boot system flash bootflash:isr4300-universalk9.16.09.08.SPA.bin

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ip vrf APPLE

ip vrf FACEBOOK

ip dhcp pool webuidhcp

login on-success log

subscriber templating

multilink bundle-name authenticated

crypto pki trustpoint TP-self-signed-2219300048

enrollment selfsigned

subject-name cn=IOS-Self-Signed-Certificate-2219300048

revocation-check none

rsakeypair TP-self-signed-2219300048

crypto pki certificate chain TP-self-signed-2219300048

certificate self-signed 01

30820330 30820218 A0030201 02020101 300D0609 2A864886 F70D0101 05050030

31312F30 2D060355 04031326 494F532D 53656C66 2D536967 6E65642D 43657274

69666963 6174652D 32323139 33303030 3438301E 170D3231 30393233 32303431

32335A17 0D333030 31303130 30303030 305A3031 312F302D 06035504 03132649

4F532D53 656C662D 5369676E 65642D43 65727469 66696361 74652D32 32313933

30303034 38308201 22300D06 092A8648 86F70D01 01010500 0382010F 00308201

0A028201 0100D2E1 691D4072 B94AEE40 DF806ADB 877D6E30 555FB16D 573E4431

4003C75B 19D766AC E2D482F7 AE381840 ABFCF1E2 67E15C77 A5272277 5A870CBE

AE4E211D 64B8808D 38CEB4B0 DD028ACA 18C5098F A905B8B7 59512F90 A7F7E2D1

9B5A4881 380F95B8 95EA6C65 E62BFD99 5BAADE18 BBBBE430 62D71970 E8520A67

92F7FBA7 BAF785F4 6B4EF912 6C9E40F1 6E32ACD1 16492461 CCF4397E C07BC684

F4DDBA0D A959F08B 36C97AEF 0349EC80 56D02174 7F862C8E 2E9716F0 F608E582

648B0798 37B4C2D4 0B850A09 16057044 3B290B48 8496B668 489F6E78 766D686B

6B8561B7 66F25333 A1A9D94D 5945D68F 192C0C19 EE083A80 4861EB26 9CC2505A

1714670D 53A30203 010001A3 53305130 0F060355 1D130101 FF040530 030101FF

301F0603 551D2304 18301680 1456CAFF 4391681C F51B0627 B1BAC712 5DD659AA

47301D06 03551D0E 04160414 56CAFF43 91681CF5 1B0627B1 BAC7125D D659AA47

300D0609 2A864886 F70D0101 05050003 82010100 81485BD1 D52EE0A8 1AA76960

8564405E D01A5B90 E08841E6 D2D61CD0 DD4BEC68 A1CDC51C 63DAB297 46A2F1C4

BBE6D4D3 84325623 776C11B9 A08DB0D7 FC7161F8 8CEAD47C 3CC1921A BE30FA3B

EBF29F3F F4672984 4FDEA274 B5092380 011EEE29 C9929FFF 6B019920 F650251C

3925B85D E7AB3338 47D765C9 E18C13D2 593E172D 6A9A00B5 715E1FFC 13C4BF8D

E187E283 70504CCE D19FE9EE B30A9676 6D97A876 582D1125 1453D141 4EDF4711

5745A320 C8F03950 76BBEB01 BE93F113 9839C364 A07E2206 3AE62EAB 8A8F6A17

D1CAF721 D2928C38 9C1584BE 0298CFEA 282BF0AB 54B740FE 806D0AE1 426B2C27

D2E4062C 46E246E9 60A3CEE9 2015D1AF AD374CA4

quit

license udi pid ISR4321/K9 sn FDO21281AAT

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface Loopback0

ip vrf forwarding APPLE

ip address 10.4.0.1 255.255.255.0

ip ospf network point-to-point

ip ospf 1 area 0

interface Loopback1

ip vrf forwarding FACEBOOK

ip address 10.4.0.2 255.255.255.0

ip ospf network point-to-point

ip ospf 2 area 0

interface GigabitEthernet0/0/0

no ip address

negotiation auto

interface GigabitEthernet0/0/0.1

encapsulation dot1Q 1 native

ip vrf forwarding APPLE

ip address 10.3.0.3 255.255.255.0

ip ospf 1 area 0

interface GigabitEthernet0/0/0.2

encapsulation dot1Q 2

ip vrf forwarding FACEBOOK

ip address 10.3.0.4 255.255.255.0

ip ospf 2 area 0

interface GigabitEthernet0/0/1

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/1/0

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/1/1

no ip address

shutdown

negotiation auto

interface Service-Engine0/2/0

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospf 1 vrf APPLE

router ospf 2 vrf FACEBOOK

ip forward-protocol nd

no ip http server

no ip http secure-server

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R4#show ip interface brief**

Interface IP-Address OK? Method Status Protocol

GigabitEthernet0/0/0 unassigned YES unset up up

GigabitEthernet0/0/0.1 10.3.0.3 YES manual up up

GigabitEthernet0/0/0.2 10.3.0.4 YES manual up up

GigabitEthernet0/0/1 unassigned YES unset administratively down down

GigabitEthernet0/1/0 unassigned YES unset administratively down down

GigabitEthernet0/1/1 unassigned YES unset administratively down down

Service-Engine0/2/0 unassigned YES unset up up

GigabitEthernet0 unassigned YES unset administratively down down

Loopback0 10.4.0.1 YES manual up up

Loopback1 10.4.0.2 YES manual up up

Vlan1 unassigned YES unset administratively down down

**R4#show ip vrf**

Name Default RD Interfaces

APPLE <not set> Lo0

Gi0/0/0.1

FACEBOOK <not set> Lo1

Gi0/0/0.2

Mgmt-intf <not set> Gi0

**R4#show ip route vrf APPLE**

Routing Table: APPLE

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O 10.0.0.0/24 [110/4] via 10.3.0.1, 00:25:42, GigabitEthernet0/0/0.1

O 10.1.0.0/24 [110/3] via 10.3.0.1, 00:32:21, GigabitEthernet0/0/0.1

O 10.2.0.0/24 [110/2] via 10.3.0.1, 00:32:21, GigabitEthernet0/0/0.1

C 10.3.0.0/24 is directly connected, GigabitEthernet0/0/0.1

L 10.3.0.3/32 is directly connected, GigabitEthernet0/0/0.1

C 10.4.0.0/24 is directly connected, Loopback0

L 10.4.0.1/32 is directly connected, Loopback0

**R4#show ip route vrf FACEBOOK**

Routing Table: FACEBOOK

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

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, H - NHRP, l - LISP

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O 10.0.0.0/24 [110/4] via 10.3.0.2, 00:25:52, GigabitEthernet0/0/0.2

O 10.1.0.0/24 [110/3] via 10.3.0.2, 00:32:29, GigabitEthernet0/0/0.2

O 10.2.0.0/24 [110/2] via 10.3.0.2, 00:32:29, GigabitEthernet0/0/0.2

C 10.3.0.0/24 is directly connected, GigabitEthernet0/0/0.2

L 10.3.0.4/32 is directly connected, GigabitEthernet0/0/0.2

C 10.4.0.0/24 is directly connected, Loopback1

L 10.4.0.2/32 is directly connected, Loopback1

**Connectivity Tests**

**APPLE PC Pings**

C:\Users\user>ping 10.1.0.1

Pinging 10.1.0.1 with 32 bytes of data:

Reply from 10.1.0.1: bytes=32 time<1ms TTL=255

Reply from 10.1.0.1: bytes=32 time<1ms TTL=255

Reply from 10.1.0.1: bytes=32 time<1ms TTL=255

Reply from 10.1.0.1: bytes=32 time<1ms TTL=255

Ping statistics for 10.1.0.1:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\user>ping 10.2.0.1

Pinging 10.2.0.1 with 32 bytes of data:

Reply from 10.2.0.1: bytes=32 time<1ms TTL=254

Reply from 10.2.0.1: bytes=32 time<1ms TTL=254

Reply from 10.2.0.1: bytes=32 time<1ms TTL=254

Reply from 10.2.0.1: bytes=32 time<1ms TTL=254

Ping statistics for 10.2.0.1:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\user>ping 10.3.0.1

Pinging 10.3.0.1 with 32 bytes of data:

Reply from 10.3.0.1: bytes=32 time<1ms TTL=253

Reply from 10.3.0.1: bytes=32 time<1ms TTL=253

Reply from 10.3.0.1: bytes=32 time<1ms TTL=253

Reply from 10.3.0.1: bytes=32 time<1ms TTL=253

Ping statistics for 10.3.0.1:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\user>ping 10.4.0.1

Pinging 10.4.0.1 with 32 bytes of data:

Reply from 10.4.0.1: bytes=32 time<1ms TTL=252

Reply from 10.4.0.1: bytes=32 time<1ms TTL=252

Reply from 10.4.0.1: bytes=32 time<1ms TTL=252

Reply from 10.4.0.1: bytes=32 time<1ms TTL=252

Ping statistics for 10.4.0.1:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\user>ping 10.0.0.2

Pinging 10.0.0.2 with 32 bytes of data:

Reply from 10.0.0.28: Destination host unreachable.

Reply from 10.0.0.28: Destination host unreachable.

Reply from 10.0.0.28: Destination host unreachable.

Reply from 10.0.0.28: Destination host unreachable.

Ping statistics for 10.0.0.2:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

C:\Users\user>ping 10.1.0.2

Pinging 10.1.0.2 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.1.0.2:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Users\user>ping 10.2.0.2

Pinging 10.2.0.2 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.2.0.2:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Users\user>ping 10.3.0.2

Pinging 10.3.0.2 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.3.0.2:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Users\user>ping 10.4.0.2

Pinging 10.4.0.2 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.4.0.2:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

**FACEBOOK PC Pings**

C:\Users\user>ping 10.1.0.2

Pinging 10.1.0.2 with 32 bytes of data:

Reply from 10.1.0.2: bytes=32 time<1ms TTL=255

Reply from 10.1.0.2: bytes=32 time<1ms TTL=255

Reply from 10.1.0.2: bytes=32 time<1ms TTL=255

Reply from 10.1.0.2: bytes=32 time<1ms TTL=255

Ping statistics for 10.1.0.2:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\user>ping 10.2.0.2

Pinging 10.2.0.2 with 32 bytes of data:

Reply from 10.2.0.2: bytes=32 time=1ms TTL=254

Reply from 10.2.0.2: bytes=32 time<1ms TTL=254

Reply from 10.2.0.2: bytes=32 time=1ms TTL=254

Reply from 10.2.0.2: bytes=32 time<1ms TTL=254

Ping statistics for 10.2.0.2:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\Users\user>ping 10.3.0.2

Pinging 10.3.0.2 with 32 bytes of data:

Reply from 10.3.0.2: bytes=32 time=1ms TTL=253

Reply from 10.3.0.2: bytes=32 time<1ms TTL=253

Reply from 10.3.0.2: bytes=32 time<1ms TTL=253

Reply from 10.3.0.2: bytes=32 time<1ms TTL=253

Ping statistics for 10.3.0.2:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\Users\user>ping 10.4.0.2

Pinging 10.4.0.2 with 32 bytes of data:

Reply from 10.4.0.2: bytes=32 time<1ms TTL=252

Reply from 10.4.0.2: bytes=32 time=1ms TTL=252

Reply from 10.4.0.2: bytes=32 time=1ms TTL=252

Reply from 10.4.0.2: bytes=32 time<1ms TTL=252

Ping statistics for 10.4.0.2:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\Users\user>ping 10.0.0.1

Pinging 10.0.0.1 with 32 bytes of data:

Reply from 10.0.0.29: Destination host unreachable.

Reply from 10.0.0.29: Destination host unreachable.

Reply from 10.0.0.29: Destination host unreachable.

Reply from 10.0.0.29: Destination host unreachable.

Ping statistics for 10.0.0.1:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

C:\Users\user>ping 10.1.0.1

Pinging 10.1.0.1 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.1.0.1:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Users\user>ping 10.2.0.1

Pinging 10.2.0.1 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.2.0.1:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Users\user>ping 10.3.0.1

Pinging 10.3.0.1 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.3.0.1:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Users\user>ping 10.4.0.1

Pinging 10.4.0.1 with 32 bytes of data:

Request timed out.

Request timed out.

Request timed out.

Request timed out.

Ping statistics for 10.4.0.1:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

**Problems**

The first problem encountered was that I could not ping from a router to the adjacent router on the same network and VRF. The problem was that in order to ping using VRFs, the VRF must be specified when typing the **ping** command. Otherwise, the router is unsure which routing table to use when initiating the ping command. Specifying the source interface to use a sub interface for a specific VRF still does not solve the problem. The correct command is **ping vrf <VRF name>.** With this, pings will now use the correct routing table to route.

The second problem encountered was that on Router 1 and 2, the APPLE VRF routing table did not have any routes from Router 3 and 4. On Router 3 and 4, the Facebook VRF did not have any routes from Router 1 and 2. Using **show ip ospf neighbors**, it was found that Router 2 and 3 was stuck in Init/Init state. This exact cause of this is uncertain, but after reconfiguring by enabling OSPF using the **ip ospf <process id> area 0** instead of the **network** command under OSPF configuration mode, the network reached full connectivity. This likely means that the **network** command might be inconsistent especially when the VRFs have overlapping network address pools. This makes the **ip ospf <process id> area 0** command in sub interface configuration mode the superior choice, especially considering OSPFv3 also exclusively activates OSPF by interface.

A problem encountered by another group I helped solve was that the PC connected to the APPLE VRF was unable to ping to other networks on the same VRF. Firstly, the default gateway and IP addressing was checked to make sure that the PC was forwarding to the router. Then, a ping to the default gateway was used to make sure the PC could reach the router. The PC configuration was verified to be correct, so the router configuration was checked. It was found that the interface connecting the router to the PC had not been configured to forward for the APPLE VRF. The **ip vrf forwarding <VRF Name>** command was entered, and connectivity was established. This was cross checked with the PC on the FACEBOOK VRF and the same missing command was entered to establish connectivity.

**Conclusion**

VRF is a useful configuration to separate networks via separate routing tables. This is particularly common in service provider networks in order to separate connections to different companies. VRF segmentation of the network can keep individual company networks the same while adding them to a service provider network because a separate VRF can use overlapping IP addressing schemes with another VRF. For this reason, a more sophisticated VRF configuration can also be considered a VPN as it separates and keeps different VRFs confidential. These applications of VRF make it crucial to understand in a networking industry with focus on scalability and integrity.