Chapter Nine

Introduction to Metropolitan Area Networks and Wide Area Networks

Data Communications and Computer Networks: A Business User's Approach

Eighth Edition

After reading this chapter, you should be able to:

- Distinguish local area networks, metropolitan area networks, and wide area networks from each other
- Identify the characteristics of metropolitan area networks and compare to LANs and WANs
- Describe how circuit-switched, datagram packet-switched, and virtual circuit packet-switched networks work
- Identify the differences between connection-oriented and connectionless networks

After reading this chapter, you should be able to:

- Describe the differences between centralized and distributed routing
- Describe the differences between static and adaptive routing
- Document the main characteristics of flooding and use hop count and hop limit in a simple example
- Discuss the basic concepts of network congestion, including quality of service

Introduction

- As we have seen, a local area network covers a room, a building or a campus.
- A metropolitan area network (MAN) covers a city or a region of a city.
- A wide area network (WAN) covers multiple cities, states, countries, and even the solar system.

Metropolitan Area Network Basics

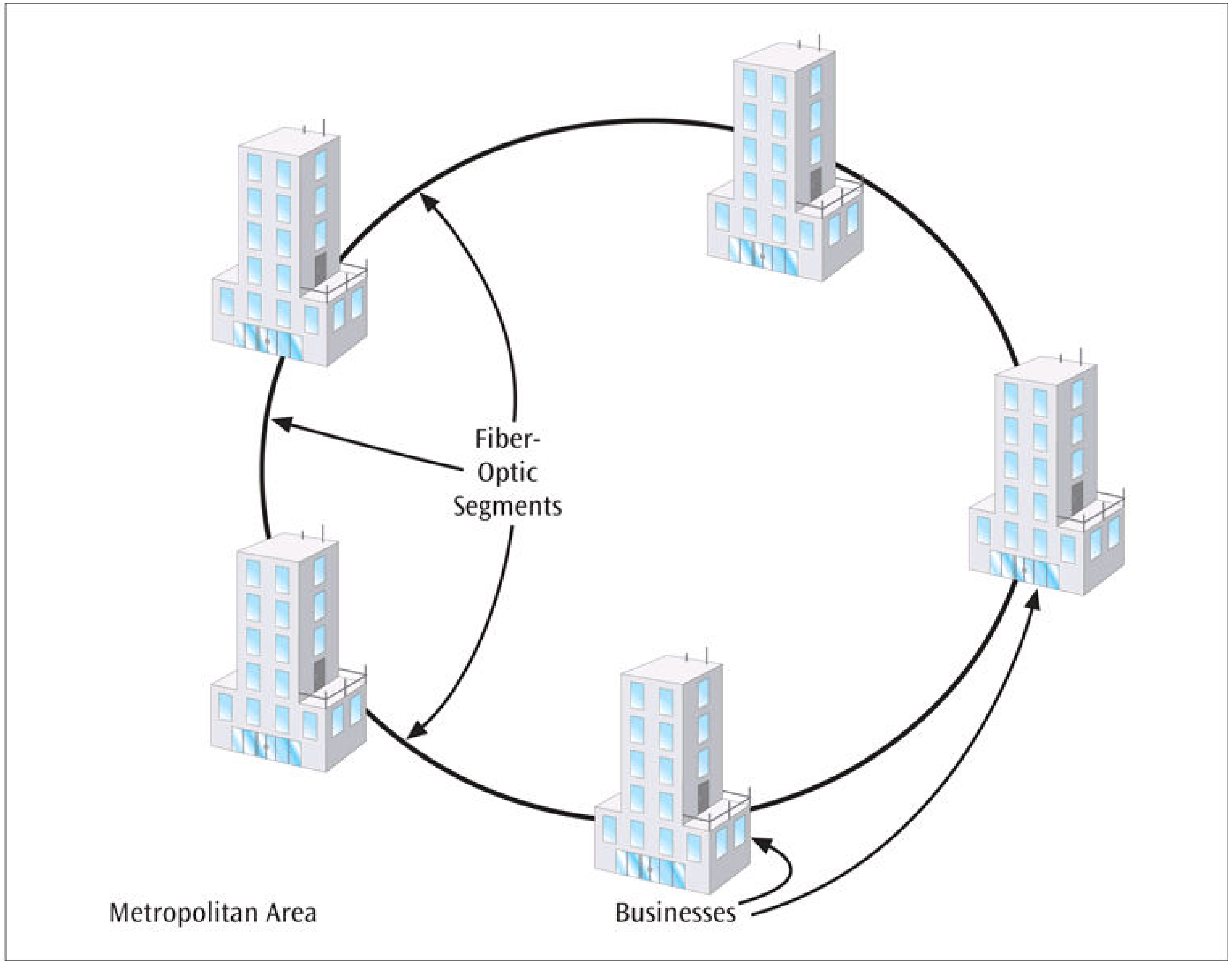
- MANs borrow technologies from LANs and WANs.
- MANs support high-speed disaster recovery systems, real-time transaction backup systems, interconnections between corporate data centers and Internet service providers, and government, business, medicine, and education high-speed interconnections.
- Almost exclusively fiber optic systems

Metropolitan Area Network Basics

- MANs have very high transfer speeds
- MANs can recover from network faults very quickly (failover time)
- MANs are very often a ring topology (not a star-wired ring)
- Some MANs can be provisioned dynamically

Metropolitan Area Network Basics

Figure 9-1
A physical ring used to support a metropolitan area network

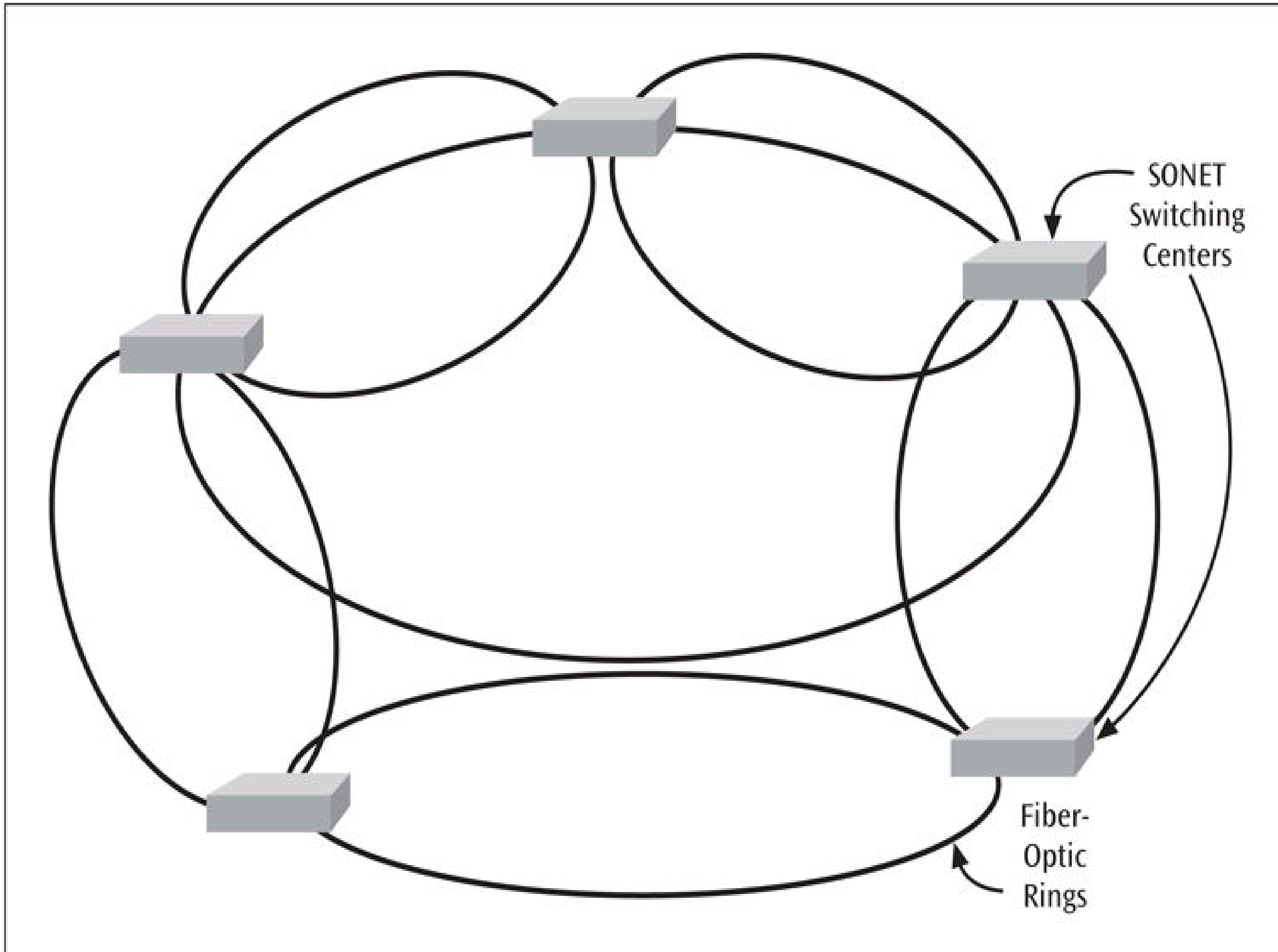


SONET versus Ethernet MANs

- Most MANs are SONET network built of multiple rings (for failover purposes)
- SONET is well-proven but complex, fairly expensive, and cannot be provisioned dynamically.
- SONET is based upon T-1 rates and does not fit nicely into 1 Mbps, 10 Mbps, 100 Mbps, 1000 Mbps chunks, like Ethernet systems do.
- Ethernet MANs generally have high failover times

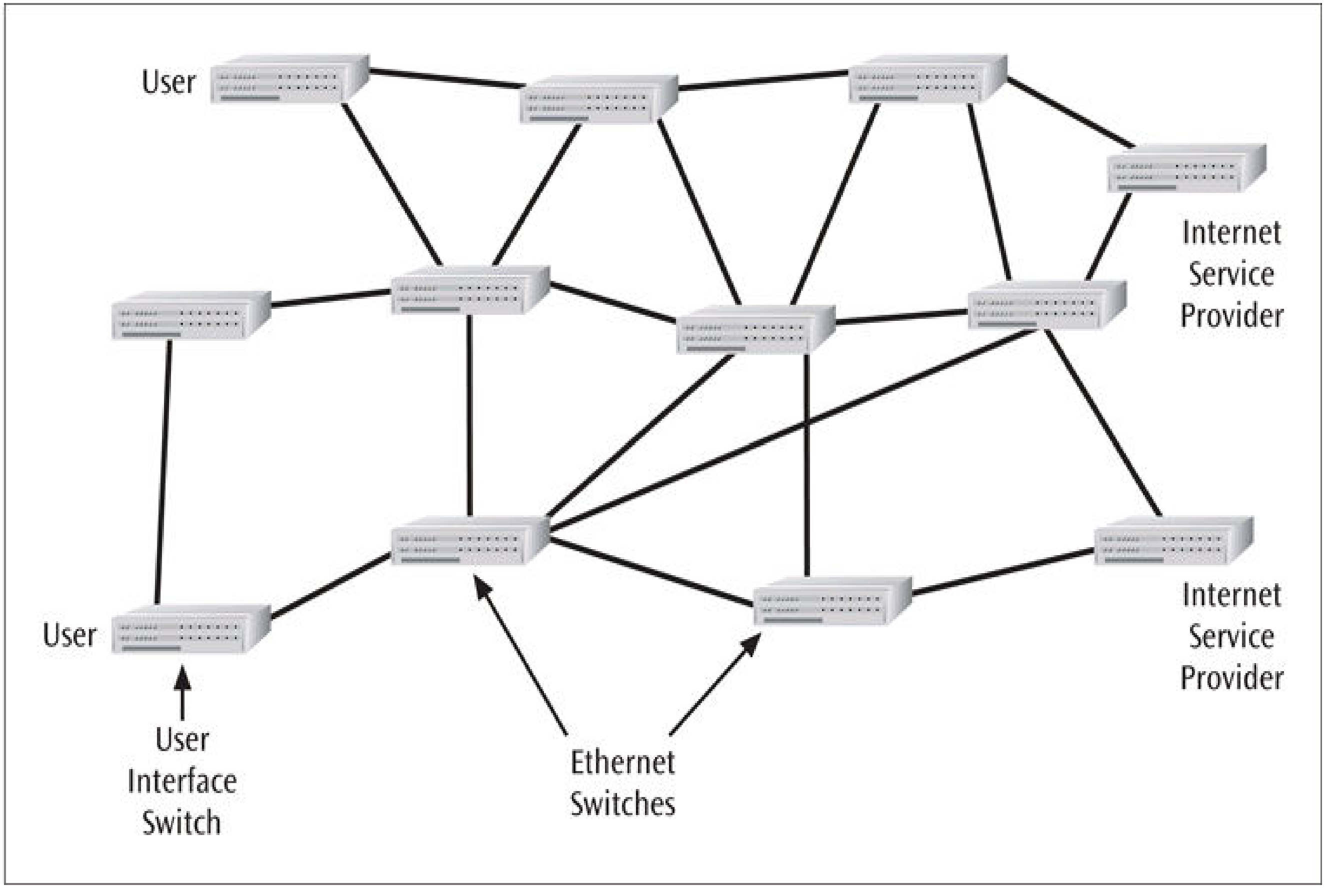
SONET versus Ethernet MANs

Figure 9-2
SONET systems are comprised of multiple rings



SONET versus Ethernet MANs

Figure 9-3
The Ethernet MAN topology

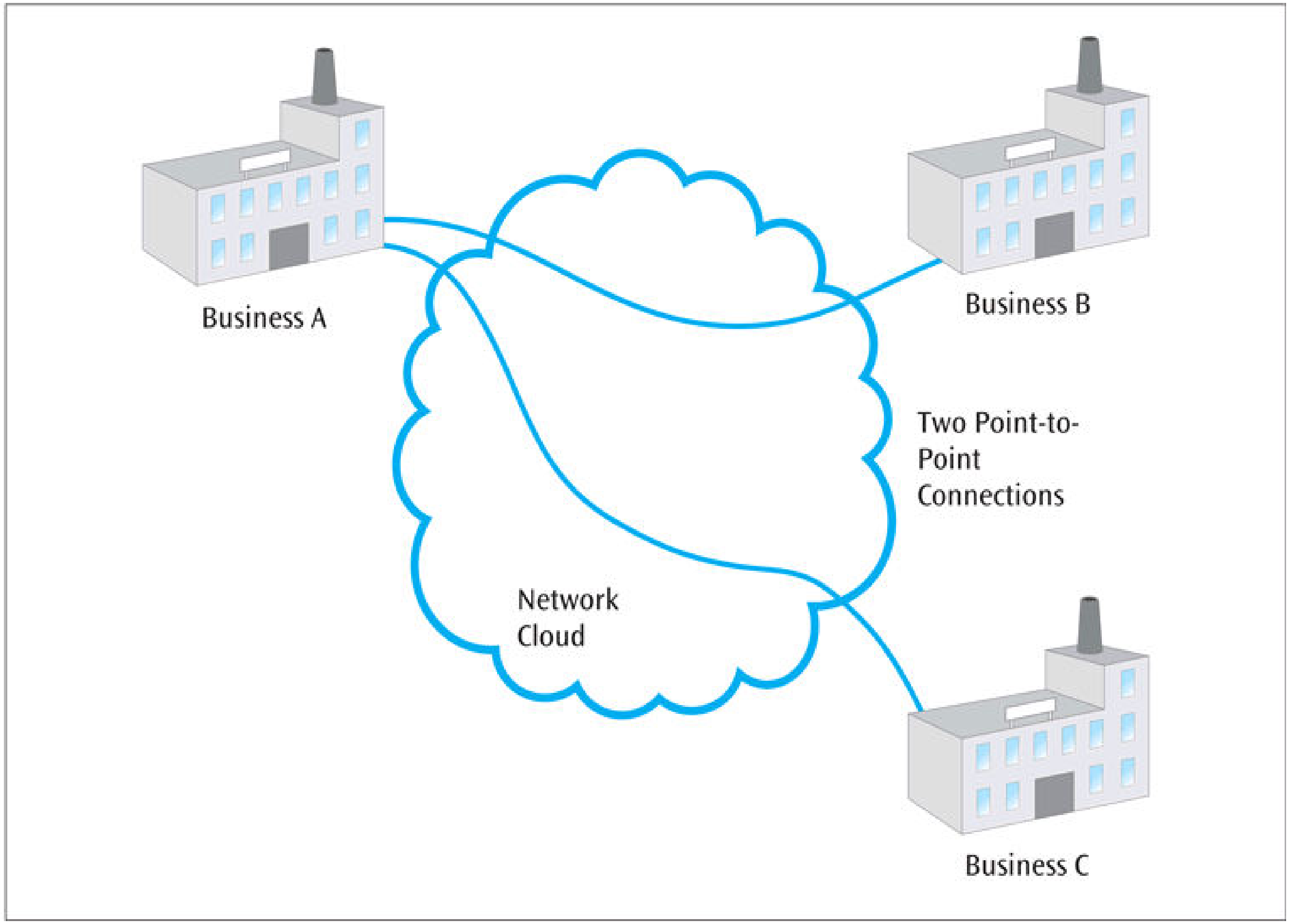


Metro Ethernet

- One of the latest forms of the metropolitan area network is *metro Ethernet*
- Metro Ethernet is a service in which the provider creates a door-to-door Ethernet connection between two locations
- For example, you may connect your business with a second business using a point-to-point Ethernet connection (Figure 9-4a)

Metro Ethernet

Figure 9-4 (a)
Two point-to-point connections

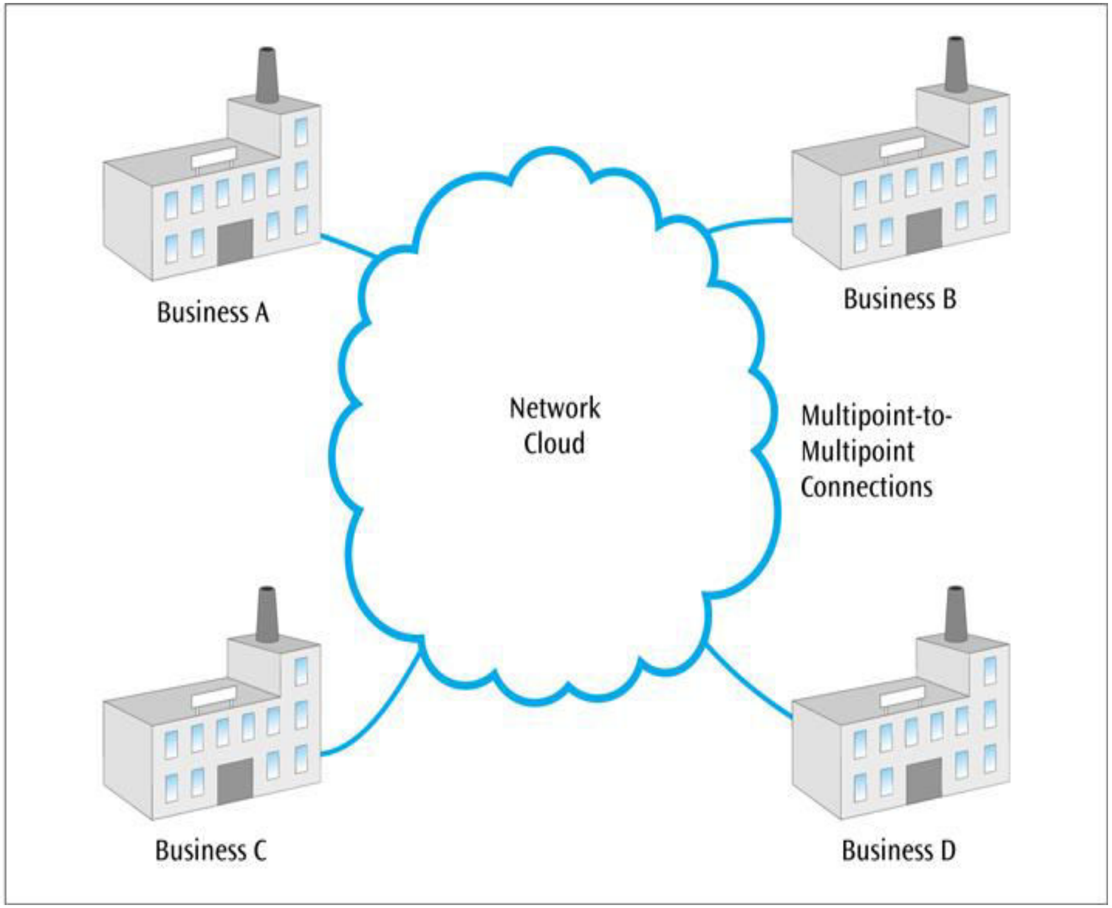


Metro Ethernet

- You may also connect your business with multiple businesses using a connection similar to a large local area network (Figure 9-4b)
- Thus, by simply sending out one packet, multiple companies may receive the data
- Neat thing about metro Ethernet is the way it seamlessly connects with a company’s internal Ethernet network(s)

Metro Ethernet

Figure 9-4(b) Multipoint-to-multipoint connections

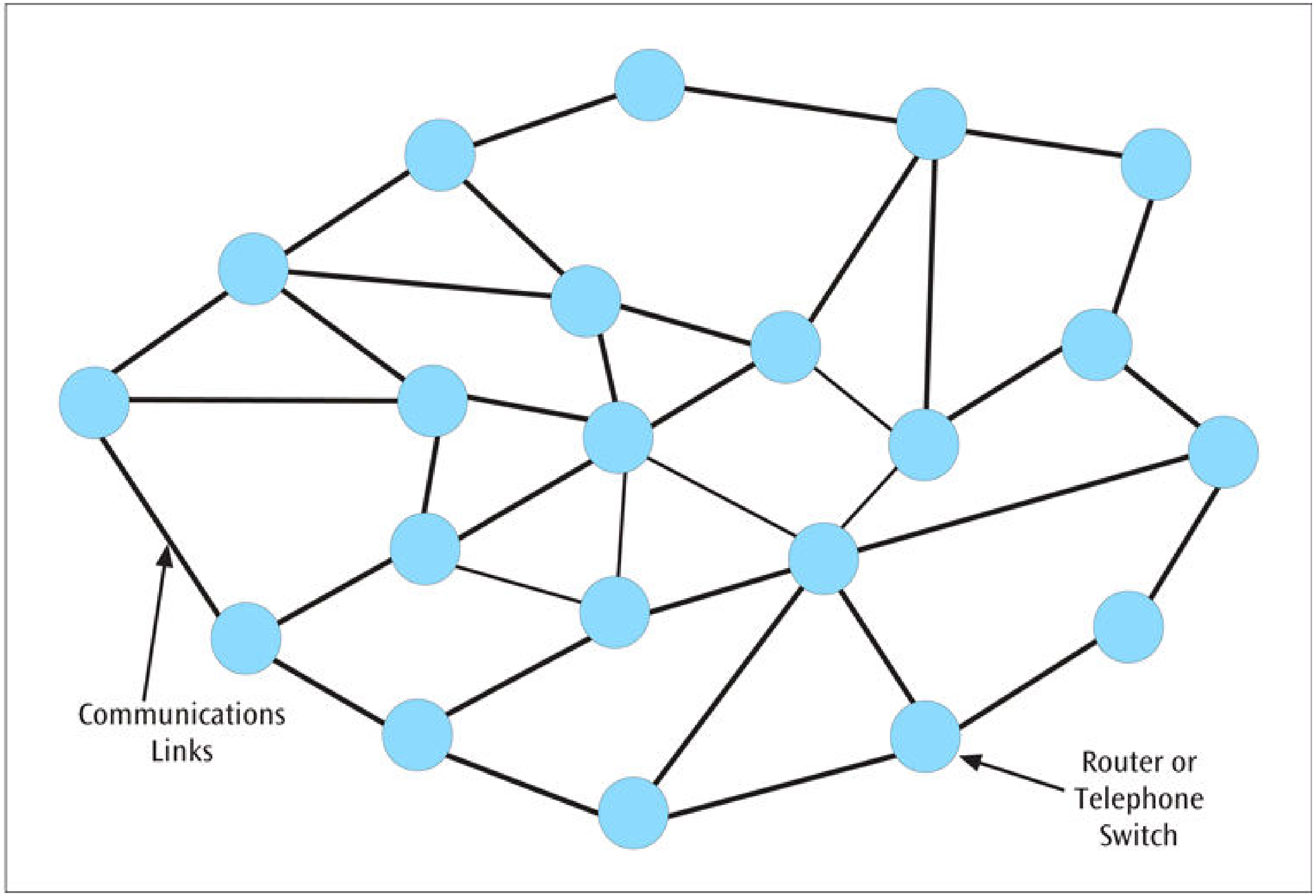


Wide Area Network Basics

- WANs used to be characterized with slow, noisy lines.
- Today WANs are very high speed with very low error rates.
- WANs usually follow a *mesh* topology.

Wide Area Network Basics

Figure 9-5
A simple mesh network

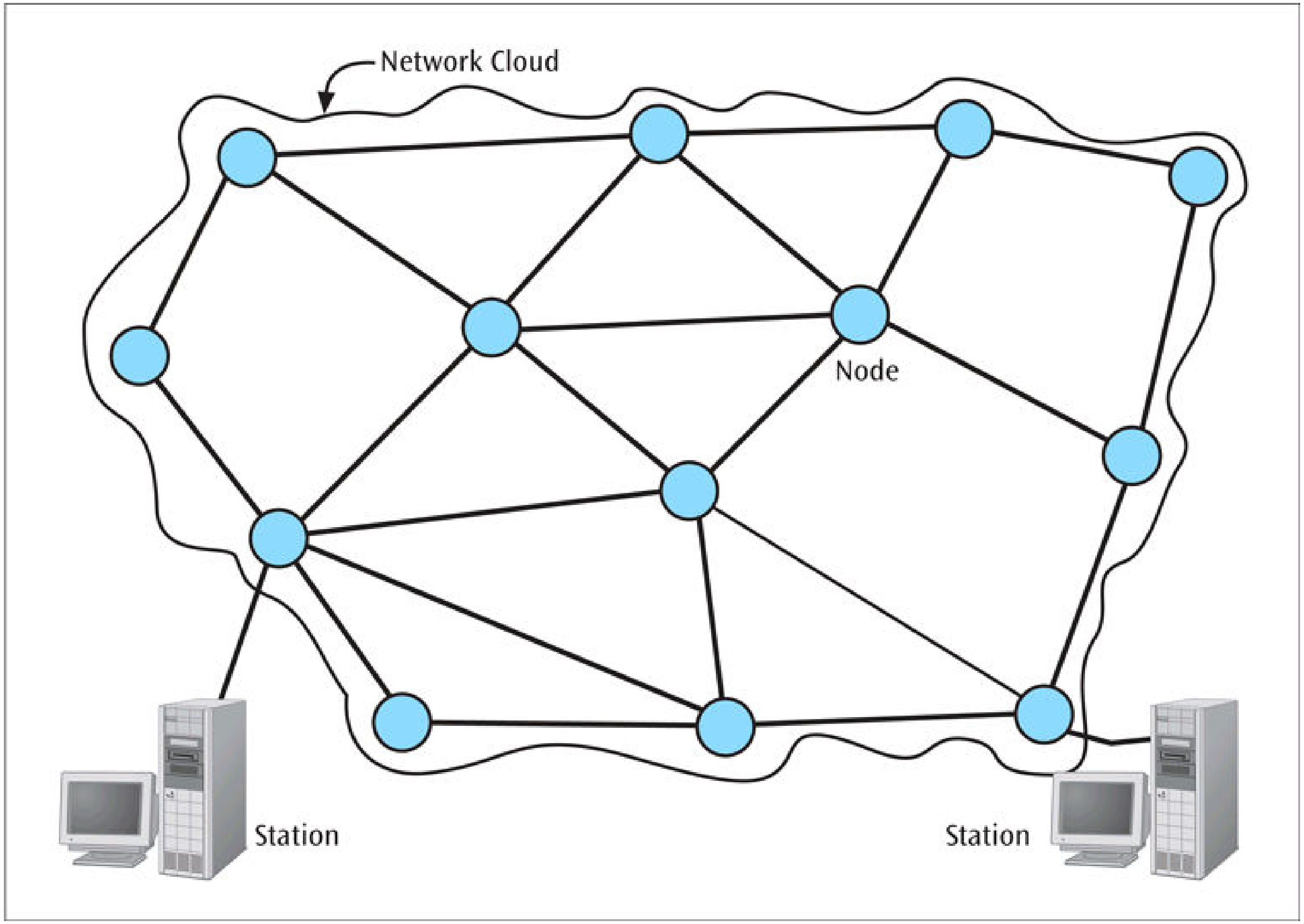


Wide Area Network Basics

- A *station* is a device that interfaces a user to a network.
- A *node* is a device that allows one or more stations to access the physical network and is a transfer point for passing information through a network.
- A node is often a computer, a router, or a telephone switch.
- The *sub-network* or physical network is the underlying connection of nodes and telecommunication links.

Wide Area Network Basics

Figure 9-6
Network cloud, nodes, and two end stations

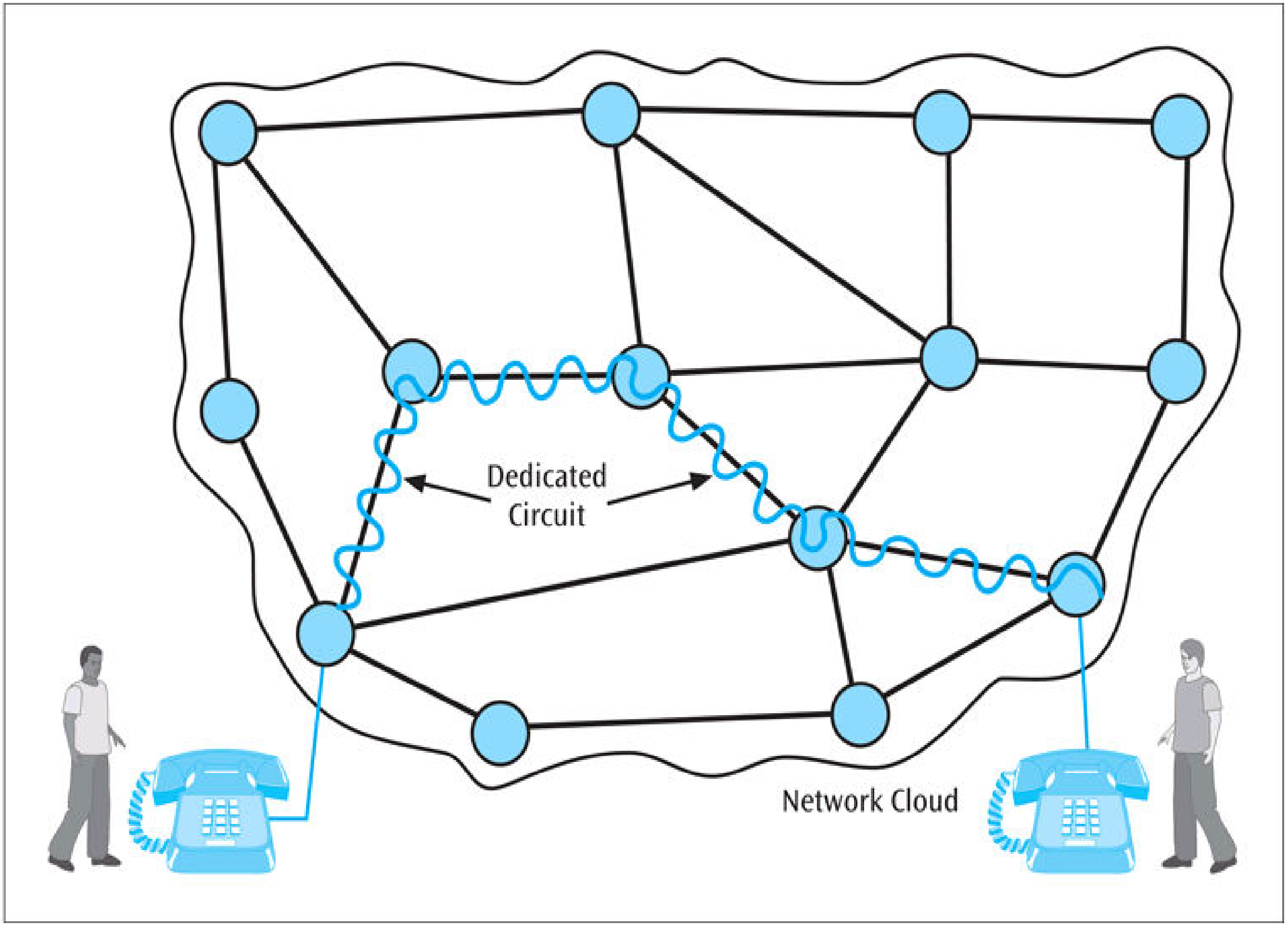


Types of Network Structures

- *Circuit switched network* - a sub-network in which a dedicated circuit is established between sender and receiver and all data passes over this circuit.
- The telephone system is a common example.
- The connection is dedicated until one party or another terminates the connection.
- AT&T announced end of 2009 that they will begin phasing out their switched networks

Types of Network Structures

Figure 9-7
Two people carrying on a telephone conversation using a circuit-switched network



Types of Network Structures

- *Packet switched network* - a network in which all data messages are transmitted using fixed-sized packages, called packets.
- More efficient use of a telecommunications line since packets from multiple sources can share the medium.
- One form of packet switched network is the *datagram*. With a datagram, each packet is on its own and may follow its own path.
- *Virtual circuit* packet switched network create a logical path through the subnet and all packets from one connection follow this path.

Types of Network Structures

- *Broadcast network* - a network typically found in local area networks but occasionally found in wide area networks.
- A workstation transmits its data and all other workstations “connected” to the network hear the data. Only the workstation(s) with the proper address will accept the data.

Summary of Network Structures

Table 9-1

Summary of network cloud characteristics

Characteristic	Circuit-Switched	Datagram Packet-Switched	Virtual Circuit Packet-Switched	Broadcast
Path setup time?	Yes	No	Yes	No
Routing decision for each packet?	No	Yes	No	Typically no routing
Dedicated path?	Yes	No	No	No
Can dynamically reroute if problems occur?	No	Yes	No	Typically no routing
Connection dedicated to your transfer only?	Yes	No	No	No

Connection-oriented versus Connectionless

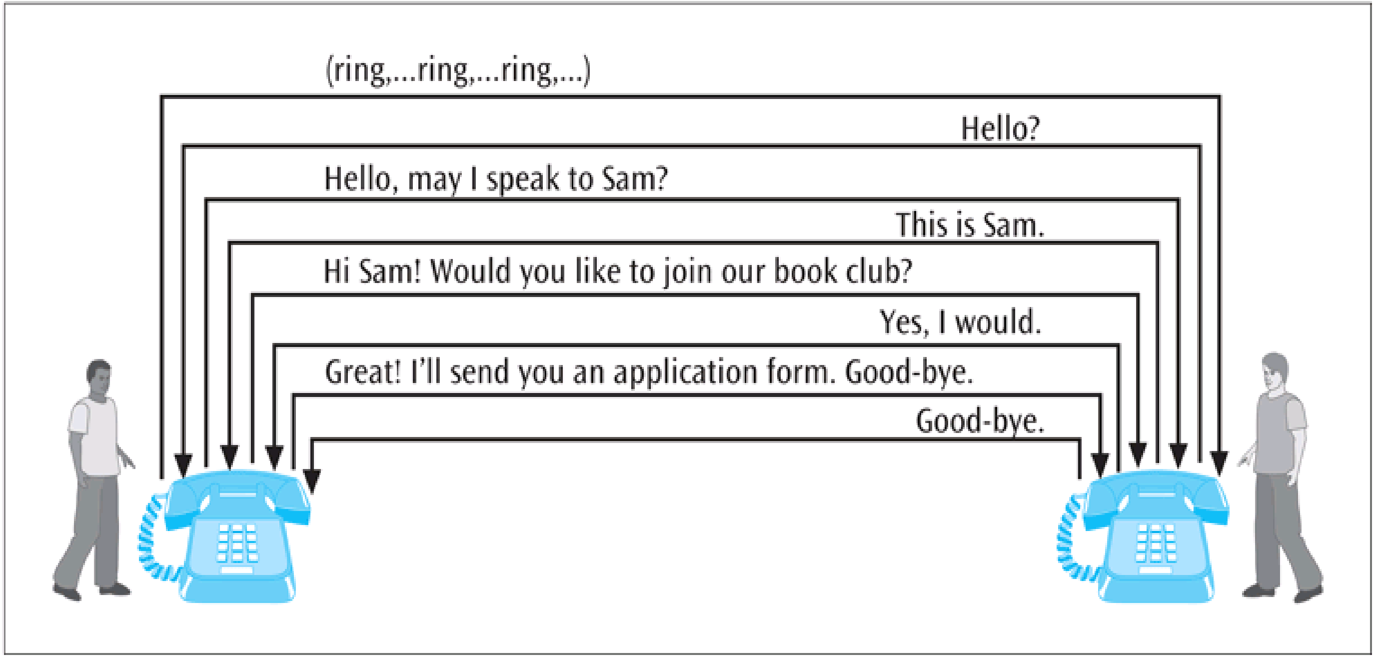
- The network structure is the underlying physical component of a network. What about the software or application that uses the network?
- A network application can be either connection-oriented or connectionless.

Connection-oriented versus Connectionless

- A connection-oriented application requires both sender and receiver to create a connection before any data is transferred.
- Applications such as large file transfers and sensitive transactions such as banking and business are typically connection-oriented.
- A connectionless application does not create a connection first but simply sends the data. Electronic mail is a common example.

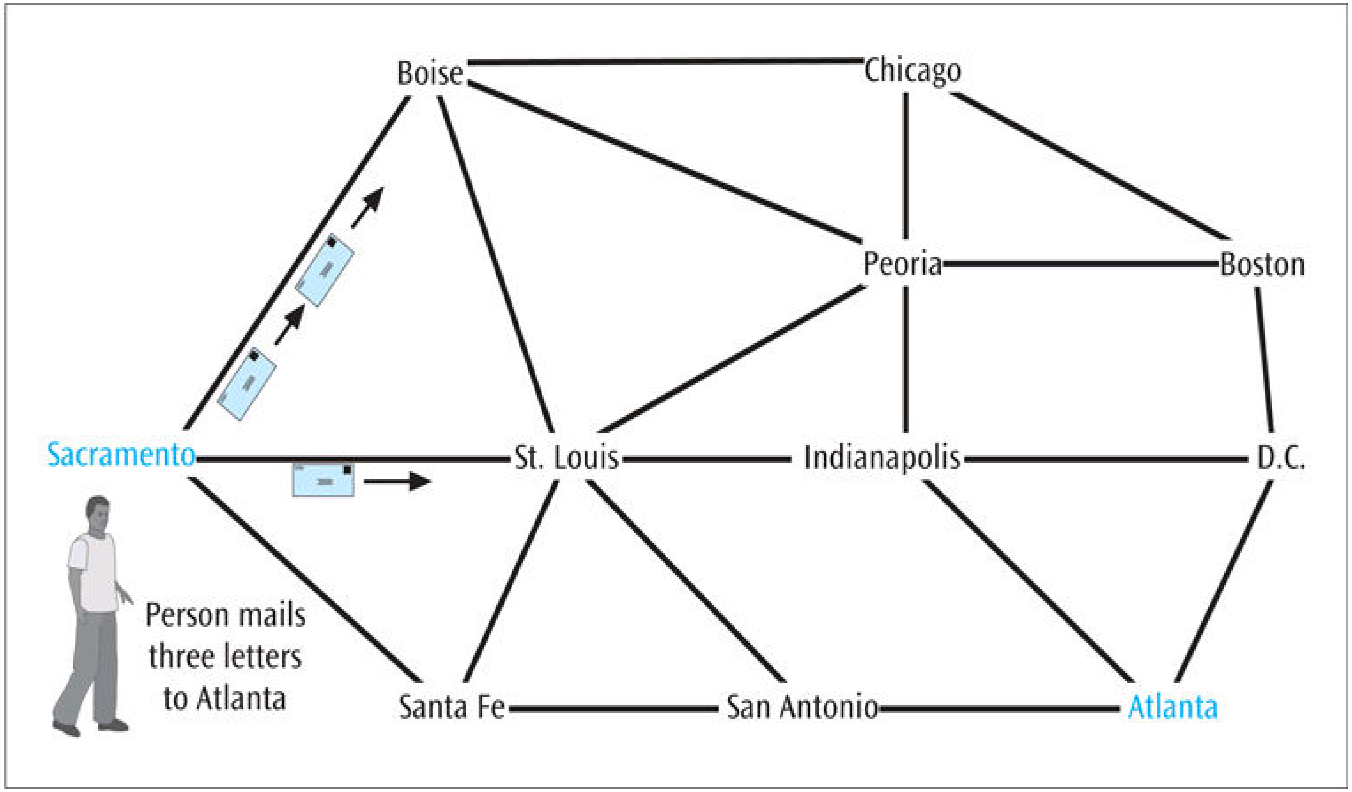
Connection-oriented versus Connectionless

Figure 9-8
Connection-oriented telephone call



Connection-oriented versus Connectionless

Figure 9-9
Connectionless postal network



Connection-oriented versus Connectionless

- A connection-oriented application can operate over both a circuit switched network or a packet switched network.
- A connectionless application can also operate over both a circuit switched network or a packet switched network but a packet switched network may be more efficient.

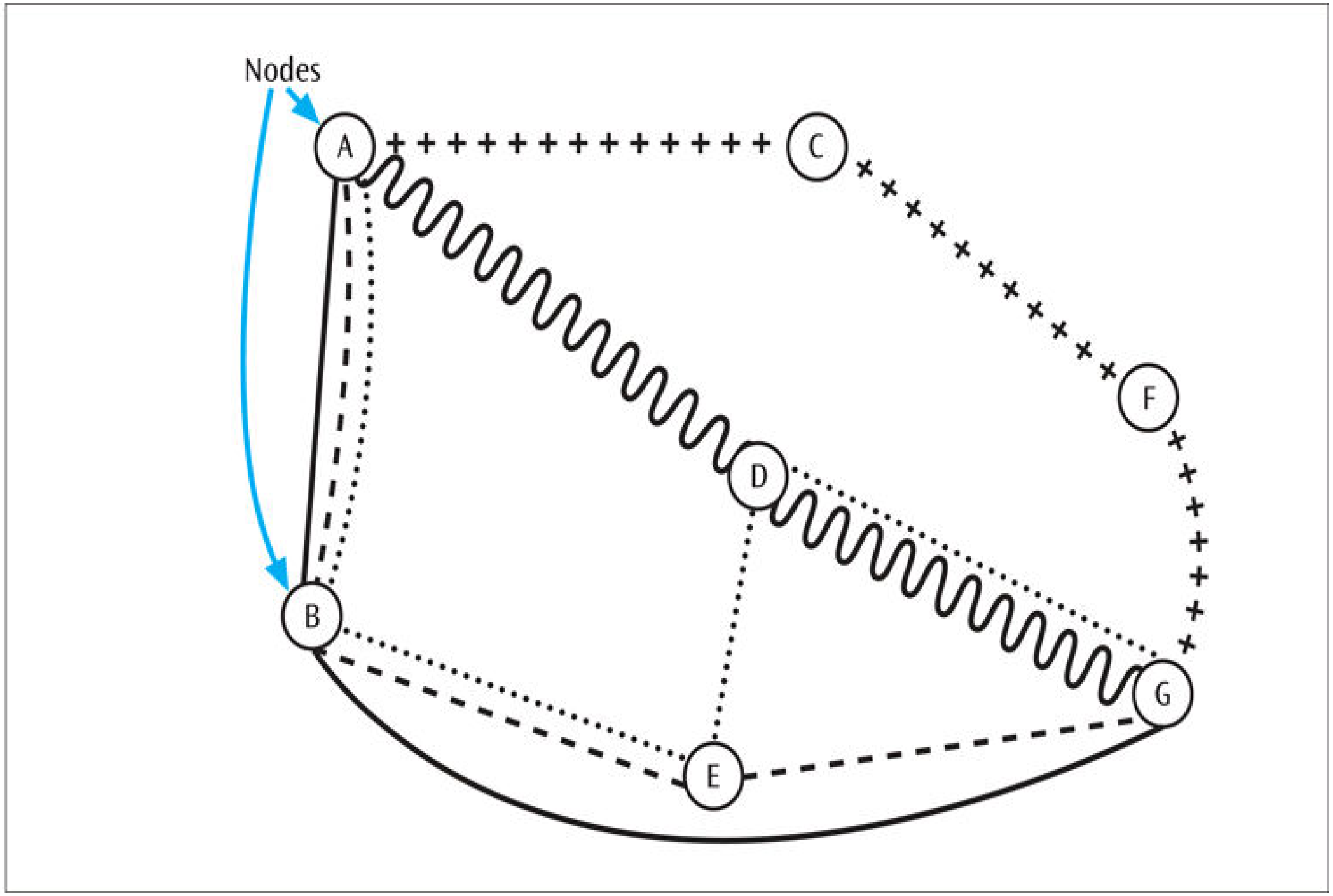
Routing

- Each node in a WAN is a router that accepts an input packet, examines the destination address, and forwards the packet on to a particular telecommunications line.
- How does a router decide which line to transmit on?
- A router must select the one transmission line that will best provide a path to the destination and in an optimal manner.
- Often many possible routes exist between sender and receiver.

Routing

Figure 9-10

A seven-node network showing multiple routes between nodes

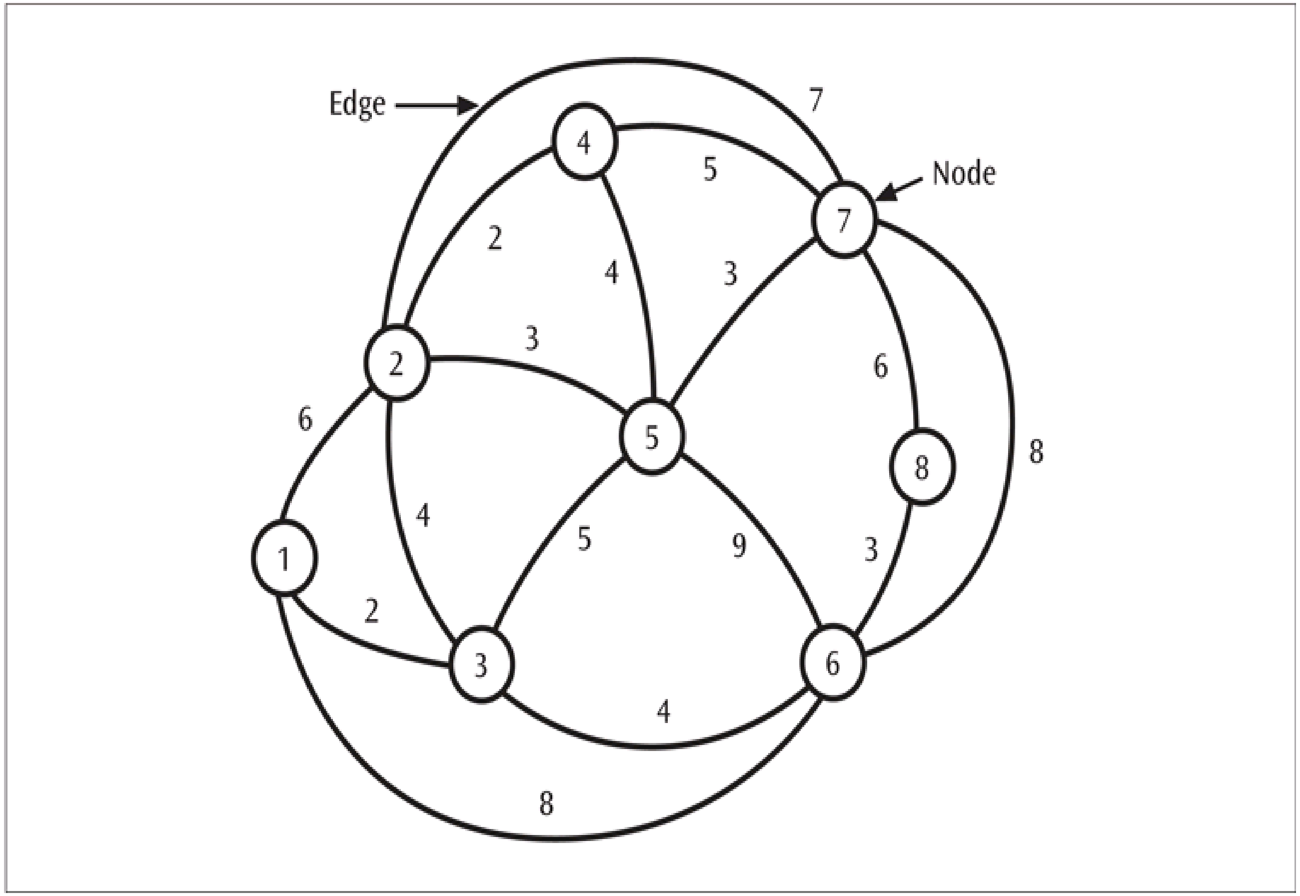


Routing

- The communications network with its nodes and telecommunication links is essentially a weighted network graph.
- The edges, or telecommunication links, between nodes, have a cost associated with them.
- The cost could be a delay cost, a queue size cost, a limiting speed, or simply a dollar amount for using that link.

Routing

Figure 9-11
A simple example of a network graph



Routing

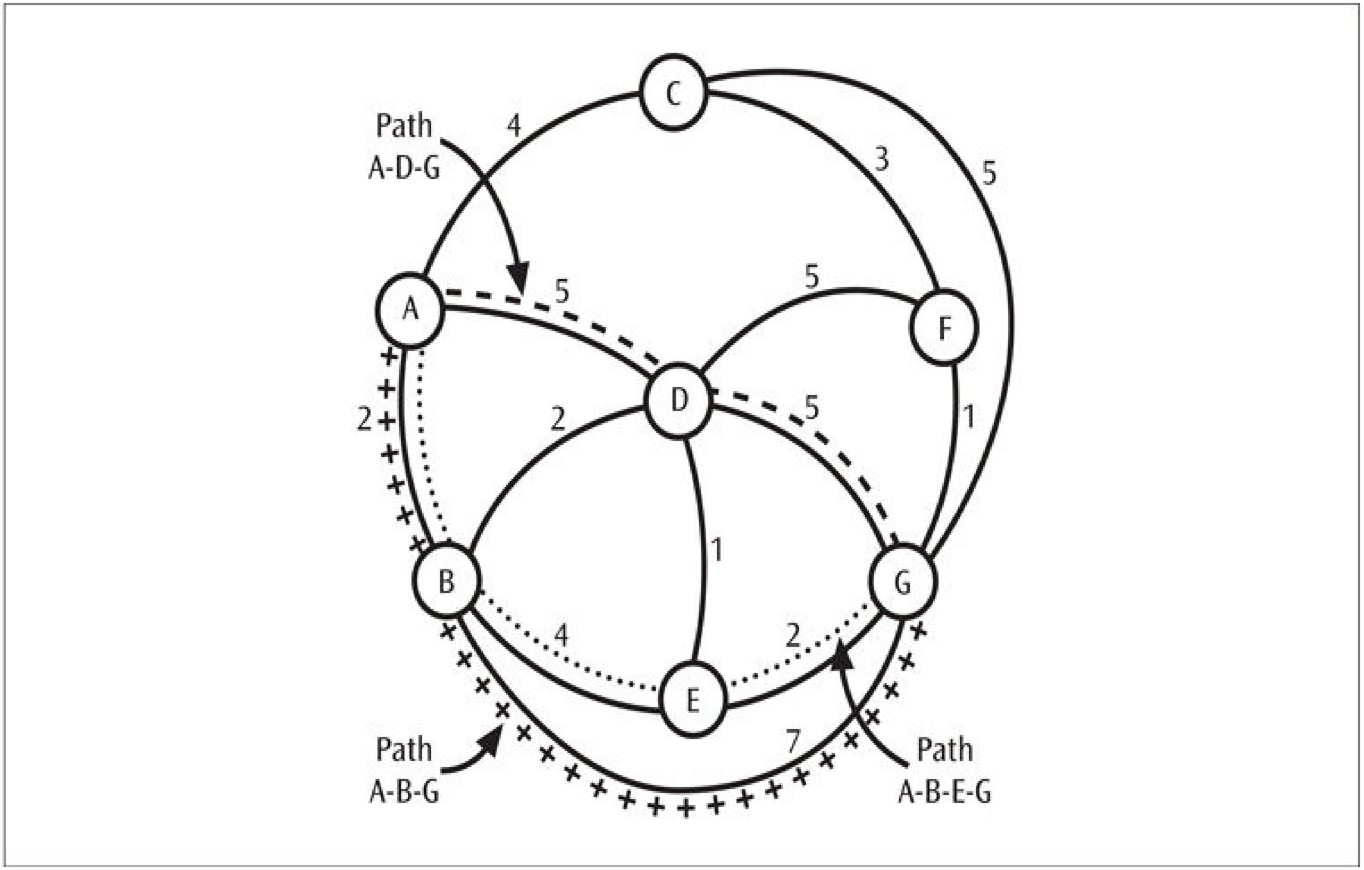
- The routing method, or algorithm, chosen to move packets through a network should be:
- Optimal, so the least cost can be found
- Fair, so all packets are treated equally
- Robust, in case link or node failures occur and the network has to reroute traffic.
- Not too robust so that the chosen paths do not oscillate too quickly between troubled spots.

Least Cost Routing Algorithm

- Dijkstra’s least cost algorithm finds all possible paths between two locations.
- By identifying all possible paths, it also identifies the least cost path.
- The algorithm can be applied to determine the least cost path between any pair of nodes.

Least Cost Routing Algorithm

Figure 9-12
Network with costs associated with each link

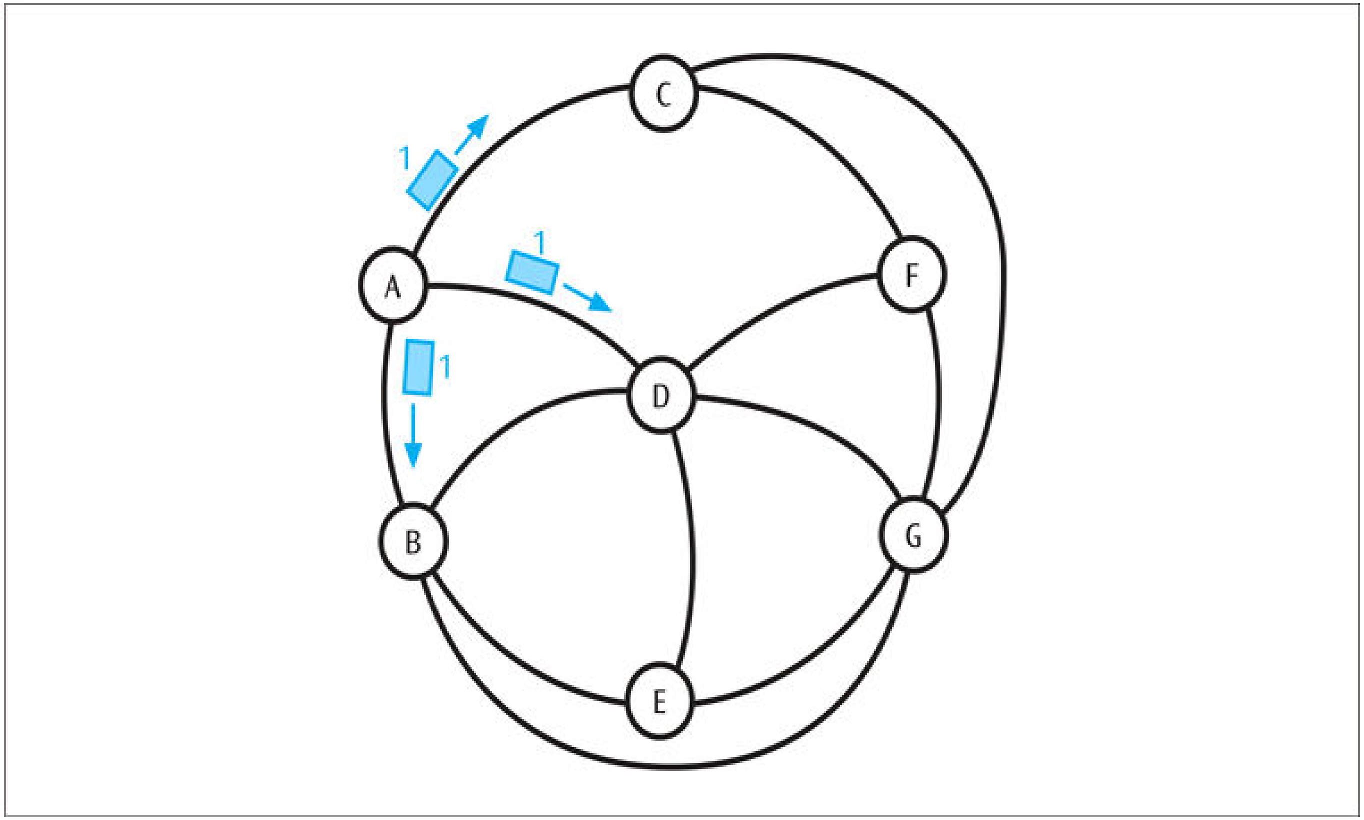


Flooding Routing

- When a packet arrives at a node, the node sends a copy of the packet out every link except the link the packet arrived on.
- Traffic grows very quickly when every node floods the packet.
- To limit uncontrolled growth, each packet has a hop count. Every time a packet hops, its hop count is incremented. When a packet's hop count equals a global hop limit, the packet is discarded.

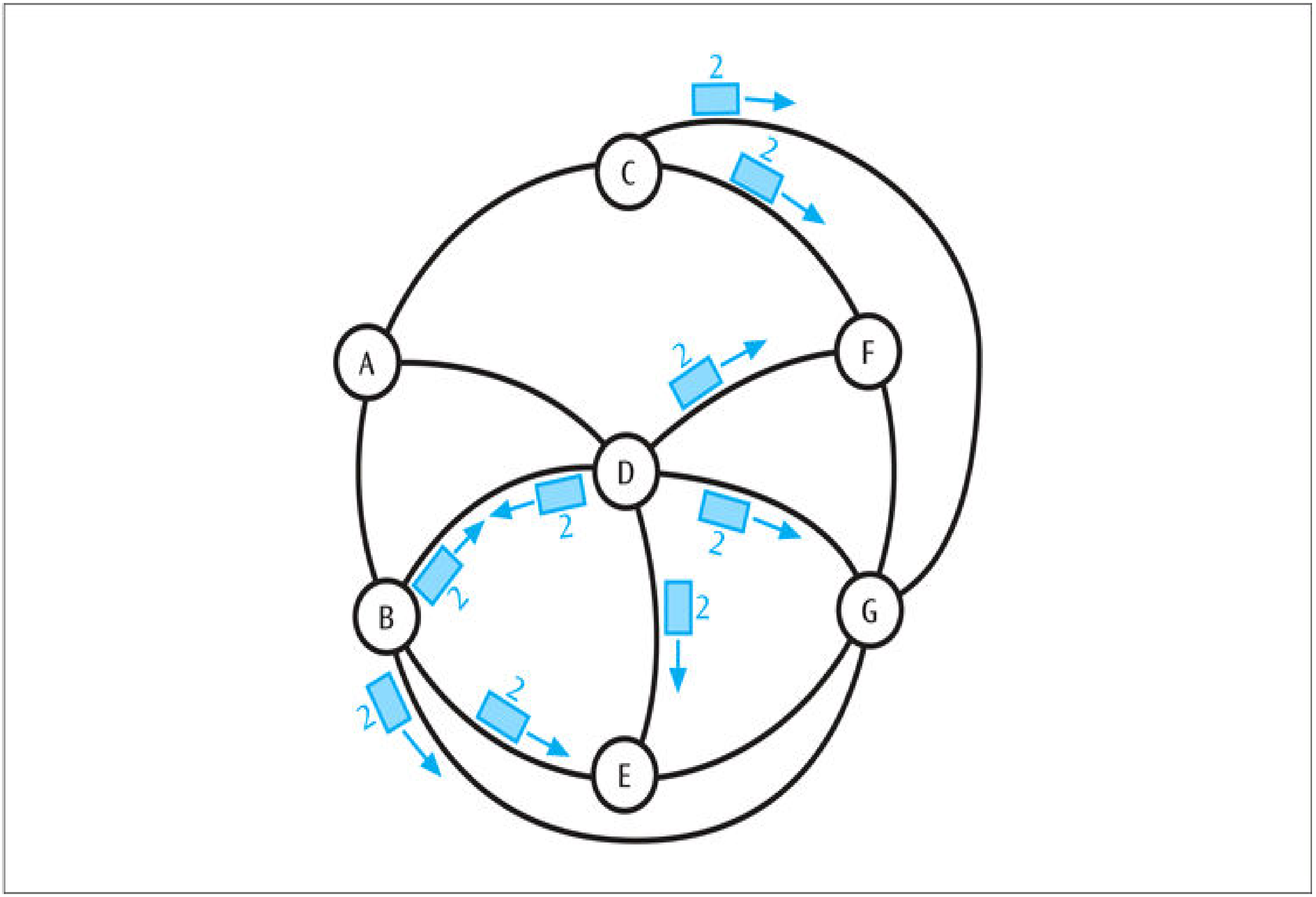
Flooding Routing

Figure 9-13
Network with flooding, starting from Node A



Flooding Routing

Figure 9-14
Flooding has continued to Nodes B, C, and D



Centralized Routing

- One routing table is kept at a “central” node.
- Whenever a node needs a routing decision, the central node is consulted.
- To survive central node failure, the routing table should be kept at a backup location.
- The central node should be designed to support a high amount of traffic consisting of routing requests.

Centralized Routing

Table 9-2

Routing table kept at a centralized network site

		Destination Node						
		A	**B**	**C**	**D**	**E**	**F**	**G**
Origination Node	**A**	-	B	C	B	B	C	B
	B	A	-	A	D	D	D	D
	C	A	A	-	A	F	F	F
	D	B	B	F	-	E	E	E
	E	D	D	G	D	-	G	G
	F	C	G	C	G	G	-	G
	G	E	E	F	E	E	F	-

Distributed Routing

- Each node maintains its own routing table.
- No central site holds a global table.
- Somehow each node has to share information with other nodes so that the individual routing tables can be created.
- Possible problem with individual routing tables holding inaccurate information.

Distributed Routing

Table 9-3
Local routing table for Node C

		Destination Node						
		A	**B**	**C**	**D**	**E**	**F**	**G**
Origination Node	C	A	A	-	A	F	F	F

Adaptive Routing versus Static Routing

- With adaptive routing, routing tables can change to reflect changes in the network
- Static routing does not allow the routing tables to change.
- Static routing is simpler but does not adapt to network congestion or failures.

Routing Examples - RIP

- Routing Information Protocol (RIP) - First routing protocol used on the Internet.
- A form of distance vector routing. It was adaptive and distributed
- Each node kept its own table and exchanged routing information with its neighbors.

Routing Examples - RIP

- Suppose that Router A has connections to four networks (123, 234, 345, and 789) and has the following current routing table:

Network	Hop Cost	Next Router
123	8	B
234	5	C
345	6	C
789	10	D

Routing Examples - RIP

- Now suppose Router D sends out the following routing information (note that Router D did not send Next Router information, since each router will determine that information for itself):
- **Network Hop Cost**
- 123 4
- 345 5
- 567 7
- 789 10

Routing Examples - RIP

- Router A will look at each entry in Router D’s table and make the following decisions:
- 1. Router D says Network 123 is 4 hops away (from Router D). Since Router D is 1 hop away from Router A, Network 123 is actually 5 hops away from Router A. That is better than the current entry of 8 hops in Router A’s table, so Router A will update the entry for Network 123.
- 2. Router D says Network 345 is 5 hops away. Add one hop to get to Router D and Network 345 is 6 hops away. That is currently the same hop count as shown in Router A’s table for Network 345, so Router A will not update its table.

Routing Examples - RIP

- Router A will look at each entry in Router D's table and make the following decisions:
- 3. Router D says Network 567 is 7 hops away. Add 1 hop to get to Router D, giving 8 hops. Since Router A has no information about Network 567, Router A will add this entry to its table. And since the information is coming from Router D, Router A's Next Router entry for network 567 is set to D.
- 4. Router D says Network 789 is 10 hops away. Add 1 hop to get to Router D. The value of 11 hops is worse than the value currently in Router A's table. Since Router A currently has information from Router D, and Router D is now saying it takes more hops to get to Network 789, then Router A has to use this information.

Routing Examples - RIP

- Router A’s updated routing table will thus look like the following:
- **Network Hop Cost Next Router**
- 123 5 D
- 234 5 C
- 345 6 C
- 567 8 D
- 789 11 D

Routing Examples - OSPF

- Open Shortest Path First (OSPF) - Second routing protocol used on the Internet
- A form of link state routing
- It too was adaptive and distributed but more complicated than RIP and performed much better

Network Congestion

- When a network or a part of a network becomes so saturated with data packets that packet transfer is noticeably impeded, network congestion occurs.
- What can cause network congestion? Node and link failures; high amounts of traffic; improper network planning.
- When serious congestion occurs buffers overflow and packets are lost.

Network Congestion

- What can we do to reduce or eliminate network congestion?
- An application can observe its own traffic and notice if packets are disappearing. If so, there may be congestion. This is called *implicit congestion control*.
- The network can inform its applications that congestion has occurred and the applications can take action. This is called *explicit congestion control*.

Congestion Avoidance

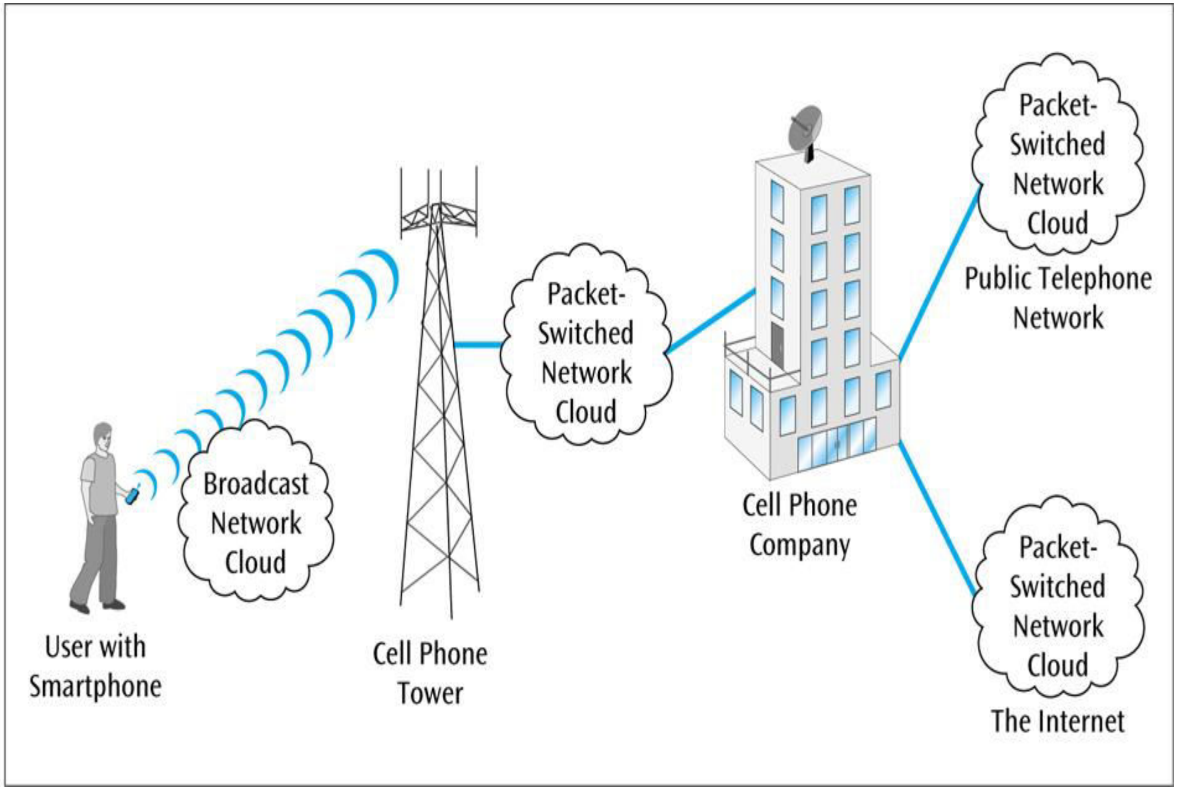
- Before making a connection, user requests how much bandwidth is needed, or if connection needs to be real-time
- Network checks to see if it can satisfy user request
- If user request can be satisfied, connection is established
- If a user does not need a high bandwidth or real-time, a simpler, cheaper connection is created
- This is often called *connection admission control*
- Asynchronous transfer mode is a very good example of this (Chapter Eleven)

WANs In Action: The Smartphone

- The network structure that support cell phones and smartphones is growing more complex every day
- All phones within transmission distance of a cell tower are participating in a broadcast network

WANs In Action: The Smartphone

Figure 9-15 Interconnection of network clouds



WANs In Action: The Smartphone

- Once your data/signal reaches the cell tower, the data becomes part of a packet-switched network within the telephone company
- If the data moves from the telephone company into the Internet, then your data is passed from one packet switched network to another

Summary

- A metropolitan area network is fast, fiber-based, has very small failover times, and is often dynamically provisional
- Early MANs were SONET-based, but Ethernet-based MANs are becoming very popular
- SONET-based MANs are rings, while Ethernet-based MANs are meshes
- Metro Ethernet is a popular form of MAN

Summary (continued)

- Wide area networks cover states, countries, the world
- User connects to a station and the station interfaces to a network node
- A WAN cloud is based upon nodes (routers/switches) and high-speed links
- WANs can be circuit-switched (fading away) or packet switched (datagram and virtual circuit)
- RIP and OSPF are two routing protocols