Top-Down Network Design

Chapter Seven

Selecting Switching and Routing Protocols

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Switching

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Objectives

- MAC address table
- Describe the features of redundant switch and bridge topologies
- Explain the problems associated with broadcast storms, multiple frame transmissions, and MAC address table instability
- Describe loop avoidance and explain how it can solve redundant switch topology issues
- Describe the purpose and operation of the STP
- Explain how to implement STP to solve the problems associated with redundant switched or bridged topologies

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Transparent Bridging (Switching) Tasks

- Forward frames transparently
- Learn which port to use for each MAC address
- Flood frames when the destination unicast address hasn't been learned yet
- Filter frames from going out ports that don't include the destination address
- Flood broadcasts and multicasts

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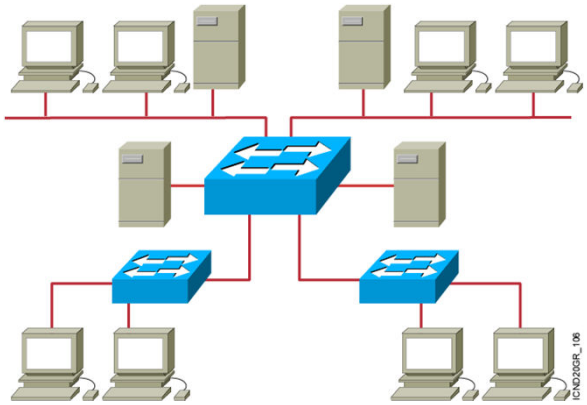
Ethernet Switches and Bridges



- Address learning
- Forward/filter decision
- Loop avoidance

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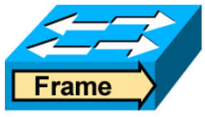
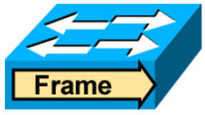
Transmitting Frames

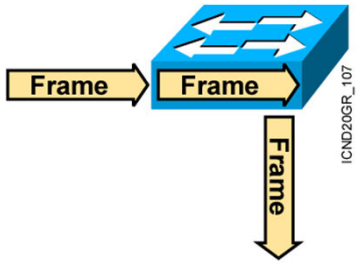
Cut-Through
Switch checks destination address and immediately begins forwarding frame.



Fragment-Free
Switch checks the first 64 bytes, then immediately begins forwarding frame.



Store and Forward
Complete frame is received and checked before forwarding.



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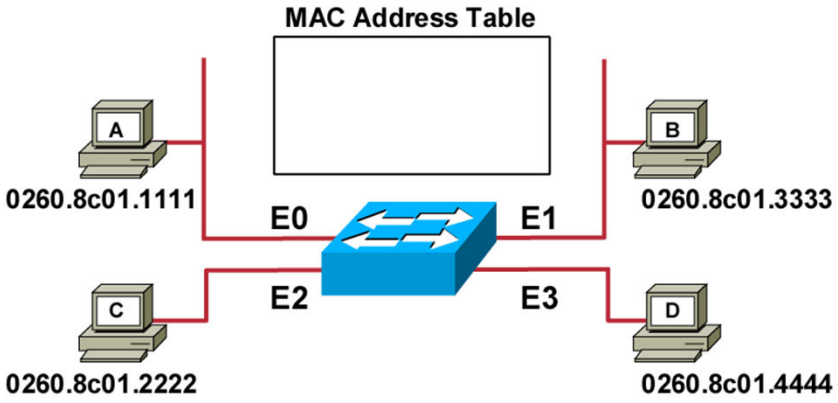
MAC Address Table



Initial MAC address table is empty.

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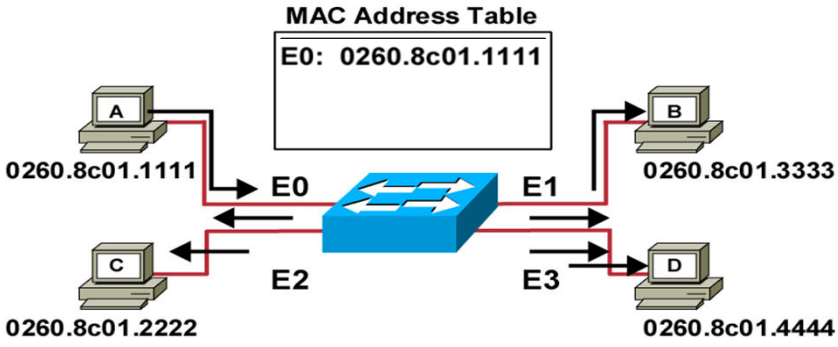
Learning Addresses



- Station A sends a frame to station C.
- Switch caches the MAC address of station A to port E0 by learning the source address of data frames.
- The frame from station A to station C is flooded out to all ports except port E0 (unknown unicasts are flooded).

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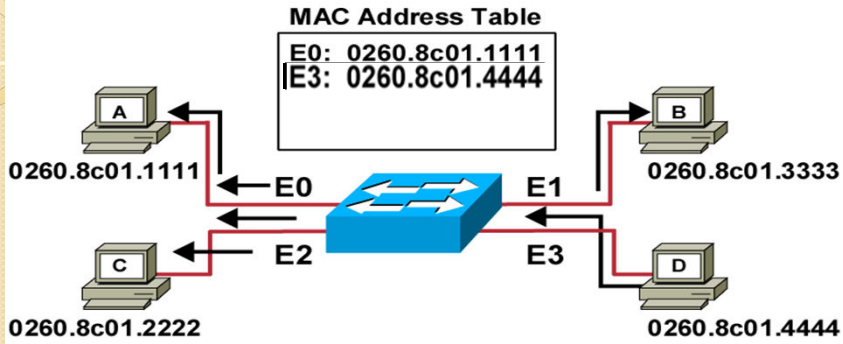
Learning Addresses (Cont.)



- Station D sends a frame to station C.
- Switch caches the MAC address of station D to port E3 by learning the source address of data frames.
- The frame from station D to station C is flooded out to all ports except port E3 (unknown unicasts are flooded).

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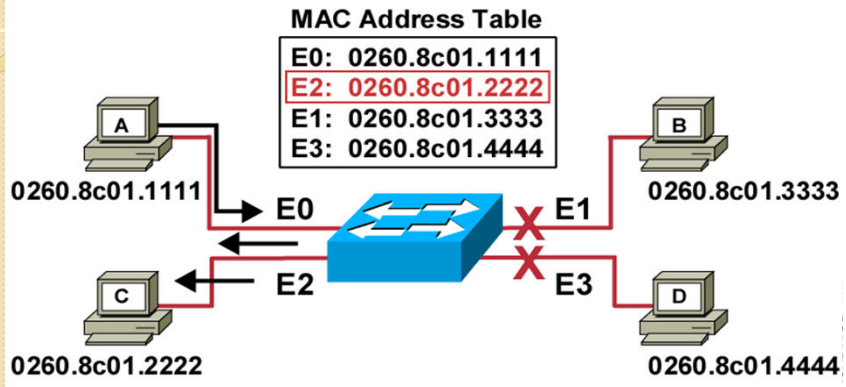
Filtering Frames



Station A sends a frame to station C.

Destination is known; frame is not flooded.

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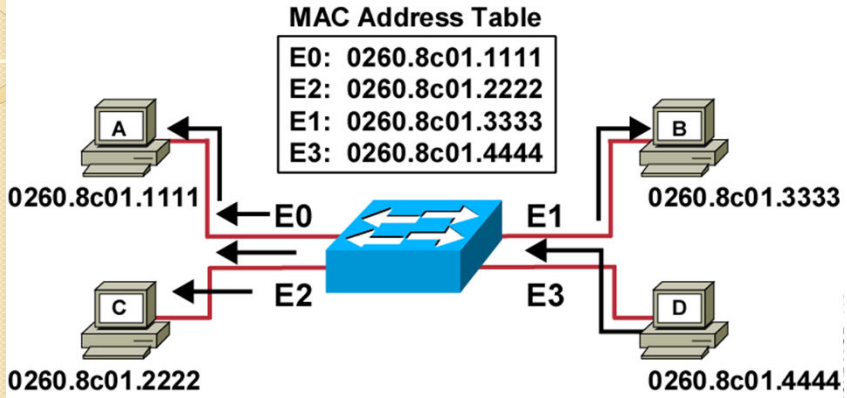
Broadcast and Multicast Frames



- Station D sends a broadcast or multicast frame.
- Broadcast and multicast frames are flooded to all ports other than the originating port.

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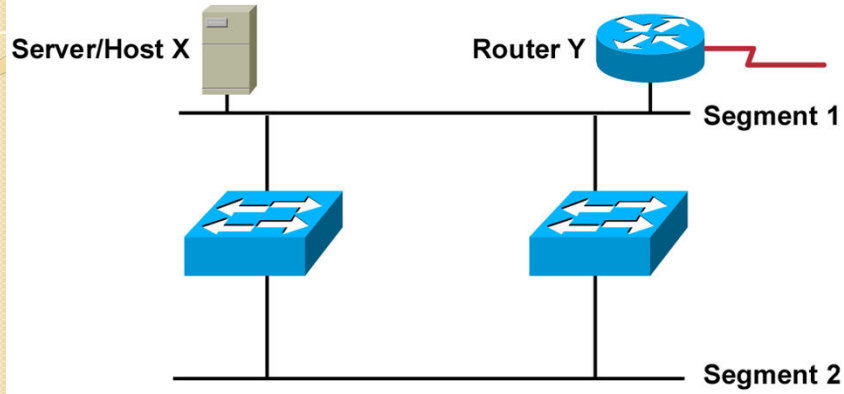
Redundant Topology



- Redundant topology eliminates single points of failure.
- Redundant topology causes broadcast storms, multiple frame copies, and MAC address table instability problems.

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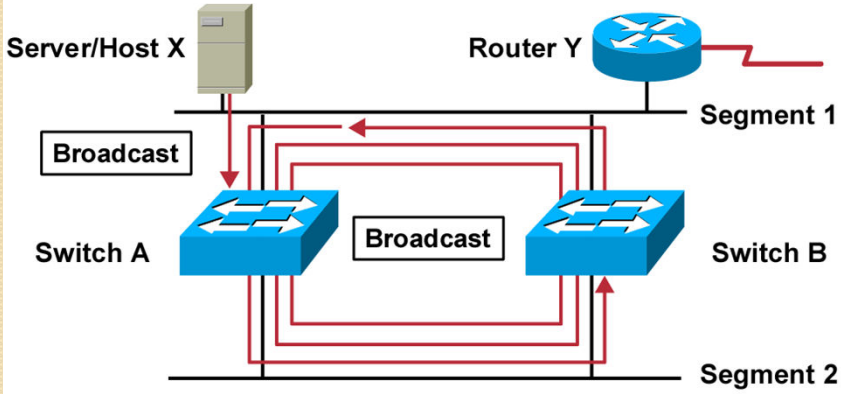
Broadcast Storms



- Host X sends a broadcast (such as ARP frame).
- Switches continue to propagate broadcast traffic endlessly.
- Switches flood broadcast frames to all ports except the port on which the frame was received

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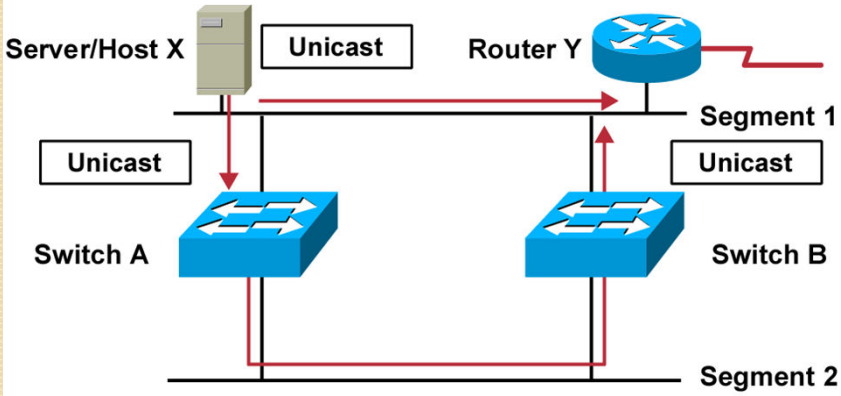
Multiple Frame Copies



- Host X sends a unicast frame to router Y.
- MAC address of router Y has not been learned by either switch yet.
- Router Y will receive two copies of the same frame.

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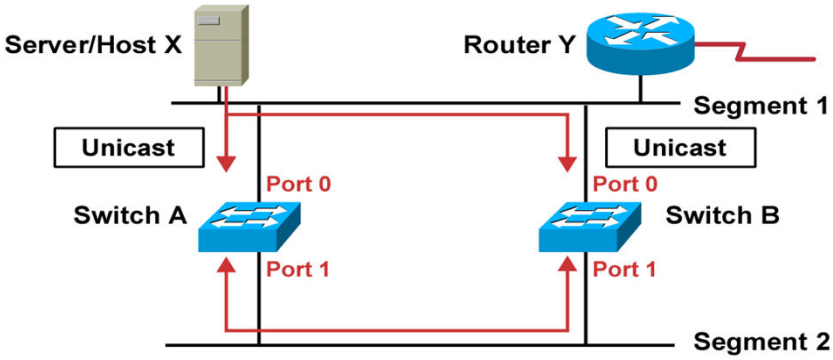
MAC Database Instability



- Host X sends a unicast frame to router Y.
- MAC address of router Y has not been learned by either switch.
- Switches A and B learn the MAC address of host X on port 0.
- The frame to router Y is flooded.
- Switches A and B incorrectly learn the MAC address of host X on port 1

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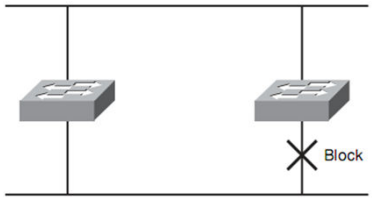
Spanning-Tree Protocol

Provides a loop-free redundant network topology.



- STP forces certain ports into a standby state (block) so that they do not listen to, forward, or flood data frames. There is only one active path to each network segment at any given time.
- If there is a problem with connectivity to any of the segments within the network, STP will re-establish connectivity by automatically activating a previously inactive path, if one exists.

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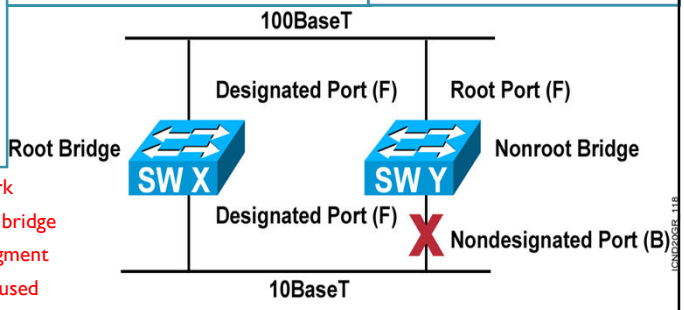
Spanning-Tree Operation

Elects one root bridge: STP has a process to elect a root bridge. Only one bridge can act as the root bridge in a given network. On the root bridge, all ports are designated ports. Designated ports are in the forwarding state and are designated to forward traffic for a given segment.

Selects the root port on the nonroot bridge: STP establishes one root port on each nonroot bridge. The root port is the lowest-cost path from the nonroot bridge to the root bridge. Root ports are in the forwarding state.

Selects the designated port on each segment: On each segment, STP establishes one designated port. The designated port is selected on the bridge that has the lowest-cost path to the root bridge.

- One root bridge per network
- One root port per nonroot bridge
- One designated port per segment
- Nondesignated ports are unused



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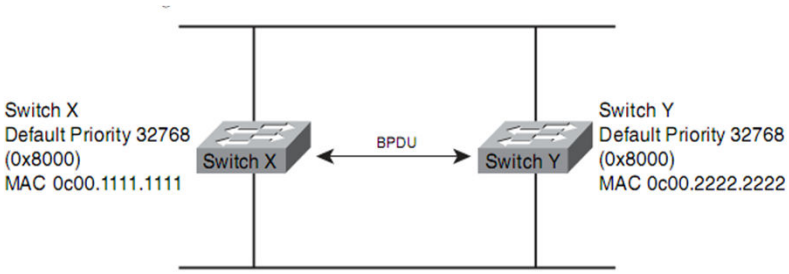
Spanning-Tree Protocol, Root Bridge Selection



- BPDU = Bridge Protocol Data Unit (default: sent every 2 seconds)
- Root bridge = Bridge with the lowest Bridge ID
- Bridge ID = | Bridge Priority | MAC Address |

In this example, which switch has the lowest Bridge ID?

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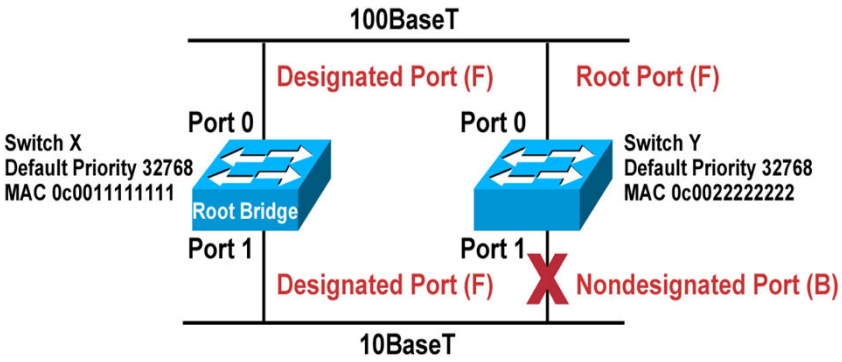
Spanning-Tree Port States



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Spanning-Tree Path Cost

Link Speed	Cost (Revised IEEE Specification)	Cost (Previous IEEE Specification)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

the spanning-tree path cost calculations based on bandwidth of a link.

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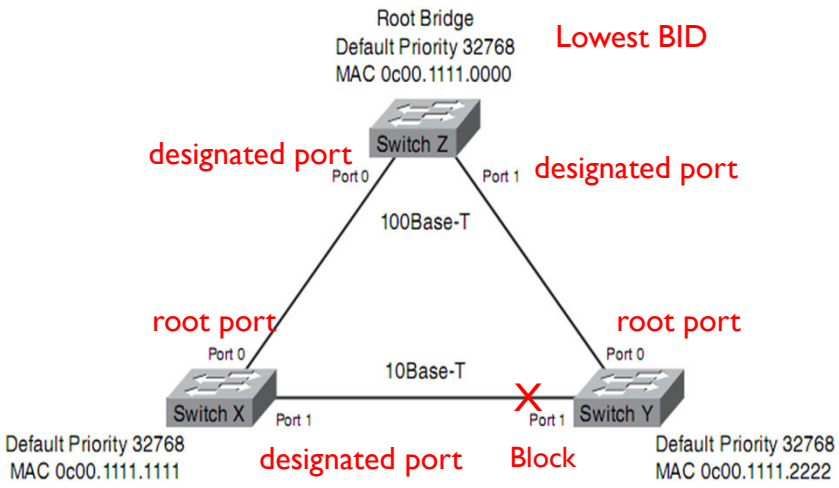
Spanning-Tree Example



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Spanning-Tree Convergence

- Convergence occurs when all the switch ports have transitioned to either the forwarding or the blocking state.
- For a switched network, a key issue is the time required for convergence when the network topology changes.
- Fast convergence is a desirable network feature because it reduces the time that switch ports are in transitional states and not sending user traffic. The normal convergence time is 30 to 50 seconds for 802.1D STP

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Routing

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Objectives

- Describe the features and operation of static routing
- Describe the features and operation of dynamic routing protocols, including RIP, IGRP, EIGRP, and OSPF
- Explain the differences between static routing and dynamic routing
- Identify the classes of routing protocols

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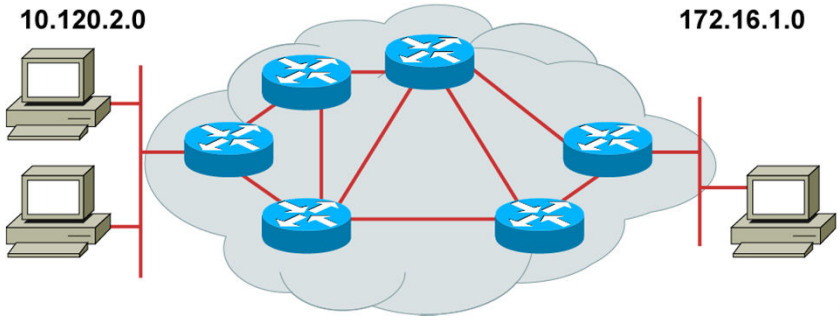
What Is Routing?



To route, a router needs to do the following:

- Know the destination address
- Identify the sources it can learn from
- Discover possible routes
- Select the best route
- Maintain and verify routing information

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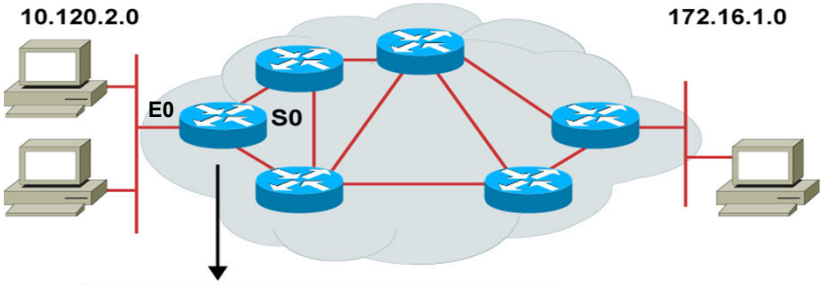
What Is Routing? (Cont.)



Network Protocol	Destination Network	Exit Interface
Connected	10.120.2.0	E0
Learned	172.16.1.0	S0

Routed Protocol: IP

Routers must learn destinations that are not directly connected

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Identifying Static and Dynamic Routes

- Routers can forward packets over static routes or dynamic routes.
- There are two ways to tell the router how to forward packets to networks that are not directly connected
- Static Route
  Uses a route that a network administrator enters into the router manually
- Dynamic Route
  Uses a route that a network routing protocol adjusts automatically for topology or traffic changes

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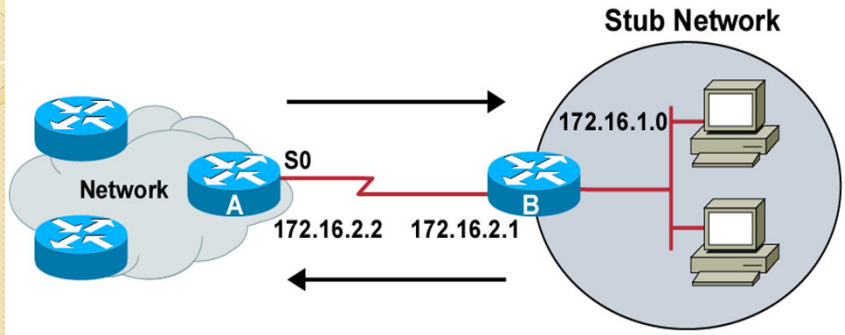
Static Routes



- Static routes are user-defined routes that specify the path that packets take when moving between a source and a destination.
- Configure unidirectional static routes to and from a stub network to allow communications to occur.

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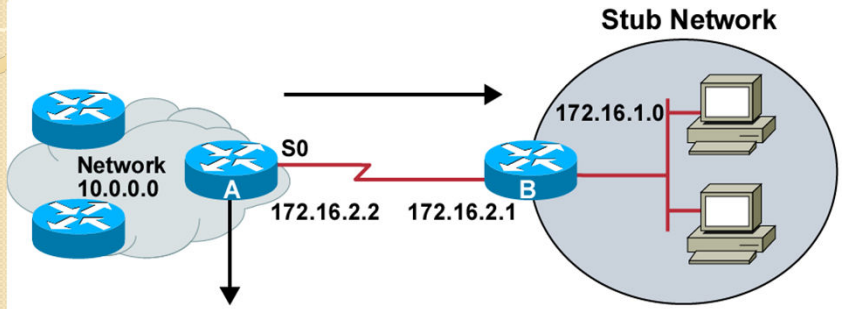
Static Route Example




```
Router(config)#ip route 172.16.1.0 255.255.255.0 172.16.2.1
```

- This is a unidirectional route.
- You must have a route configured in the opposite direction.

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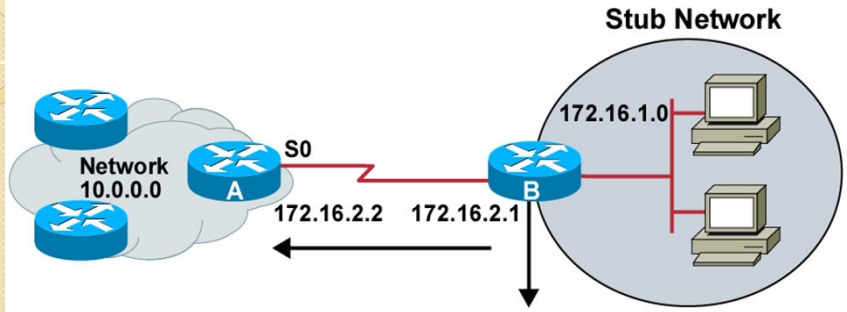
Default Routes




```
Router(config)#ip route 0.0.0.0 0.0.0.0 172.16.2.2
```

This route allows the stub network to reach all known networks beyond router A.

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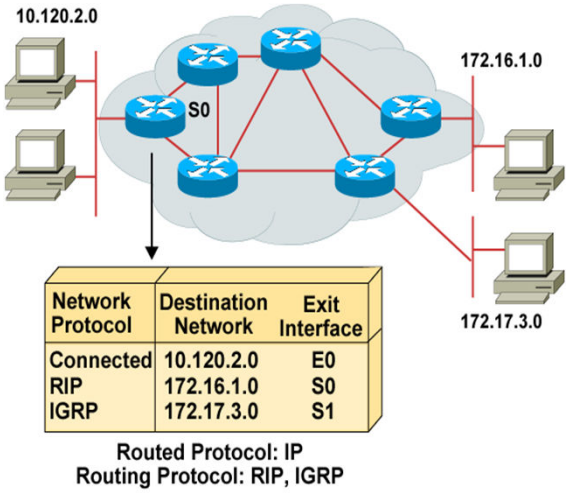
What Is a Routing Protocol?

- Routing protocols are used between routers to determine paths and maintain routing tables.
- Once the path is determined, a router can route a routed protocol.



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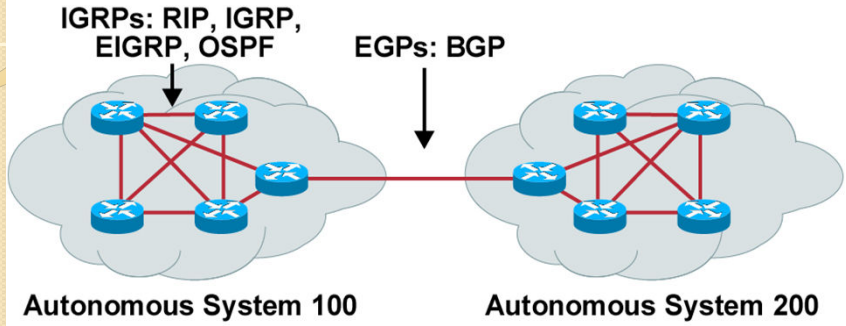
Autonomous Systems: Interior or Exterior Routing Protocols



- An autonomous system is a collection of networks under a common administration that share a common routing strategy.
- IGPs operate within an autonomous system.
- EGPs connect different autonomous systems.

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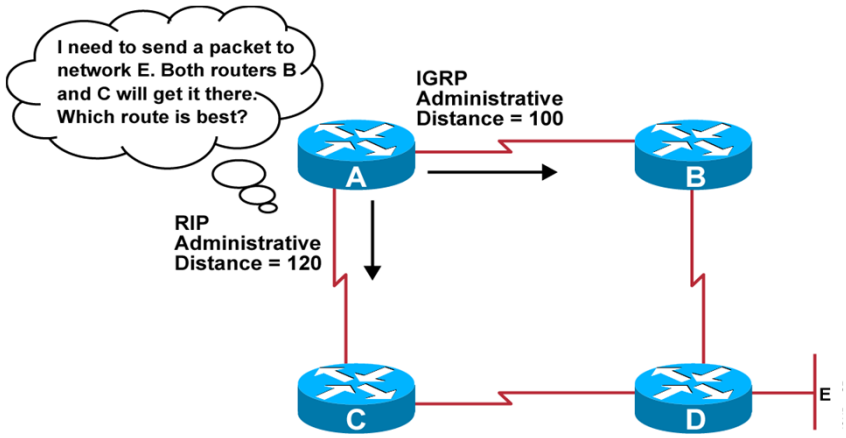
Administrative Distance: Ranking Routes



- Multiple routing protocols and static routes can be used at the same time.
- AD value is used to rate the trustworthiness of each routing information source

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Default Administrative Distance Values

Route Source	Default Distance
Connected network	0
Static route	1
EIGRP	90
OSPF	110
RIPv2	120
External EIGRP	170
Unknown or unbelievable	255 (will not be added to the routing table to pass traffic)

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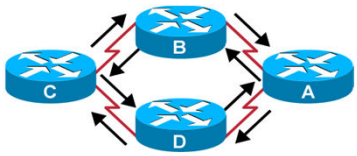
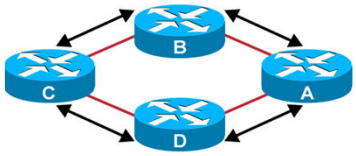
Classes of Routing Protocols

Distance Vector



Hybrid Routing



Link State

ICND20GR_198

Category	Routing Protocol
Distance vector	RIPv1, RIPv2, IGRP
Link-state	OSPF, Integrated IS-IS
Hybrid	EIGRP

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Classful Routing Overview

- Classful routing protocols do not include the subnet mask with the route advertisement.
- Within the same network, consistency of the subnet masks is assumed.
- Summary routes are exchanged between foreign networks.
- Examples of classful routing protocols:
  - RIP Version 1 (RIPv1)
  - IGRP

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Classless Routing Overview

- Classless routing protocols include the subnet mask with the route advertisement.
- Classless routing protocols support variable-length subnet masking (VLSM).
- Summary routes can be manually controlled within the network.
- Examples of classless routing protocols:
  - RIP Version 2 (RIPv2)
  - EIGRP
  - OSPF
  - IS-IS

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Routing Protocol Comparison Chart

Characteristic	RIPv1	IGRP	EIGRP*	IS-IS	OSPF
Distance vector	X	X	X		
Link-state				X	X
Automatic route summarization	X	X	X		
Manual route summarization			X	X	X
VLSM support			X	X	X
Proprietary		X	X		
Convergence time	Slow	Slow	Very Fast	Fast	Fast

* EIGRP is an advanced distance vector protocol with some link features.

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Selecting Routing Protocols

- They all have the same general goal:
  - To share network reachability information among routers
- They differ in many ways:
  - Interior versus exterior
  - Metrics supported
  - Dynamic versus static and default
  - Distance-vector versus link-state
  - Classful versus classless
  - Scalability

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Routing Protocol Metrics

- Metric: the determining factor used by a routing algorithm to decide which route to a network is better than another
- Examples of metrics:
  - Bandwidth - capacity
  - Delay - time
  - Load - amount of network traffic
  - Reliability - error rate
  - Hop count - number of routers that a packet must travel through before reaching the destination network
  - Cost - arbitrary value defined by the protocol or administrator

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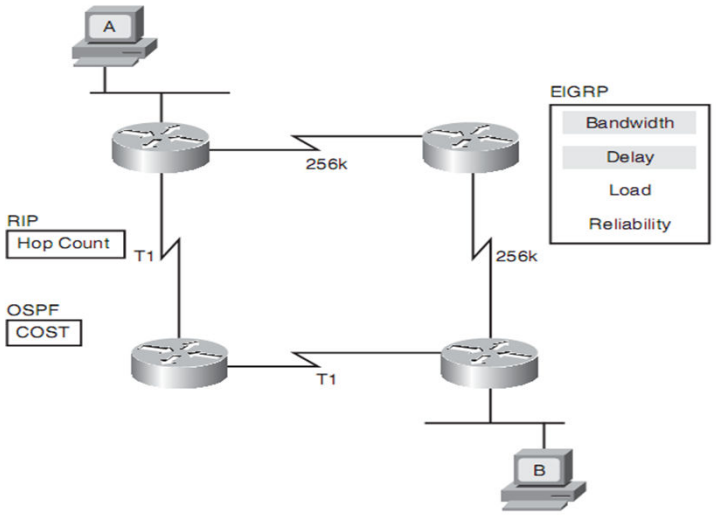
Routing Protocol Metrics



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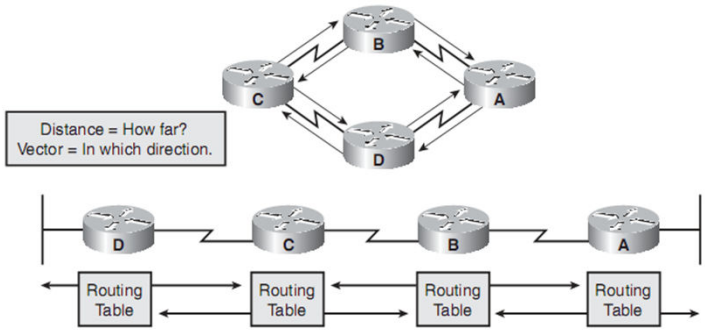
Distance-Vector Routing

- Router maintains a routing table that lists known networks, direction (vector) to each network, and the distance to each network
- Router periodically (every 30 seconds, RIP) transmits the routing table via a broadcast packet that reaches all other routers on the local segments
- Router updates the routing table based on received broadcasts



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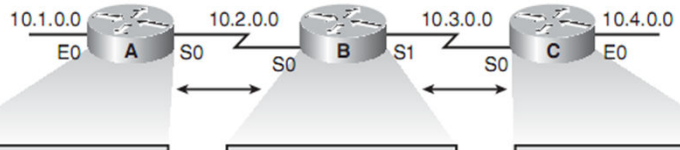
Distance-Vector Routing Tables



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	E0	0
10.2.0.0	S0	1
10.1.0.0	S0	2

- As the distance vector network discovery process proceeds, routers discover the best path to nondirectly connected destination networks based on accumulated metrics from each neighbor
- When all routers had consistent knowledge and correct routing tables. The network is said to have converged.

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Link-State Routing

- Routers send updates only when there's a change
- Router that detects change creates a link-state advertisement (LSA) and sends it to neighbors
- Neighbors propagate the change to their neighbors
- Routers update their topological database if necessary

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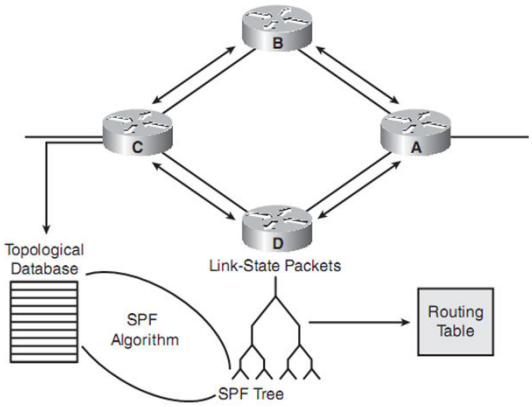
Link-State Routing

Link-state protocols build routing tables based on a topology database.



- This database is built from link-state packets that are passed between all the routers to describe the state of a network.
- The shortest path first algorithm uses the database to build the routing table.

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Distance-Vector Vs. Link-State

- Distance-vector algorithms keep a list of networks, with next hop and distance (metric) information
- Link-state algorithms keep a database of routers and links between them
  - Link-state algorithms think of the internetwork as a graph instead of a list
  - When changes occur, link-state algorithms apply Dijkstra's shortest-path algorithm to find the shortest path between any two nodes

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Choosing Between Distance-Vector and Link-State

Choose Distance-Vector	Choose Link-State
○ Simple, flat topology	○ Hierarchical topology
○ Hub-and-spoke topology	
○ Junior network administrators	○ More senior network administrators
○ Convergence time is not a big concern	○ Fast convergence is critical

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Routing Information Protocol (RIP)

- First standard routing protocol developed for TCP/IP environments
  - RIP Version 1 is documented in RFC 1058 (1988)
  - RIP Version 2 is documented in RFC 2453 (1998)
- Easy to configure and troubleshoot
- Broadcasts its routing table every 30 seconds; 25 routes per packet
- Uses a single routing metric (hop count) to measure the distance to a destination network; max hop count is 15

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RIP V2 Features

- Includes the subnet mask with route updates
  - Supports prefix routing (classless routing, supernetting)
  - Supports variable-length subnet masking (VLSM)
- Includes simple authentication to avoid crackers sending routing updates

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IGRP Solved Problems with RIP

- 15-hop limitation in RIP
  - IGRP supports 255 hops
- RIP uses just one metric (hop count)
  - IGRP uses bandwidth, delay, reliability, load

  (By default just uses bandwidth and delay)
- RIP's 30-second update timer
  - IGRP uses 90 seconds

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EIGRP

- Adjusts to changes in internetwork very quickly
- Incremental updates contain only changes, not full routing table
- Updates are delivered reliably
- Router keeps track of neighbors' routing tables and uses them as feasible successor
- Same metric as IGRP

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Open Shortest Path First (OSPF)

- Open standard, defined in RFC 2328
- Adjusts to changes quickly
- Supports very large internetworks
- Does not use a lot of bandwidth
- Authenticates protocol exchanges to meet security goals

- OSPF collect routing information from all other routers in the network or within a defined area of the internetwork.
- After all the information is collected, each router, independently of the other routers, calculates its best paths to all destinations in the network.

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OSPF Metric

- A single dimensionless value called *cost*. A network administrator assigns an OSPF cost to each router interface on the path to a network. The lower the cost, the more likely the interface is to be used to forward data traffic.
- On a Cisco router, the cost of an interface defaults to 100,000,000 divided by the bandwidth for the interface. For example, a 100-Mbps Ethernet interface has a cost of 1.

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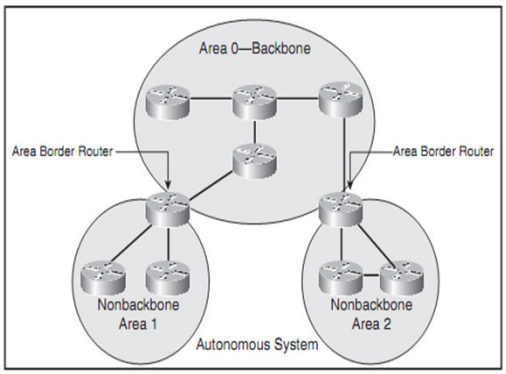
OSPF Areas Connected via Area Border Routers (ABRs)

- Link-state protocols use a two-layer network hierarchy
- Area: An area is a grouping of networks. Areas are logical subdivisions of the autonomous system (AS).
- An AS consists of a collection of networks under a common administration that share a common routing strategy.



Within each AS, a contiguous backbone area must be defined. All other nonbackbone areas are connected off the backbone area. The backbone area is the transition area because all other areas communicate through it.

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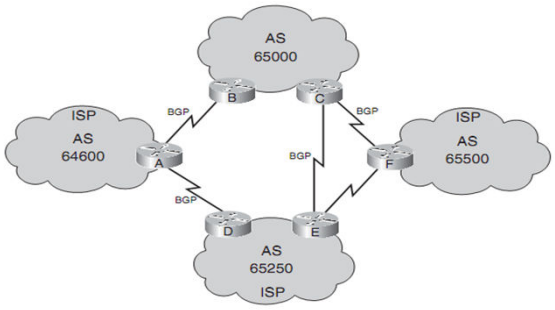
Border Gateway Protocol (BGP)

- Allows routers in different autonomous systems to exchange routing information
  - Exterior routing protocol
  - Used on the Internet among large ISPs and major companies
- Supports route aggregation
- Main metric is the length of the list of autonomous system numbers, but BGP also supports routing based on policies



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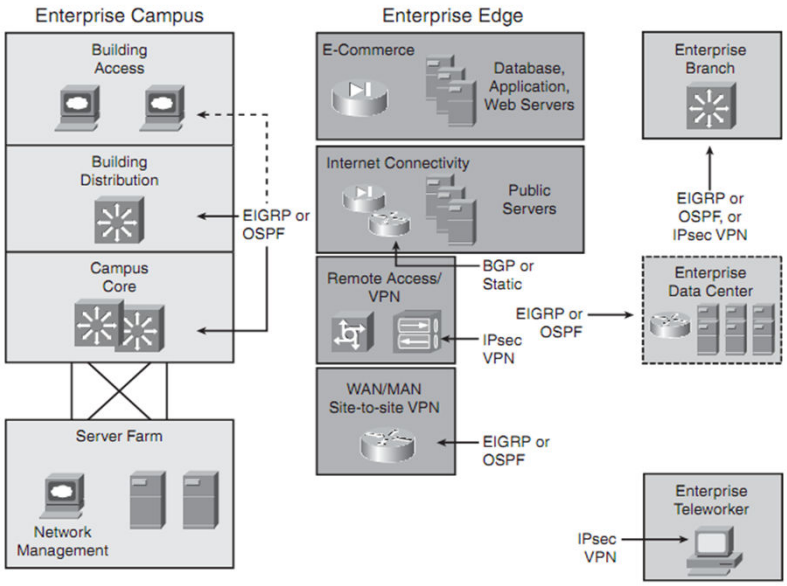
Routing Protocols in the Enterprise Architecture



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Summary (switching)

- Ethernet switches increase the available bandwidth of a network by creating dedicated network segments and interconnecting the segments.
- Switches use one of three operating modes to transmit frames: store and forward, cut-through, and fragment-free.
- Switches maintain a MAC address table to store address-to-port mappings so it can determine the locations of connected devices.
- When a frame arrives with a known destination address, it is forwarded only on the specific port connected to the destination station.
- Switched networks are commonly designed with redundant links and devices, which can introduce problems, such as broadcast storms, multiple frame transmission, and MAC database instability.
- A broadcast storm is when each switch on a redundant network floods broadcast frames endlessly.

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Summary (switching)

- In a redundant topology, multiple copies of the same frame can arrive at the intended host, potentially causing problems with the receiving protocol.
- MAC database instability results when multiple copies of a frame arrive on different ports of a switch.
- STP is a protocol used to maintain a loop-free network. STP establishes a root bridge, a root port, and designated ports.
- With STP, the root bridge has the lowest bridge ID, which is made up of the bridge's priority and MAC address.
- With STP, ports transition through four states: blocking, listening, learning, and forwarding.
- If a change occurs to the network topology, STP maintains connectivity by transitioning some blocked ports to the forwarding state.

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Summary (routing)

- Routing is the process by which an item gets from one location to another
- Routers can forward packets over static routes or dynamic routes.
- A default route is a special type of static route used for situations when the route from a source to a destination is not known.
- Dynamic routing relies on a routing protocol to disseminate knowledge. A routing protocol defines the set of rules used by a router when it communicates with neighboring routers.
- A distance vector routing algorithm sends its entire routing table to its neighbors. Link-state routing algorithms maintain a complex database of topology information, which routers use to maintain full awareness of distant routers.
- There are many types of routing protocols and many choices within each

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