NETWORK CONCEPTS

2.1 Install and configure routers and switches.

Distance vector

I. **Enhanced Interior Gateway Routing Protocol (EIGRP**) is an advanced distance-vector routing protocol that is used on a Computer network to help automate routing decisions and configuration

II. Growth of the Internet in the 1980s led to changes initiated through Internet governing entities

   a. Internet Society (ISOC) and its committees

      i. Internet Assigned Numbers Authority (IANA)

      ii. Internet Engineering Task Force (IETF)

- OSPF: the acronym for Open Shortest Path First
- Standardized in RFC 2328
- Uses link-state routing
- Offers several advantages:
  - Updates routing tables more quickly when changes occur on the network
  - Balances the network load by splitting traffic between routes with equal metrics
  - Supports authentication of routing protocol messages

Link State

OSPF

I. Open Shortest Path First (OSPF) most commonly used IGP in the entire Internet
II. Complex protocol for routers
    a. Not found on cheap home routers
    b. Requires a great deal of computational power

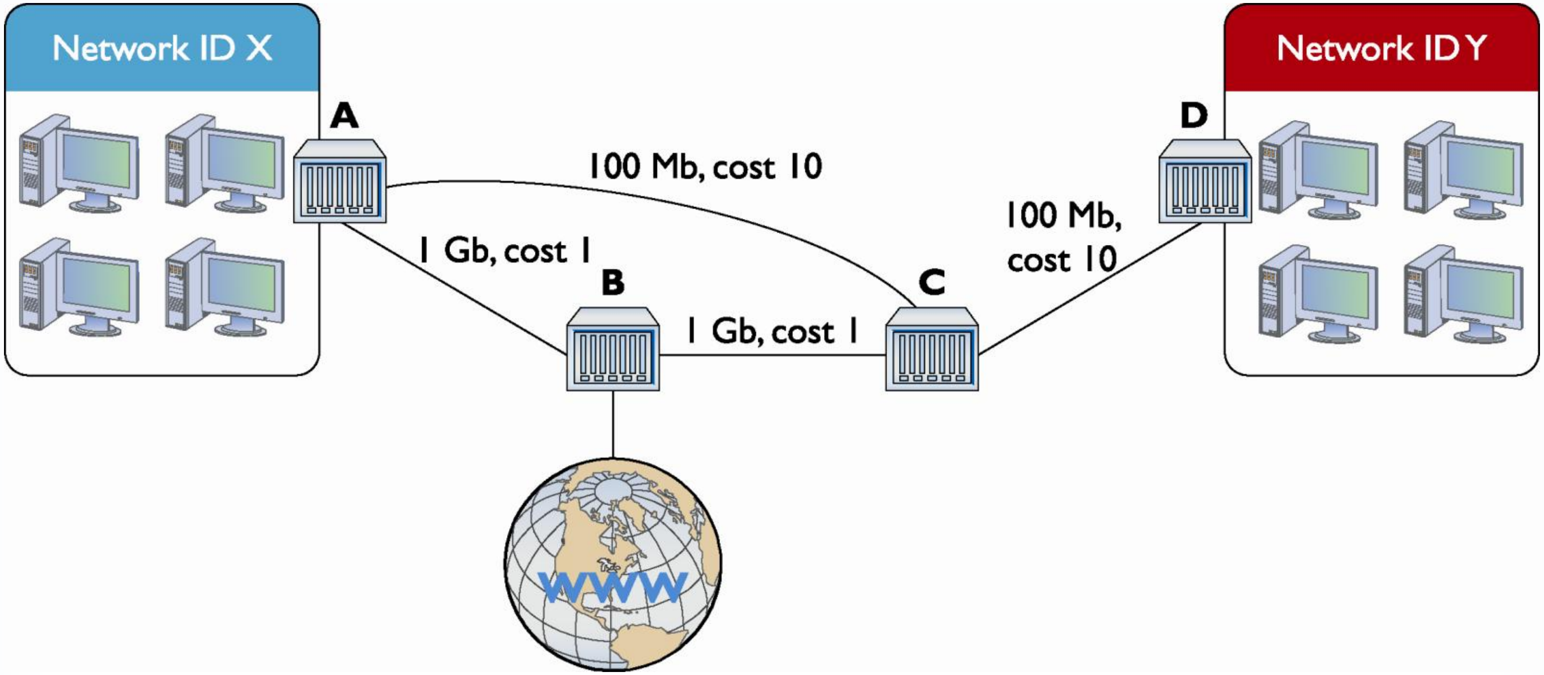

Figure 1.4.1 Link states

Dynamic Routing Makes the Internet

1. Internet depends on dynamic routing for self-healing
2. Manual updating impossible with so many routes coming up and going down

Table 8.1 Dynamic Routing Protocols

Protocol	Type	IGP or BGP?	Notes
RIPv1	Distance vector	IGP	Old; only used classful subnets
RIPv2	Distance vector	IGP	Supports CIDR
BGP-4	Distance vector	BGP	Used on the Internet, connects Autonomous Systems
OSPF	Link state	IGP	Fast, popular, uses Area IDs (Area 0/backbone)
IS-IS	Link state	IGP	Alternative to OSPF
EIGRP	Hybrid	IGP	Cisco proprietary

Distance vector

1. First TCP/IP routing protocols
2. Cornerstone is total cost
3. Simple total cost adds up the hop count between a router and a destination network

Distance vector

Problem:

I. Simple hop count does not take into account speed differences

II. Administrators set metric values higher on slower routes

Distance vector

Problem:

Distance vector routing protocols:

a. Calculate the total cost to a network ID
b. Compare total cost of all possible routes to same destination
c. Selects route with the lowest cost
d. Routers transfer their entire routing table to other routers in the WAN

Distance vector

Problem:

Distance vector routing protocols:

a. Each distance vector routing protocol has a maximum number of hops that a router will send its routing table
b. When there are multiple routes to a destination network ID, router will keep only the lowest-cost route and delete the others
c. Routers continue to update each other, even when there are no changes

Distance vector

Problem:

I. Distance vector routing protocols:
   a. Convergence is the point at which the updating of routing tables is complete for all routers.
   b. If a low-cost link breaks router can no longer send to that destination network ID until several iterations of updating include the slower link
   c. Distance vector routing protocols work for fewer than 10 routers

- RIP: the acronym for Routing Information Protocol
- Most common interior gateway protocol (IGP) in the TCP/IP suite
- Originally designed for UNIX systems as a daemon called routed
- Eventually ported to other platforms
- Standardized in Request for Comments (RFC) 1058
- Updated to version 2, published as RFC 2453

Distance vector

RIPv1

I. Routing Information Protocol (RIP) is oldest distance vector routing protocol
II. Originated in the 1960s, but first full version dates from the 1980s
III. Maximum hop count of 15
IV. Routing table request could loop all the way back to the initial router

Distance vector

RIPv1

V. Every router updated every 30 seconds, causing huge network overloads
VI. Only routed classful subnets
VII. Did not work with Classless Inter-Domain Routing (CIDR) subnets
VIII. No authorization, left routers open to hackers sending false routing table information

Distance vector

RIPv2

I. Current version of RIP – 1994
II. Fixed many problems with RIPv1
    a. CIDR support added
    b. Updates are set a random intervals
    c. Authentication built into the protocol

Distance vector

RIPv2

III. Only suitable for small network
IV. Still has 15-hop limit
V. Still has time-to-convergence problems for larger WANS

Figure 8.30 Setting RIP in a home router

VLANs today

- Every Ethernet switch uses IEEE 802.1Q
- Connect switches from different sources

Introduction to VLANS

- Todays networks are complex
  - Remote incoming connections
  - Public Web or e-mail servers
  - Wireless networks
  - String of connected switches
  - Tremendous amount of traffic
  - Security Issues

VLANs as solution

- Separate networks with multiple switches
- Segment networks using switches
  - Break up broadcast domains
  - Serious networks have more than one switch
  - **Trunking** connects VLANs on separate switches
  - One port on each switch is **trunk port**

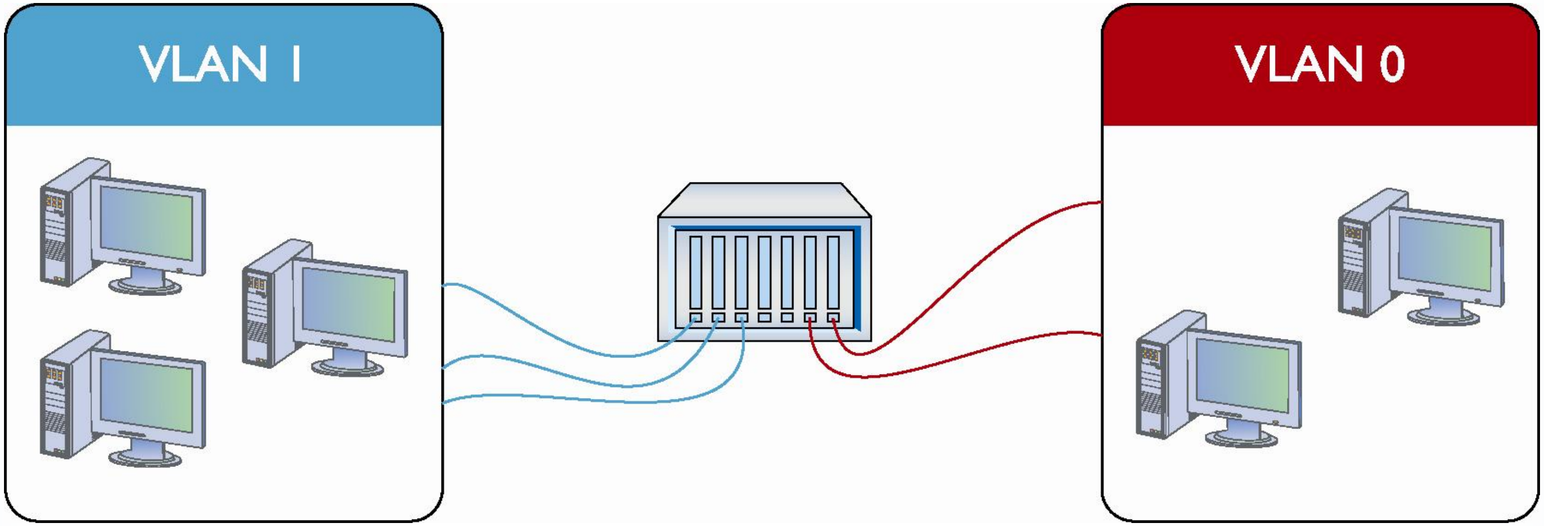

Figure 12.15 Switch with two VLANs

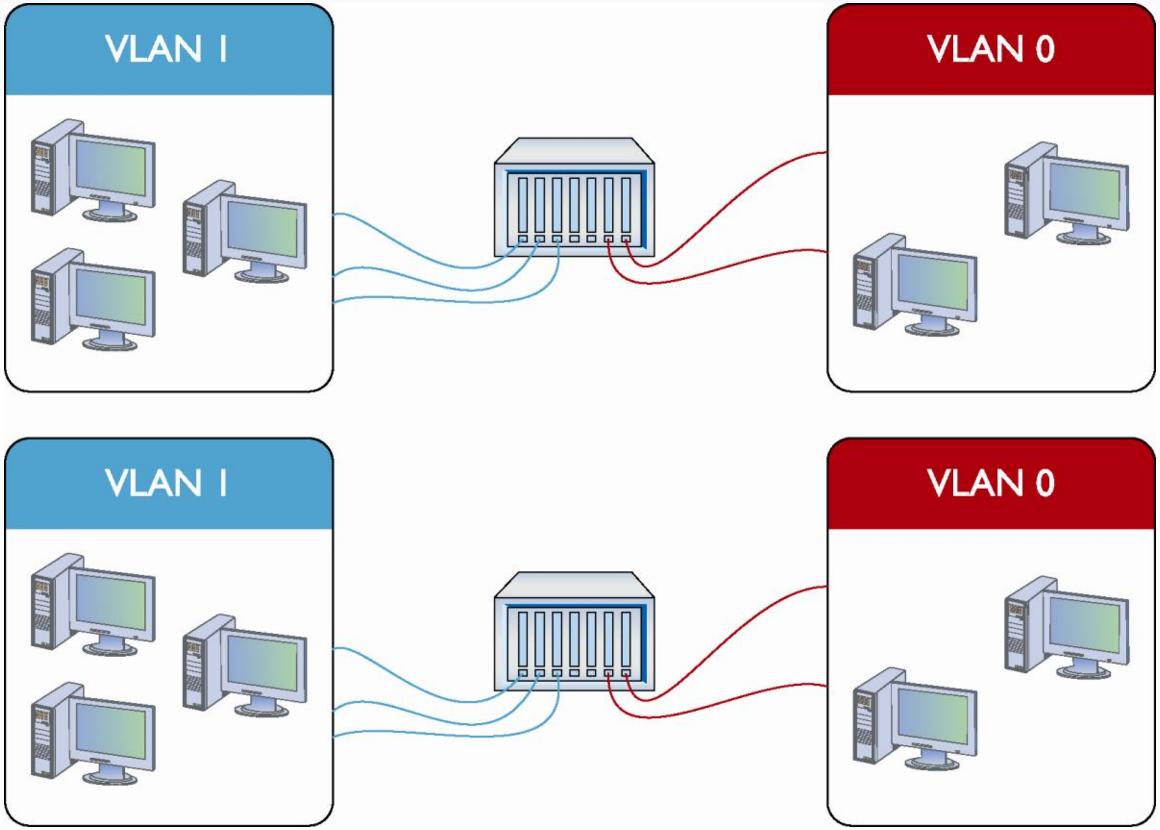

Figure 12.16 Two switches, each with a VLAN 0 and a VLAN 1

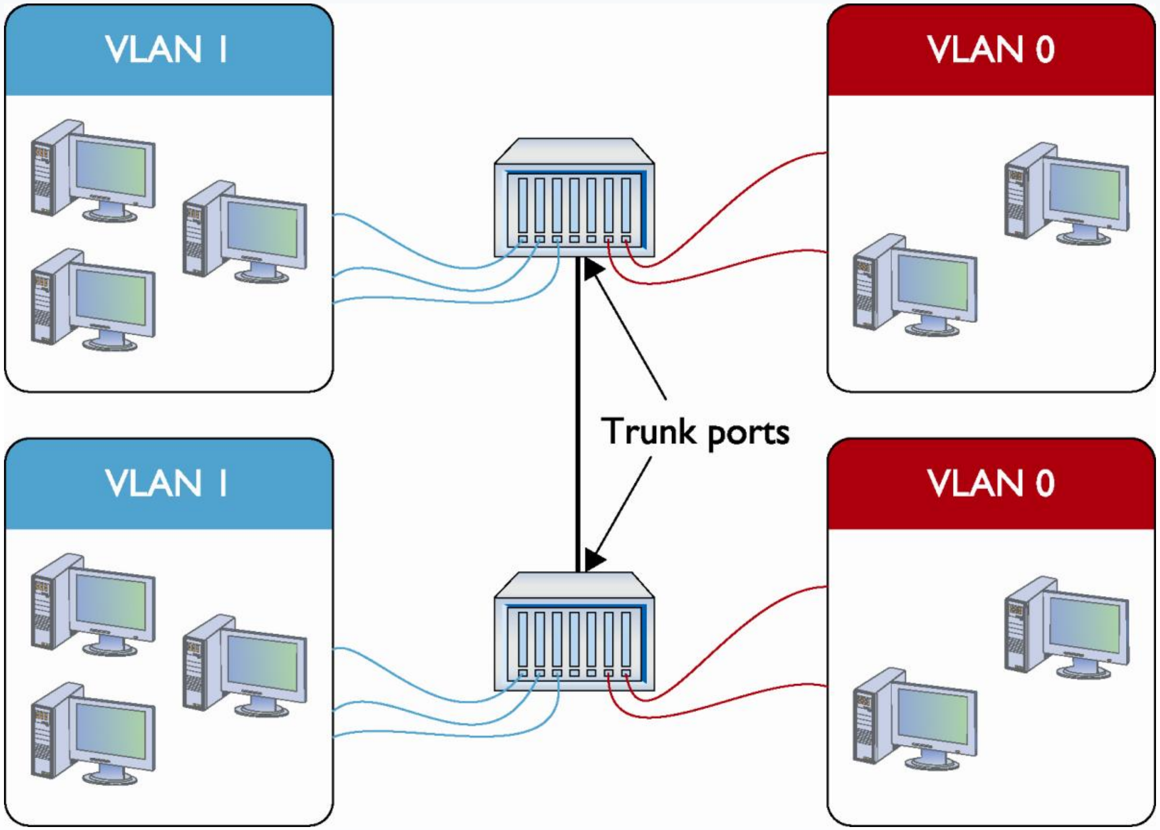

Figure 12.17 Trunk ports

Assigning an IP address, subnet mask, and default gateway

- Static addressing
  - Type in all the information
- Dynamic addressing
  - Server program automatically passes out the information to computers on the network

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- A router is a system connected to two or more networks that forwards packets from one network to another.
- Routers operate at the network layer of the Open Systems Interconnection (OSI) reference model.
- Routers can connect networks running different data-link layer protocols and different network media.
- Large internetworks often have redundant routers, providing multiple routes to a

Static IP Addresses

- Manually type in all IP information
  - What are you typing in?
  - Where do you type it?
- Assuming a Class C license for 197.156.4/24
  - You can do whatever you want with your own network ID
  - Use legit IP address and mask for network ID
  - Every IP address must be unique
  - You don't have to use the numbers in order

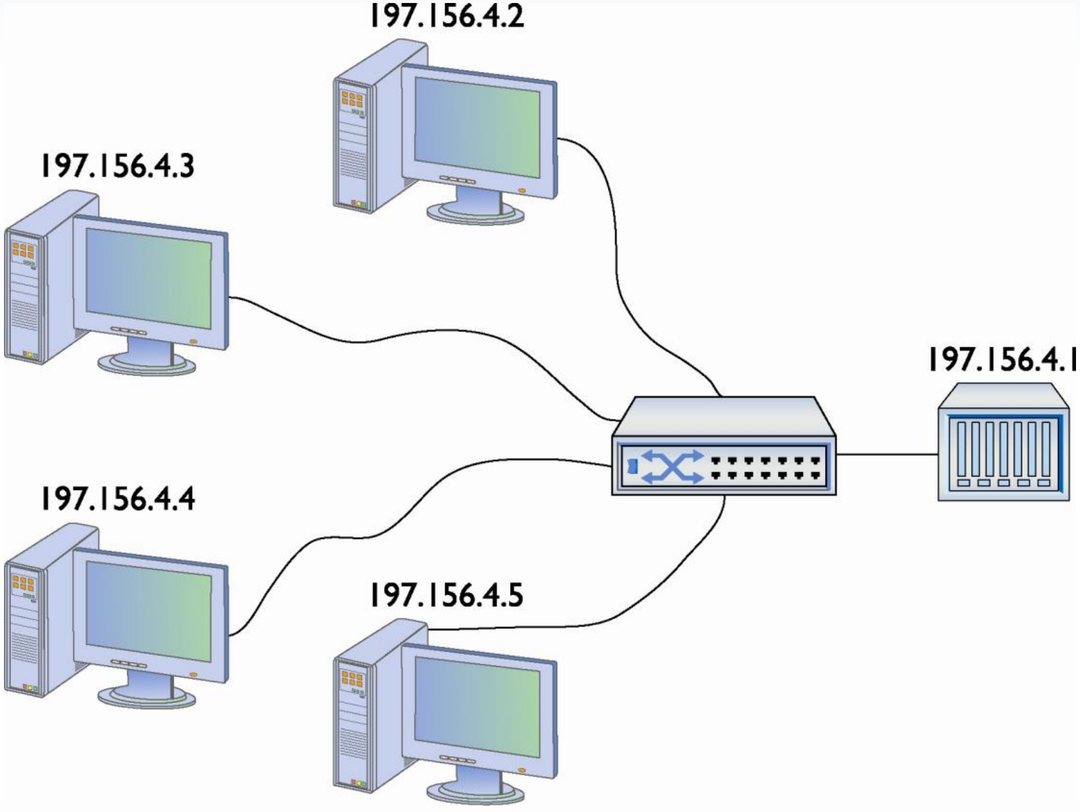

Figure 1.4.1 A small network

- Direct route. The route taken when a computer running Transmission Control Protocol/Internet Protocol (TCP/IP) transmits a packet to a destination on the local network
- Indirect route. The route taken when a computer running TCP/IP transmits a packet to a destination on another network by forwarding the packet to a router on the local network

Windows 2008 Routing Table: Sample

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Network Address	Netmask	Gateway Address	Interface
0.0.0.0	0.0.0.0	192.168.2.99	192.168.2.2
127.0.0.0	255.0.0.0	127.0.0.1	127.0.0.1
192.168.2.0	255.255.255.0	192.168.2.2	192.168.2.2
192.168.2.2	255.255.255.255	127.0.0.1	127.0.0.1
192.168.2.255	255.255.255.255	192.168.2.2	192.168.2.2
224.0.0.0	224.0.0.0	192.168.2.2	192.168.2.2
255.255.255.255	255.255.255.255	192.168.2.2	192.168.2.2

- A routing table on a router is more complex than a workstation routing table because it contains
  - Entries for all of the networks that the router is attached to
  - Entries provided manually by administrators or dynamically by routing protocols
- Routers use the Interface and Metric columns more than workstations do.

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Static Routing

- Requires administrators to create routing table entries manually
- Suitable only for small networks

Dynamic Routing

- Creates routing table entries automatically by using routing protocols.
- Suitable for large networks
- Automatically compensates for network infrastructure

- UNIX uses route.
- Windows uses ROUTE.EXE.

ROUTE [-f] [-p] [*command* [*destination*] [MASK *netmask*] [*gateway*] [METRIC *metric*] [IF *interface*]]

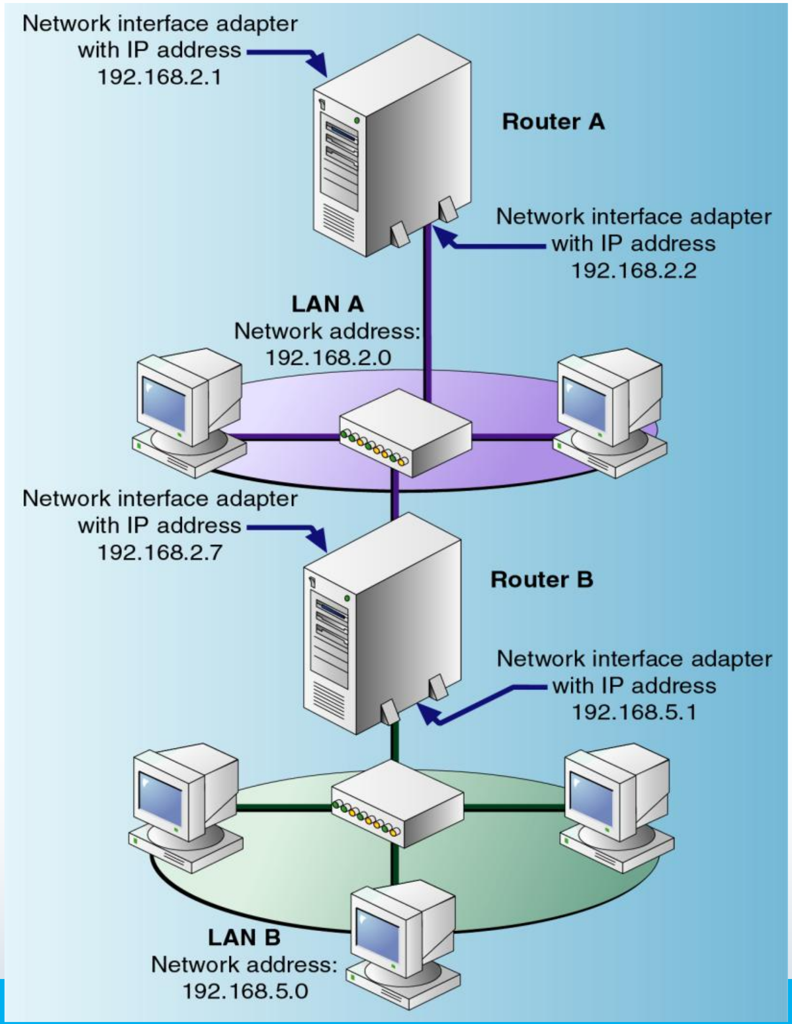
Parameter or Variable	**Function**
-f	Deletes all entries from the routing table
-p	Creates a persistent route entry in the table
command	Contains a keyword specifying the command function
destination	Specifies the network or host address of the table entry
MASK *netmask*	Specifies the subnet mask to be applied to the *destination* address
gateway	Specifies the address of the router that the system should use to reach the *destination* host or network
METRIC *metric*	Specifies a value that indicates the relative efficiency of the route
IF *interface*	Specifies the number of the network interface adapter the system should use to reach the *gateway* router

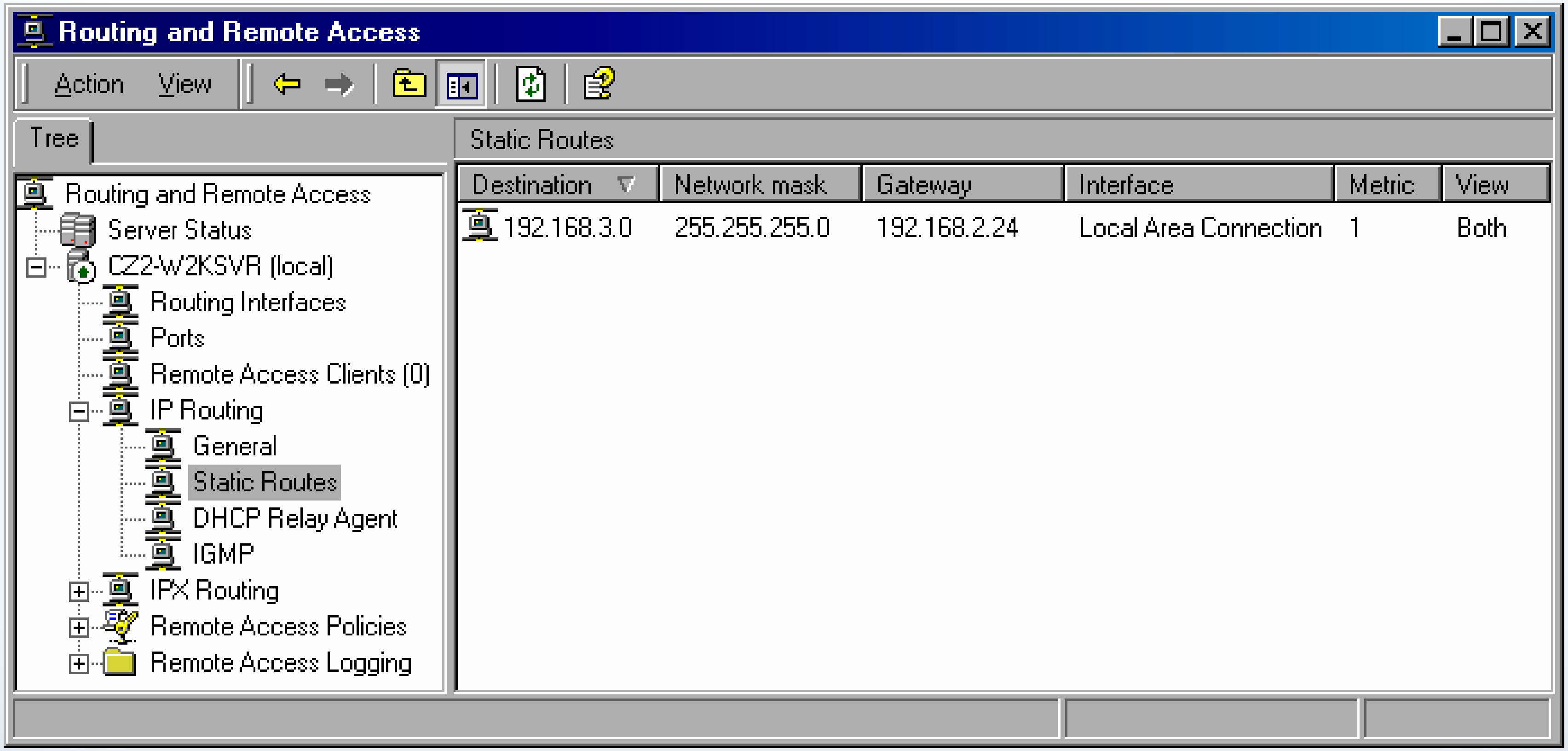
- PRINT. Displays the contents of the routing table
- ADD. Creates a new entry in the routing table
- DELETE. Deletes an existing entry from the routing table
- CHANGE. Modifies the parameters of an entry in the routing table

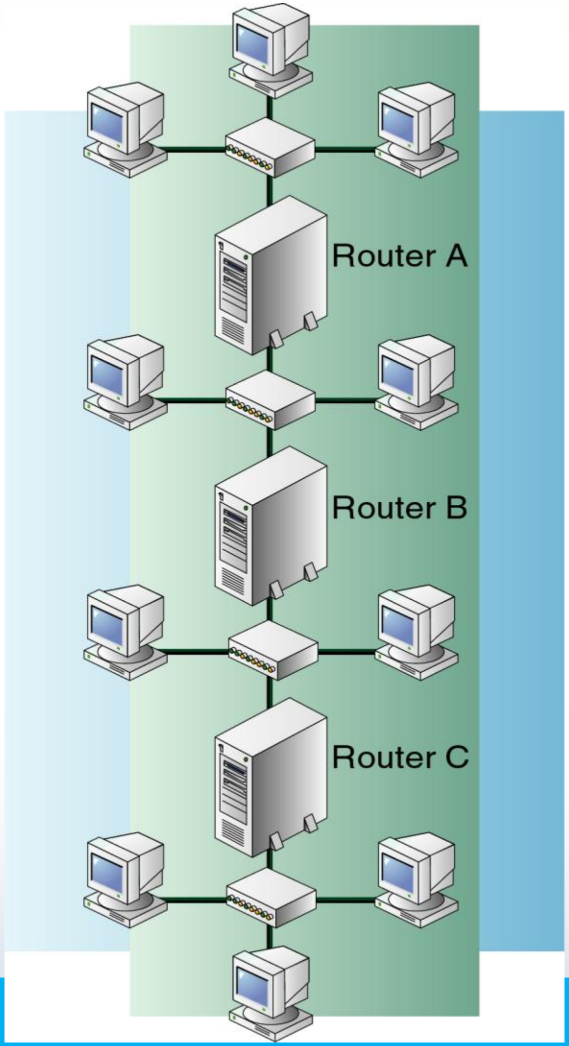
```
ROUTE ADD 192.168.5.0 MASK 255.255.255.0 192.168.2.7
IF 1 METRIC 1
```

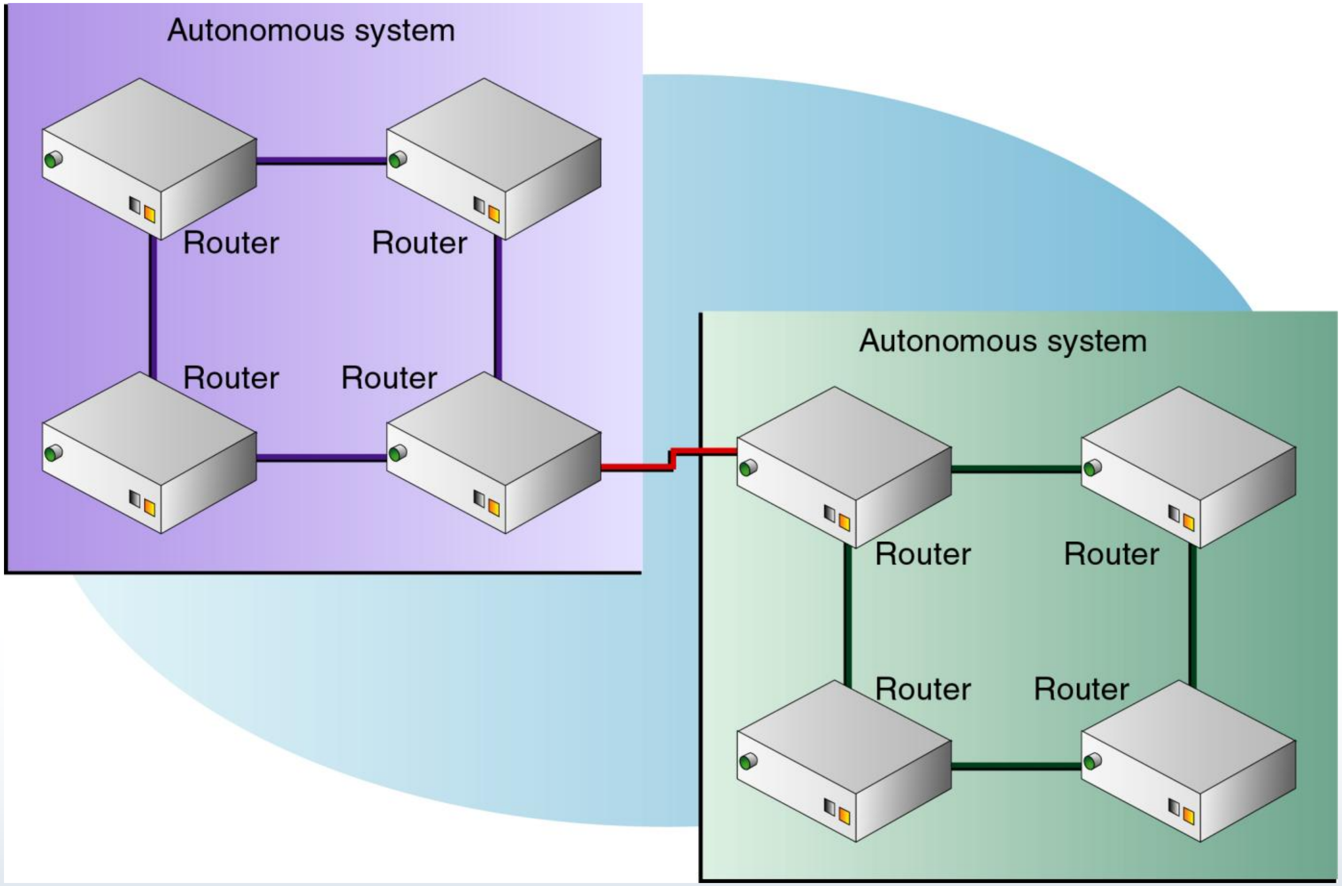
Parameter or Variable	Function
ADD	Indicates that the program should create a new entry in the existing routing table
192.168.5.0	Specifies the address of the other network to which Router B provides access
MASK 255.255.255.0	Specifies the subnet mask to be applied to the destination address
192.168.2.7	Specifies the address of the network interface adapter with which Router B is connected to the same network as Router A
IF 1	Specifies the number of the network interface adapter in Router A that provides access to the network it shares with Router B
METRIC 1	Indicates that the destination network is one hop away

ROUTE.EXE Example Network




Routing and Remote Access
Action View
Tree
Static Routes
Routing and Remote Access
Server Status
CZ2-W2KSVR (local)
Routing Interfaces
Ports
Remote Access Clients (0)
IP Routing
General
Static Routes
DHCP Relay Agent
IGMP
IPX Routing
Remote Access Policies
Remote Access Logging
Destination
Network mask
Gateway
Interface
Metric
View
192.168.3.0
255.255.255.0
192.168.2.24
Local Area Connection
1
Both


Router A
Router B
Router C


Autonomous system
Router
Router
Router
Router
Autonomous system
Router
Router
Router
Router

- RIP routers initiate communications when starting up by broadcasting a request message on all network interfaces.
- All RIP routers receiving the broadcast respond with reply messages containing their entire routing table.
- The router receiving the replies updates its own routing table with the information in the reply messages.

Summary

- Routing principles
  - Routers receive packets and use the most efficient path to forward them to their destinations.
  - Complex internetworks can have redundant routers that provide multiple paths to the same destination.
  - Routers store information about the network in a routing table.
- Building routing tables
  - Information gets into the routing table in one of two ways: static routing or dynamic routing.
  - The Windows 2000 ROUTE.EXE program provides direct access to the routing table.

Static IP Addresses

- Network techs' set of principles
  - Give the default gateway the first host IP address in the network ID
  - Try to use the IP addresses in some kind of sequential order
  - Try to separate servers from clients
    - Servers host addresses: 197.156.4.10 to 197.156.4.19
    - Client host addresses: 197.156.4.200 to 197.156.4.254
  - Write down whatever you do so person who comes after you understands what you did

Static IP Addresses (cont.)

- Give each computer an IP address, subnet mask, and default gateway
  - In Windows use the Internet Protocol Version 4 (TCP/IPv4) Properties dialog box

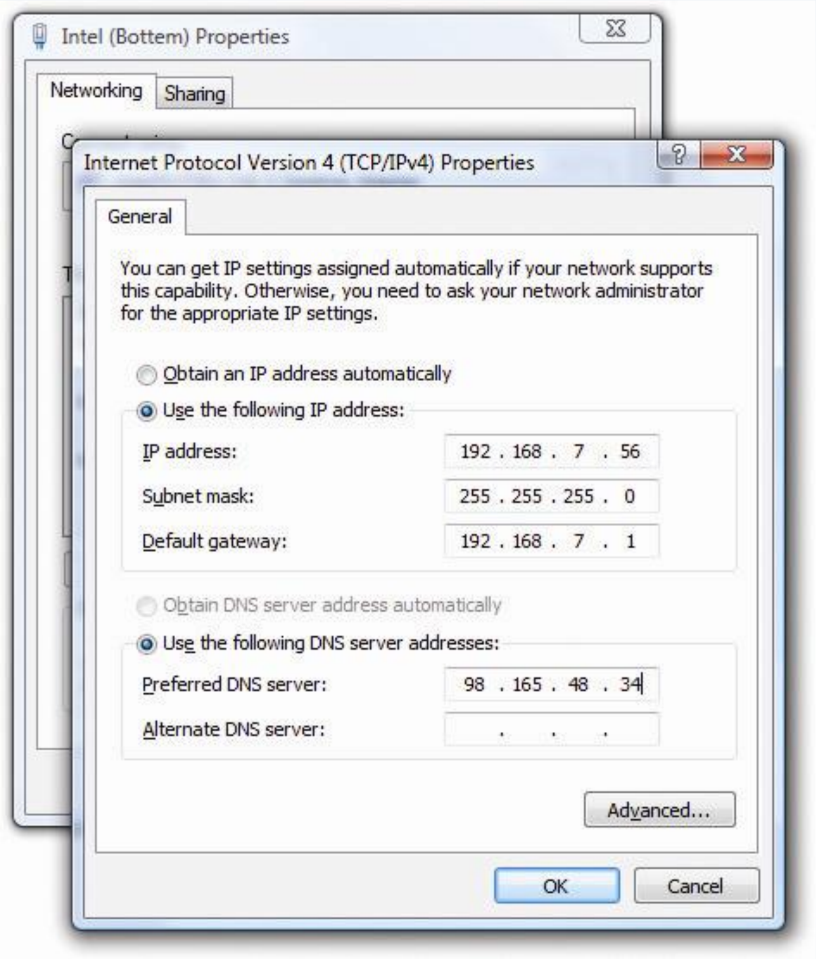


Figure 7.33 Entering static IP information in Windows Internet Protocol Version 4 (TCP/IPv4) Properties

Static IP Addresses (cont.)

- After adding IP information to at least two systems, verify with the PING command
- Successful PING confirms two systems can communicate
- If the PING is not successful
  - Check your IP settings
  - Check connections, driver, etc.
- Static addressing used for most critical systems
- Most systems today use dynamic IP addressing

Dynamic IP Addressing

- Dynamic Host Configuration Protocol (DHCP)
  - More popular form of dynamic IP addressing
  - Bootstrap Protocol (BOOTP) older version
- Automatically assigns an IP address whenever a computer connects to the network
- DHCP uses a simple process
  - Computer is configured to use DHCP
  - Every OS has a method to tell computer to use DHCP
  - Windows setting: Obtain an IP address automatically

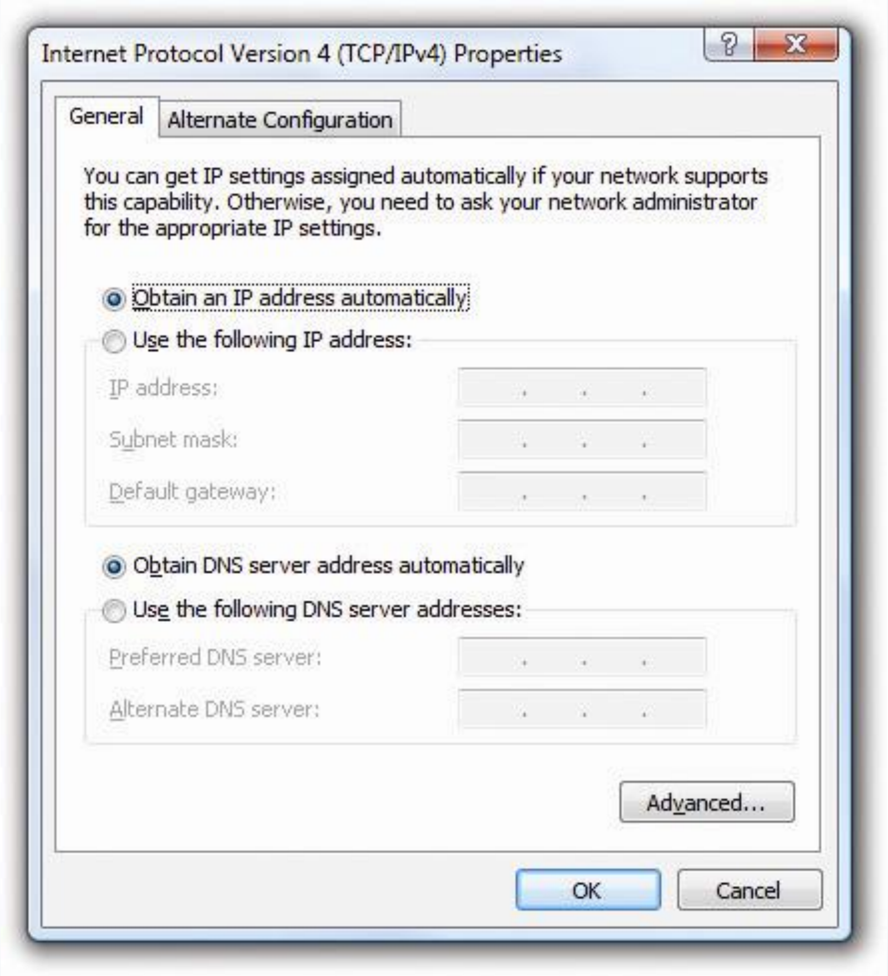


Figure 7.38 Setting up for DHCP

Routing Tables

- Router strips off Layer 2 information
- Drops IP packet into a queue
  - Source address is not important
  - Every packet dropped into the same queue based on time of arrival
- Router inspects the destination IP address
- Router send IP packet out correct port
- **Routing table** tells router where to send packets
- A **Broadcast Domain** (or Collision Domain) is a network of computers that will hear each other's broadcasts.

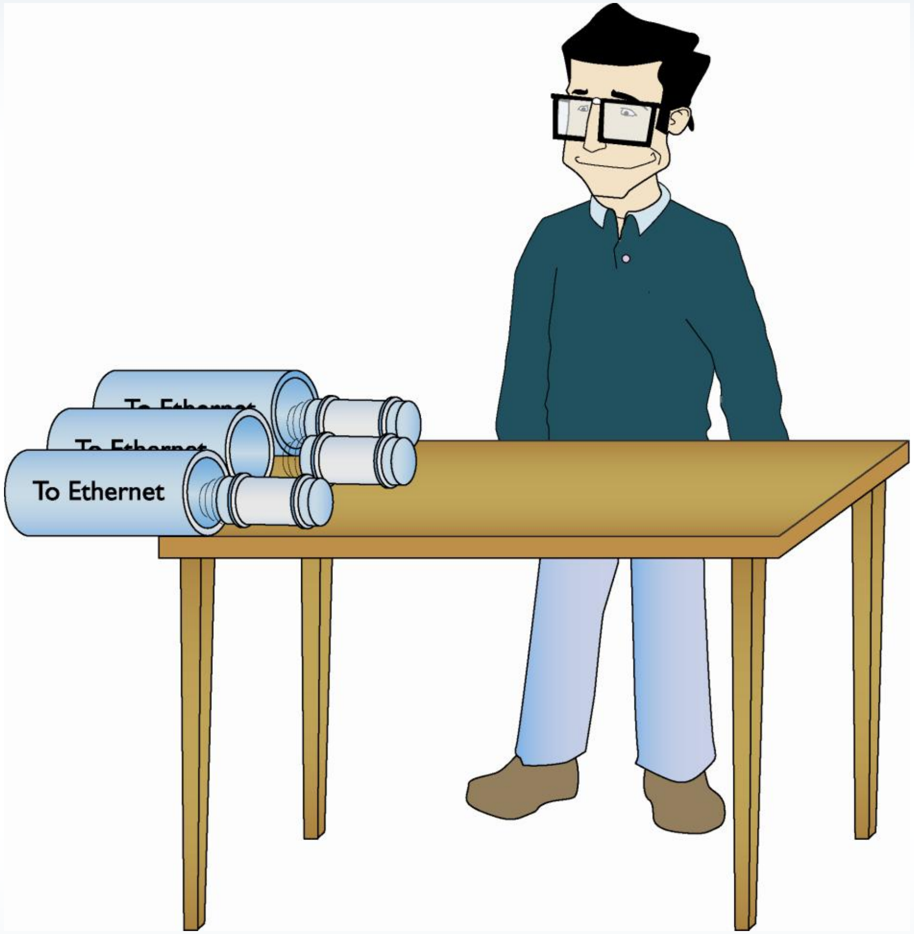


Figure 8.5 Incoming packets

Figure 8.6 All incoming packets stripped of Layer 2 data and dropped into a common queue

Routing Tables (cont.)

- Example home router (Figure 8.7)
  - Two ports
  - Each row in table defines a single route
  - Each column identifies specific criteria
    - Destination LAN IP
    - Subnet Mask
  - If packet's network ID matches a Destination LAN IP, router uses other information in row to determine where to send it

Routing Table Entry List

Refresh

Destination LAN IP	Subnet Mask	Gateway	Interface
10.12.14.0	255.255.255.0	0.0.0.0	LAN
76.30.4.0	255.255.254.0	0.0.0.0	WAN
0.0.0.0	0.0.0.0	76.30.4.1	WAN

Close

Figure 8.7 Routing table from a home router

Routing Tables (cont.)

- Example home router (Figure 8.7)
  - Third and fourth columns
    - Gateway
      - IP address for the **next hop** router
      - Packet sent to Gateway if network ID does not match one of the directly connected ports
    - Interface
      - Tells router which port to use
      - "LAN" or "WAN" on sample router
      - Other routing tables use IP address or other info

Routing Table Entry List

Refresh

Destination LAN IP	Subnet Mask	Gateway	Interface
10.12.14.0	255.255.255.0	0.0.0.0	LAN
76.30.4.0	255.255.254.0	0.0.0.0	WAN
0.0.0.0	0.0.0.0	76.30.4.1	WAN

Close

Figure 8.7 Routing table from a home router

Routing Tables (cont.)

- Example home router (Figure 8.7)
  - *First* Router compares destination IP address to every listing in the routing table
  - *Then* router makes a decision

Routing Table Entry List

Refresh

Destination LAN IP	Subnet Mask	Gateway	Interface
10.12.14.0	255.255.255.0	0.0.0.0	LAN
76.30.4.0	255.255.254.0	0.0.0.0	WAN
0.0.0.0	0.0.0.0	76.30.4.1	WAN

Close

Figure 8.7 Routing table from a home router

Routing Tables (cont.)

- Example home router (Figure 8.7)
  - Every router (with two exceptions) has a default route
  - Default route in Figure 8.7
    - Destination LAN IP: 0.0.0.0
    - Subnet Mask: 0.0.0.0
    - Gateway: 76.30.4.1
    - Interface: WAN
  - Router sends incoming packet to default route *unless* another line gives another route

Routing Tables (cont.)

- Example home router (Figure 8.7)
  - Destination LAN IP: 10.12.14.0 (any packet for this network)
  - Subnet Mask: 255.255.255.0 (using /24 network ID)
  - Gateway: 0.0.0.0 (don't use a gateway)
  - Interface: LAN (ARP on the LAN interface to get MAC address and send directly to host)

Routing Table Entry List Refresh

Destination LAN IP	Subnet Mask	Gateway	Interface
10.12.14.0	255.255.255.0	0.0.0.0	LAN
76.30.4.0	255.255.254.0	0.0.0.0	WAN
0.0.0.0	0.0.0.0	76.30.4.1	WAN

Close

Figure 8.7 Routing table from a home router

Routing Tables (cont.)

- Example home router (Figure 8.7)
  - Destination LAN IP: 76.30.4.0 (any packet for this network)
  - Subnet Mask: 255.255.254.0 (using /23 network ID)
  - Gateway: 0.0.0.0 (don't use a gateway)
  - Interface: WAN (ARP on the WAN interface to get MAC address and send directly to host)

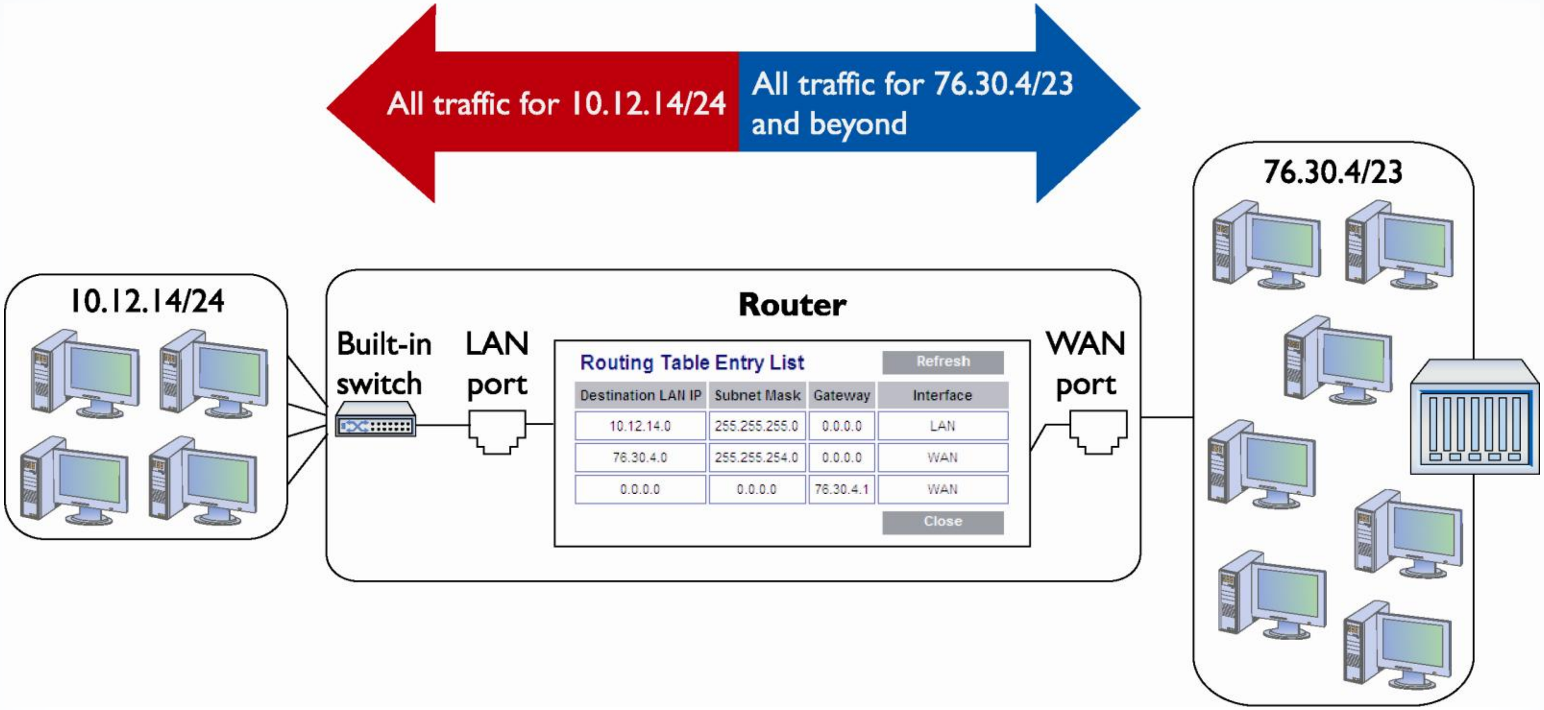


Figure 8.9 The network based on the routing table

Routing Tables (cont.)

- Every node on the network has a routing table
  - Some computers (multi-homed) have more than one NIC
  - IP uses a routing table for every packet it sends
    - Send directly to a host on a LAN or …
    - Send to the default gateway

Routing Tables (cont.)

- Computer routing table (next slide)
  - More routes than example home router
  - Computer IP address: 10.12.14.201/24
  - Computer loopback: 127.0.0.1
  - **Metric**: a relative value defining the "cost" of using a route
    - When more than one route to a destination, lower metric is used
    - When route with lower metric goes down, other route used

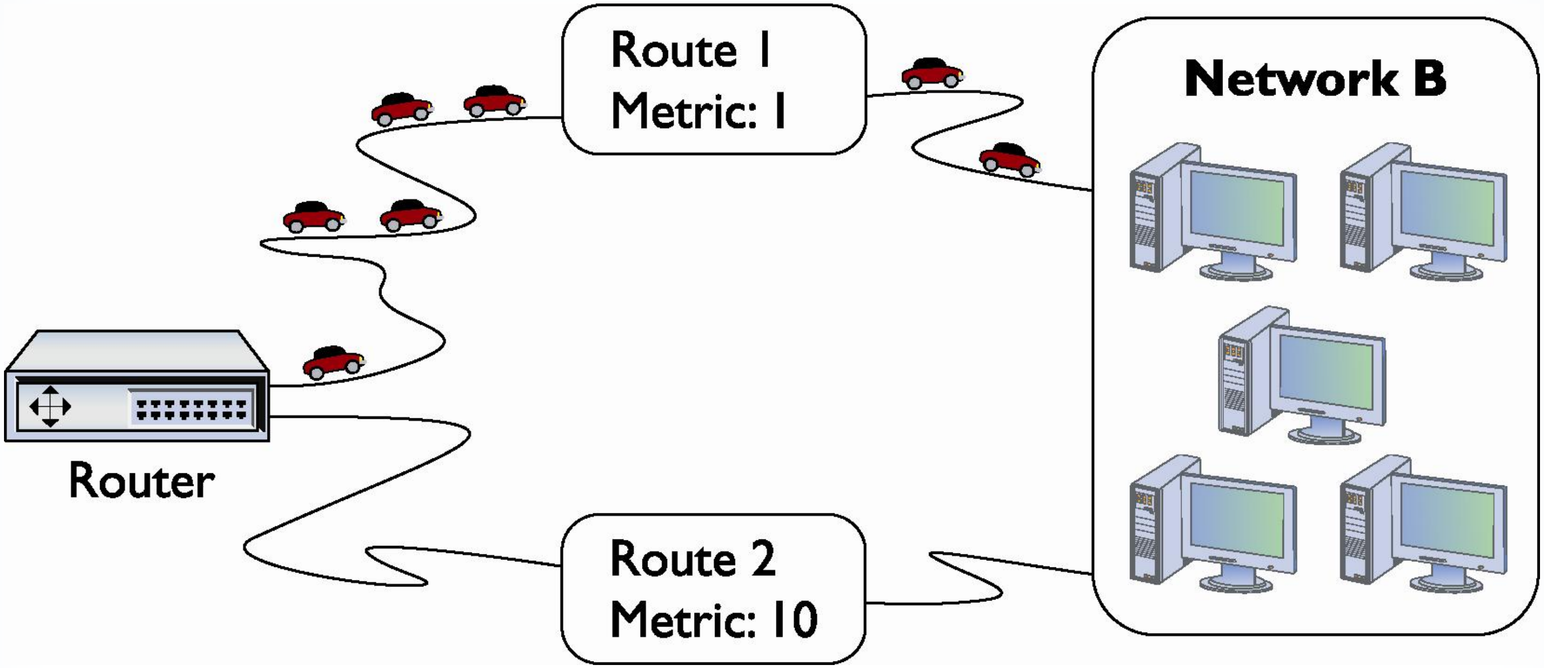


Figure 8.10 Two routes to the same network

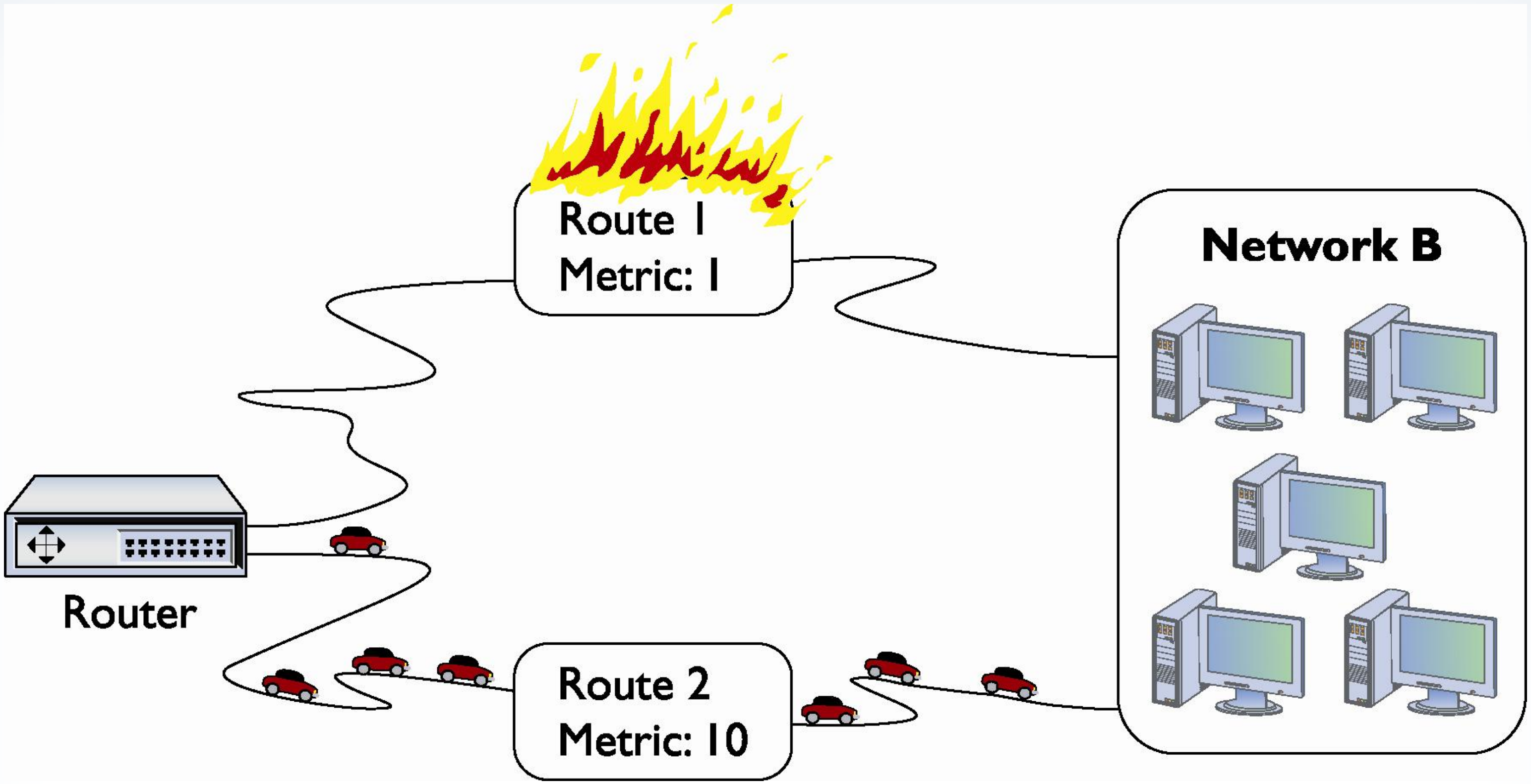


Figure 8.11 When a route no longer works, the router automatically switches

Routing Tables (cont.)

- Computer routing table (next slide)
  - Line 1 (beginning 0.0.0.0) defines default route
  - Line 2 defines local connections
  - Line 3 defines loopback as 127.0.0.1
  - Line 4 defines loopback as any 127/8 address
  - Line 5 defines action for APIPA addresses
  - Line 6 defines action for multicast addresses
  - Line 7 defines action for broadcast packets
  - Line 8 defines default gateway address

```
C:\>route print
===========================================================================
Interface List
0x1 ........................... MS TCP Loopback Interface
0x2...00 11 d8 30 16 c0 ....... NVIDIA nForce Networking Controller
===========================================================================
===========================================================================
Active Routes
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0       10.12.14.1   10.12.14.201       1
       10.12.14.0    255.255.255.0     10.12.14.201   10.12.14.201       1
     10.12.14.201  255.255.255.255        127.0.0.1      127.0.0.1       1

        127.0.0.1        255.0.0.0        127.0.0.1      127.0.0.1       1
      169.254.0.0      255.255.0.0     10.12.14.201   10.12.14.201      20
        224.0.0.0        240.0.0.0     10.12.14.201   10.12.14.201       1
  255.255.255.255  255.255.255.255     10.12.14.201   10.12.14.201       1
 Default Gateway:       10.12.14.1
===========================================================================
Persistent Routes:
  None
```

Routing table on an XP computer connected to Figure 8.7 router

Routing Tables (cont.)

- XP route print vs. Win7 route print
  - XP: gateway for local destination is shown as local NIC IP
  - Win7: gateway for local traffic is shown as “on-link”

```
===========================================================================
IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0      192.168.1.1    192.168.1.77    276
        127.0.0.0        255.0.0.0         On-link        127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link        127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link        127.0.0.1    306
      169.254.0.0      255.255.0.0         On-link     192.168.1.77     30
  169.254.255.255  255.255.255.255         On-link     192.168.1.77    276
      192.168.1.0    255.255.255.0         On-link     192.168.1.77    276
     192.168.1.77  255.255.255.255         On-link     192.168.1.77    276
    192.168.1.255  255.255.255.255         On-link     192.168.1.77    276
        224.0.0.0        240.0.0.0         On-link        127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link     192.168.1.77    276
  255.255.255.255  255.255.255.255         On-link        127.0.0.1    306
  255.255.255.255  255.255.255.255         On-link     192.168.1.77    276
===========================================================================
Persistent Routes:
  Network Address          Netmask  Gateway Address  Metric
          0.0.0.0          0.0.0.0      192.168.1.1  Default
===========================================================================
```

IPv4 portion of Win7 route print command

- Freedom from Layer 2
  - Routers can connect different network technologies
  - Routers strip off all Layer 2 data
  - Routers can connect almost anything that stores IP packets
  - Non-Ethernet network technologies
    - Data Over Cable Service Interface Specification (DOCSIS)
    - Frame Relay
    - Asynchronous Transfer Mode

Spanning Tree Protocol

- **Spanning Tree Protocol** enables switches to detect and repair bridge loops automatically

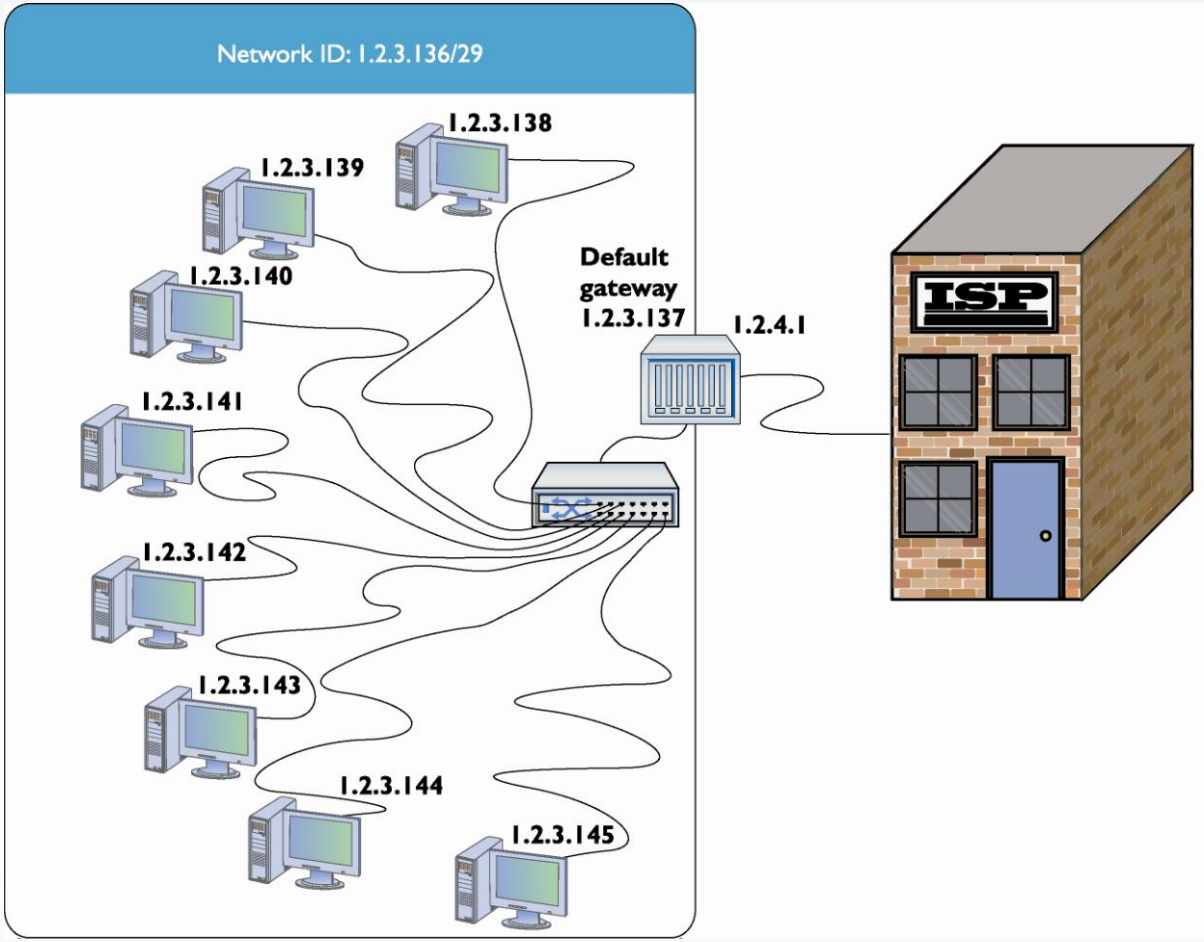


Figure 8.13 Network setup

Dynamic Routing

Background

Routers have static routes

I. Manually entered
II. Detected at setup by the router

Background (cont.)

Dynamic routing protocols defined

I. Routers communicate among themselves with change information
II. Update each other on changes about direct connections and distant routers
III. A passage of a packet through a single router is a hop

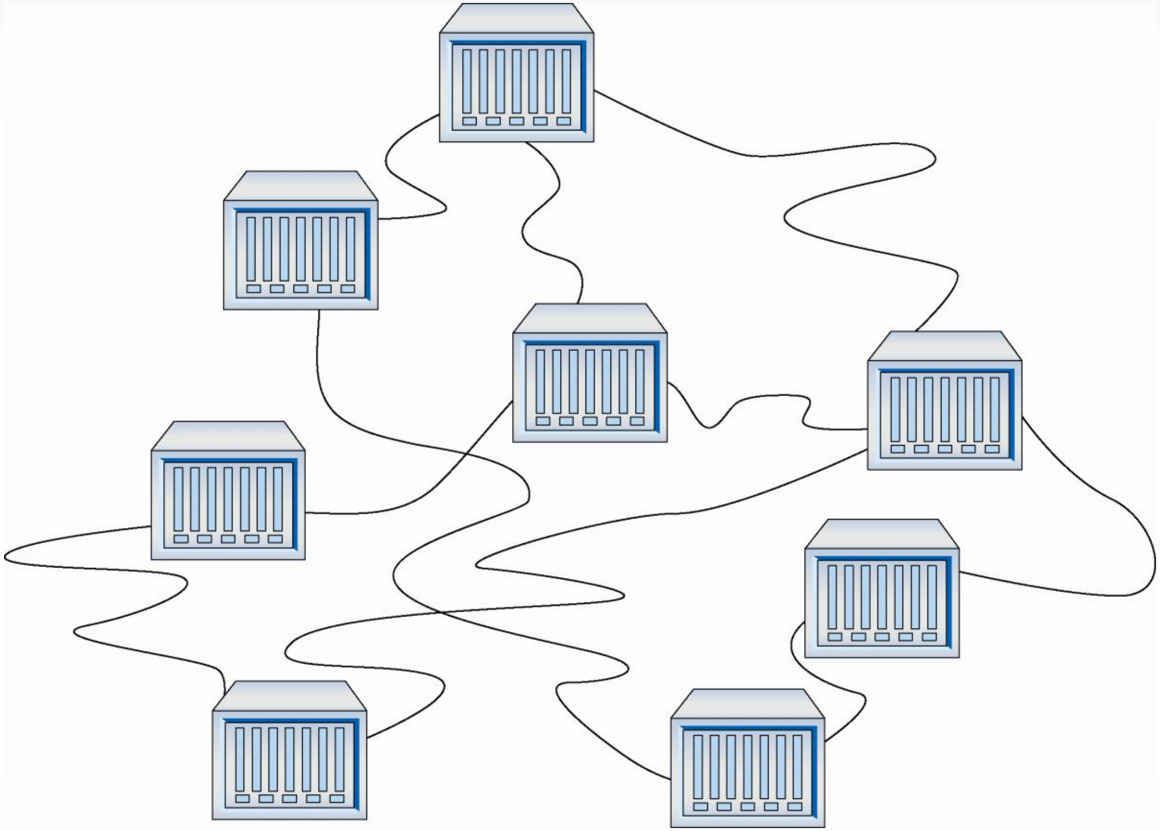


Figure 8.22 Lots of routers

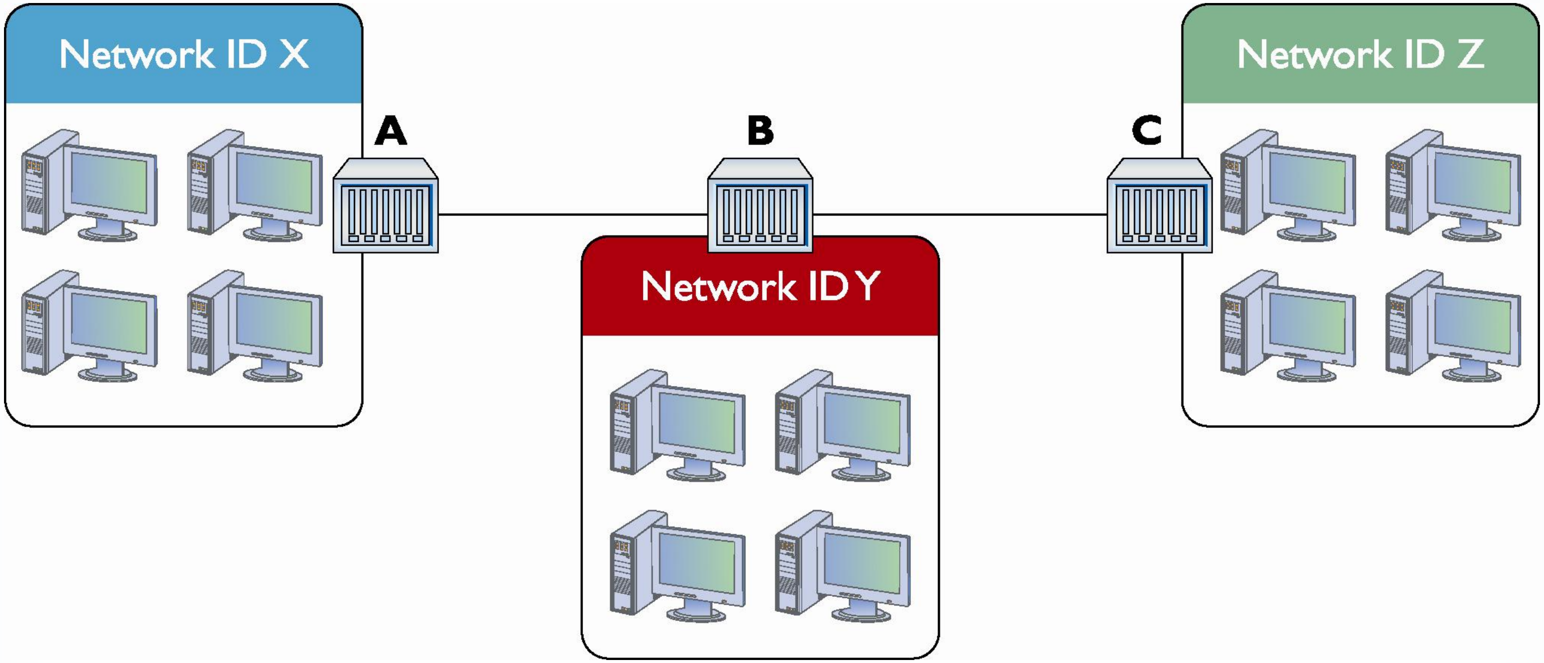


Figure 8.23 Hopping through a WAN

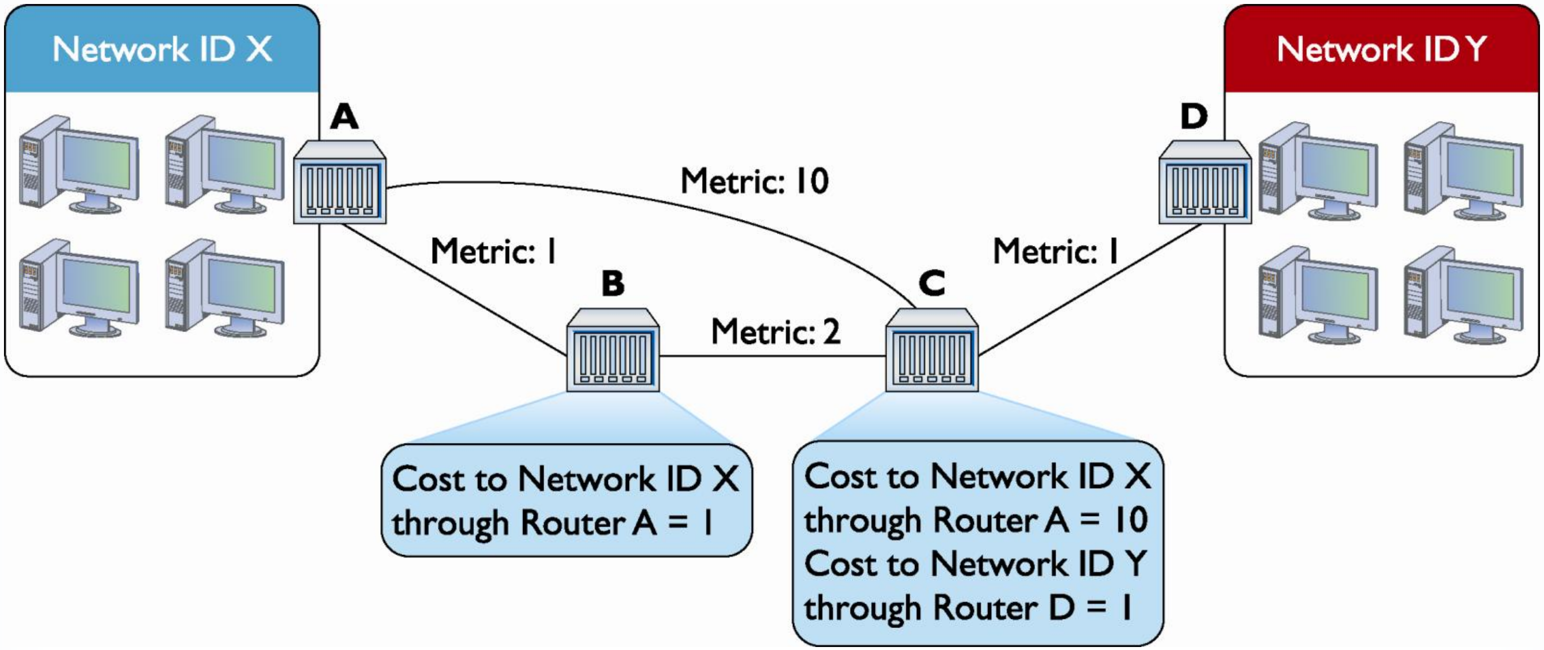


Figure 8.25 Routes updated

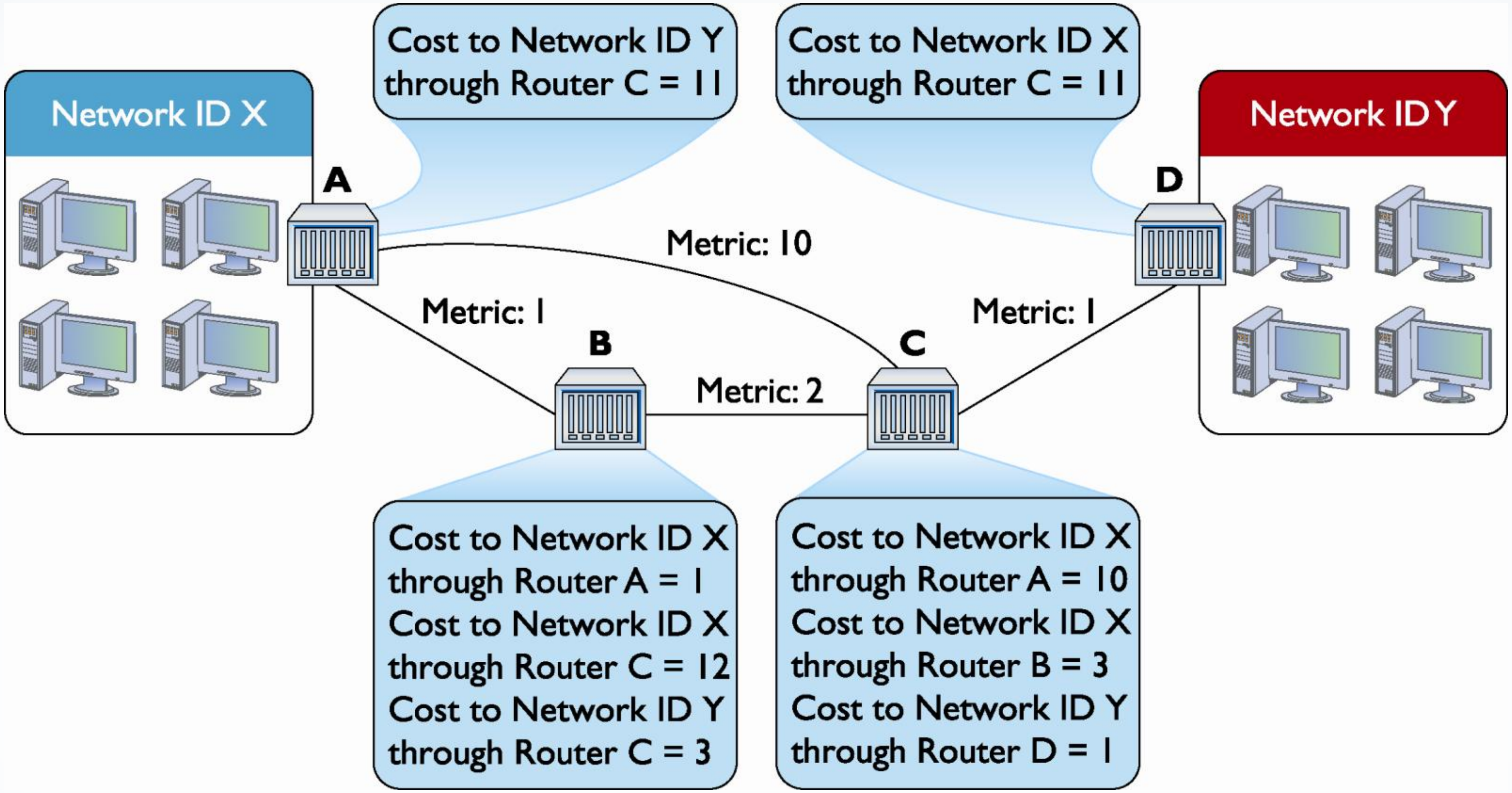


Figure 8.26 Updated routing tables

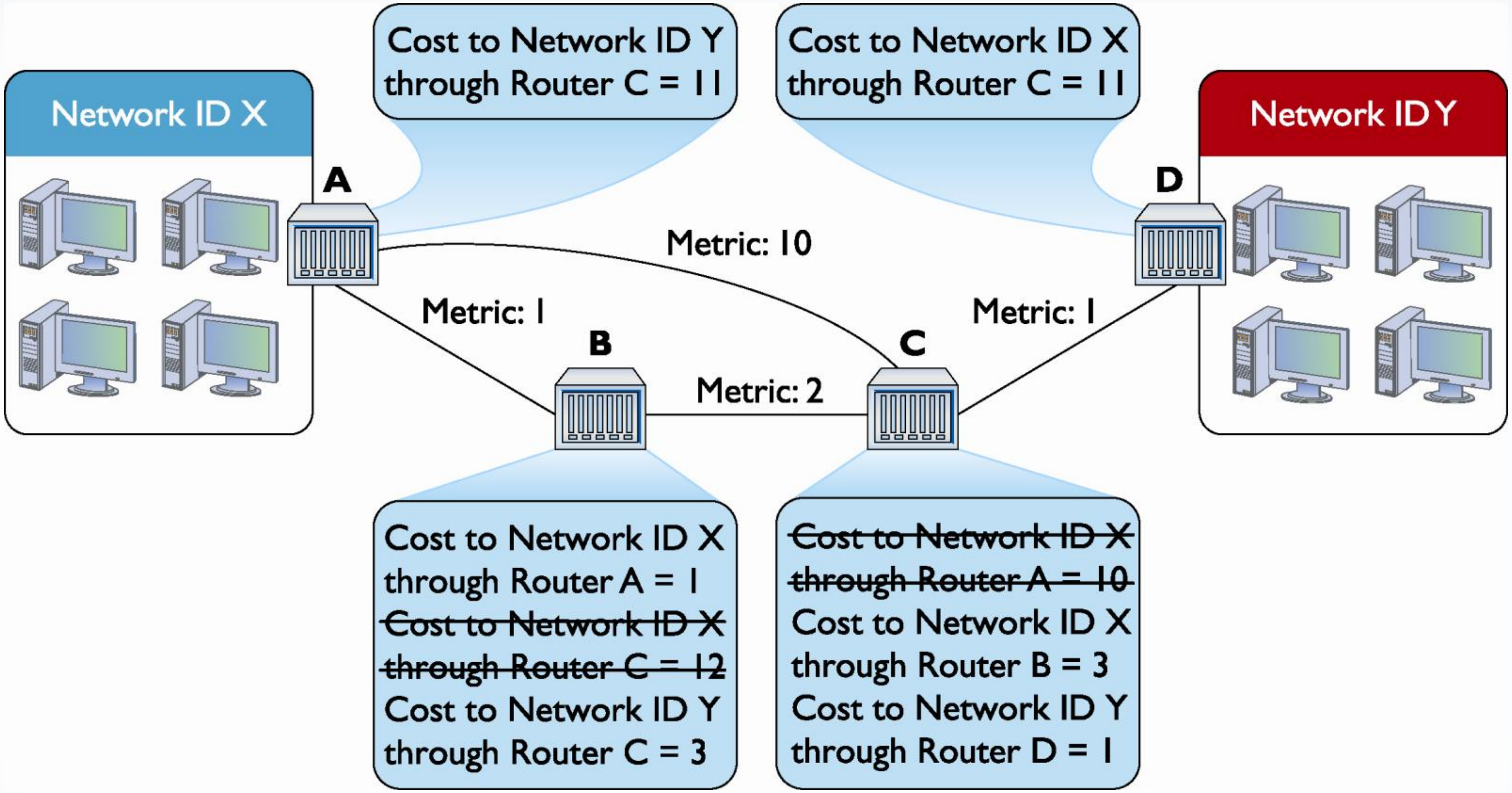


Figure 8.27 Deleting higher-cost routes

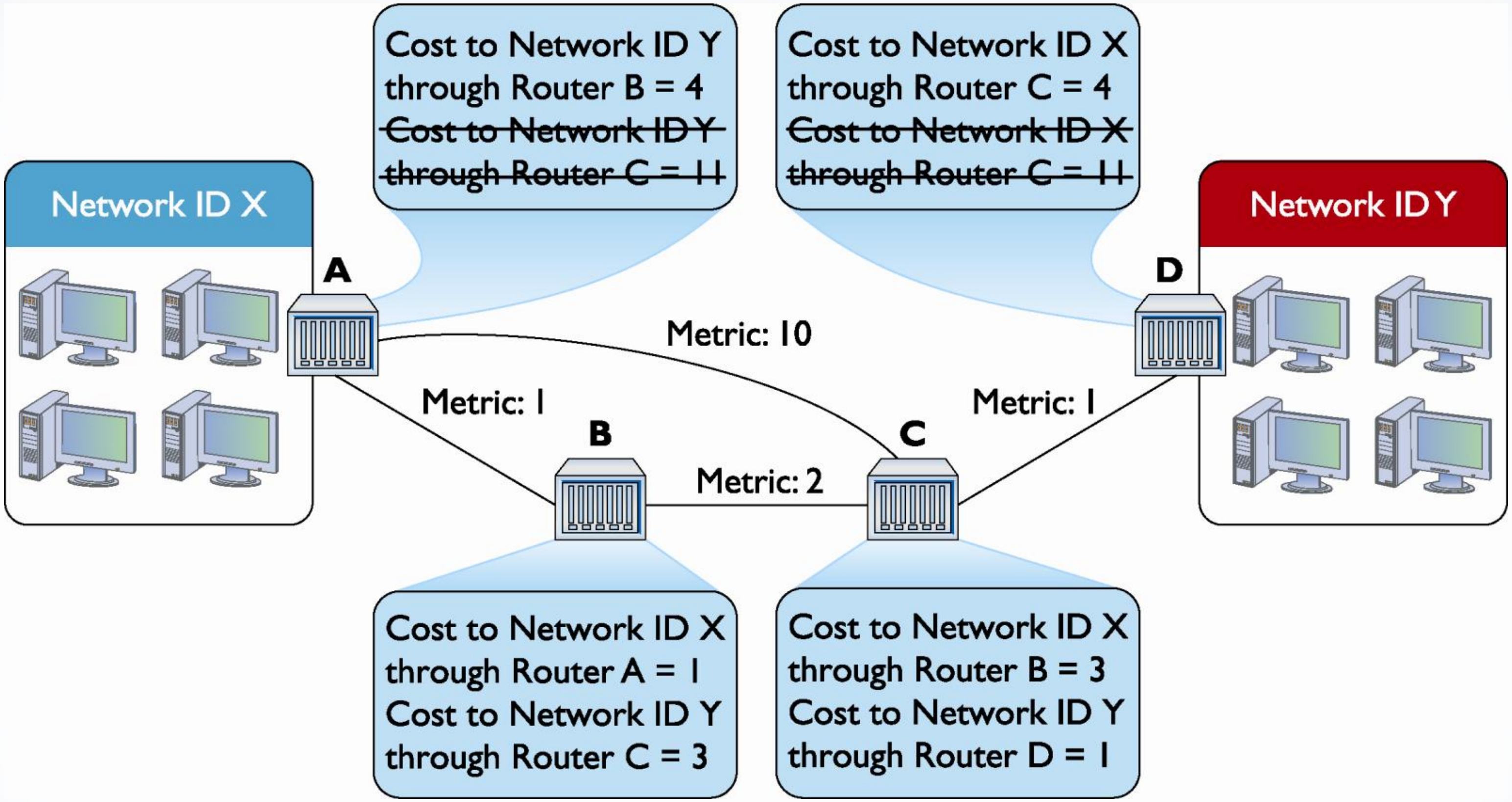


Figure 8.28 Argh! Multiple routes!

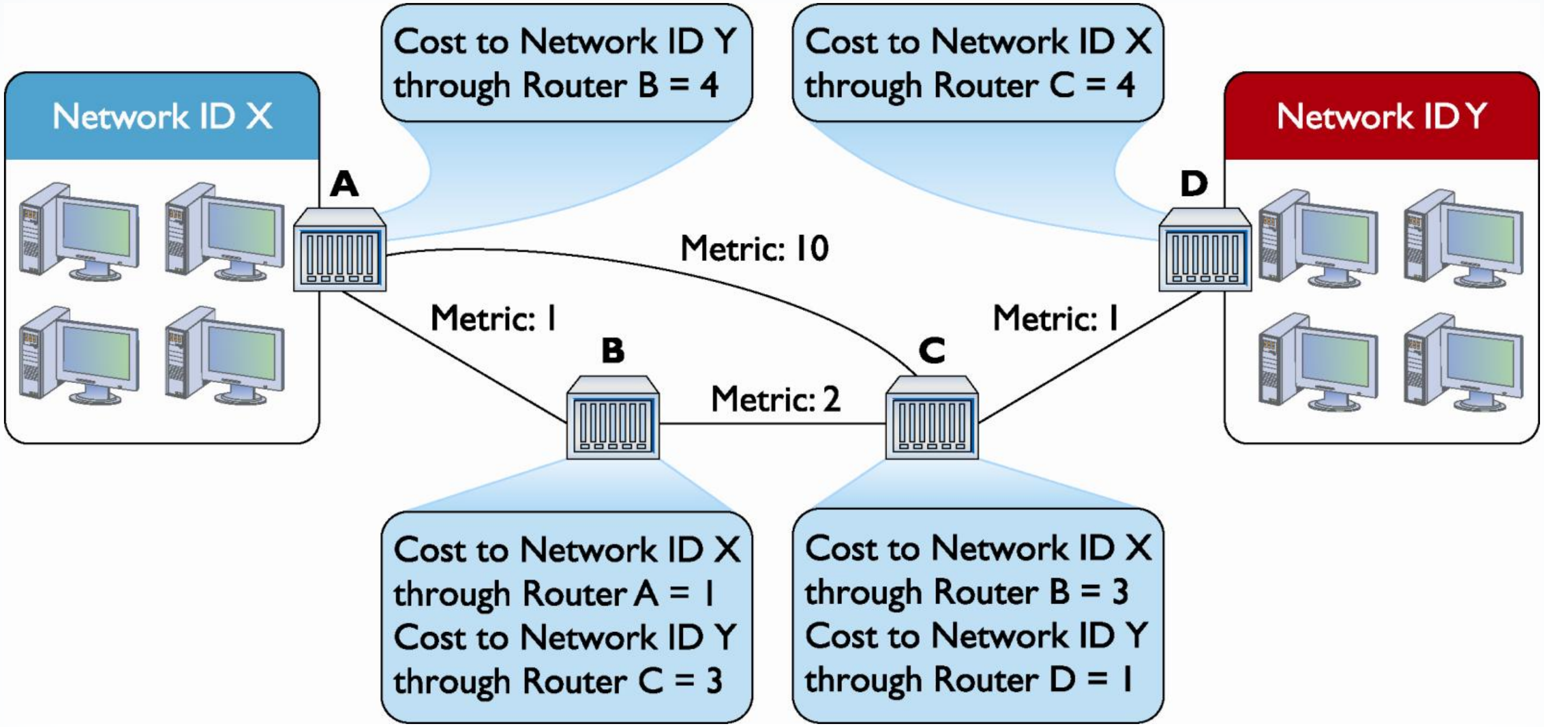


Figure 8.29 Last iteration

Interior Gateway Protocols (IGPs)

Handle routing within an Autonomous System (one routing domain). In plain English, IGP's figure out how to get from place to place between the routers you own. These dynamic routing protocols keep track of paths used to move data from one end system to another inside a network or set of networks.

Exterior Gateway Protocol (EGP)

Exterior Gateway Protocols handle routing outside an Autonomous System and get you from your network through your Internet provider's network and onto any other network. BGP is used by companies with more than one Internet provider to allow them to have redundancy and load balancing of their data transported to and from the Internet.

Maximum transmission unit (**MTU**) of a communications protocol of a layer is the size (in bytes) of the largest protocol data unit that the layer can pass onwards.

Network bandwidth a measurement of bit-rate of available or consumed data communication resources expressed in bits per second or multiples of it (bit/s, kbit/s, Mbit/s, Gbit/s, etc.).

IEEE 802.1Q is the networking standard that supports virtual LANs (VLANs) on an Ethernet network

Next hop is a routing term that refers to the next closest router a packet can go through.

Port Mirroring

- Port mirroring is an approach to monitoring network traffic that involves forwarding a copy of each packet from one network switch port to another.

Broadcast Domain

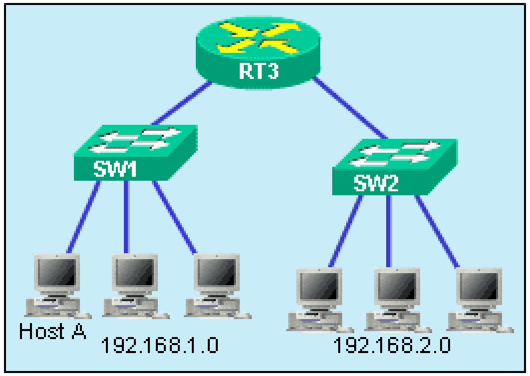
- A **Broadcast Domain** (or Collision Domain) is a network of computers that will hear each other's broadcasts.

-layer 2 of the OSI model

- a switch creates an entire broadcast domain (provided that there's only one VLAN) since broadcasts are a layer 2 concept (mac address related) .

- routers don't forward layer 2 broadcasts, hence they separate broadcast domains

A broadcast domain is a logical division of a computer network, in which all nodes can reach each other by broadcast at the data link layer.



2 broadcast domains (1 router that separates 2 LAN segments composed by one or many switches, with only 1 VLAN per segment). There are 6 collision domains in the diagram above

Collision Domain

- A **collision domain** is, as the name implies, a part of a network where packet collisions can occur. A collision occurs when two devices send a packet at the same time on the shared network segment
- The packets collide and both devices must send the packets again, which reduces network efficiency. Collisions are often in a hub environment, because each port on a hub is in the same collision domain. By contrast, each port on a bridge, a switch or a router is in a separate collision domain