CHAPTER 1

Introduction to Scaling Networks

As a business grows, so does its networking requirements. To keep pace with a business's expansion and new emerging technologies, a network must be designed to scale. A network that scales well is not only one that can handle growing traffic demands, but also one designed with the inevitable need to expand. This short chapter sets the stage for the rest of the course. This chapter covers the hierarchical network design model, the Cisco Enterprise Architecture modules, and appropriate device selections that you can use to systematically design a highly functional network.

Implementing a Network Design

An enterprise network must be designed to support the exchange of various types of network traffic, including data files, email, IP telephony, and video applications for multiple business units.

Hierarchical Network Design

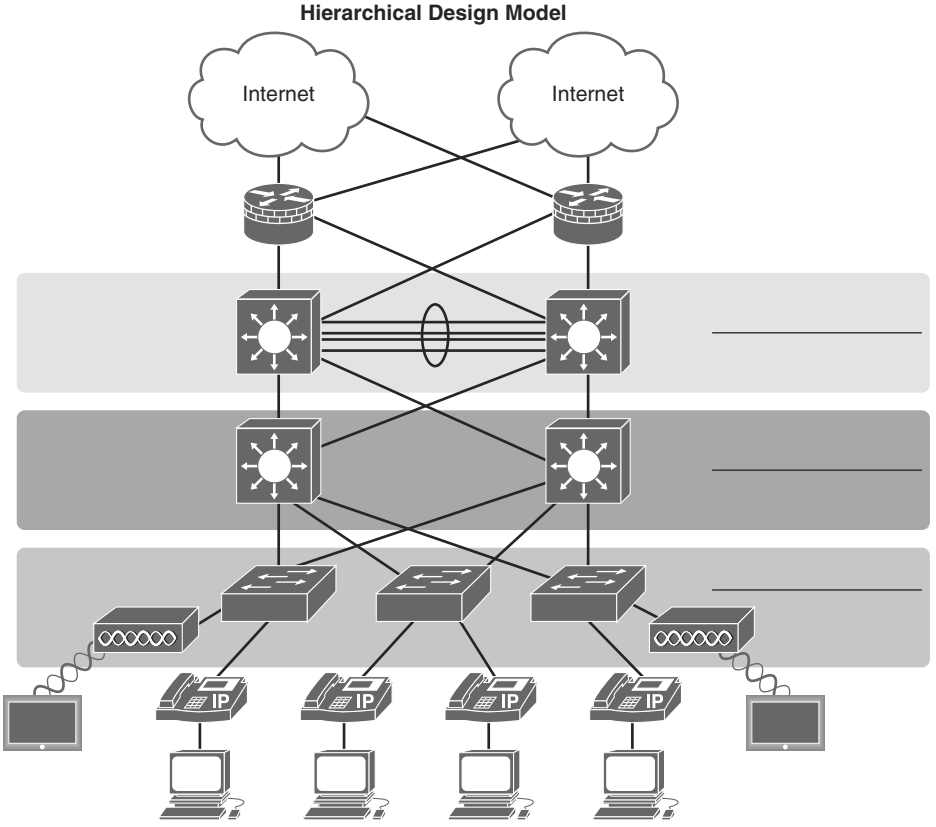
Users expect enterprise networks to be up _____ percent of the time. To provide this kind of reliability, enterprise class equipment uses _____ power supplies and has failover capabilities.

Describe what failover capability means for enterprise class equipment.

Why should a network be organized so that traffic stays local and is not propagated unnecessarily on to other portions of the network?

Designing a network using the three-layer hierarchical design model helps optimize the network. In Figure 1-1, label the three layers of the hierarchical design model.

Figure 1-1 Hierarchical Design Model



Briefly describe each layer of the hierarchical design model.

The Cisco Enterprise Architecture divides the network into functional components while still maintaining the core, distribution, and access layers. The primary Cisco Enterprise Architecture modules include Enterprise Campus, Enterprise Edge, Service Provider Edge, and Remote.

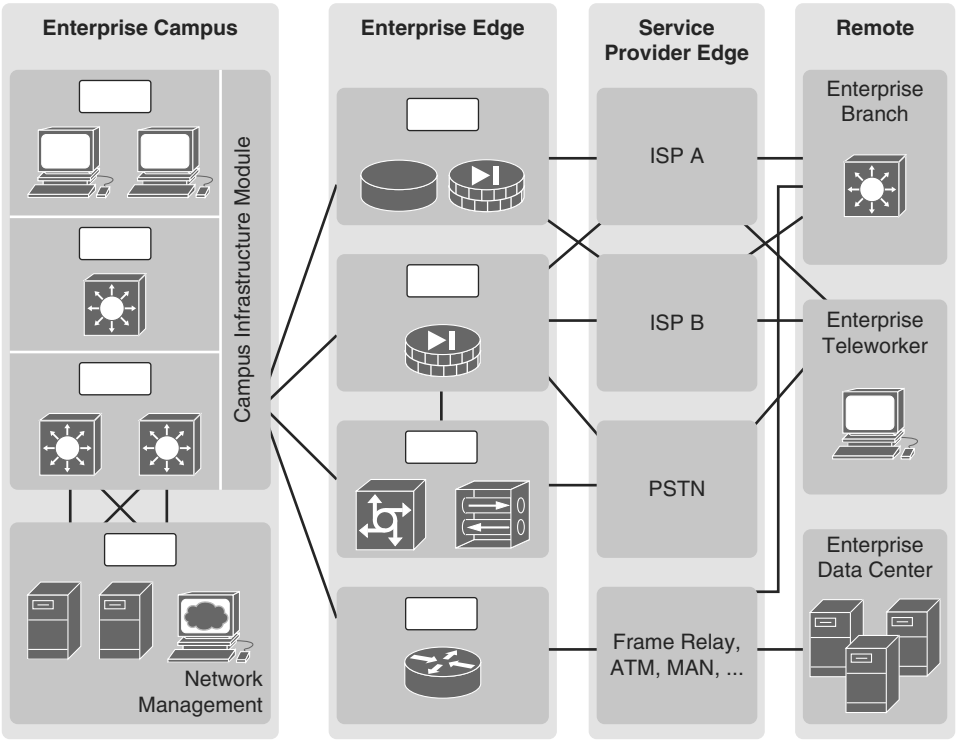
A well-designed network not only controls traffic but also limits the size of failure domains. Briefly describe a failure domain.

Use the list of modules to label the parts of the Cisco Enterprise Architecture in Figure 1-2.

Modules

1 Campus Core
2 Remote Access & VPN
3 Building Distribution
4 Internet Connectivity
5 Building Access
6 Server Farm & Data Center
7 WAN Site-to-Site VPN
8 E-Commerce

Figure 1-2 Cisco Enterprise Architecture



Identify Scalability Terminology

Match the definition on the left with the term on the right. This is a one-to-one matching exercise.

Definition

____ Isolates routing updates and minimizes the size of routing tables

____ Cisco proprietary distance vector routing protocol

____ Allows for redundant paths by eliminating switching loops

____ Technique for aggregating multiple links between equipment to increase bandwidth

____ Minimizes the possibility of a single point of failure

____ Supports new features and devices without requiring major equipment upgrades

____ Link-state routing protocol with a two-layer hierarchical design

____ Increases flexibility, reduces costs, and provides mobility to users

Terms

a. Modular equipment

b. OSPF

c. EIGRP

d. Wireless LANs

e. Redundancy

f. Spanning Tree Protocol

g. Scalable Routing Protocol

h. EtherChannel

Selecting Network Devices

When designing a network, it is important to select the proper hardware to meet current network requirements and to allow for network growth. Within an enterprise network, both switches and routers play a critical role in network communication.

Selecting Switch Hardware

Match the business consideration on the left with the switch feature on the right. This is a one-to-one matching exercise.

Business Consideration

____ Should provide continuous access to the network

____ Daisy-chain switches with high-bandwidth throughput

____ Refers to a switch's ability to support the appropriate number of devices on the network

____ Ability to adjust to growth of network users

____ How fast the interfaces will process network data

____ Important consideration in a network where there may be congested ports to servers or other areas of the network

____ Provides electrical current to other device and support redundant power supplies

____ Switches with preset features or options

____ Depends on the number and speed of the interfaces, supported features, and expansion capability

____ Switches with insertable switching line/port cards

Switch Feature

a. Reliability
b. Modular
c. Power
d. Stackable
e. Frame buffers
f. Cost
g. Fixed configuration
h. Scalability
i. Port speed
j. Port density

Packet Tracer ☐ Activity

Packet Tracer - Comparing 2960 and 3560 Switches (SN 1.2.1.7/SwN 1.1.2.5)

Selecting Router Hardware

In Table 1-1, select the router category that applies to each description.

Table 1-1 Identify Router Category Features

Router Description	Branch Routers	Network Edge Routers	Service Provider Routers
Fast performance with high security for data centers, campus, and branch networks			
Simple network configuration and management for LANs and WANs			
Optimizes services on a single platform			
End-to-end delivery of subscriber services			
Deliver next-generation Internet experiences across all devices and locations			
High capacity and scalability with hierarchical quality of service			
Maximizes local services and ensures 24/7/365 uptime			
Unites campus, data center, and branch networks			

Managing Devices

A basic router or switch configuration includes the hostname for identification, passwords for security, and assignment of IP addresses to interfaces for connectivity. A router configuration also includes basic routing.

In addition to configuration commands, router and switch verification commands are used to verify the operational status of the router or switch and related network functionality. Use the address scheme in Table 1-2 in the following exercises that review the most common router and switch configuration and verification commands.

Table 1-2 Router and Switch Addressing Table

Device	Interface	IPv4 Address	Subnet Mask	Default Gateway
R1	G0/0	172.16.1.1	255.255.255.0	N/A
	S0/0/0	172.16.3.1	255.255.255.252	N/A
	S0/0/1	192.168.10.5	255.255.255.252	N/A
S1	VLAN 1	192.168.1.5	255.255.255.0	192.168.1.1

Basic Router Configuration Review

Using Table 1-2 and the following requirements, record the commands, including the router prompt, to implement a basic router configuration:

- Hostname is R1.
- Console and Telnet line's password is cisco.
- Privileged EXEC password is class.
- Banner message-of-the-day.
- Interface addressing.
- OSPF routing, including an appropriate router ID.
- Save the configuration.

```
Router(config)#
```

Basic Router Verification Review

In Table 1-3, record the verification command that will generate the described output.

Table 1-3 Router Verification Commands

Command	Command Output
	Displays the routing table for known networks, including administrative distance, metric, and outbound interface
	Displays information about routing protocols, including process ID, router ID, and neighbors
	Displays information about directly connected Cisco devices
	Displays all interfaces in an abbreviated format, including IP address and status
	Displays information about neighbors, including router ID, state, IP address, and local interface that learned of neighbor
	Displays one or all interfaces, including status, bandwidth, and duplex type

Basic Switch Configuration Review

Using Table 1-2 and the following requirements, record the commands, including the switch prompt, to implement a basic switch configuration:

- Hostname is S1.
- Console and Telnet line's password is cisco.
- Privileged EXEC password is class.
- Banner message-of-the-day.
- VLAN 1 interface addressing.
- Save the configuration.

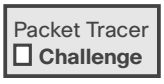
```
Switch(config)# _____
```

Basic Switch Verification Review

In Table 1-4, record the verification command that will generate the described output.

Table 1-4 Router Verification Commands

Command	Command Output
	Displays information about directly connected Cisco devices
	Displays all secure MAC addresses
	Displays a table of learned MAC addresses, including the port number and VLAN assigned to the port
	Displays one or all interfaces, including status, bandwidth, and duplex type
	Displays information about maximum MAC addresses allowed, current counts, security violation count, and action to be taken



Packet Tracer - Skills Integration Challenge (SN 1.3.1.2)

CHAPTER 2

LAN Redundancy

Computer networks are inextricably linked to productivity in today's small and medium-sized businesses. Consequently, IT administrators have to implement redundancy in their hierarchical networks. When a switch connection is lost, another link needs to quickly take its place without introducing any traffic loops. This chapter investigates how Spanning Tree Protocol (STP) logically blocks physical loops in the network and how STP has evolved into a robust protocol that rapidly calculates which ports should be blocked in a VLAN-based network. In addition, the chapter briefly explores how Layer 3 redundancy is implemented through First Hop Redundancy Protocols (FHRPs).

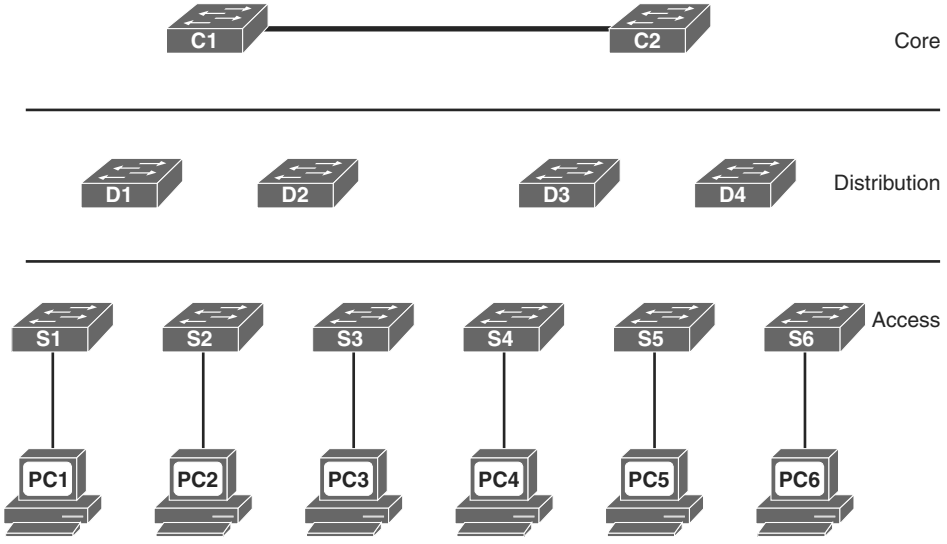
Spanning-Tree Concepts

Redundancy increases the availability of a network topology by protecting the network from a single point of failure, such as a failed network cable or switch. STP was developed to address the issue of loops in a redundant Layer 2 design.

Draw a Redundant Topology

In Figure 2-1, draw redundant links between the access, distribution, and core switches. Each access switch should have two links to the distribution layer with each link connecting to a different distribution layer switch. Each distribution layer switch should have two links to the core layer with each link connecting to a different core layer switch.

Figure 2-1 Redundant Topology



Purpose of Spanning Tree

STP prevents specific types of issues in a redundant topology like the one in Figure 2-1. Specifically, three potential issues would occur if STP was not implemented. Describe each of the following issues:

- **MAC database instability:**

- **Broadcast storms:**

- **Multiple frame transmission:**

You should be prepared to use a topology like Figure 2-1 to explain exactly how these three issues would occur if STP was not implemented.

Packet Tracer ☐ Activity

Packet Tracer - Examining a Redundant Design (SN 2.1.1.5/SwN 4.1.1.5)

Spanning-Tree Operation

Because _____ (RSTP), which is documented in IEEE _____ -2004, supersedes the original STP documented in IEEE _____ -1998, all references to STP assume RSTP unless otherwise indicated.

STP ensures that there is only one logical path between all destinations on the network by intentionally blocking redundant paths that could cause a _____ . A switch port is considered _____ when network traffic is prevented from entering or leaving that port.

STP uses the _____ (STA) to determine which switch ports on a network need to be _____ to prevent _____ from occurring. The STA designates a single switch as the _____ bridge and uses it as the reference point for all subsequent calculations. Switches participating in STP determine which switch has the lowest _____ (BID) on the network. This switch automatically becomes the _____ bridge.

A _____ (BPDU) is a frame containing STP information exchanged by switches running STP. Each BPDU contains a BID that identifies the switch that sent the BPDU. The _____ BID value determines which switch is root.

After the root bridge has been determined, the STA calculates the shortest path to the root bridge. If there is more than one path to choose from, STA chooses the path with the lowest _____.

When the STA has determined the "best" paths emanating from the root bridge, it configures the switch ports into distinct port roles. The port roles describe their relation in the network to the root bridge and whether they are allowed to forward traffic:

- _____ **ports:** Switch ports closest to the root bridge
- _____ **ports:** Nonroot ports that are still permitted to forward traffic on the network
- _____ **ports:** Ports in a blocking state to prevent loops
- _____ **port:** Ports that are administratively shut down

After a switch boots, it sends BPDU frames containing the switch BID and the root ID every _ seconds. Initially, each switch identifies itself as the ____ bridge after boot.

How would a switch determine that another switch is now the root bridge?

How does the STA determine path cost?

Record the default port costs for various link speeds in Table 2-1.

Table 2-1 Port Costs

Link Speed	Cost (Revised IEEE Specification)	Cost (Previous IEEE Specification)
10 Gbps		
1 Gbps		
100 Mbps		
10 Mbps		

Although switch ports have a default port cost associated with them, the port cost is configurable.

To configure the port cost of an interface, enter the _____ command in interface configuration mode. The range value can be between _____ and _____ .

Record the commands, including the switch prompt, to configure the port cost for F0/1 as 15:

To verify the port and path cost to the root bridge, enter the _____ privileged EXEC mode command, as shown here:

```
S2# _________________


VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     c025.5cd7.ef00
              Cost        15
              Port        1 (FastEthernet0/1)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     c07b.bcc4.a980
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  15  sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Fa0/1               Root FWD 15        128.1    P2p
Fa0/2               Altn BLK 19        128.2    P2p
Fa0/3               Desg LIS 19        128.3    P2p
Fa0/4               Desg LIS 19        128.4    P2p
Fa0/6               Desg FWD 19        128.6    P2p<output omitted>
```

The BID field of a BPDU frame contains three separate fields: _____ , _____ , and _____ .

Of these three fields, the _____ is a customizable value that you can use to influence which switch becomes the root bridge. The default value for this field is _____ .

Cisco enhanced its implementation of STP to include support for the extended system ID field, which contains the ID of the _____ with which the BPDU is associated.

Because using the extended system ID changes the number of bits available for the bridge priority, the customizable values can only be multiples of _____ .

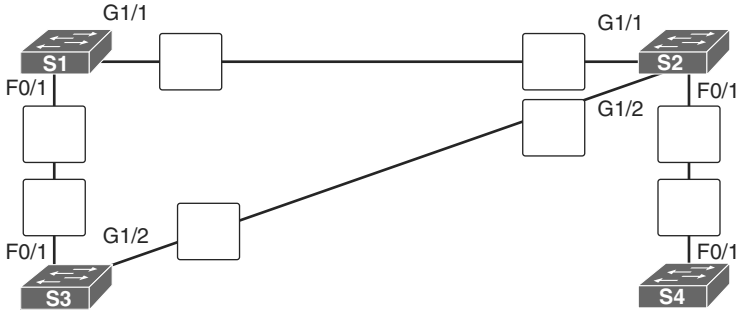
When two switches are configured with the same priority and have the same extended system ID, the switch with the lowest _____ has the lower BID.

Identify the 802.1D Port Roles

The topologies in the next three figures do not necessarily represent an appropriate network design. However, they provide good exercise topologies for you to practice determining the STP port roles. In Figures 2-2 through 2-4, use the priority values and MAC addresses to determine the root bridge. Then label the ports with one of the following:

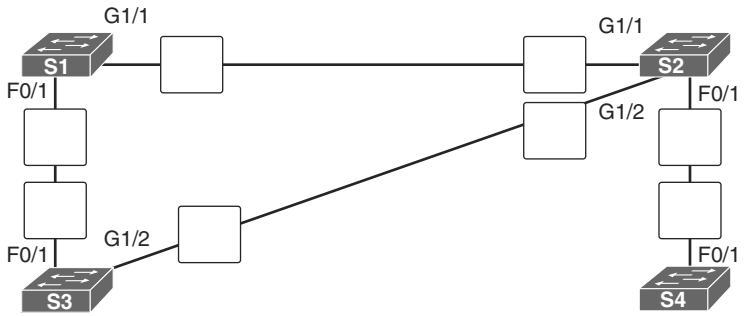
- RP: Root Port
- DP: Designated Port
- AP: Alternate Port

Figure 2-2 802.1D Port Roles - Scenario 1



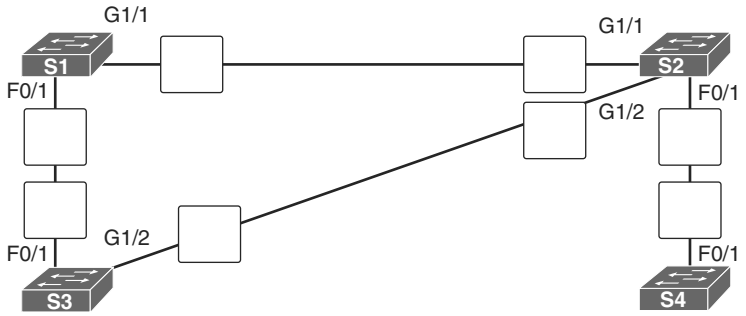
Device	Priority	MAC Address
S1	32769	000a:0001:1111
S2	24577	000a:0002:2222
S3	32769	000a:0003:3333
S4	32769	000a:0004:4444

Figure 2-3 802.1D Port Roles - Scenario 2



Device	Priority	MAC Address
S1	24577	000a:0001:1111
S2	32769	000a:0002:2222
S3	32769	000a:0003:3333
S4	32769	000a:0004:4444

Figure 2-4 802.1D Port Roles - Scenario 3



Device	Priority	MAC Address
S1	32769	000a:0001:1111
S2	32769	000a:0002:2222
S3	24577	000a:0003:3333
S4	32769	000a:0004:4444

Lab – Building a Switched Network with Redundant Links (SN 2.1.2.10/SwN 4.1.2.10)

Varieties of Spanning Tree Protocols

STP has been improved multiple times since its introduction in the original IEEE 802.1D specification. A network administrator should know which type to implement based on the equipment and topology needs.

Comparing the STP Varieties

Identify each of the STP varieties described in the following list:

- _____ : This is an IEEE that maps multiple VLANs into the same spanning tree instance.
- _____ : This is an evolution of STP that provides faster convergence than STP.

- _____ : This is an updated version of the STP standard, incorporating IEEE 802.1w.
- _____ : This is a Cisco enhancement of STP that provides a separate 802.1D spanning tree instance for each VLAN configured in the network.
- _____ : This is a Cisco enhancement that provides a separate instance of 802.1w per VLAN.
- _____ : This is the original IEEE 802.1D version (802.1D-1998 and earlier) that provides a loop-free topology in a network with redundant links.

Complete the cells in Table 2-2 to identify each the characteristics of each STP variety.

Table 2-2 STP Characteristics - Exercise 1

Protocol	Standard	Resources Needed	Convergence	Tree Calculation
STP		Low		
	Cisco			
	802.1w			
Rapid PVST+				
	802.1s, Cisco	Medium or high		

In Table 2-3, indicate which varieties of STP are best described by the characteristic. Some characteristics apply to more than one STP variety.

Table 2-3 STP Characteristics - Exercise 2

Characteristic	STP	PVST+	RSTP	Rapid PVST+	MSTP	MST
A Cisco implementation of 802.1s that provides up to 16 instances of RSTP.						
Cisco enhancement of RSTP.						
The default STP mode for Cisco Catalyst switches.						
Has the highest CPU and memory requirements.						
Can lead to suboptimal traffic flows.						
Cisco proprietary versions of STP.						
Cisco enhancement of STP. Provides a separate 802.1D spanning-tree instance for each VLAN.						
There is only 1 root bridge and 1 tree.						
Uses 1 IEEE 802.1D spanning-tree instance for the entire bridged network, regardless of the number of VLANs.						
Supports PortFast, BPDU guard, BPDU filter, root guard, and loop guard.						
An evolution of STP that provides faster STP convergence.						

Characteristic	STP	PVST+	RSTP	Rapid PVST+	MSTP	MST
Maps multiple VLANs that have the same traffic flow requirements into the same spanning-tree instance.						
First version of STP to address convergence issues, but still provided only one STP instance.						

PVST+ Operation

After a switch boots, the spanning tree is immediately determined as ports transition through five possible states and three BPDU timers on the way to convergence. Briefly describe each state:

- **Blocking:**
- **Listening:**
- **Learning:**
- **Forwarding:**
- **Disabled:**

Once stable, every active port in the switched network is either in the _____ state or the _____ state.

List and briefly describe the four steps PVST+ performs for each VLAN to provide a loop-free logical topology.

In Table 2-4, answer the "Operation Allowed" question with "yes" or "no" for each port state.

Table 2-4 Operations Allowed at Each Port State

Operation Allowed	Port State				
	Blocking	Listening	Learning	Forwarding	Disabled
Can receive and process BPDUs					
Can forward data frames received on interface					
Can forward data frames switched from another interface					
Can learn MAC addresses					

Rapid PVST+ Operation

RSTP (IEEE _____) is an evolution of the original _____ standard and is incorporated into the IEEE _____ -2004 standard. Rapid PVST+ is the Cisco implementation of RSTP on a per-VLAN basis. What is the primary difference between Rapid PVST+ and RSTP?

Briefly describe the RSTP concept that corresponds to the PVST+ PortFast feature.

What command implements Cisco's version of an edge port?

In Table 2-5, indicate whether the characteristic describes PVST+, Rapid PVST+, or both.

Table 2-5 Comparing PVST+ and Rapid PVST+

Characteristic	PVST+	Rapid PVST+	Both
Cisco proprietary protocol.			
Port roles: root, designated, alternate, edge, backup.			
CPU processing and trunk bandwidth usage is greater than with STP.			
Ports can transition to forwarding state without relying on a timer.			
The root bridge is determined by the lowest BID + VLAN ID + MAC.			
Runs a separate IEEE 802.1D STP instance for each VLAN.			
Possible to have load sharing with some VLANS forwarding on each trunk.			
Sends a BPDU "hello message" every 2 seconds.			

Spanning-Tree Configuration

It is crucial to understand the impact of a default switch configuration on STP convergence and what configurations can be applied to adjust the default behavior.

PVST+ and Rapid PVST+ Configuration

Complete Table 2-6 to show the default spanning-tree configuration for a Cisco Catalyst 2960 series switch.

Table 2-6 Default Switch Configuration

Feature	Default Setting
Enable state	Enabled on VLAN 1
Spanning-tree mode	
Switch priority	
Spanning-tree port priority (configurable on a per-interface basis)	
Spanning-tree port cost (configurable on a per-interface basis)	1000 Mbps: 100 Mbps: 10 Mbps:
Spanning-tree VLAN port priority (configurable on a per-VLAN basis)	
Spanning-tree VLAN port cost (configurable on a per-VLAN basis)	1000 Mbps: 100 Mbps: 10 Mbps:
Spanning-tree timers	Hello time: seconds Forward-delay time: seconds Maximum-aging time: seconds Transmit hold count: BPDUs

Document the two different configuration commands that you can use to configure the bridge priority value so that the switch is root for VLAN 1. Use the value 4096 when necessary:

Record the command to verify that the local switch is now root:

```
S1# _____________________

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    24577
             Address     000A.0033.3333
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
```

```
  Bridge ID  Priority    24577  (priority 24576 sys-id-ext 1)
             Address     0019.aa9e.b000
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Desg FWD 4         128.1    Shr
Fa0/2            Desg FWD 4         128.2    Shr
```

Explain the purpose of the BPDU guard feature on Cisco switches.

What command interface configuration command enables BPDU guard?

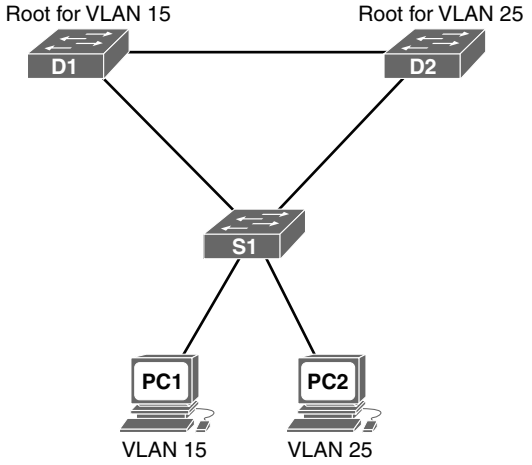
What global configuration command will configure all nontrunking ports as edge ports?

What global configuration command will configure BPDU guard on all PortFast-enabled ports?

The power of PVST+ is that it can load balance across redundant links. By default, the least-favored redundant link is not used. So, you must manually configure PVST+ to use the link.

Figure 2-5 represents a small section of Figure 2-1, showing only two distribution layer switches and one access layer switch. For this example, we have attached PC2 to S1. PC1 is assigned to VLAN 15, and PC2 is assigned to VLAN 25. D1 should be the primary root for VLAN 1 and VLAN 15 and the secondary root for VLAN 25. D2 should be the primary root for VLAN 25 and the secondary root for VLAN 15.

Figure 2-5 PVST+ Configuration Topology



Based on these requirements, document the commands to modify the default PVST+ operation on D1 and D2.

D1 commands

D2 commands

Document the commands to configure all nontrunking ports on S1 as edge ports with BPDU guard enabled.

Now, assume that you want to run rapid PVST+ on all three switches. What command is required?

Lab - Configuring Rapid PVST+, PortFast, and BPDU Guard (SN 2.3.2.3/SwN 4.3.2.3)

Packet Tracer - Configuring PVST+ (SN 2.3.1.5/SwN 4.3.1.5)

Packet Tracer - Configuring Rapid PVST+ (SN 2.3.2.2/SwN 4.3.2.2)

First Hop Redundancy Protocols

Up to this point, we've been reviewing STP and how to manipulate the election of root bridges and load balance across redundant links. In addition to Layer 1 and Layer 2 redundancy, a high-availability network might also implement Layer 3 redundancy by sharing the default gateway responsibility across multiple devices. Through the use of a virtual IP address, two Layer 3 devices can share the default gateway responsibility. The section reviews First Hop Redundancy Protocols (FHRPs) that provide Layer 3 redundancy.

Identify FHRP Terminology

Match the definition on the left with the terms on the right. This is a one-to-one matching exercise.

Definitions

____ The ability to dynamically recover from the failure of a device acting as the default gateway

____ Two or more routers sharing a single MAC and IP address

____ A device that is part of a virtual router group assigned to the role of default gateway

____ Provides the mechanism for determining which router should take the active role in forwarding traffic

____ A device that routes traffic destined to network segments beyond the source network segment

____ A device that is part of a virtual router group assigned the role of alternate default gateway

____ A Layer 3 address assigned to a protocol that shares the single address among multiple devices

____ The Layer 2 address returned by ARP for an FHRP gateway

Terms

a. Default gateway
b. First-hop redundancy
c. Forwarding router
d. Redundancy rrotocol
e. Standby router
f. Virtual IP address
g. Virtual MAC address
h. Virtual router

Identify the Type of FHRP

In Table 2-7, indicate whether the characteristic describes HSRP, VRRP, or GLBP.

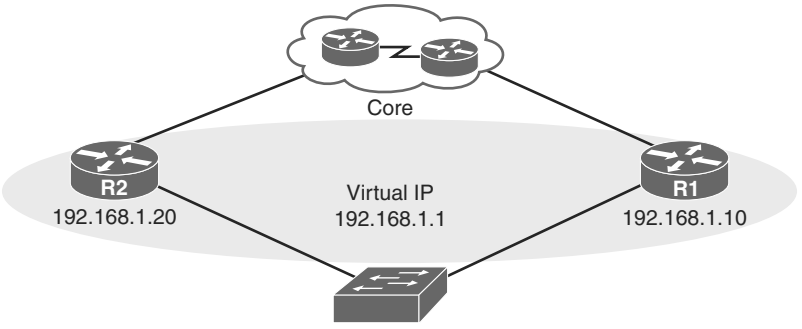
Table 2-7 FHRP Characteristics

FHRP Characteristic	HSRP	VRRP	GLBP
Used in a group of routers for selecting an active device and a standby device.			
A nonproprietary election protocol that allows several routers on a multi-access link to use the same virtual IPv4 address.			
Cisco-proprietary FHRP protocol designed to allow for transparent failover of a first-hop IPv4 devices.			
Cisco-proprietary FHRP protocol that protects data traffic from a failed router or circuit while also allowing load sharing between a group of redundant routers.			
One router is elected as the virtual router master, with the other routers acting as backups in case the virtual router master fails.			

HSRP and GLBP Configuration and Verification

Refer to the topology in Figure 2-6. R2 has been configured for HSRP group 20, priority 120, IP address 192.168.1.20, and virtual IP address 192.168.1.1.

Figure 2-6 HSRP and GLBP Configuration Topology



Example 2-1 shows the HSRP configuration for R2.

Example 2-1 R2 HSRP Configuration

```
R2# show run interface g0/1
<output omitted>
interface GigabitEthernet0/1
 ip address 192.168.1.20 255.255.255.0
 standby 20 ip 192.168.1.1
 standby 20 priority 120
<output omitted>
```

Using the information in Example 2-1, document the commands to configure R1 as the HSRP active router in group 20 using a priority of 210.

What command would generate the following output to verify the HSRP configuration?

```
R1#_____________________
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State   Active          Standby         Virtual IP
Gi0/1       20   210   Active  local           192.168.1.20    192.168.1.1
```

Now assume that all HSRP configurations have been removed. R2 has been configured for GLBP group 20, priority 120, IP address 192.168.1.20, and virtual IP address 192.168.1.1.

Example 2-2 shows the GLBP configuration for R2.

Example 2-2 R2 GLBP Configuration

```
R2# show run interface g0/1
<output omitted>
interface GigabitEthernet0/1
 ip address 192.168.1.20 255.255.255.0
 glbp 20 ip 192.168.1.1
 glbp 20 priority 120
<output omitted>
```

Using the information in Example 2-2, document the commands to configure R1 to be in GLBP group 20 using a priority of 210.

What command would generate the following output to verify the GLBP configuration?

```
R1#_____________________
GigabitEthernet0/0 - Group 20
  State is Active
    1 state change, last state change 00:03:05
  Virtual IP address is 192.168.1.1
```

```
Hello time 3 sec, hold time 10 sec
  Next hello sent in 1.792 secs
Redirect time 600 sec, forwarder timeout 14400 sec
Preemption disabled
Active is local
Standby is 192.168.1.20, priority 120 (expires in 9.024 sec)
Priority 210 (configured)
Weighting 100 (default 100), thresholds: lower 1, upper 100
Load balancing: round-robin
Group members:
  0006.f671.db58 (192.168.1.10) local
  0006.f671.eb38 (192.168.1.20)
There are 2 forwarders (1 active)
Forwarder 1
  State is Active
    1 state change, last state change 00:02:53
  MAC address is 0007.b400.0a01 (default)
  Owner ID is 0006.f671.db58
  Redirection enabled
  Preemption enabled, min delay 30 sec
  Active is local, weighting 100
Forwarder 2
  State is Listen
  MAC address is 0007.b400.0a02 (learnt)
  Owner ID is 0006.f671.eb38
  Redirection enabled, 599.040 sec remaining (maximum 600 sec)
  Time to live: 14399.040 sec (maximum 14400 sec)
  Preemption enabled, min delay 30 sec
  Active is 192.168.1.20 (primary), weighting 100 (expires in 9.312 sec)
```

Lab - Configuring HSRP and GLBP (SN 2.4.3.4/SwN 4.4.3.4)

CHAPTER 3

Link Aggregation

Link aggregation is the ability to create one logical link using multiple physical links between two devices. This allows load sharing among the physical links, rather than having a STP block one or more of the links.

Link Aggregation Concepts

One of the best ways to reduce the time it takes for STP convergence is to simply avoid STP. EtherChannel is a form of link aggregation used in switched networks.

EtherChannel Advantages

EtherChannel technology was originally developed by Cisco as a technique of grouping several Fast Ethernet or Gigabit Ethernet switch ports into one logical channel.

List at least three advantages to using EtherChannel:

-
-
-
-
-

EtherChannel Operation

You can configure EtherChannel as static or unconditional. However, there are also two protocols that can be used to configure the negotiation process: Port Aggregation Protocol (PAgP—Cisco proprietary) and Link Aggregation Control Protocol (LACP—IEEE 802.3ad).

These two protocols ensure that both sides of the link have compatible configurations—same speed, duplex setting, and VLAN information. The modes for each differ slightly.

For PAgP, briefly describe each of the following modes:

- **On:**
- **Desirable:**
- **Auto:**

For LACP, briefly describe each of the following modes:

- **On:**
- **Active:**
- **Passive:**

In Table 3-1, indicate the mode that is described.

Table 3-1 PAgP and LACP Modes

Mode	PAgP and/or LACP Mode Description
	Initiates LACP negotiations with other interfaces.
	Forces EtherChannel state without PAgP or LACP initiated negotiations.
	Places an interface in a passive, responding state. Does not initiate PAgP negotiations.
	Actively initiates PAgP negotiations with other interfaces.
	Places an interface in a passive, responding state. Does not initiate LACP negotiations.

The mode that is configured on each side of the EtherChannel link determines whether EtherChannel will be operational.

In Table 3-2, two switches are using PAgP. Indicate with "yes" or "no" whether EtherChannel is established.

Table 3-2 EtherChannel Negotiation Using PAgP

Switch 1 Mode	Switch 2 Mode	EtherChannel Established?
Auto	Auto	
Auto	Desirable	
On	Desirable	
On	Off	
Desirable	Desirable	

In Table 3-3, two switches are using LACP. Indicate with "yes" or "no" whether EtherChannel is established.

Table 3-3 EtherChannel Negotiation Using LACP

Switch 1 Mode	Switch 2 Mode	EtherChannel Established?
Passive	On	
Passive	Active	
On	On	
Passive	Passive	
On	Active	

Link Aggregation Configuration

EtherChannel configuration is rather straightforward once you decide on which protocol you will use. In fact, the easiest method is to just force both sides to be on.

Configuring EtherChannel

To configure EtherChannel, complete the following steps:

Step 1. Specify the interfaces that, participate in the EtherChannel group using the **interface range** *interface* command.

What are the requirements for each interface before they can form an EtherChannel?

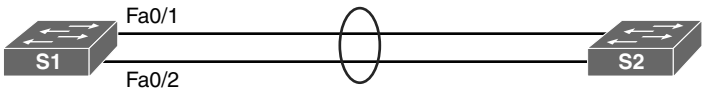
Step 2. Create the port channel interface with the **channel-group** *identifier* **mode** {**on** | **auto** | **desirable** | **active** | **passive**} command in interface range configuration mode. The keyword _____ forces the port to channel without PAgP or LACP. The keywords _____ and _____ enable PAgP. The keywords _____ and _____ enable LACP.

Step 3. The **channel-group** command automatically creates a port channel interface using the *identifier* as the number. Use the **interface port-channel** *identifier* command to configure channel-wide settings like trunking, native VLANs, or allowed VLANs.

As you can see from the configuration steps, the way you specify whether to use PAgP, LACP, or no negotiations is by configuring one keyword in the **channel-group** command.

So, with those steps in mind, consider Figure 3-1 in each of the following configuration scenarios.

Figure 3-1 EtherChannel Topology



EtherChannel Configuration Scenario 1

Record the commands, including the switch prompt, to configure the S1 Fa0/1 and Fa0/2 into an EtherChannel without negotiations. Then force the channel to trunking using native VLAN 99.

```
S1(config)#
```

EtherChannel Configuration Scenario 1

Record the commands, including the switch prompt, to configure the S1 Fa0/1 and Fa0/2 into an EtherChannel using PAgP. S1 should initiate the negotiations. The channel should trunk, allowing only VLANs 1, 10, and 20.

```
S1(config)#
```

EtherChannel Configuration Scenario 1

Record the commands, including the switch prompt, to configure the S1 Fa0/1 and Fa0/2 into an EtherChannel using LACP. S1 should not initiate the negotiations. The channel should trunk, allowing all VLANs.

```
S1(config)#
```

Lab - Configuring EtherChannel (SN 3.2.1.4/SwN 5.2.1.4)

Packet Tracer - Configuring EtherChannel (SN 3.2.1.3/SwN 5.2.1.3)

Verifying and Troubleshooting EtherChannel

Record the commands used to display the output in Example 3-1.

Example 3-1 EtherChannel Verification Commands

```
S1# _____________________________________________________________________
Port-channel1 is up, line protocol is up (connected)
  Hardware is EtherChannel, address is 0cd9.96e8.8a01 (bia 0cd9.96e8.8a01)
  MTU 1500 bytes, BW 200000 Kbit/sec, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>

S1# _____________________________________________________________________
Flags:  D - down        P - bundled in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator

        M - not in use, minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 1
Number of aggregators:           1
```

```
Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------------------------------
1      Po1(SU)         LACP      Fa0/1(P)    Fa0/2(P)

S1# ____________________________________________________________________________
               Channel-group listing:
               ----------------------

Group: 1
----------
               Port-channels in the group:
               ---------------------------

Port-channel: Po1    (Primary Aggregator)

------------

Age of the Port-channel   = 0d:00h:25m:17s
Logical slot/port   = 2/1          Number of ports = 2
HotStandBy port = null
Port state          = Port-channel Ag-Inuse
Protocol            =   LACP
Port security       = Disabled

Ports in the Port-channel:

Index   Load   Port     EC state        No of bits
------+------+------+-----------------+-----------
  0     00     Fa0/1    Active             0
  0     00     Fa0/2    Active             0

Time since last port bundled:    0d:00h:05m:41s    Fa0/2
Time since last port Un-bundled: 0d:00h:05m:48s    Fa0/2

S1# ____________________________________________________________________________
Port state    = Up Mstr Assoc In-Bndl
Channel group = 1           Mode = Active          Gcchange = -
Port-channel  = Po1         GC   =   -             Pseudo port-channel = Po1
Port index    = 0           Load = 0x00            Protocol =   LACP

Flags:  S - Device is sending Slow LACPDUs   F - Device is sending fast LACPDUs.
        A - Device is in active mode.        P - Device is in passive mode.
```

```
Local information:
                            LACP port     Admin     Oper    Port         Port
Port      Flags   State     Priority      Key       Key     Number       State
Fa0/1     SA      bndl      32768         0x1       0x1     0x102        0x3D

Partner's information:

                  LACP port                        Admin  Oper   Port    Port
Port      Flags   Priority  Dev ID          Age    key    Key    Number  State
Fa0/1     SA      32768     0cd9.96d2.4000   4s    0x0    0x1    0x102   0x3D

Age of the port in the current state: 0d:00h:24m:59s
S1#
```

When troubleshooting an EtherChannel issue, keep in mind the configuration restrictions for interfaces that participate in the channel. List at least four restrictions.

-
-
-
-
-

Refer to the output for S1 and S2 in Example 3-2. Record the command that generated the output.

Example 3-2 Troubleshooting an EtherChannel Issue

```
S1# _____________________________________________________________________
Flags:  D - down        P - bundled in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        M - not in use, minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port
Number of channel-groups in use: 1
Number of aggregators:           1
Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------------------------------
1      Po1(SD)           -        Fa0/1(D)    Fa0/2(D)
S1# show run | begin interface Port-channel
```

```
interface Port-channel1
 switchport mode trunk
!
interface FastEthernet0/1
 switchport mode trunk
 channel-group 1 mode auto
!
interface FastEthernet0/2
 switchport mode trunk
 channel-group 1 mode auto
!
<output omitted>
S 1#
```

```
S2# show run | begin interface Port-channel
interface Port-channel1
 switchport mode trunk
!
interface FastEthernet0/1
 switchport mode trunk
 channel-group 1 mode auto
!
interface FastEthernet0/2
 switchport mode trunk
 channel-group 1 mode auto
!
<output omitted>
S2#
```

Explain why the EtherChannel between S1 and S2 is down.

EtherChannel and spanning tree must interoperate. For this reason, the order in which EtherChannel-related commands are entered is important. To correct this issue, you must first remove the port channel. Otherwise, spanning-tree errors cause the associated ports to go into blocking or errdisabled state. With that in mind, what would you suggest to correct the issue shown in Example 3-2 if the requirement is to use PAgP? What commands would be required?

Lab - Troubleshooting EtherChannel (SN 3.2.2.4/SwN 5.2.2.4)

Packet Tracer - Troubleshooting EtherChannel (SN 3.2.2.3/SwN 5.2.2.3)

Packet Tracer - Skills Integration Challenge (SN 3.3.1.2/SwN 5.3.1.2)