Building a Medium-Sized Network

Interconnecting Cisco Networking Devices, Part 1 (ICND1) v2.0

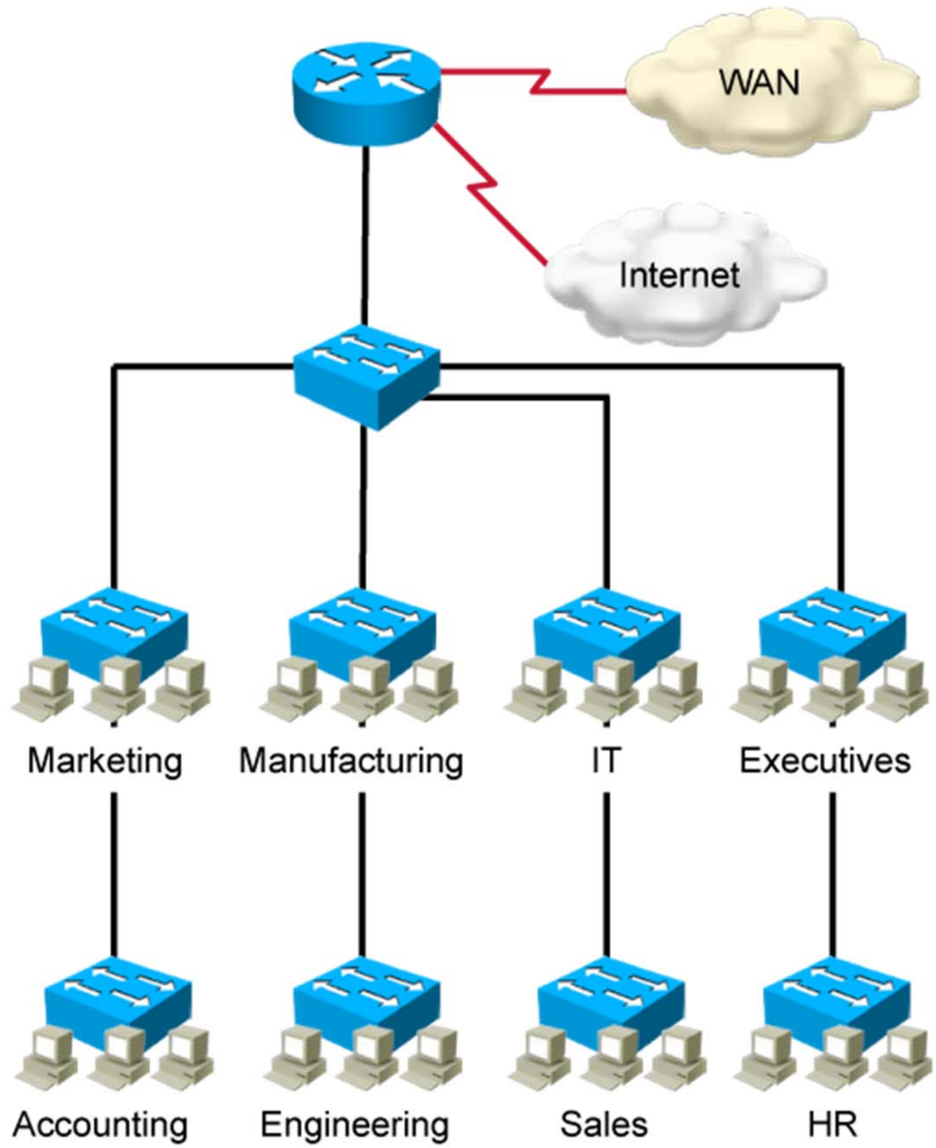
Implementing VLANs and Trunks

Building a Medium-Sized Network

Issues in a Poorly Designed Network

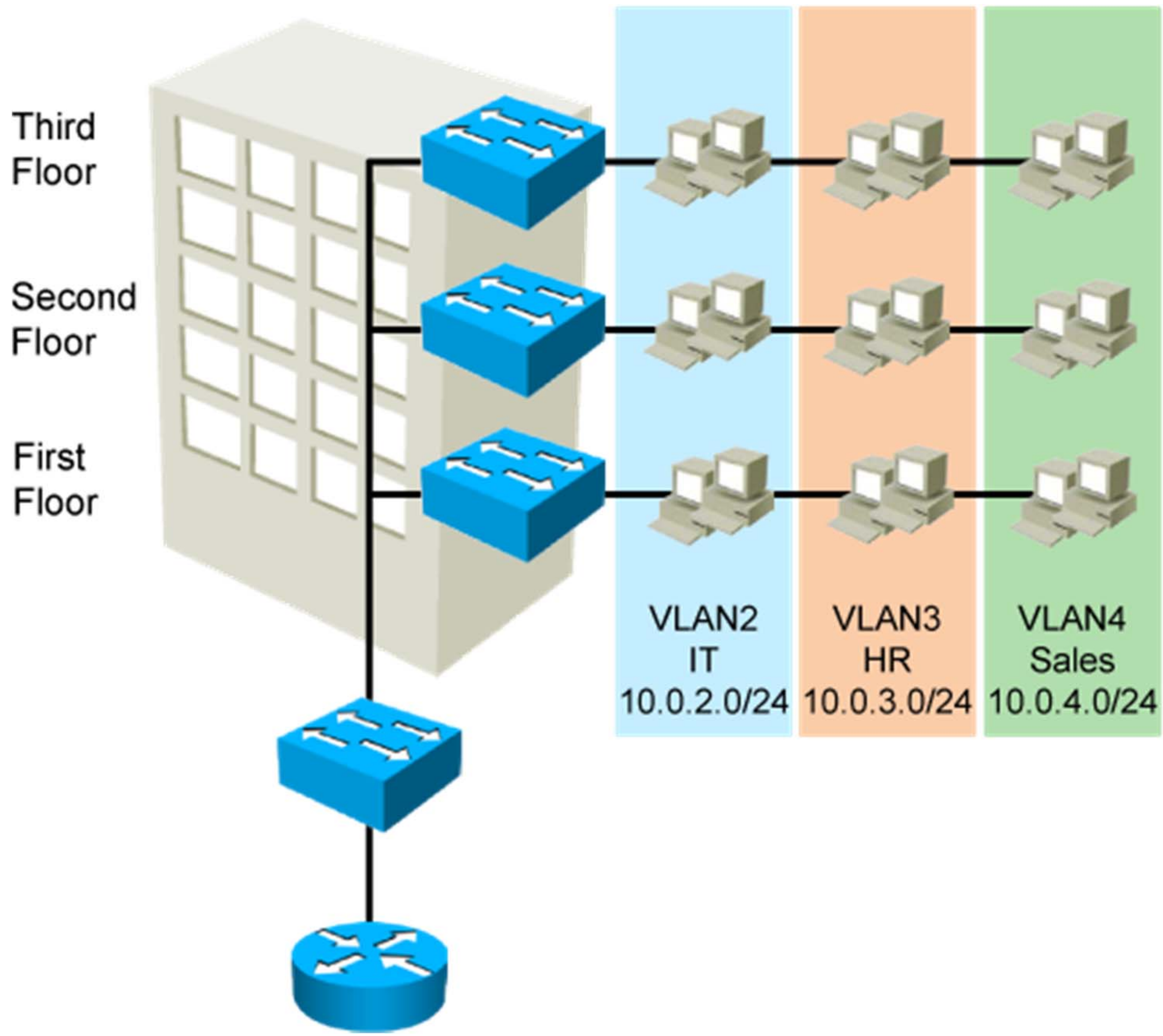
These issues are often found in poorly designed networks:

- Large broadcast domains
- Management and support challenges
- Possible security vulnerabilities



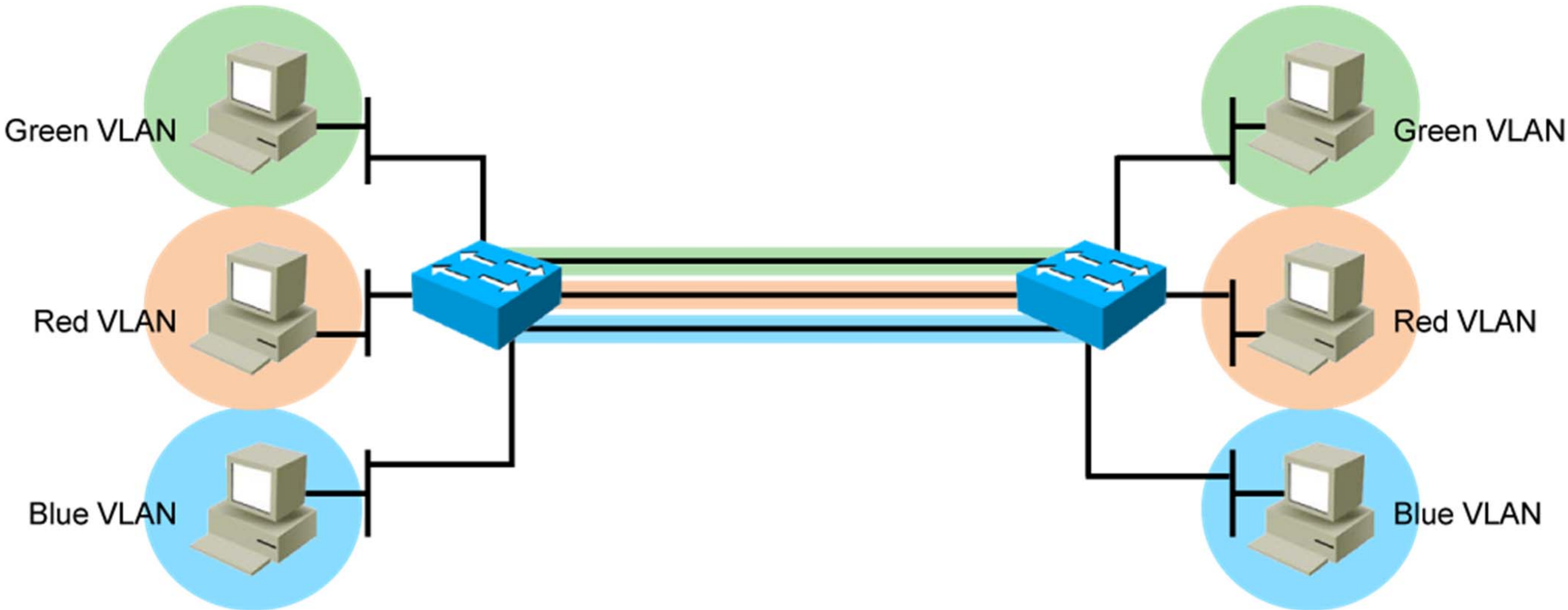
VLAN Introduction

- A VLAN is a virtual LAN.
- VLAN = broadcast domain
- VLAN = logical network (subnet)
- VLANs address these needs:
  - Segmentation
  - Security
  - Network flexibility



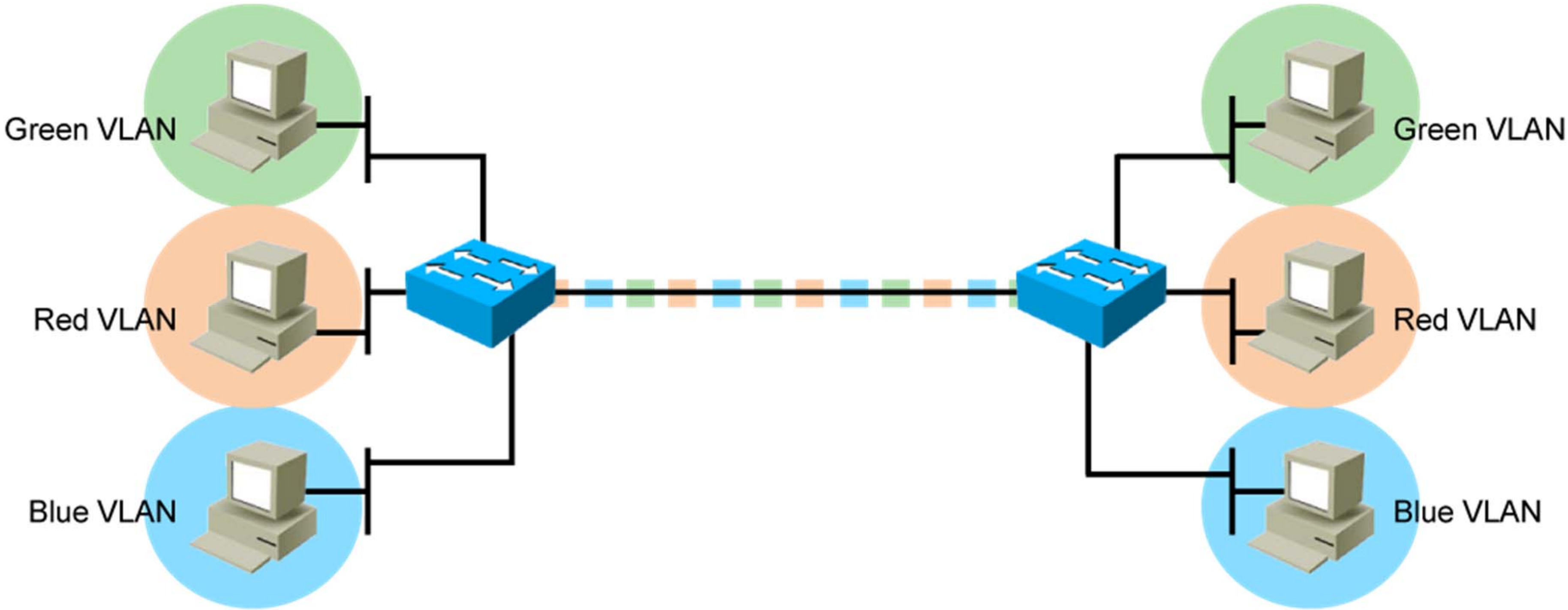
Trunking with 802.1Q

Running many VLANs between switches would require the same number of interconnecting links.

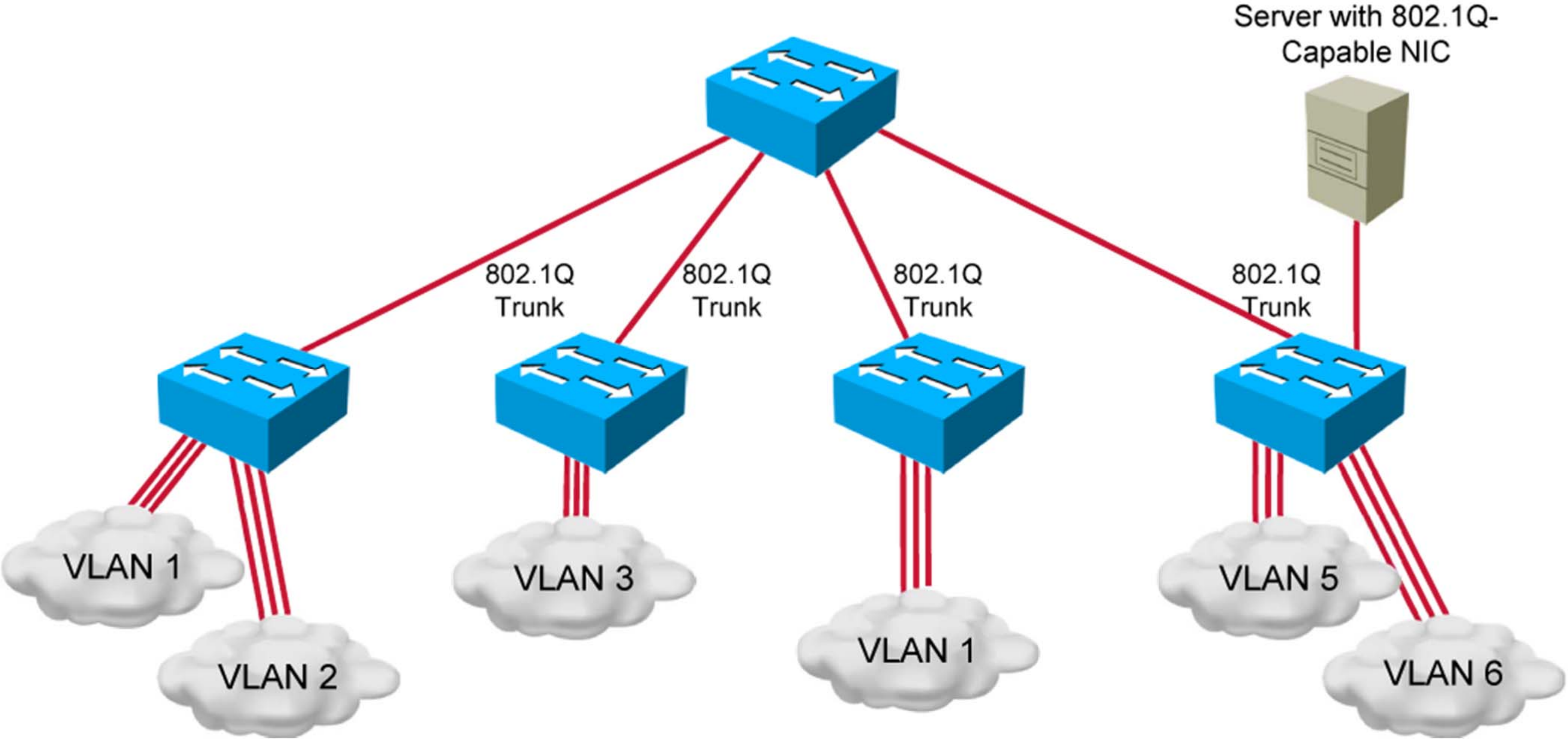


Trunking with 802.1Q (Cont.)

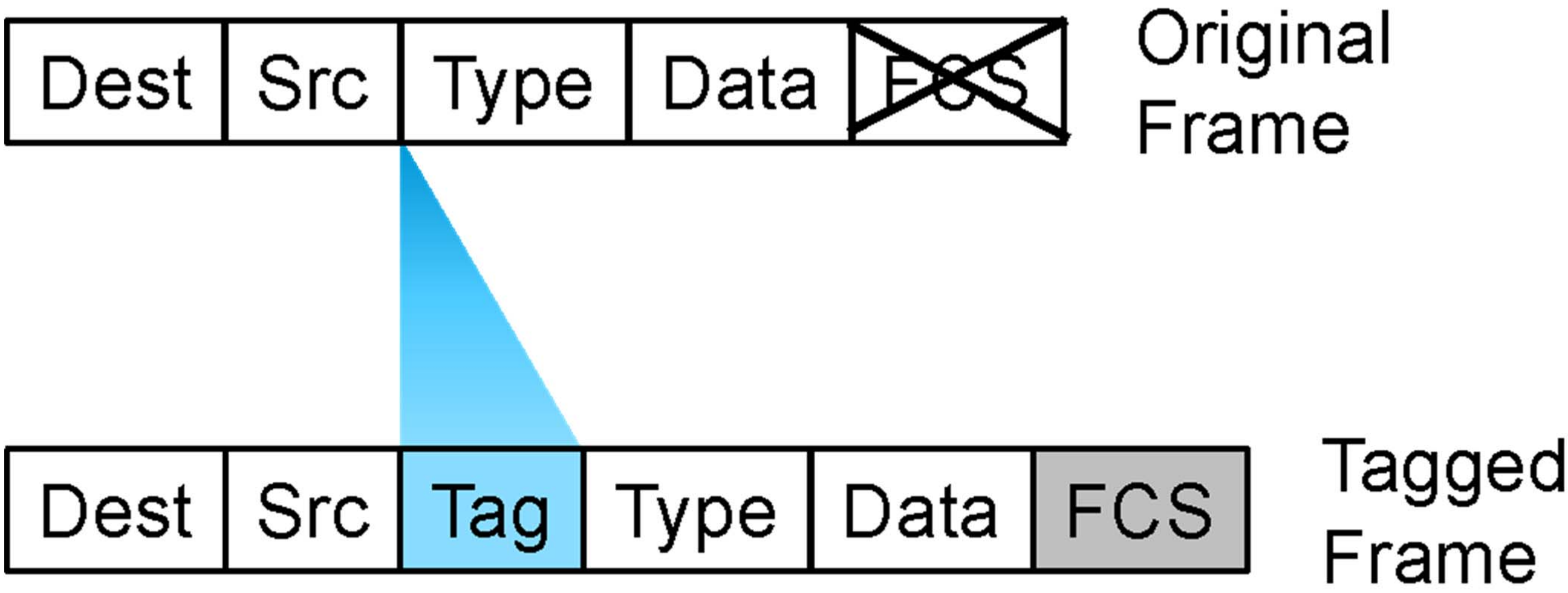
- Combining many VLANs on the same port is called *trunking*.
- A trunk allows the transportation of frames from different VLANs.
- Each frame has a tag that specifies the VLAN that it belongs to.
- Frames are forwarded to the corresponding VLAN based on the tag information.



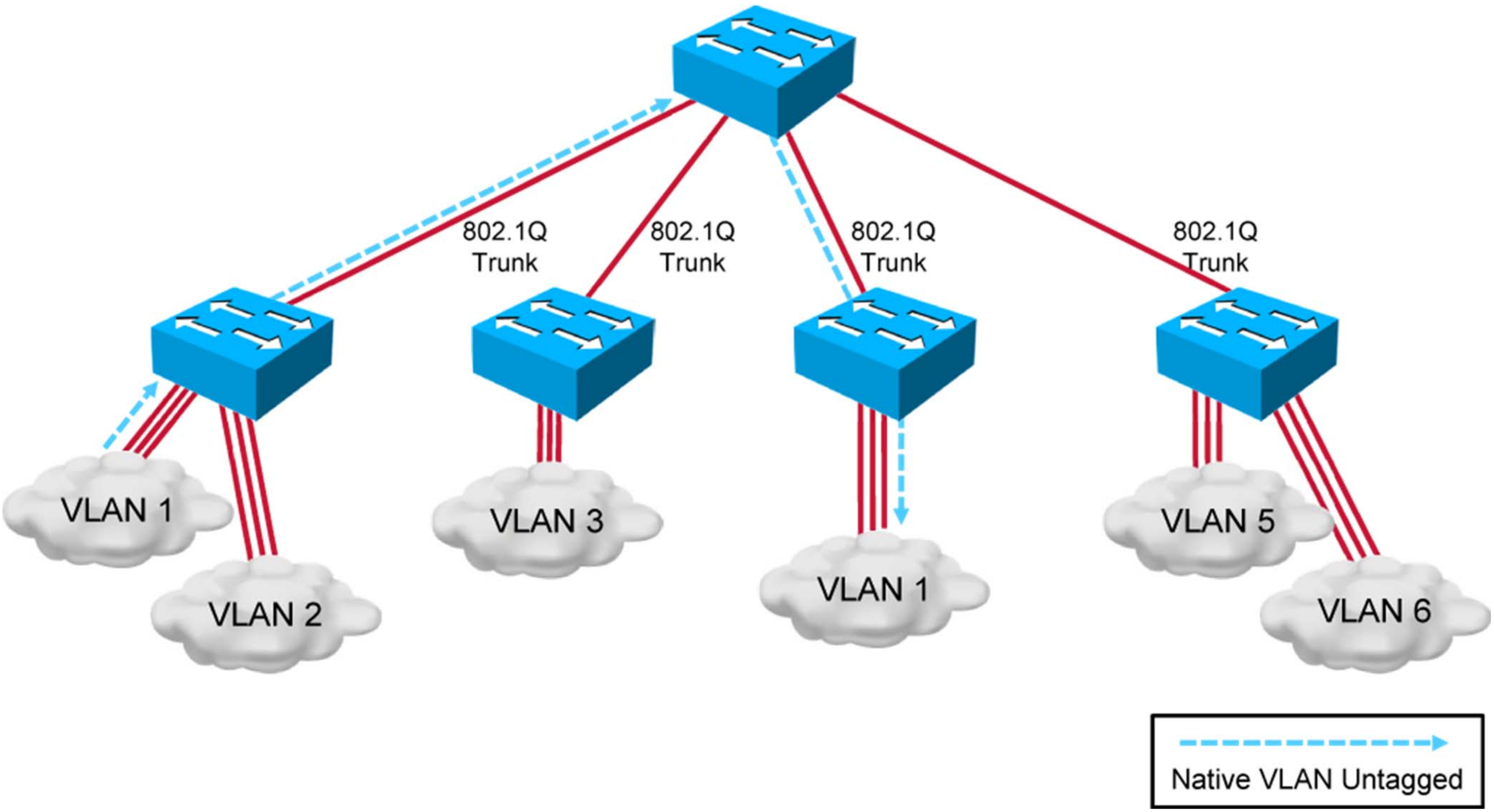
Trunking with 802.1Q (Cont.)



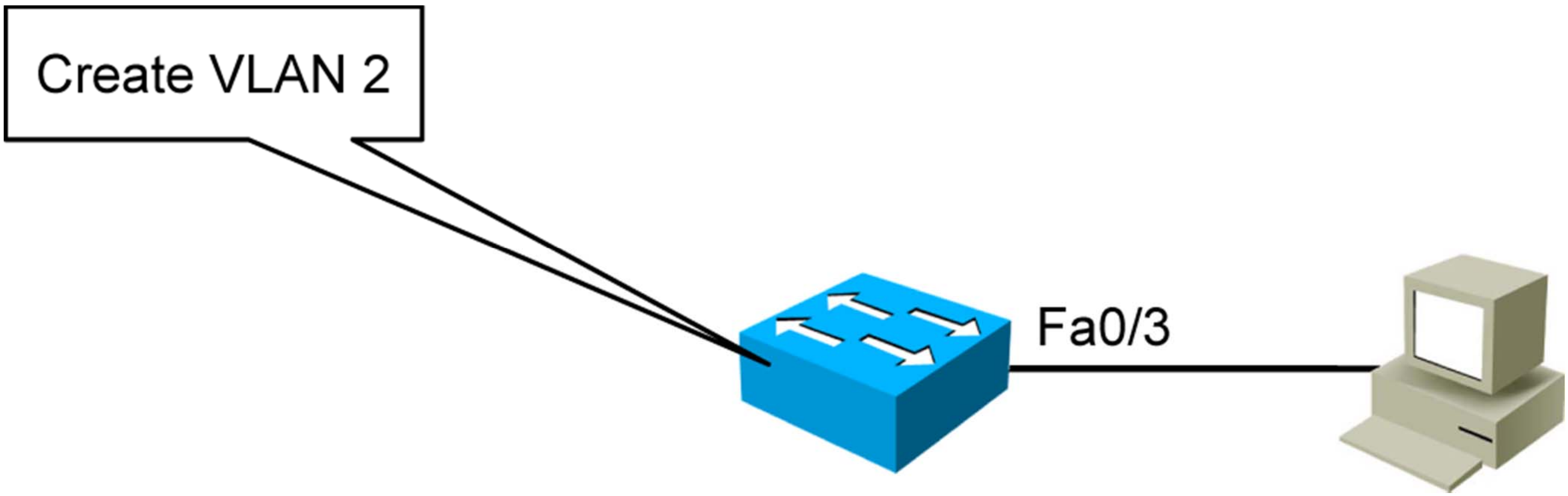
Trunking with 802.1Q (Cont.)



Trunking with 802.1Q (Cont.)



Creating a VLAN




```
SwitchX#configure terminal
SwitchX(config)#vlan 2
SwitchX(config-vlan)#name Sales
```

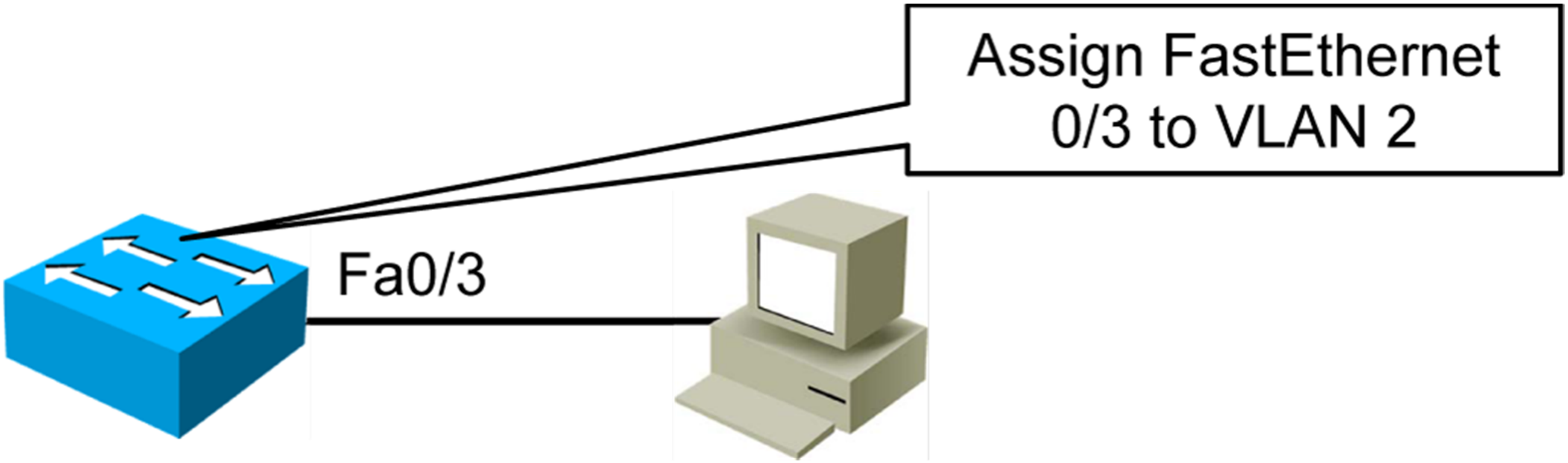
- Adds VLAN 2 and names it "Sales"

Creating a VLAN (Cont.)

```
SwitchX# show vlan id 2

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
2          Sales                      active    Fa0/2, Fa0/12

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
2    enet  100002     1500  -      -      -        -    -        0      0

<output omitted>
```

- Verifies VLAN2

Assigning a Port to a VLAN




```
SwitchX#configure terminal
SwitchX(config)#interface FastEthernet 0/3
SwitchX(config-if)#switchport access vlan 2
```

- Assigns port FastEthernet0/3 to VLAN 2

Assigning a Port to a VLAN (Cont.)

```
SwitchX#show vlan brief
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------
1    default                          active    Fa0/1
2    Sales                            active    Fa0/3
3    vlan3                            active
4    vlan4                            active

<output omitted>
```

- Verifies that port FastEthernet0/3 was assigned to VLAN 2

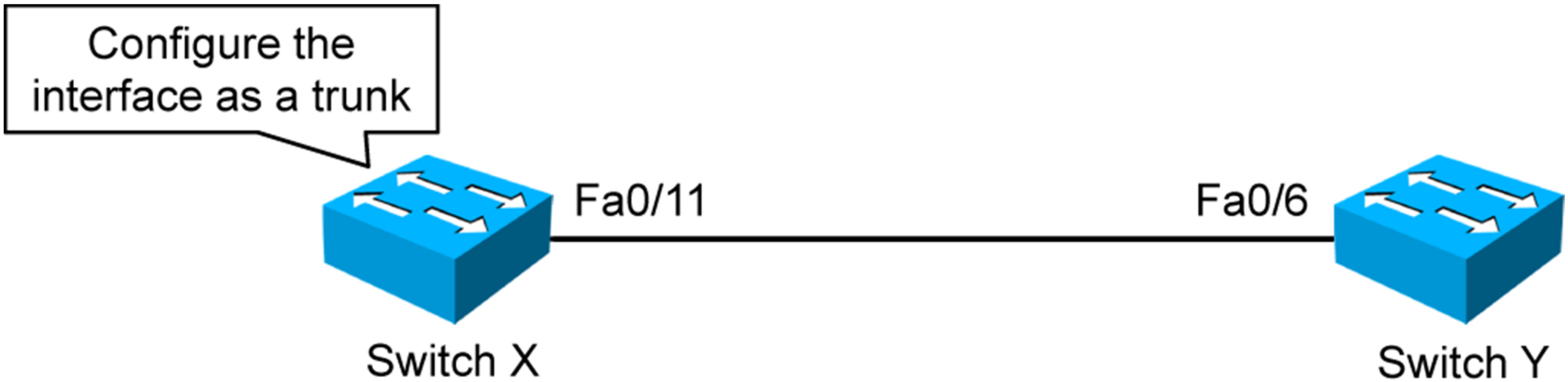
Assigning a Port to a VLAN (Cont.)

```
SwitchX#show interface FastEthernet0/3 switchport
Name: Fa0/3
Switchport: Enabled
Administrative Mode: dynamic auto
Operational Mode: static access
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: On
Access Mode VLAN: 2 (Sales)

<output omitted>
```

- Verifies VLAN membership on the Fa0/3 interface

Configuring an 802.1Q Trunk

- Enter the interface configuration mode.
- Configure the Fa0/11 interface as a VLAN trunk.
- Change the native VLAN from 1 to 99.




```
SwitchX#configure terminal
SwitchX(config)#interface FastEthernet 0/11
SwitchX(config-if)#switchport mode trunk
SwitchX(config-if)#switchport trunk native vlan 99
```

Configuring an 802.1Q Trunk (Cont.)

```
SwitchX#show interfaces FastEthernet0/11 switchport
Name: Fa0/11
Switchport: Enabled
Administrative Mode: trunk
Operational Mode: trunk
Administrative Trunking Encapsulation: dot1q
Negotiation of Trunking: On
Access Mode VLAN: 99
Trunking Native Mode VLAN: 99

<output omitted>
```

```
SwitchX#show interfaces FastEthernet0/11 trunk
Port     Mode    Encapsulation  Status        Native vlan
Fa0/11   on      802.1q         trunking      99
 Port       Vlans allowed on trunk
Fa0/11      1-4094
 Port        Vlans allowed and active in management domain
Fa0/11      1-13

<output omitted>
```

- Verifies a trunk on the Fa0/11 interface

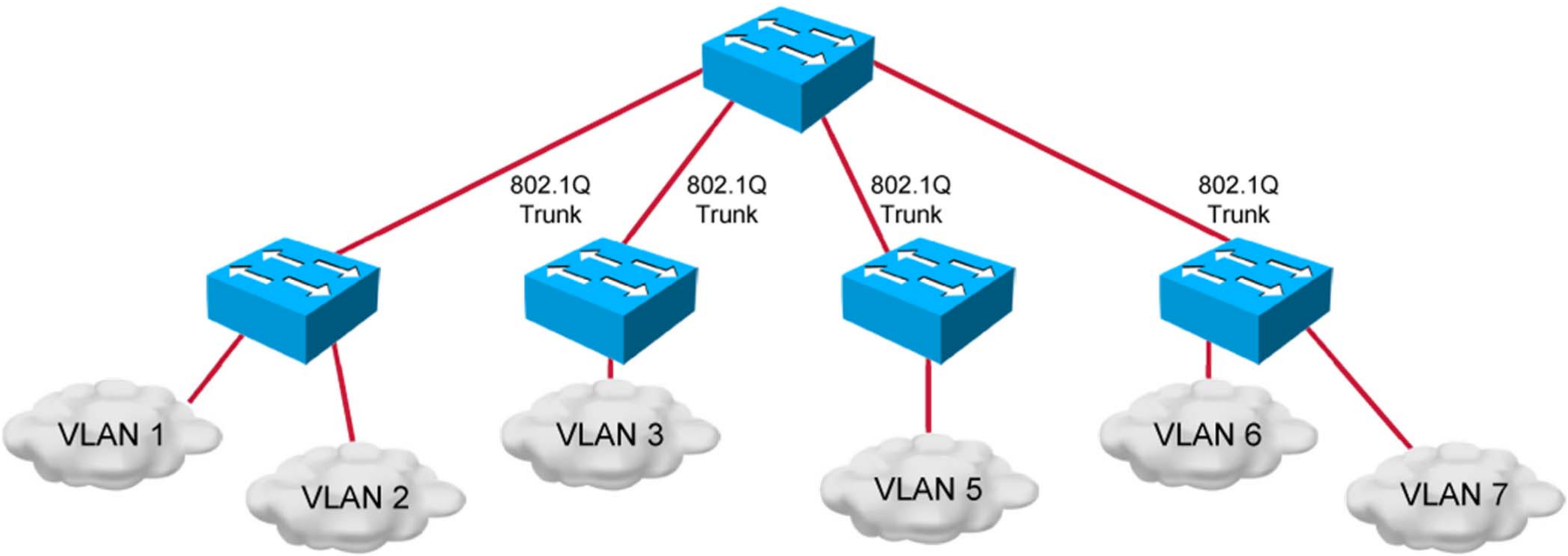
VLAN Design Considerations

- The maximum number of VLANs is switch-dependent.
- VLAN 1 is the factory-default Ethernet VLAN.
- A use-dedicated VLAN is for the Cisco switch management IP address.
- Keep management traffic in a separate VLAN.
- Change the native VLAN to something other than VLAN 1.

VLAN Design Considerations (Cont.)

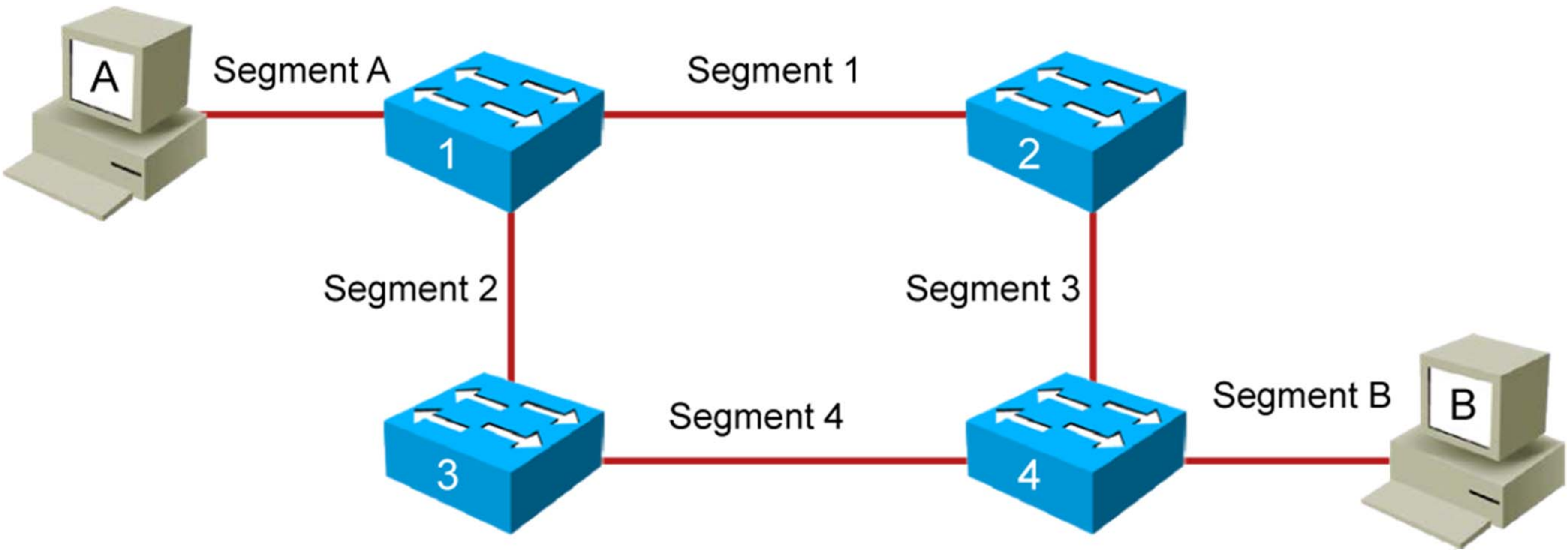
When configuring a trunk link, consider the following:

- Make sure that the native VLAN for an 802.1Q trunk is the same on both ends of the trunk link.
- DTP manages trunk negotiations between Cisco switches.

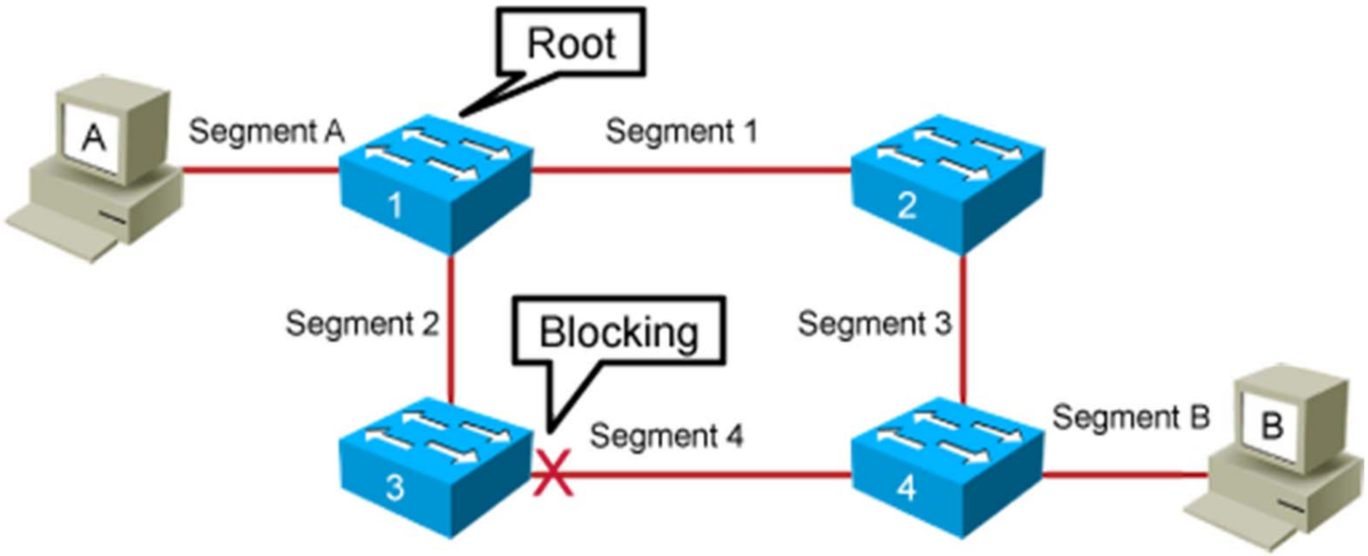


Physical Redundancy in a LAN

Loops may occur in the network as part of a design strategy for redundancy.



Physical Redundancy in a LAN (Cont.)



Summary

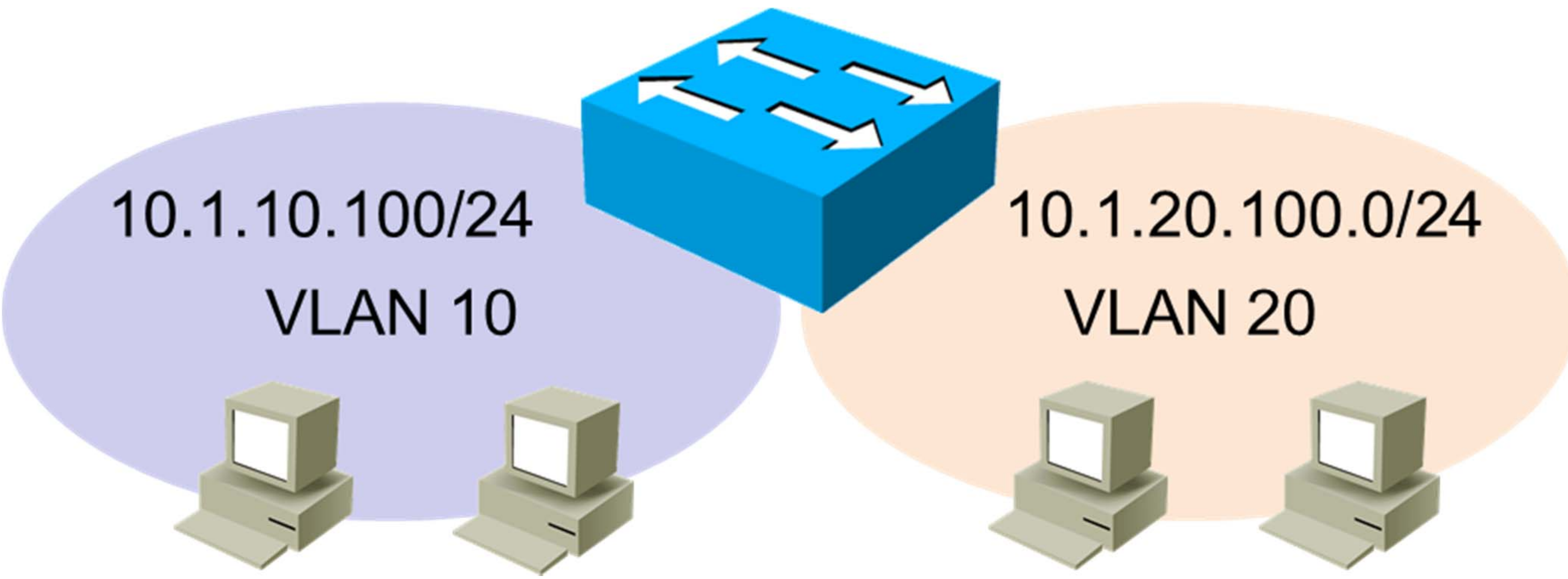
- VLANs are independent LAN networks and address segmentation, security, and organizational flexibility.
- Ethernet trunks carry the traffic of multiple VLANs over a single link and allow you to extend VLANs across many switches.
- To implement VLANs and trunking, you need to create VLANs, configure trunk links, and assign switch ports to selected VLANs.
- Physical redundancy is required for network reliability.
- STP ensures a loop-free topology.

Routing Between VLANs

Building a Medium-Sized Network

Purpose of Inter-VLAN Routing

- A VLAN creates a separate switching segment.
- Traffic cannot be switched between VLANs.
- VLANs have different IP subnets.
- Routing is necessary to forward traffic between VLANs.



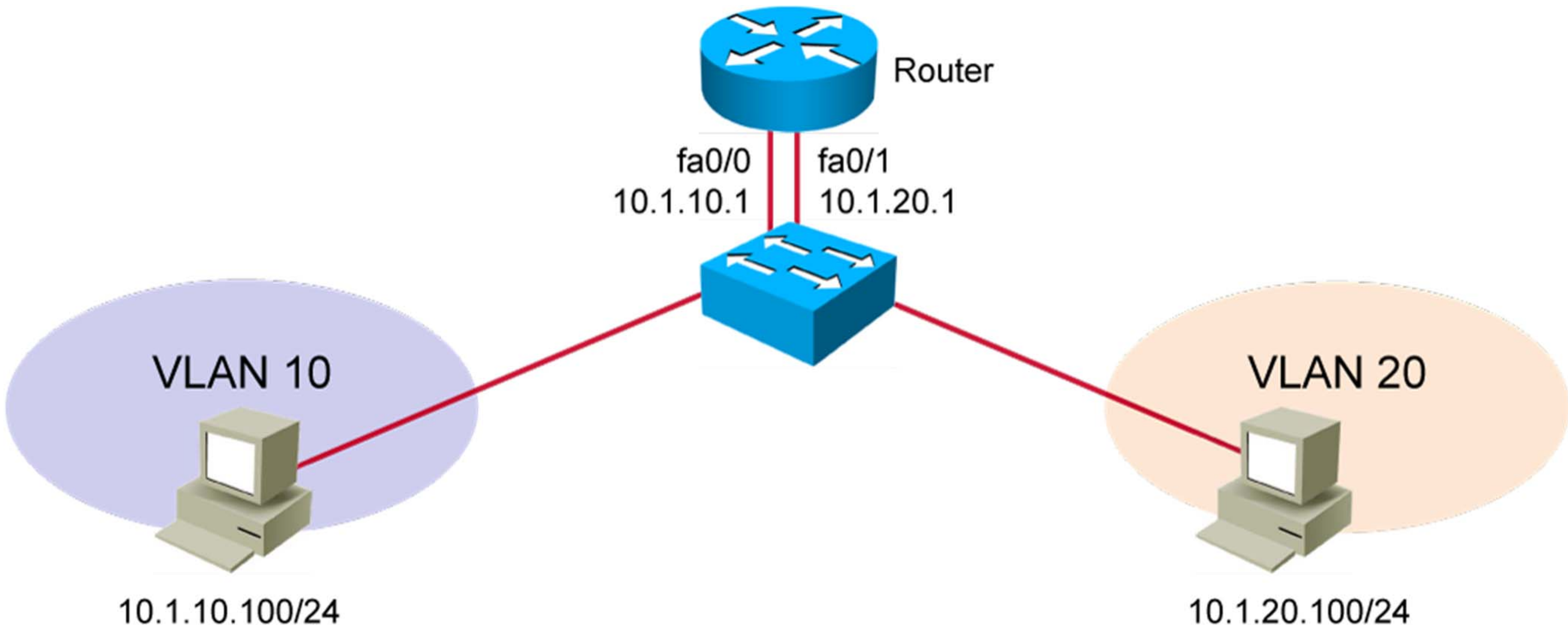
Options for Inter-VLAN Routing

These solutions can provide inter-VLAN routing:

- Router with a separate interface in each VLAN
- Router with a trunk link
- Layer 3 switch

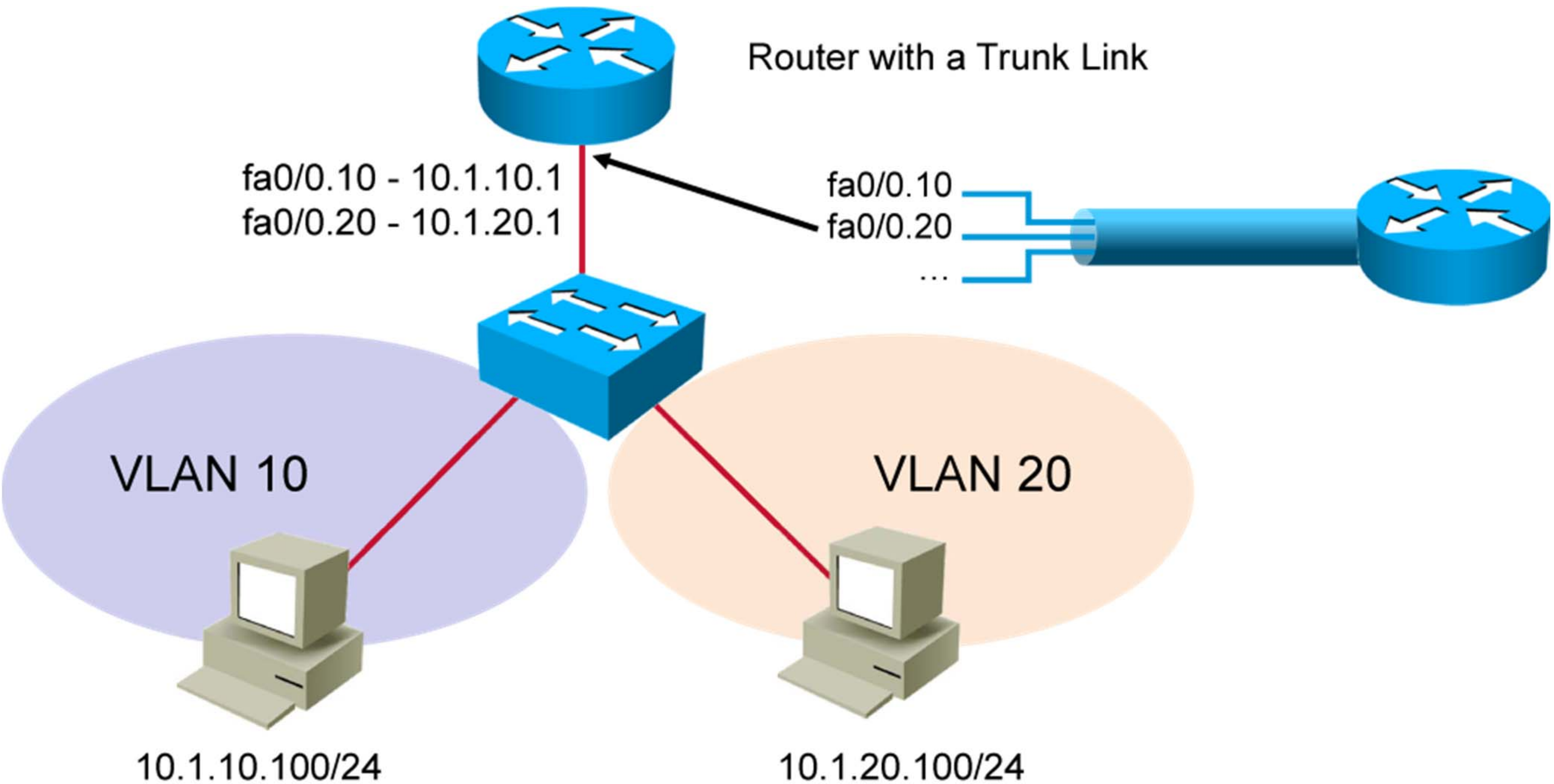
Options for Inter-VLAN Routing (Cont.)

Option: Router with a separate interface in each VLAN



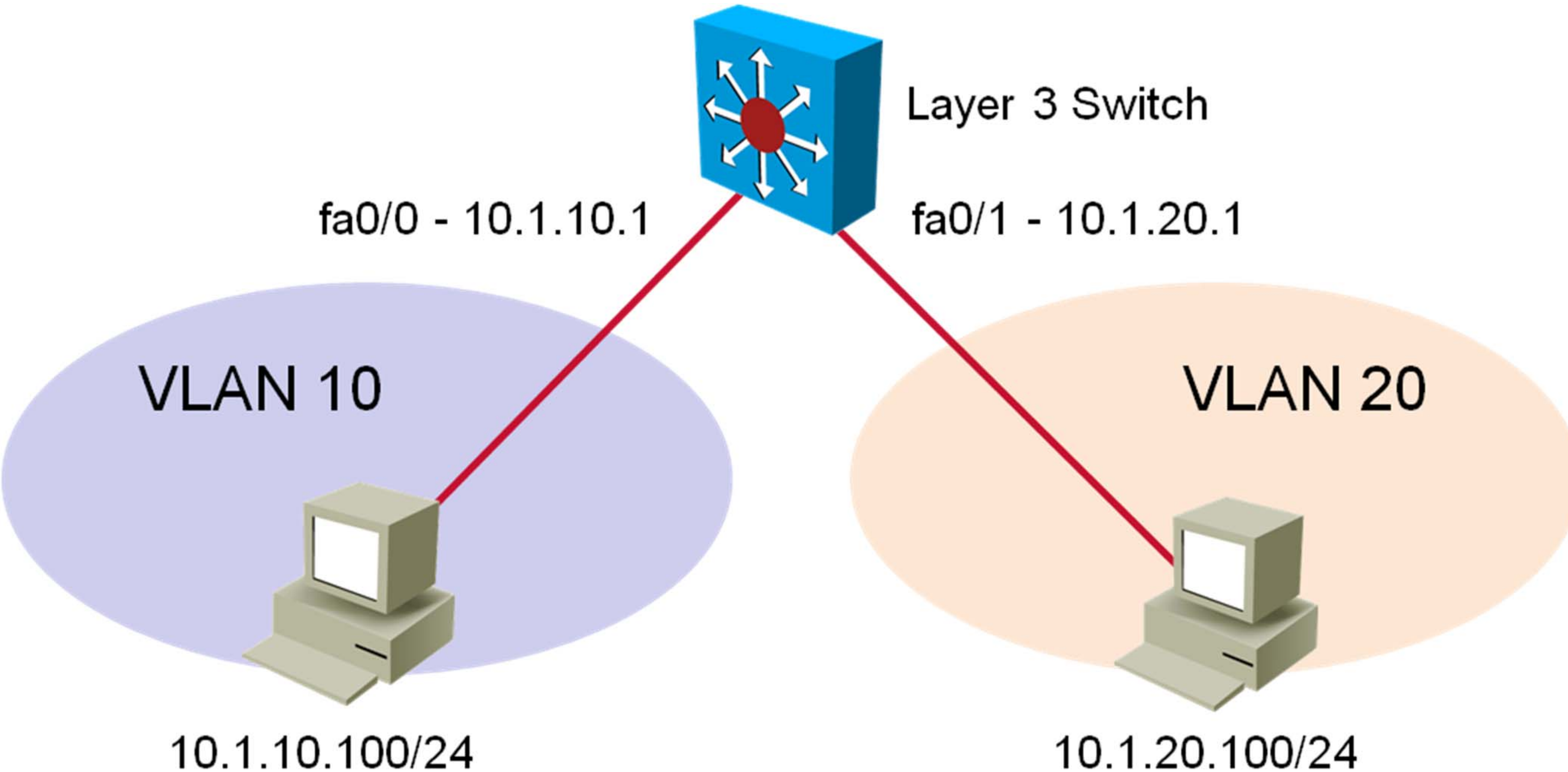
Options for Inter-VLAN Routing (Cont.)

Option: Router with a trunk link



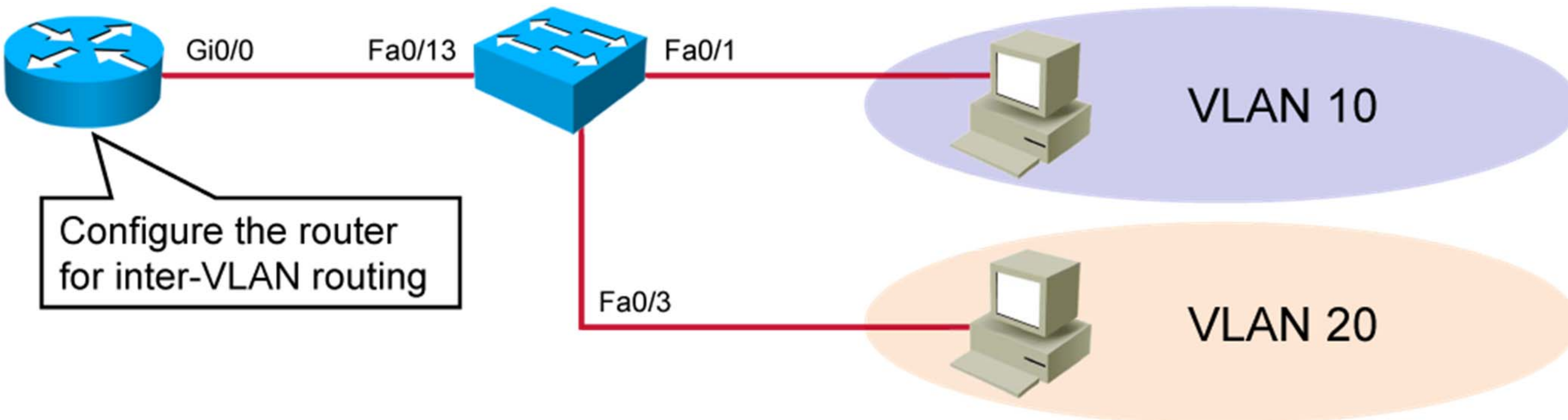
Options for Inter-VLAN Routing (Cont.)

Option: Layer 3 switch



Configuring a Router with a Trunk Link

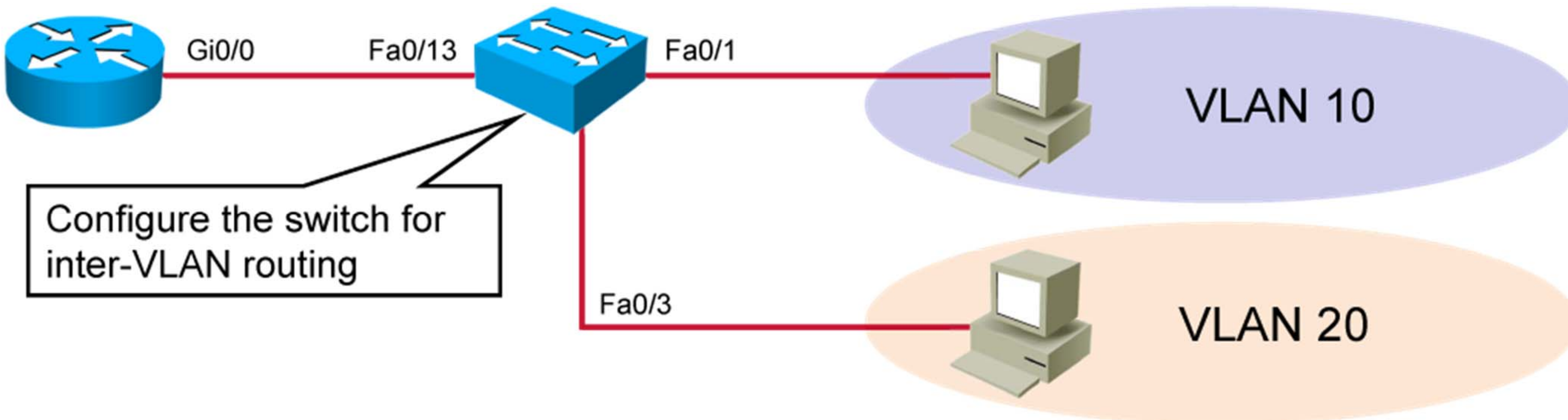
Configures subinterfaces and trunking on the router




```
Router(config)#interface GigabitEthernet 0/0.10
Router(config-if)#encapsulation dot1Q 10
Router(config-if)#ip address 10.1.10.1 255.255.255.0
Router(config-if)#interface GigabitEthernet 0/0.20
Router(config-if)#encapsulation dot1Q 20
Router(config-if)#ip address 10.1.20.1 255.255.255.0
```

Configuring Router with a Trunk Link (Cont.)

Assigns ports to specific VLANs and configures the port toward the router as a trunk




```
Switch(config)#interface FastEthernet 0/13
Switch(config-if)#switchport mode trunk
Switch(config-if)#interface FastEthernet 0/1
Switch(config-if)#switchport access vlan 10
Switch(config-if)#interface FastEthernet 0/3
Switch(config-if)#switchport access vlan 20
```

Configuring Router with a Trunk Link (Cont.)

Verifies the VLAN subinterfaces

```
Router#show vlans

<output omitted>

Virtual LAN ID:  10 (IEEE 802.1Q Encapsulation)

   vLAN Trunk Interface:   GigabitEthernet0/0.10

   Protocols Configured:   Address:        Received:  Transmitted:
           IP              10.1.10.1             11            18

<output omitted>

Virtual LAN ID:  20 (IEEE 802.1Q Encapsulation)

   vLAN Trunk Interface:   GigabitEthernet0/0.20

   Protocols Configured:   Address:        Received:  Transmitted:
           IP              10.1.20.1             11             8

<output omitted>
```

Configuring Router with a Trunk Link (Cont.)

Verifies the IP routing table for VLAN subinterfaces

```
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
       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
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C        10.1.10.0/24 is directly connected, GigabitEthernet0/0.10
L        10.1.10.1/32 is directly connected, GigabitEthernet0/0.10
C        10.1.20.0/24 is directly connected, GigabitEthernet0/0.20
L        10.1.20.1/32 is directly connected, GigabitEthernet0/0.20
```

Summary

- Inter-VLAN communication cannot occur without a Layer 3 device (Layer 3 switch or router).
- Routing is necessary to forward traffic between VLANs.
- A router with a trunk link is configured with a subinterface for each VLAN.

Using a Cisco Network Device as a DHCP Server

Building a Medium-Sized Network

Need for a DHCP Server

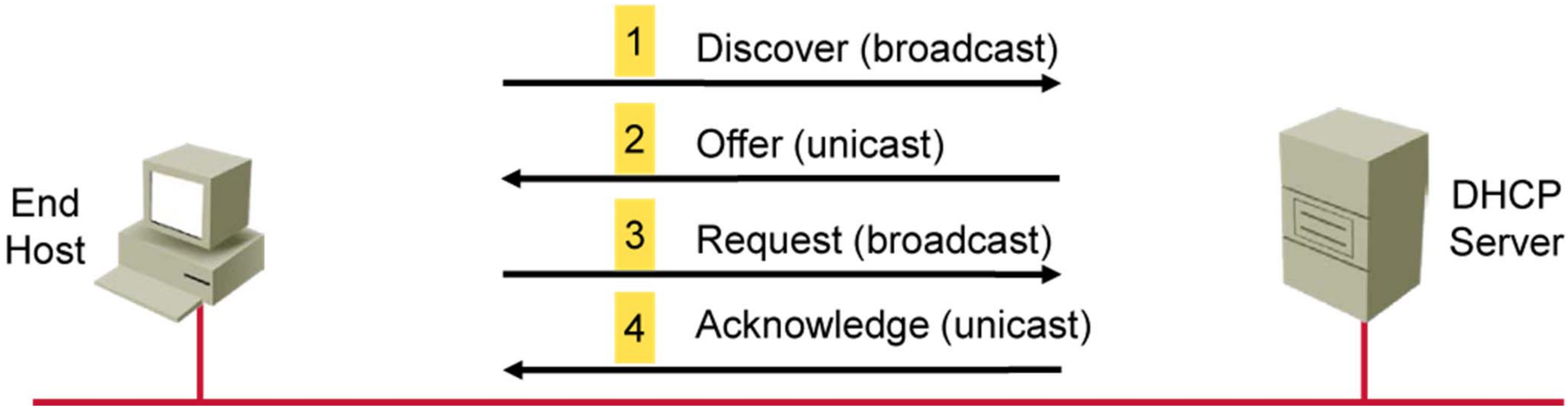
A manual IP address assignment in a medium-sized LAN is as follows:

- Time consuming
- Prone to errors
- Unfavorable to employee mobility

A DHCP IP address assignment in a segmented LAN is as follows:

- An IP address that is automatically assigned in accordance with user VLAN settings
- A centralized IP address allocation that enables consistency across the whole organization

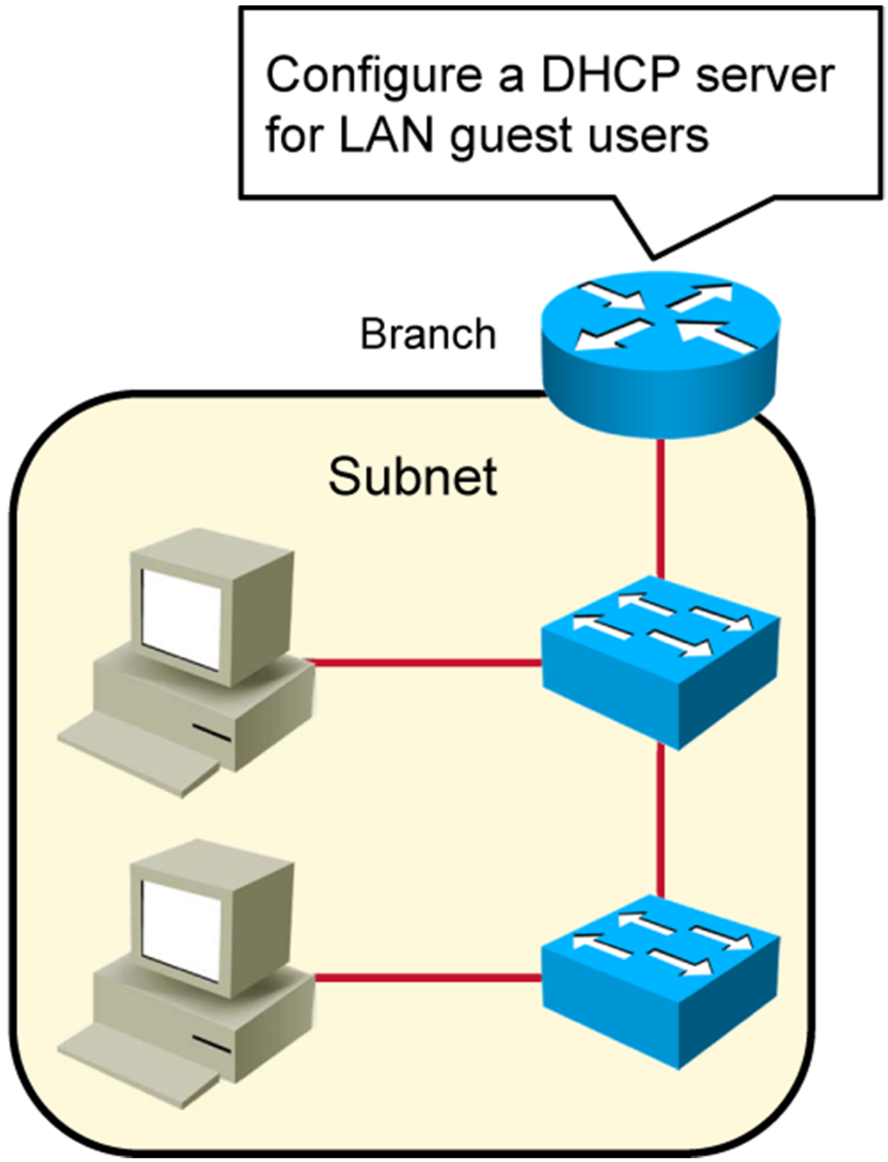
Understanding DHCP



Configuring a DHCP Server

Configuration scenario:

- Configure a DHCP server on a Cisco router
- Assign IP addresses from address pool 10.1.50.0/24 with a lease time of 12 hours
- Do not assign IP addresses from 10.1.50.1 to 10.1.50.50
- Additional parameters: default gateway, domain name, and DNS server



Configuring a DHCP Server (Cont.)

Cisco IOS DHCP server configuration:

- Enter the DHCP pool configuration mode
- Assign DHCP parameters to the DHCP pool
- Exclude IP addresses from the DHCP assignment

```
Branch(config)# ip dhcp pool Guests
Branch(dhcp-config) #network 10.1.50.0 /24
Branch(dhcp-config)# default-router 10.1.50.1
Branch(dhcp-config)# dns-server 10.1.50.1
Branch(dhcp-config)# domain-name example.com
Branch(dhcp-config)# lease 0 12
Branch(dhcp-config)# exit
Branch(config)# ip dhcp excluded-address 10.1.50.1 10.1.50.50
```

Monitoring DHCP Server Functions

```
Branch# show ip dhcp pool

Pool Guests :
 Utilization mark (high/low)    : 100 / 0
 Subnet size (first/next)       : 0 / 0
 Total addresses                : 254
 Leased addresses               : 2
 Pending event                  : none
 1 subnet is currently in the pool :
 Current index      IP address range               Leased addresses
 10.1.50.55         10.1.50.1   - 10.1.50.254      2
```

- Verifies information about configured DHCP address pools

Monitoring DHCP Server Functions (Cont.)

```
Branch# show ip dhcp binding
Bindings from all pools not associated with VRF:
IP address     Client-ID/          Lease expiration       Type
               Hardware address/
               User name
10.1.50.54     0100.0c29.8807.34   Oct 18 2012 06:56 PM   Automatic
10.1.50.56     0100.0c29.4532.be   Oct 18 2012 07:08 PM   Automatic
```

- Displays address bindings information

Monitoring DHCP Server Functions (Cont.)

```
Branch# show ip dhcp conflict
IP address         Detection method    Detection time          VRF
10.1.50.52         Gratuitous ARP      Oct 18 2012 06:56 AM
10.1.50.53         Ping                Oct 18 2012 07:08 AM
```

- Displays the address conflicts that are found by a DHCP server
  - **IP Address:** The IP address of the host as recorded on the DHCP server
  - **Detection Method:** The manner in which the IP address of the hosts were found on the DHCP server; can be a ping or a gratuitous ARP
  - **Detection time:** The time when the conflict was found

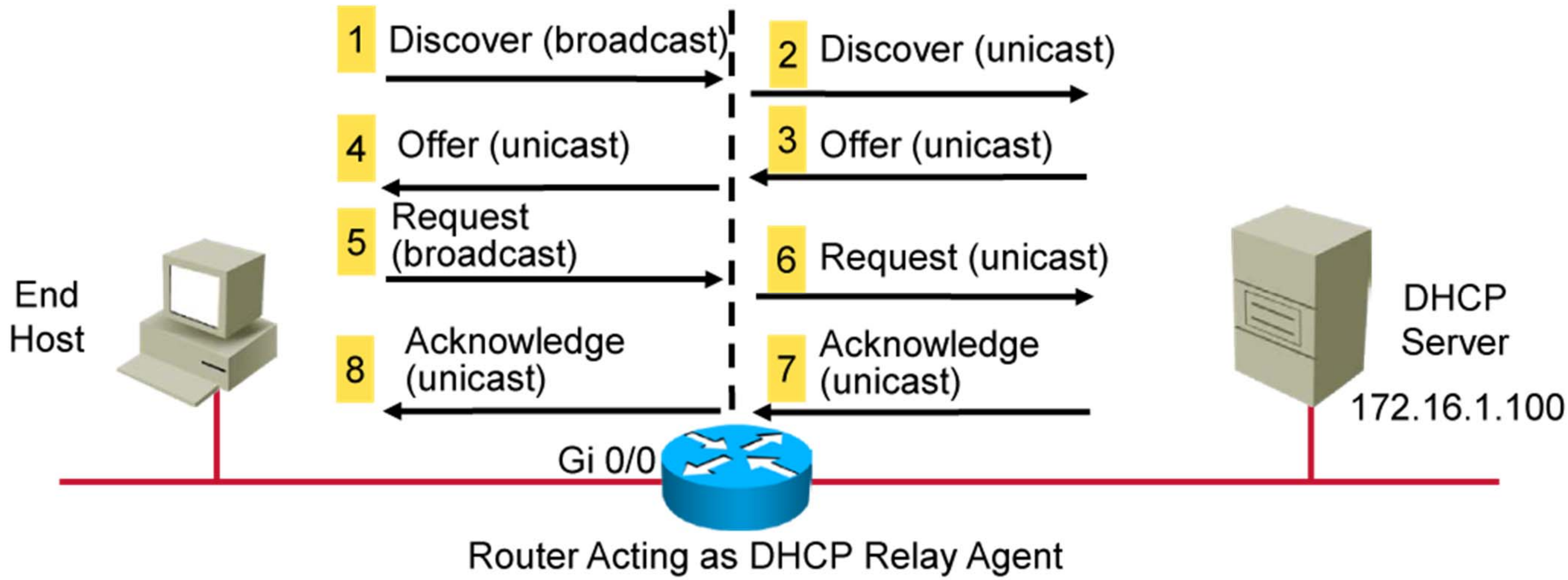
DHCP Relay Agent

The need for a centralized DHCP solution:

- Managing individual DHCP servers across many locations is time-consuming.
- Ensuring consistency in several different places can easily lead to errors.

To support a centralized DHCP solution in branch offices, only the DHCP relay agent needs to be configured.

DHCP Relay Agent (Cont.)




```
Branch(config-if)# ip helper-address 172.16.1.100
```

- Enables DHCP relay agent on a local interface

Summary

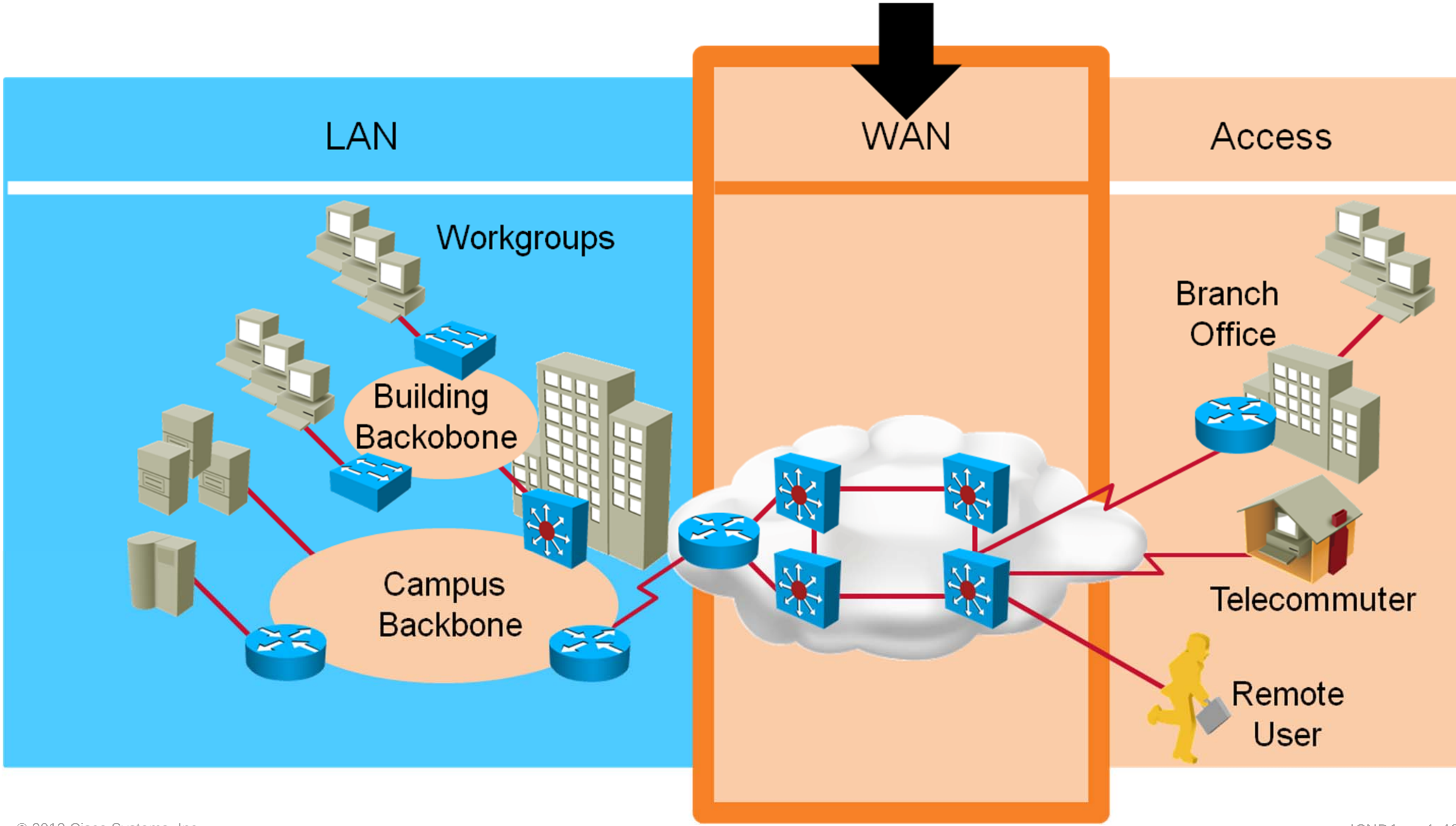
- A DHCP server provides dynamic IP address assignment to end hosts, reducing errors and the time that is needed to administer address assignment.
- Before a client obtains an IP address from a DHCP server, it exchanges DHCP discover, offer, request, and acknowledge messages with the DHCP server.
- Both Cisco routers and Cisco Catalyst switches can be configured as DHCP servers.
- Use the verification commands **show ip dhcp pool**, **show ip dhcp binding**, and **show ip dhcp conflict** to monitor a DHCP server.
- When a centralized DHCP server is in use, configure DHCP relay agent functionally using the **ip helper-address** interface configuration command.

Introducing WAN Technologies

Building a Medium-Sized Network

Introducing WANs

What is a WAN?



Introducing WANs (Cont.)

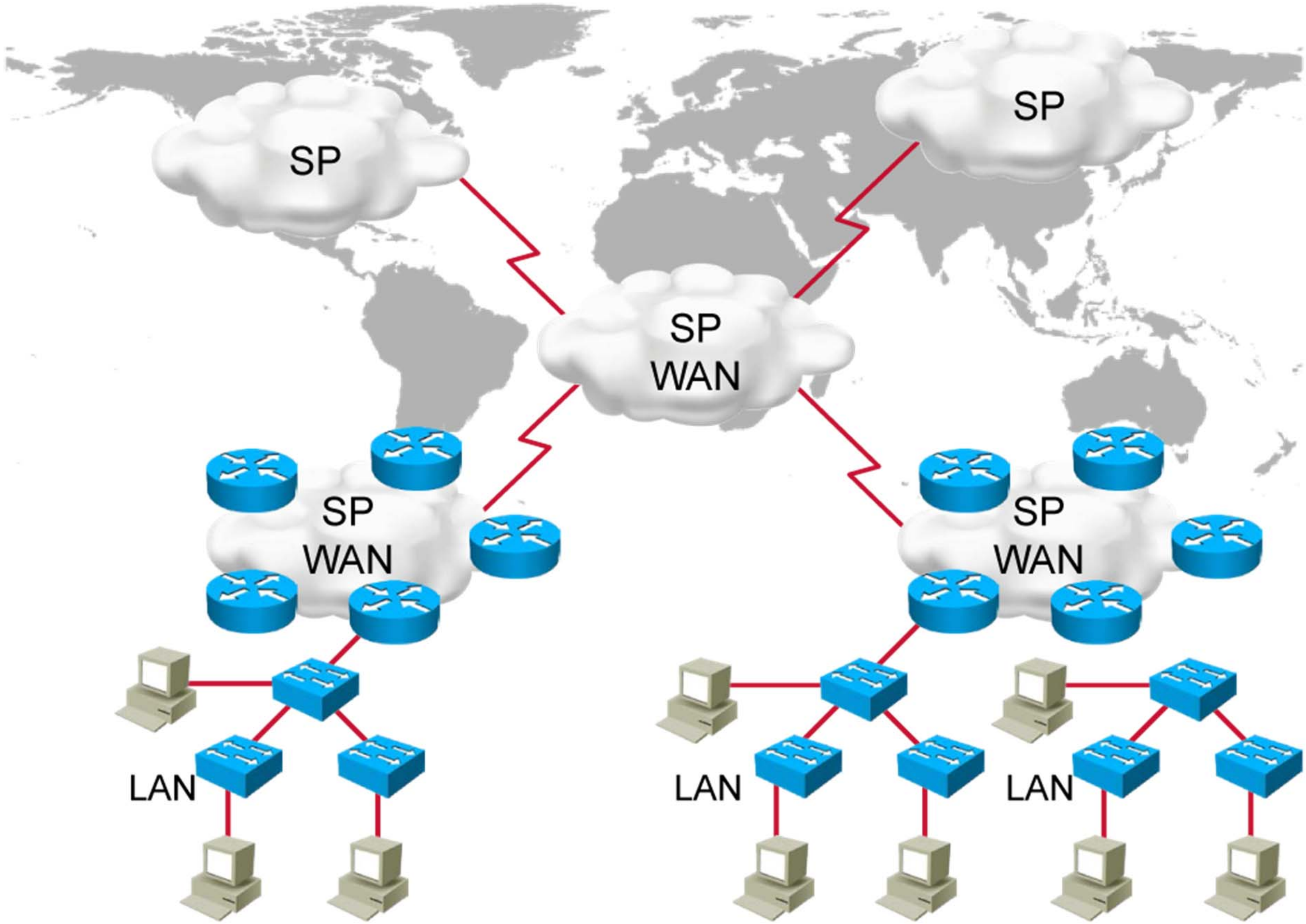
Why are WANs needed?

WANs vs. LANs

WAN = A collection of LANs

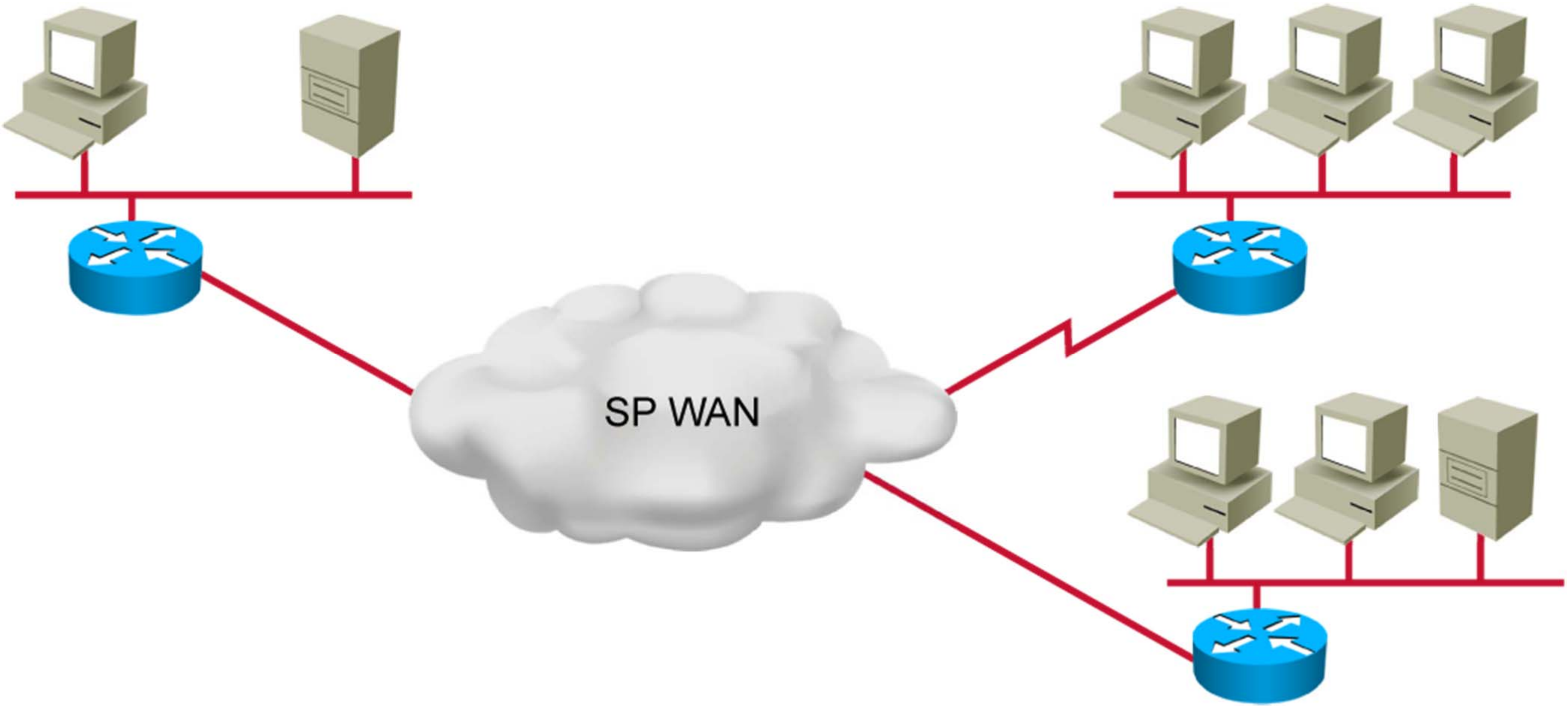
	WANs	LANs
Area	Wide geographic area	Single building or small geographic area
Ownership	Subscription to outside service provider	Owned by organization
Cost	Recurring	Fixed

WANs vs. LANs (Cont.)

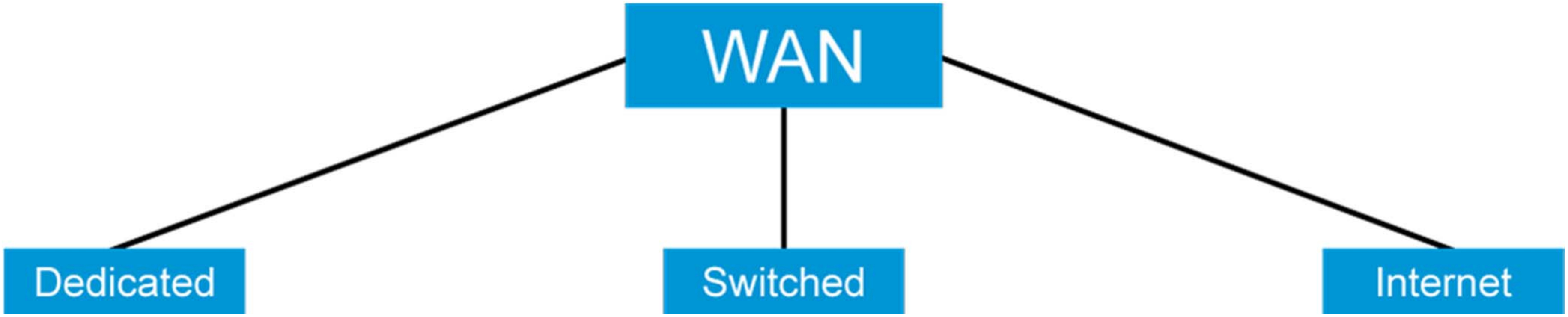


Role of Routers in WANs

WANs vs. LANs



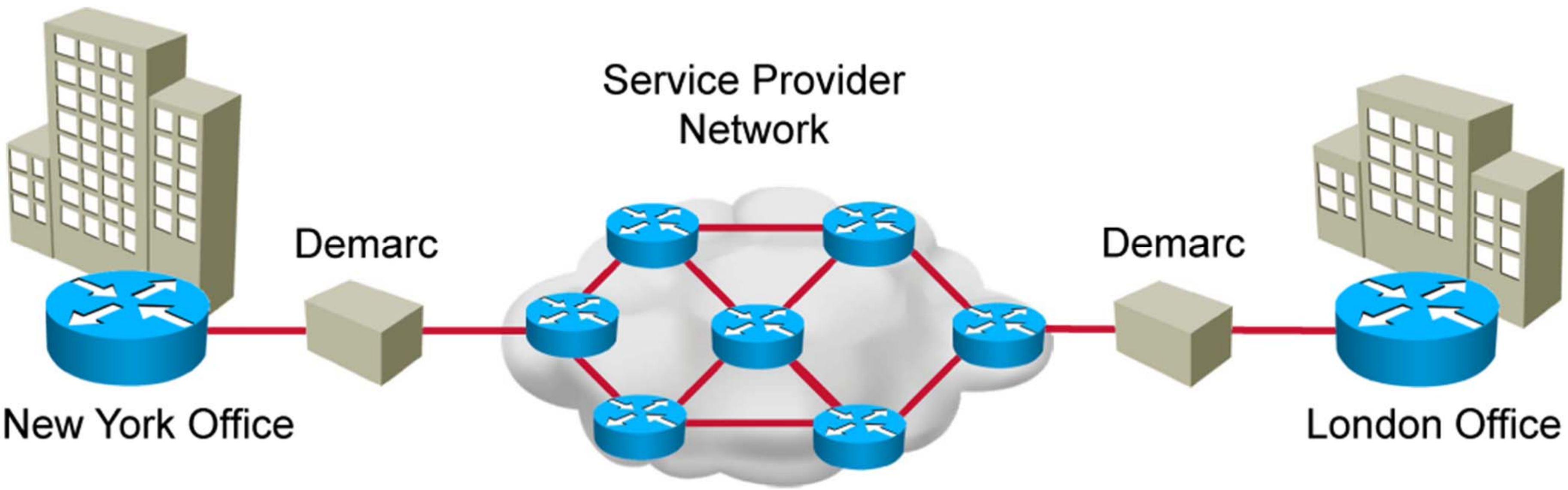
WAN Communication Link Options



Point-to-Point Connectivity

Ethernet emulation:

- Simple
- Affordable
- Flexible



Configuring a Point-to-Point Link

Configuring the Branch router with an IP address and interface description


```
Branch(config)#interface GigabitEthernet0/1
Branch(config-if)#ip address 192.168.1.1 255.255.255.252
Branch(config-if)#description WAN Link to HQ
Branch(config-if)#no shutdown
```

- Use ping to verify end-to-end connectivity

Summary

- A WAN allows the transmission of data across broad geographic distances.
- A WAN is a collection of LANs, and routers play a central role in transmitting data through WANs.
- There are three WAN communication link options: dedicated communication links, switched communication links, and public connections.
- A common type of WAN connectivity is the point-to-point connection that emulates Ethernet.
- Configuring an interface for emulated Ethernet WAN connectivity consists of setting the IP address and enabling the interface.

Introducing Dynamic Routing Protocols

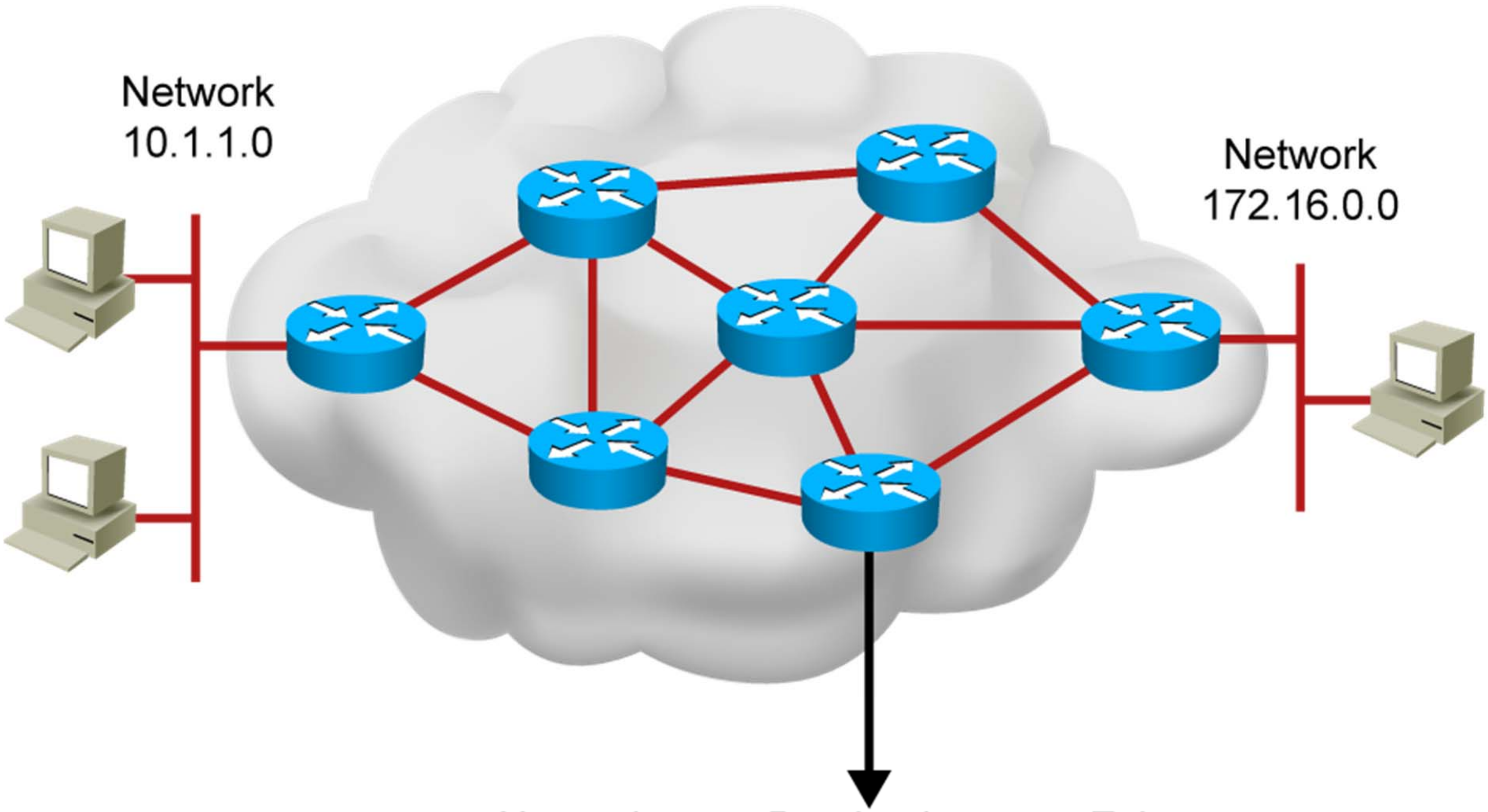
Building a Medium-Sized Network

Purpose of Dynamic Routing Protocols

Dynamic routing protocol characteristics follow:

- Routing protocols are sets of processes, algorithms, and messages that are used to exchange routing information.
- After directly connected routes have been installed, a router populates its routing table with the best paths to remote destinations, as chosen by the routing protocol.
- After the path is determined, a router can route to the learned networks.

Purpose of Dynamic Routing Protocols (Cont.)



Network Protocol	Destination Network	Exit Interface
EIGRP	10.1.1.0	FA0/1
OSPF	172.16.0.0	FA0/2

Purpose of Dynamic Routing Protocols (Cont.)

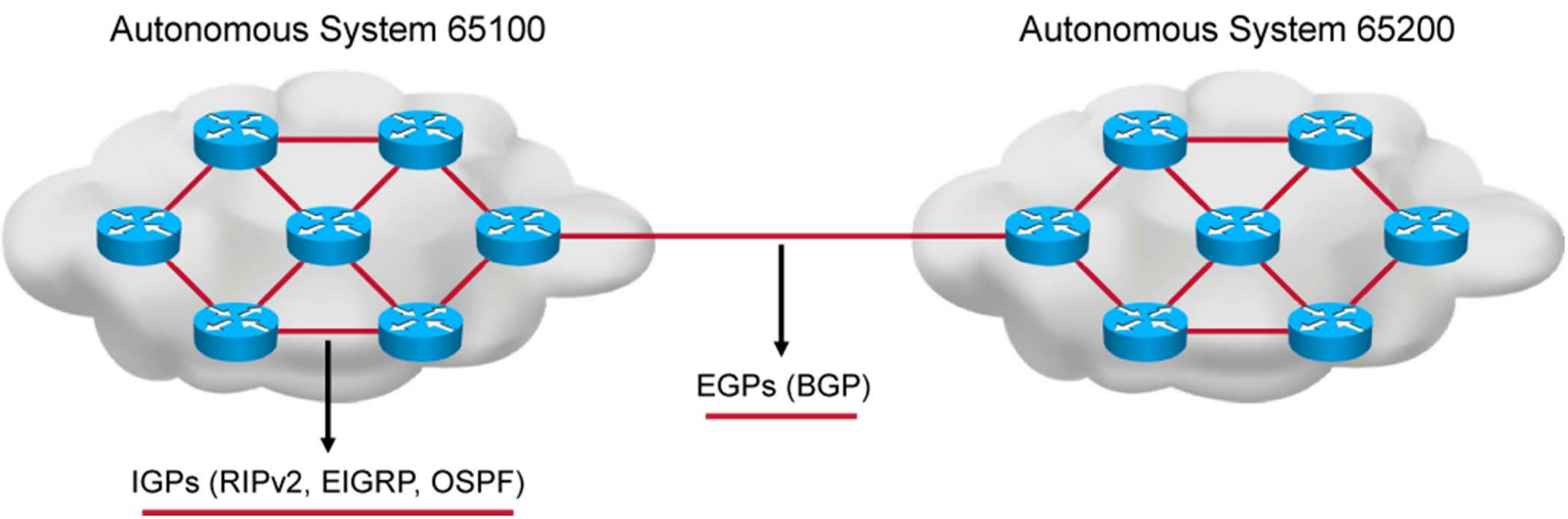
Dynamic routing protocols do as follows:

- Discover remote networks
- Maintain up-to-date routing information
- Choose the best path to destination networks
- Find a new best path if the current path is no longer available

Interior and Exterior Routing Protocols

Characteristics of autonomous systems:

- An AS is a collection of networks within a common administrative domain.
- IGPs operate within an AS.
- EGPs connect different autonomous systems.



Distance Vector and Link-State Routing Protocols

The types of dynamic routing protocols follow:

- **Distance vector:** RIP
- **Advanced distance vector:** EIGRP
- **Link-state:** OSPF and IS-IS

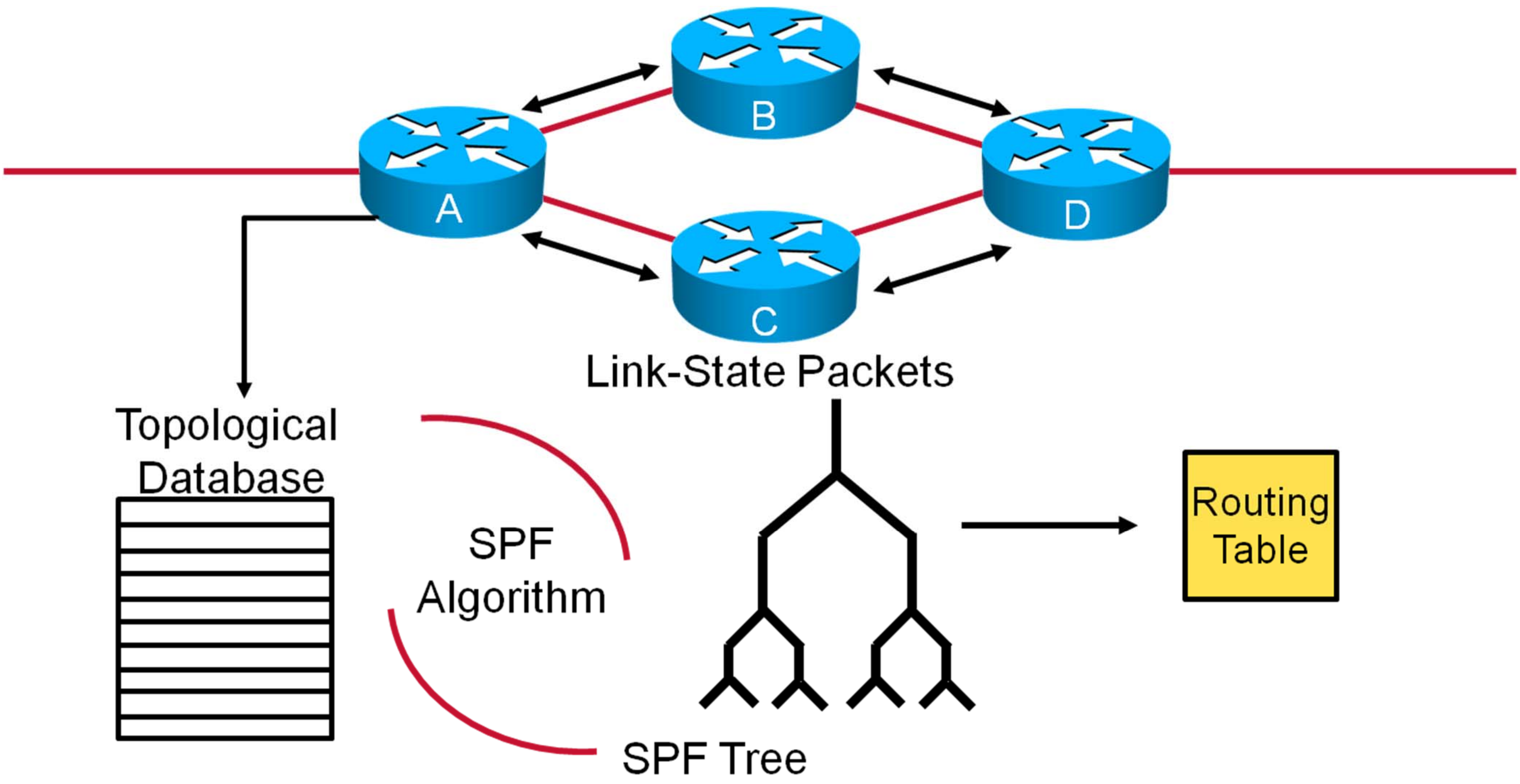
Understanding Link-State Routing Protocols

Characteristics of link-state routing protocols follow:

- A complete view of the network topology is created.
- Updates are sent when there is a link change.
- They are associated with SPF calculations.
- They use the link-state information to do as follows:
  - Create a topology map.
  - Select the best path to all destination networks in the topology.

Understanding Link-State Routing Protocols (Cont.)

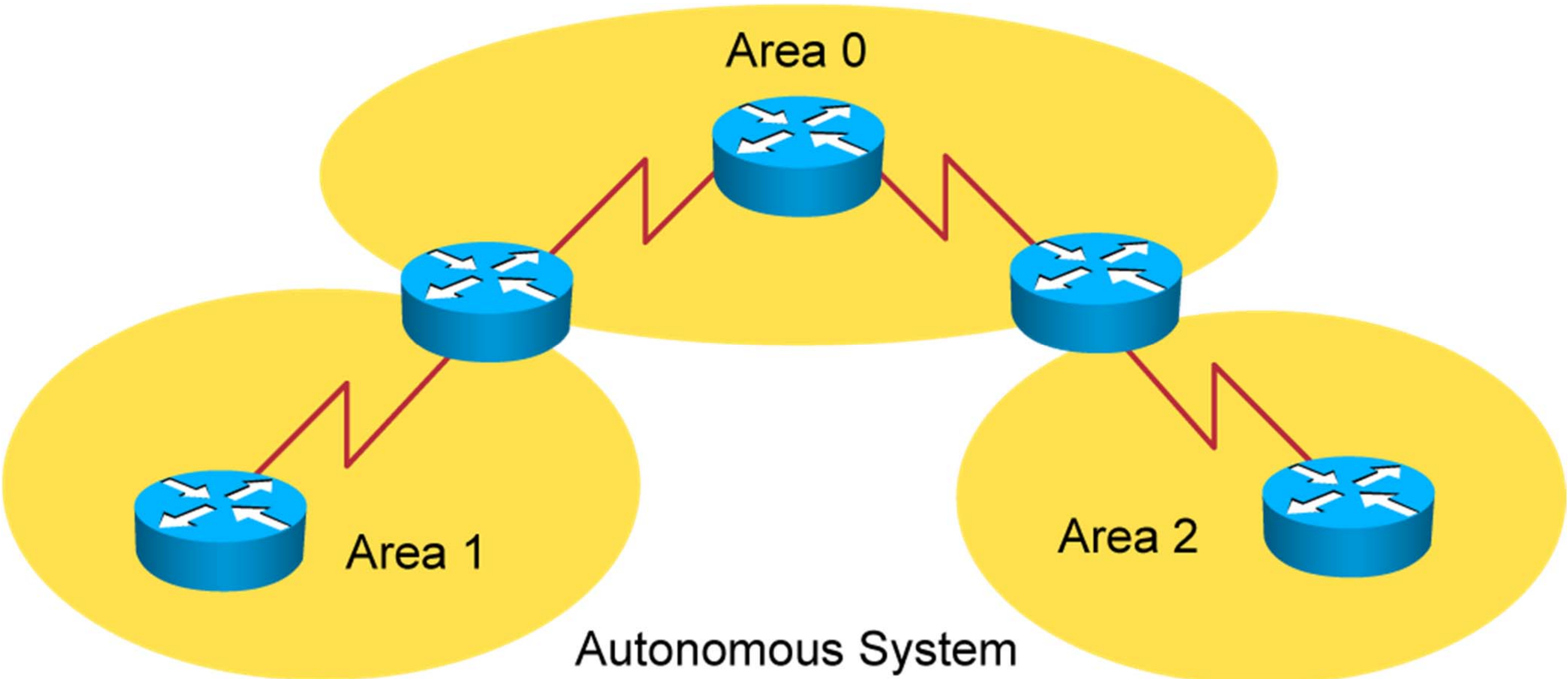
Link-state protocol components:



Understanding Link-State Routing Protocols (Cont.)

Hierarchical routing:

- Consists of areas and autonomous systems



Summary

- Routing protocols are a set of processes, algorithms, and messages that are used to exchange routing information.
- IGPs operate within an AS, while EGPs connect different autonomous systems.
- The distance vector routing approach determines the direction (vector) and distance to any link in the internetwork.
- Routers running link-state routing protocols maintain their own view of the network, so the router is less likely to propagate incorrect information that is provided by another router.

Implementing OSPF

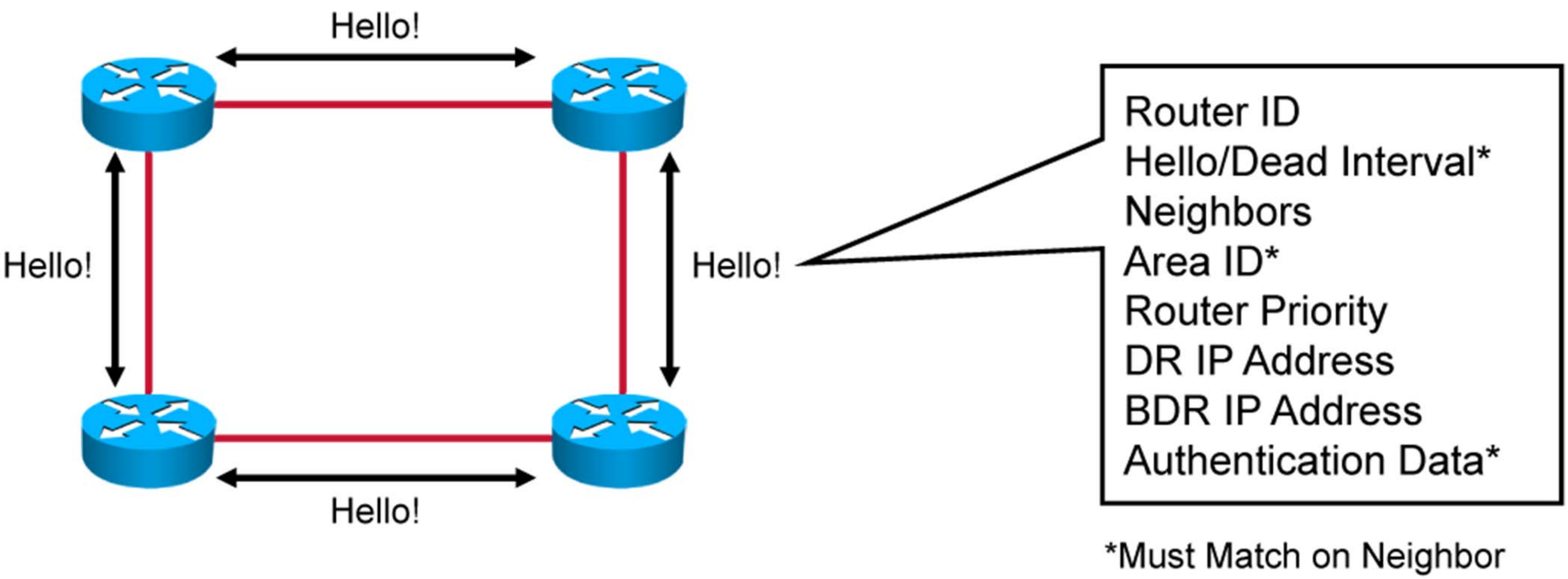
Building a Medium-Sized Network

Introducing OSPF

- Developed by the IETF
- Creates a neighbor relationship by exchanging hello packets
- Propagates LSAs rather than routing table updates:
  - Link: Router interface
  - State: Description of an interface and its relationship to neighboring routers
- Floods LSAs to all OSPF routers in the area, not just directly connected routers
- Pieces together all of the LSAs that are generated by the OSPF routers to create the OSPF link-state database
- Uses the SPF algorithm to calculate the shortest path to each destination and places it in the routing table

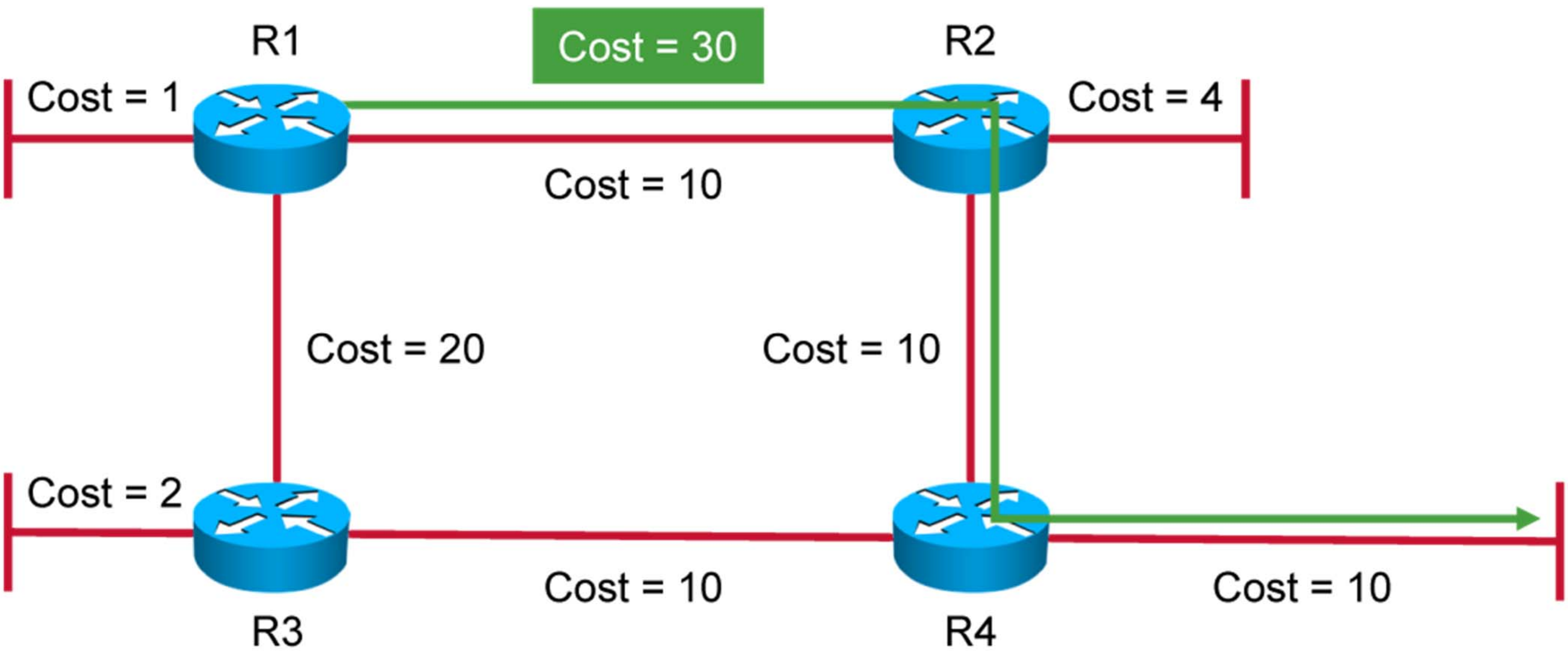
OSPF Adjacencies

- OSPF routers first establish adjacencies.
- Hello packets are periodically sent to multicast address 224.0.0.5.
- Routers must agree on certain information inside the hello packet before an adjacency can be established.

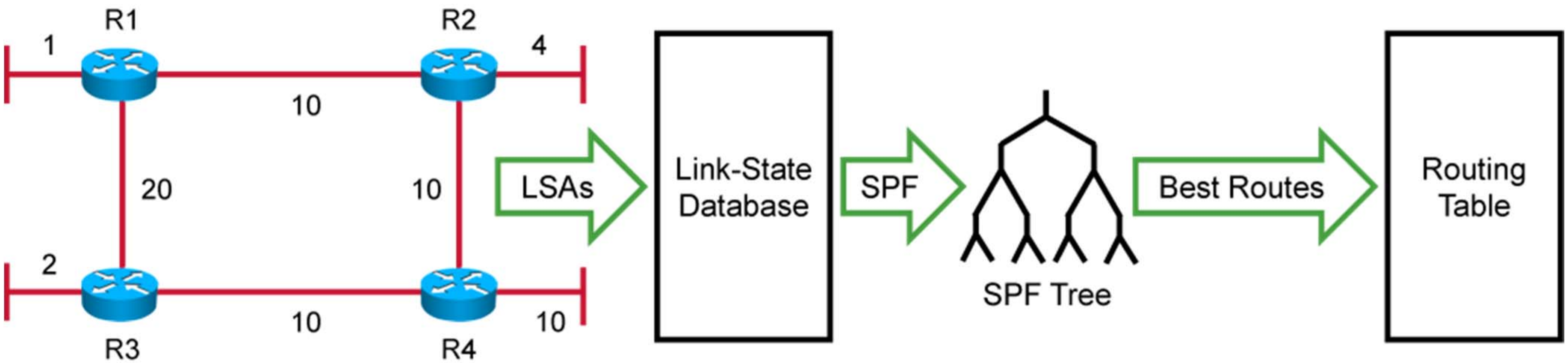


SPF Algorithm

- OSPF uses a path cost as a metric.
- By default, cost is calculated based on interface bandwidth.
- Cost = Reference bandwidth / interface bandwidth, where reference bandwidth is 100 Mb/s.



SPF Algorithm (Cont.)



R1 SPF Tree		
Destination	**Shortest Path**	**Cost**
R2 LAN	R1 to R2	14
R3 LAN	R1 to R3	22
R4 LAN	R1 to R4	30

Router ID

- The number by which the router is known to OSPF can be set manually using the **router-id** command.
- If **router-id** is not configured, the highest IP address on the active loopback interface at the moment of OSPF process startup is selected as the router ID.
- If there is no active loopback interface, then the router selects the highest IP address on the active interface at the moment of OSPF process startup.

Router ID (Cont.)

```
RouterX#show ip protocols

Routing Protocol is "ospf 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.2.2.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4

<output omitted>
```

- Verifies the device OSPF router ID

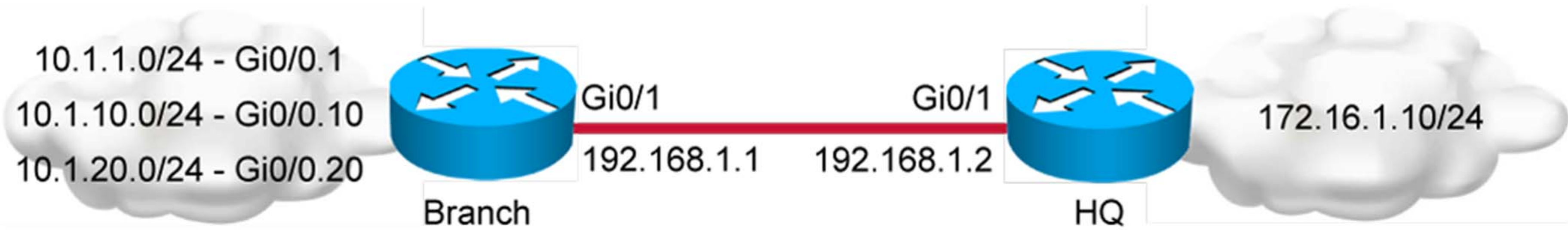
Configuring Single-Area OSPF


```
Branch(config)#router ospf 1
Branch(config-router)#network 10.0.0.0 0.255.255.255 area 0
```

```
Branch(config)#interface GigabitEthernet 0/1
Branch(config-if)#ip ospf 1 area 0
```

- Configures OSPF on the Branch router

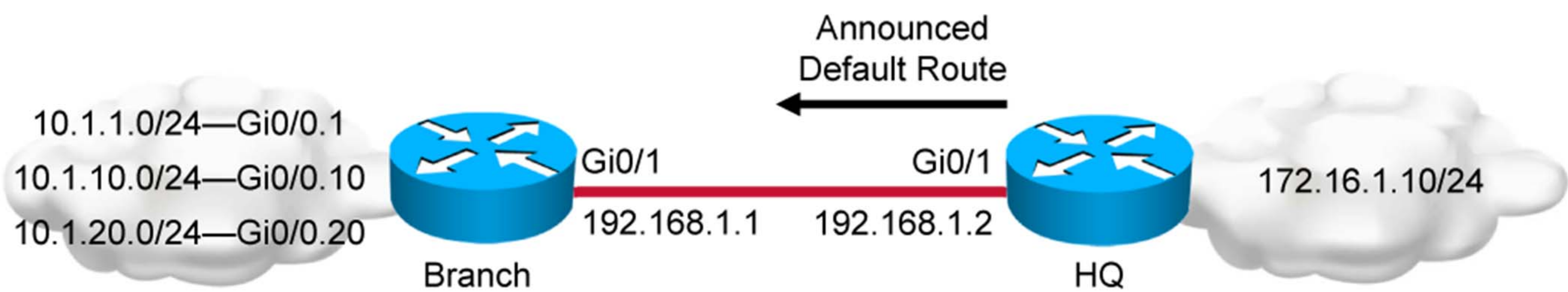
Configuring Single-Area OSPF (Cont.)




```
Branch(config)#router ospf 1
Branch(config-router)#passive-interface GigabitEthernet 0/0.1
```

- Configures the passive interface on GigabitEthernet 0/0.1 on the Branch router.

Configuring Single-Area OSPF (Cont.)



- The HQ router announces the default route through OSPF.

Verifying OSPF Configuration

```
Branch#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.255.255.255 area 0
  Routing on Interfaces Configured Explicitly (Area 0):
    GigabitEthernet0/1
  Passive Interface(s):
    GigabitEthernet0/0.1
  Routing Information Sources:
    Gateway         Distance      Last Update
    1.1.1.1              110      00:50:43
  Distance: (default is 110)
```

- Verifies that OSPF on the Branch router is routing for all networks that it needs to

Verifying OSPF Configuration (Cont.)

```
Branch#show ip ospf interface brief
Interface      PID    Area              IP Address/Mask     Cost   State Nbrs F/C
Gi0/0.1        1      0                 10.1.1.1/24         1      DR    0/0
Gi0/1          1      0                 192.168.1.1/24      1      BDR   1/1
Gi0/0.20       1      0                 10.1.20.1/24        1      DR    0/0
Gi0/0.10       1      0                 10.1.10.1/24        1      DR    0/0
```

- Shows which interfaces are enabled for the OSPF routing process

Verifying OSPF Configuration (Cont.)

```
Branch#show ip ospf neighbor

Neighbor ID   Pri   State       Dead Time    Address        Interface
1.1.1.1         1   FULL/DR     00:00:36     192.168.1.2    GigabitEthernet0/1
```

- Shows OSPF neighbors

Verifying OSPF Configuration (Cont.)

```
Branch# 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
<output omitted>
Gateway of last resort is 192.168.1.2 to network 0.0.0.0
O*E2  0.0.0.0/0 [110/1] via 192.168.1.2, 00:02:45, GigabitEthernet0/1
      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.1.1.0/24 is directly connected, GigabitEthernet0/0.1
L        10.1.1.1/32 is directly connected, GigabitEthernet0/0.1
C        10.1.10.0/24 is directly connected, GigabitEthernet0/0.10
L        10.1.10.1/32 is directly connected, GigabitEthernet0/0.10
C        10.1.20.0/24 is directly connected, GigabitEthernet0/0.20
L        10.1.20.1/32 is directly connected, GigabitEthernet0/0.20
      172.16.0.0/32 is subnetted, 1 subnets
O        172.16.1.100 [110/2] via 192.168.1.2, 00:56:58, GigabitEthernet0/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/1
L        192.168.1.1/32 is directly connected, GigabitEthernet0/1
```

- The routing table displays OSPF routes.

Summary

- OSPF is a link-state routing protocol that uses an area hierarchy.
- OSPF exchanges hello packets to establish neighbor adjacencies between routers.
- The SPF algorithm uses a cost metric to determine the best path. Lower cost indicates a better path.
- Configuration of basic OSPF requires two steps:
  - Enable the OSPF routing process.
  - Identify the networks to advertise.
- The **show ip ospf neighbor** command displays OSPF neighbor information on a per-interface basis.

Module Summary

- VLANs are independent LAN networks that address segmentation, security, and organizational flexibility.
- Inter-VLAN communication cannot occur without a Layer 3 device (a Layer 3 switch or router).
- The DHCP server provides dynamic IP address assignments to end hosts, reducing errors and the time that is needed to administer address assignment.
- A WAN is a collection of LANs, and routers play a central role in transmitting data through these networks.
- Routing protocols are a set of processes, algorithms, and messages that are used to exchange routing information.
- Configuration of basic OSPF requires two steps:
  - Enable the OSPF routing process.
  - Identify the networks to advertise.