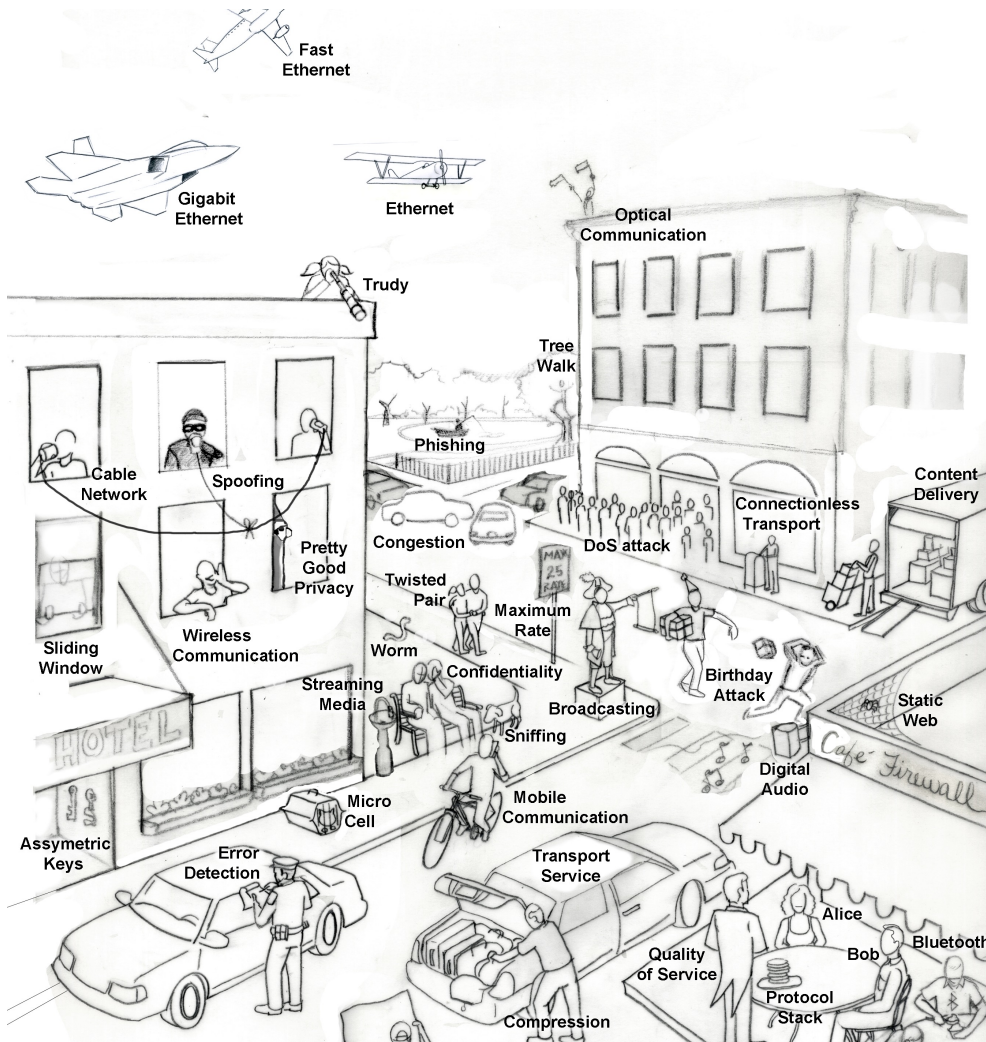


## Sixth edition



# Chapter 1

# Types of Networks

# Types of Computer Networks

- Mobile and broadband access networks
  - Networks used to access the Internet
- Data-center networks
  - Networks that house data and applications
- Transit networks
  - Networks that connect access networks to data centers
- Enterprise networks
  - Networks used on campuses, in office buildings, or at other organizations

# What *Really* Characterizes Networks?

(Remember this?)

- The Characteristics of the Media creates bounds:
  - Point-to-point or multi-access
  - Physical limits on distance
  - Error characteristics
    - Single bit errors, bursts, affects packet size
  - Bandwidth
  - If wireless
    - Propagation characteristics
  - Cost, Cost, Cost
- Then it is a Resource Allocation Problem.
- To this, let us add:
  - Number of elements
  - Geographic Span

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# What is *Really* Important?

(and this?)

- Network technologies should not be built to support specific applications
- Network technologies support a specific operating range.
- Applications require a particular operating range.
  - Some applications require different ranges, some may require the same range.
- The problem in designing a network or the equipment is to match the operating range of the equipment to the operating range of a collection of applications.
  - Don't believe what management tells you.
- It still applies here. The boundaries between these categories are not firm, especially if the category is not based on the physical media and even then it may be market-motivated.

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# As we go through these, think about:

- What kind of layers would they need?
- What sorts of policies would those layer require?
- We don't have all of the elements yet but keep them in mind and think about it.

# Broadband Access Networks

- Home network use
  - Listen to, look at, and create music, photos, and videos
  - Access information, communicate with other people, buy products and services
- Metcalfe's law
  - Explains how tremendous Internet popularity comes from its size
- Broadband access networks
  - Delivered to homes using copper, coaxial cable, or optical fiber
  - Broadband Internet speeds: gigabit per second to individual homes

# Mobile and Wireless Access Networks

## (1 of 3)

- Wireless hotspots are based on the 802.11 standard
- Wireless networking and mobile computing
  - Related but not identical
- Smartphones combine aspects of mobile phones and mobile computers
- Text messaging or texting short message
- GPS (Global Positioning System): locates a device
- Geo-tagging: annotating photos and videos with the location where they were made
  - Why is this here? Has nothing to do with networking

# Mobile and Wireless Access Networks

## (2 of 3)

Wireless	Mobile	Typical applications
Yes	No	Desktop computers in offices
Yes	Yes	A laptop computer used in a hotel room
Yes	No	Networks in unwired buildings
Yes	Yes	Store inventory with a handheld computer

Although wireless networking and mobile computing are often related, they are not identical.



# Mobile and Wireless Access Networks

## (3 of 3)

- M-commerce (mobile-commerce) uses mobile phones
- NFC (Near Field Communication)
  - Allows mobile device to act as an RFID smartcard and interact with a nearby reader for payment
- Sensor networks use nodes gathering and relaying information about the physical state of the world
  - Nodes may be embedded in familiar devices (cars or phones)
  - Nodes may be small, separate devices
  - Provide a wealth of data on behavior
  - Example: wireless parking meters

# Content Provider Networks

- Data-center network
  - Internet services are served from “the cloud”
  - Serves the increasingly growing demands of cloud computing
  - Moves large amounts of data between servers in the data center
  - Moves data between the data center and the rest of the Internet
- Data center network challenges
  - Network throughput and energy usage scaling
  - “Cross-section bandwidth”
- CDN (Content Delivery Network)
  - Large collection of servers, geographically distributed so content is close to the users requesting it

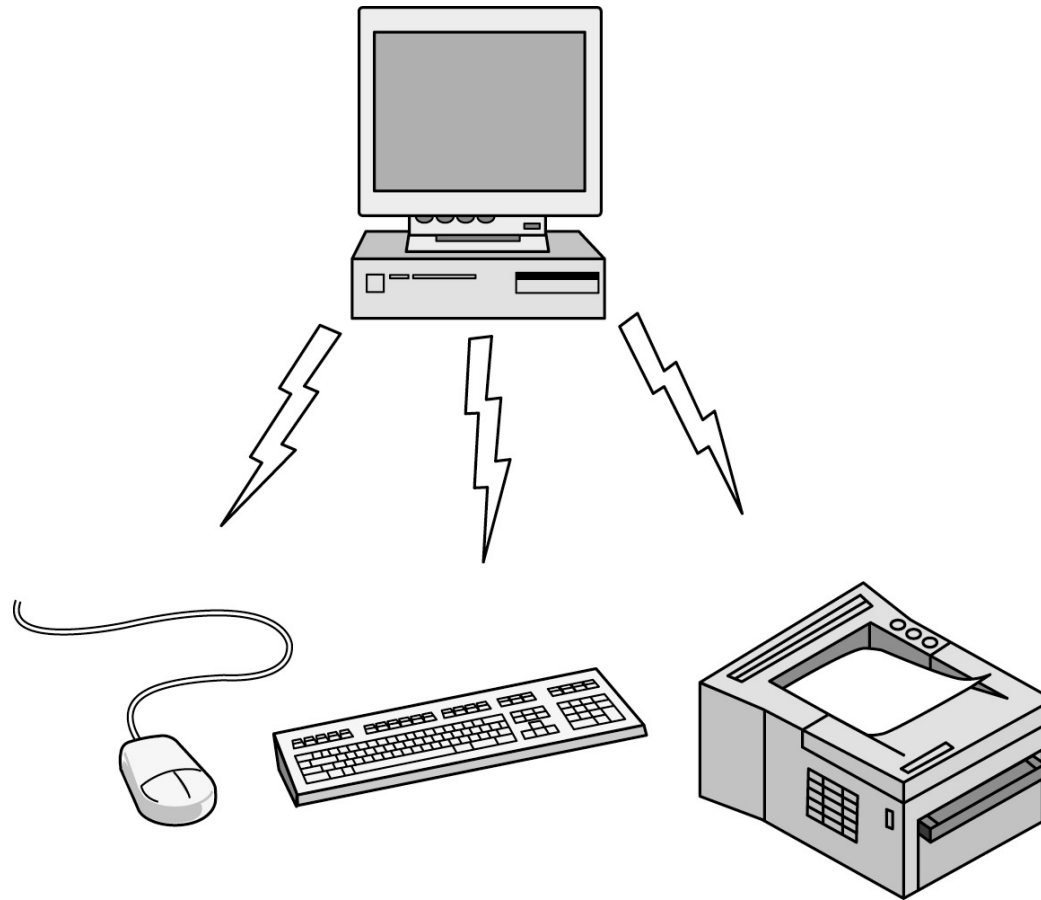
# Transit Networks

- Transit network
  - Carry traffic between the content provider and the ISP (Internet Service Provider) when they are not directly connected
  - Typically charge both the ISP and the content provider for carrying traffic from end-to-end
  - Traditionally called backbone networks because they carry traffic between two endpoints
- Two trends
  - Consolidation of content in a handful of large content providers
  - Expansion of the footprint of individual access ISP networks

# Enterprise Networks

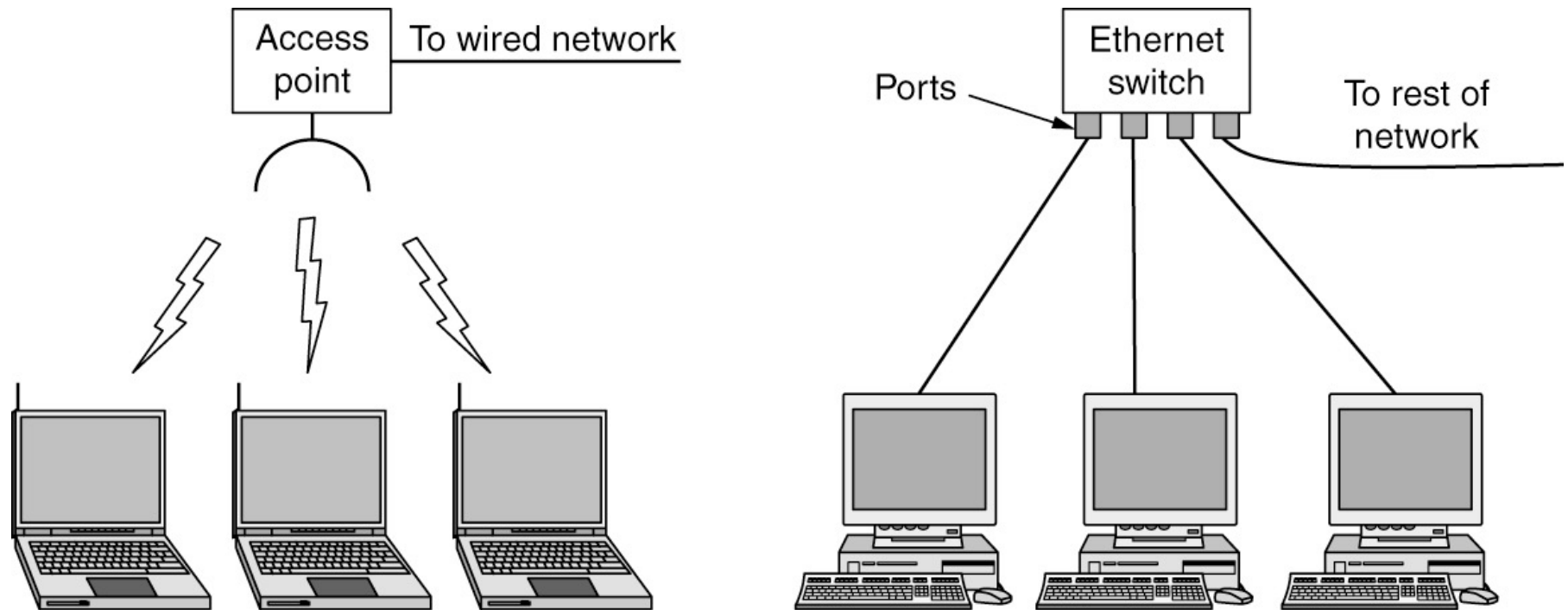
- Allows resource sharing for devices and information
- VPNs (Virtual Private Networks)
  - Connect individual networks at different sites into one logical network
  - Act as a communication medium among employees
- Allows IP telephony or VoIP (Voice over IP)
  - Internet technology and computer networks for telephone calls
- Allows desktop sharing
  - Remote workers can see and interact with a computer screen
- Allows electronic business communication

# Personal Area Networks



PANs (Personal Area Networks) let devices communicate over the range of a person. Bluetooth is a short-range wireless network used to connect components without wires.

# Local Area Networks



The configuration on the left represents a wireless 802.11 network. The configuration on the right represents a wired switched Ethernet network.

# Home Networks

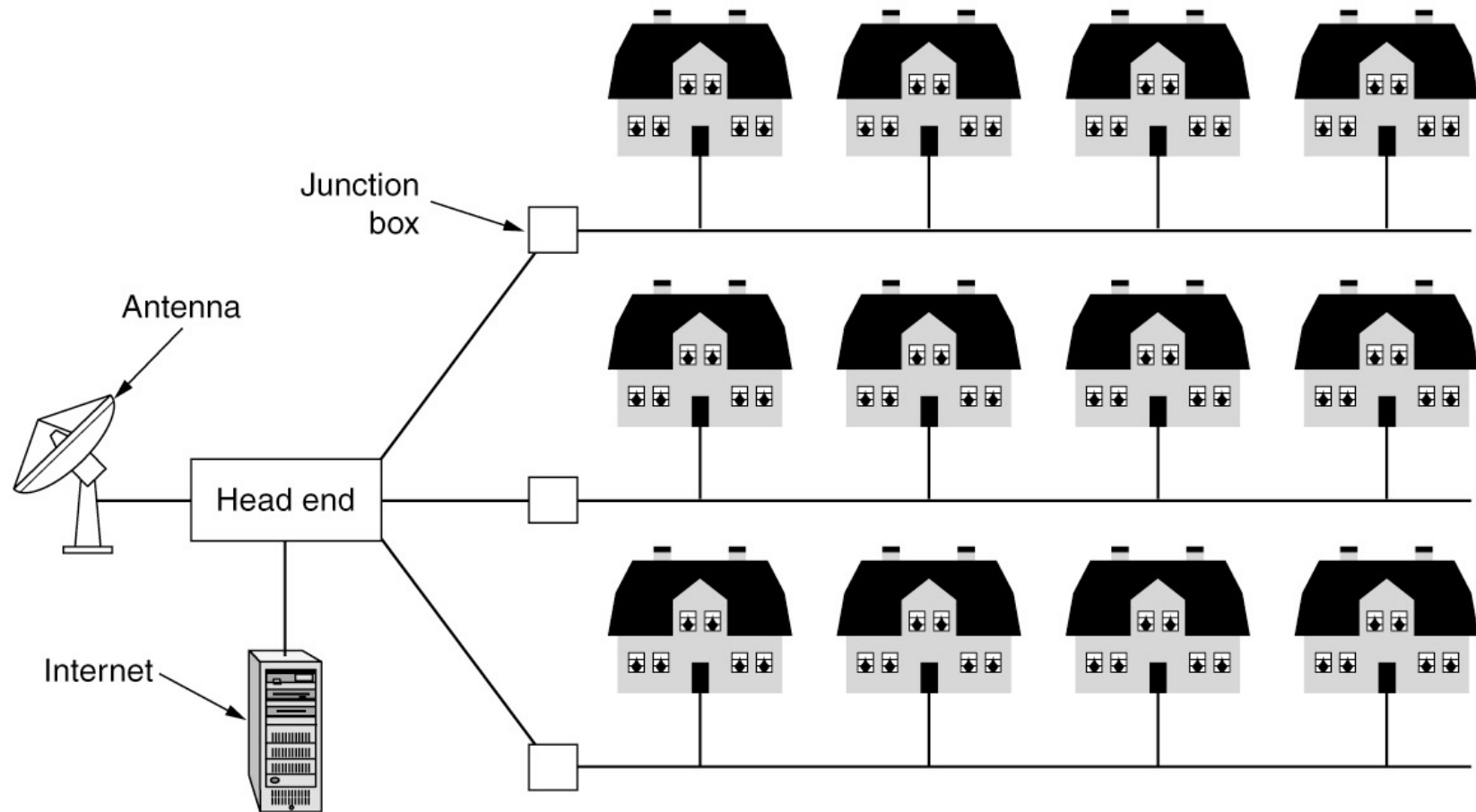
- Home network LAN
  - Broad, diverse range of Internet-connected devices
  - Characteristics: manageable, dependable, and secure
- Internet of things
  - Allows almost any device to connect
- Required home network properties
  - Easy to install
  - Secure and reliable
  - Interfaces work between all products
  - Reduced consumer device costs

# Community Networks

- How Many WiFi Networks Can You See?
  - How Many Do You Think Your Neighbors See?
  - Do You Think They Are The Same Ones? ;-)
- How Far Do You Think You Could Go Hopping From One to Another?
- Groups around the World Have Done Just This.
  - Urbana, Il; Barcelona, Athens, etc.
    - Modified WiFi Routers and put Routing Software in Them
    - Cable and Fiber Access is Hierarchical. This is a Mesh.
    - With Access to Everyone's Cable or Fiber.

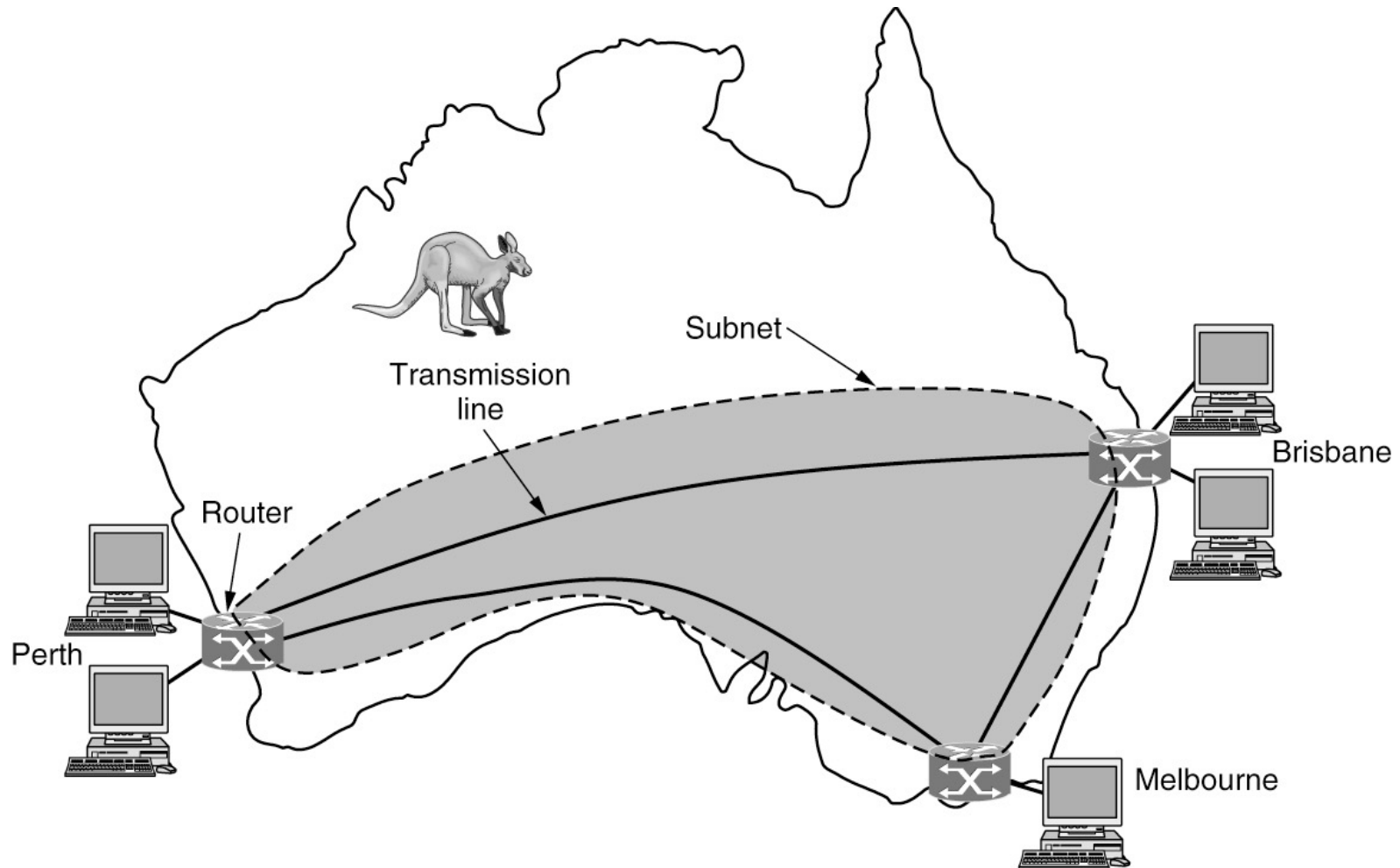


# Metropolitan Area Networks



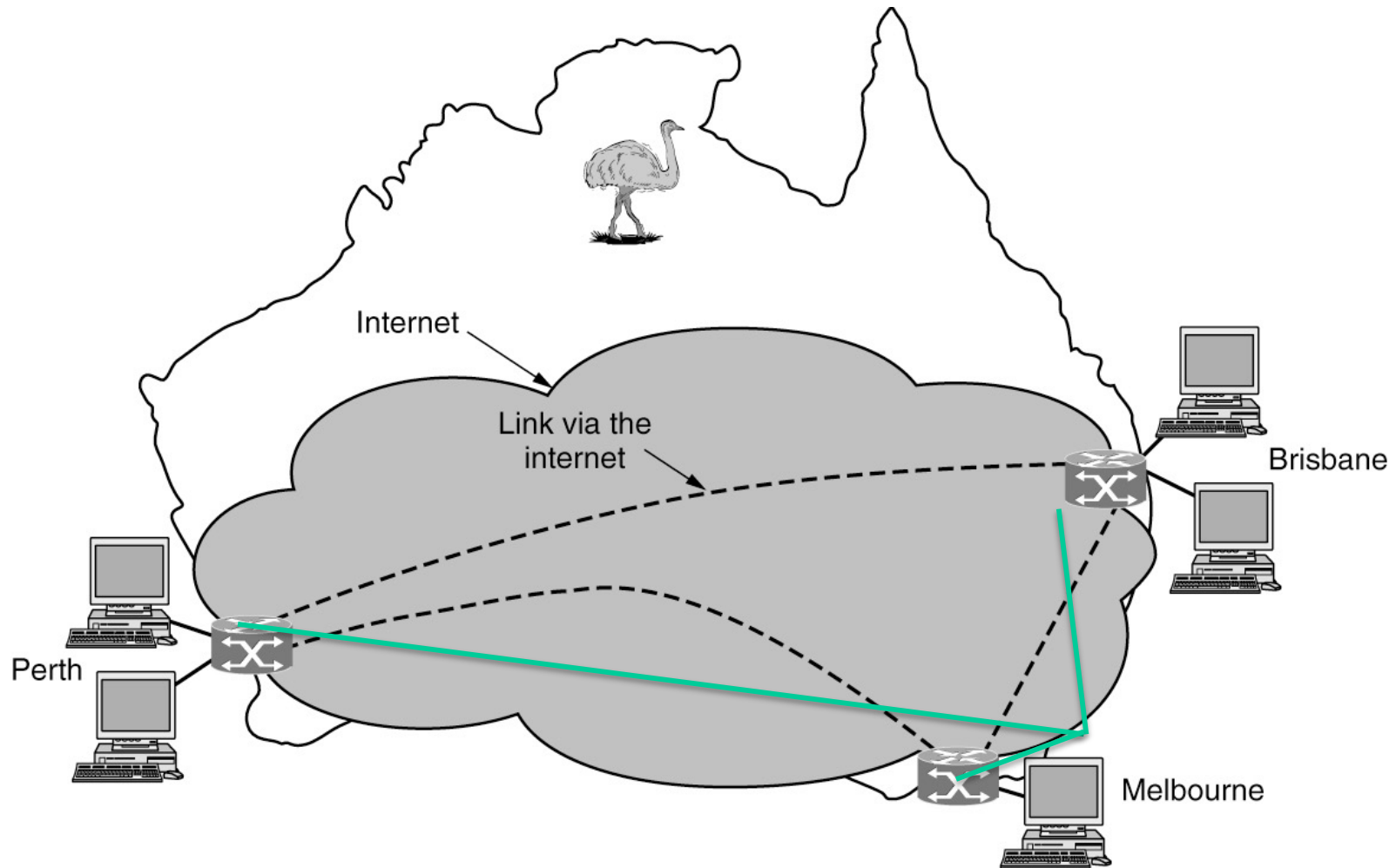
A MAN (metropolitan area network) where both television signals and the Internet are being fed into the centralized cable head-end (or cable modem termination system) for subsequent distribution to people's homes.

# Wide Area Networks (1 of 3)



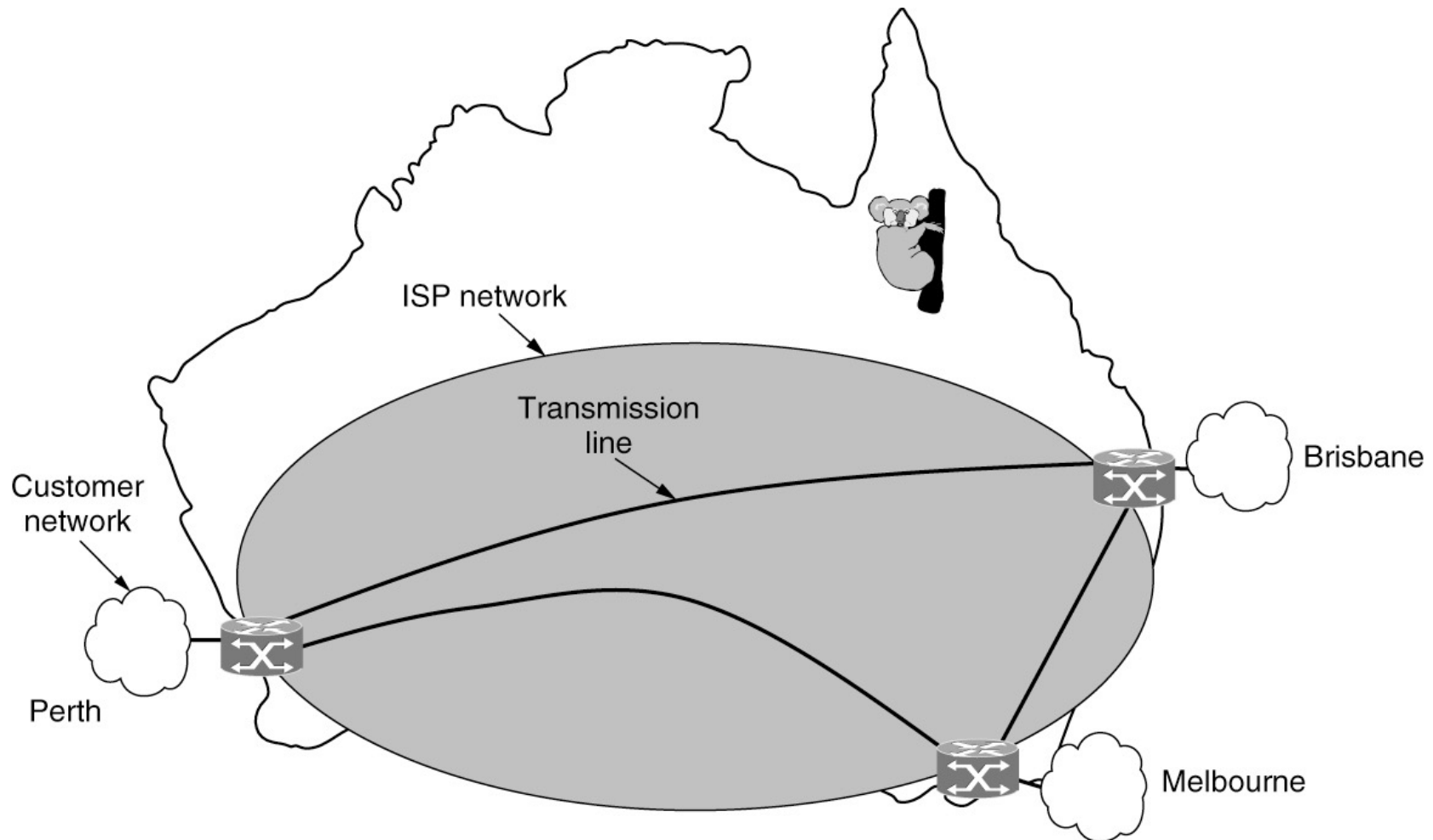
This wide area network illustrates how hosts in Perth, Brisbane, and Melbourne can communicate using leased lines.

# Wide Area Networks (2 of 3)



This wide area network illustrates how hosts in Perth, Brisbane, and Melbourne can communicate via the Internet.

# Wide Area Networks (3 of 3)



This wide area network illustrates how hosts in Perth, Brisbane, and Melbourne can communicate via an ISP.

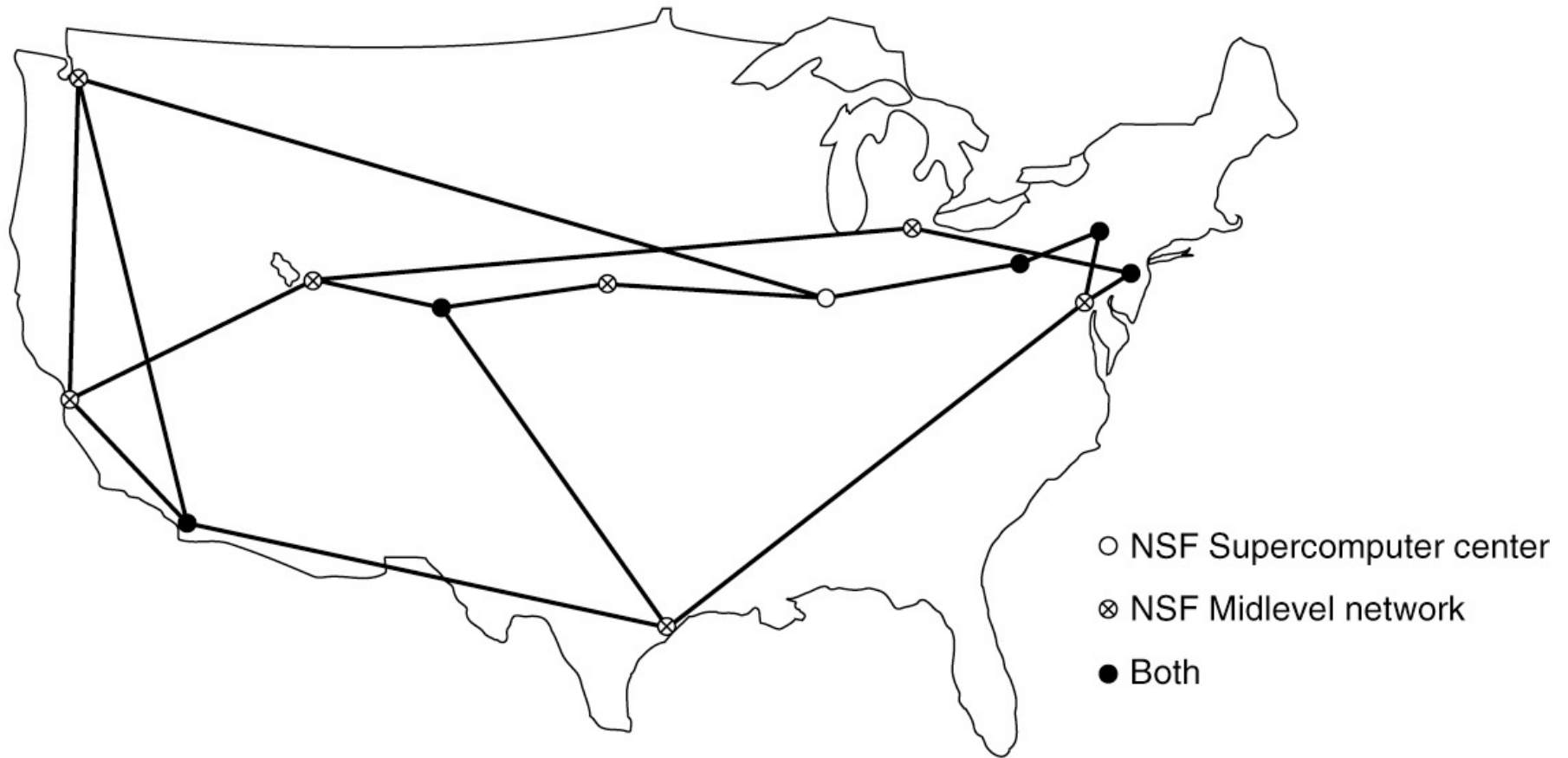
# Internetworks

- Internetwork or internet
  - A collection of interconnected networks
- Network combines subnets and hosts
  - Subnet can be described as a LAN network (Figure 1-11)
  - Internetwork might be described as a WAN network (Figure 1-9)
- An internet
  - Interconnection of distinct, independently operated networks
  - Connecting a LAN and a WAN or connecting two LANs
  - Gateway device makes a connection between two or more networks

# Examples of Networks (1 of 9)

- The Internet
  - The ARPANET
  - NSFNET
  - The Internet architecture
  - CYCLADES
- Mobile networks
  - Mobile network architecture
  - Packet switching and circuit switching
  - Early generation mobile networks: 1G, 2G, and 3G
  - Modern mobile networks: 4G and 5G
- Wireless networks (WiFi)

# Examples of Networks (5 of 9)



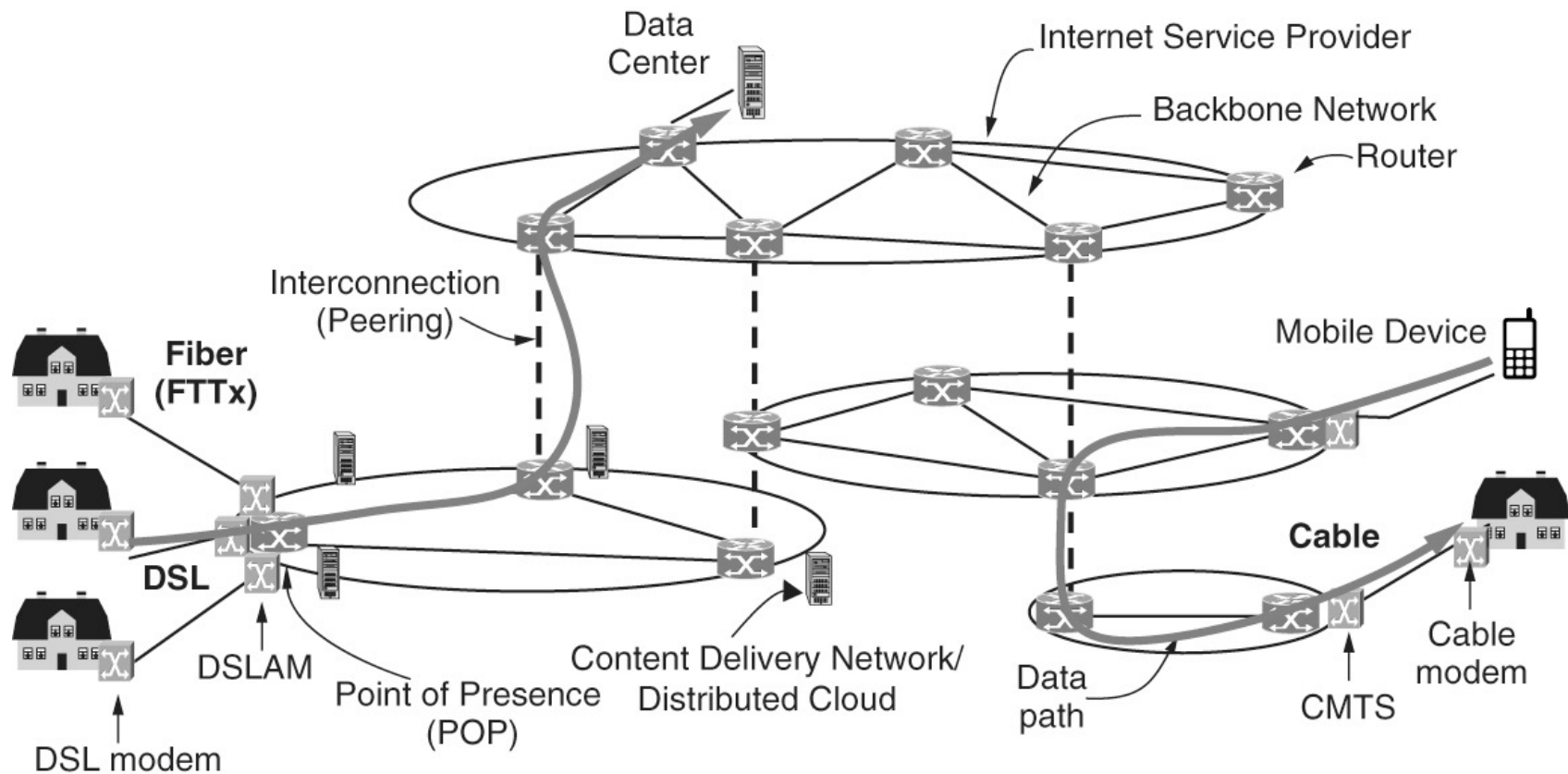
NSFNET was a backbone network designed to be a successor to the ARPANET that would be open to all university research groups, allowing them to communicate without having to contract with the Department of Defense.

# Examples of Networks (6 of 9)

- Cable television infrastructure connects to the Internet
- HFC (Hybrid Fiber-Coaxial) network is a single integrated infrastructure
  - Uses packet-based transport called DOCSIS (Data Over Cable Service Interface Specification)
- DOCSIS transmits a variety of data services, including television channels, high-speed data, and voice
  - Device at the home end is called a cable modem
  - Device at the cable headend is called the CMTS (Cable Modem Termination System)
  - Modem is short for “**mod**ulator **dem**odulator”

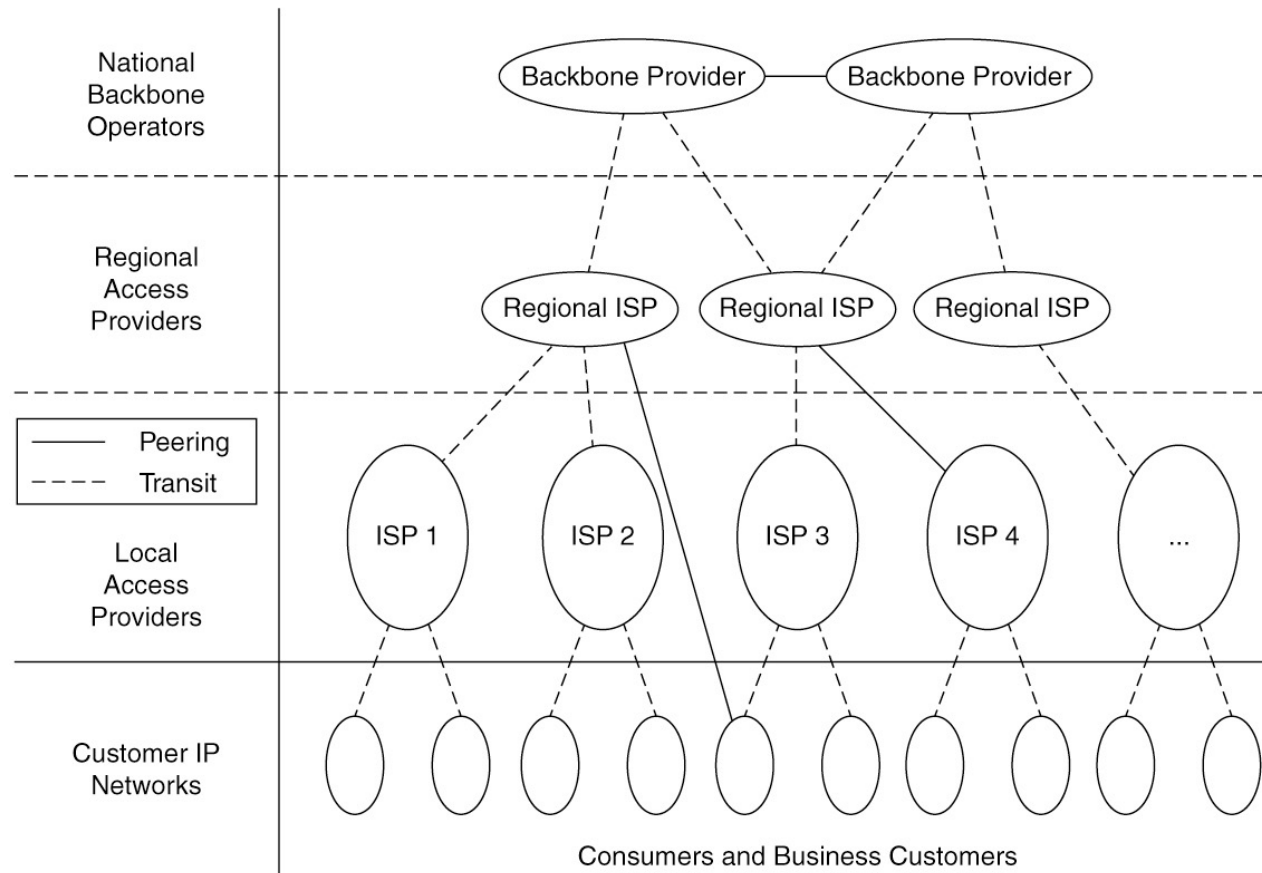


# Examples of Networks (7 of 9)



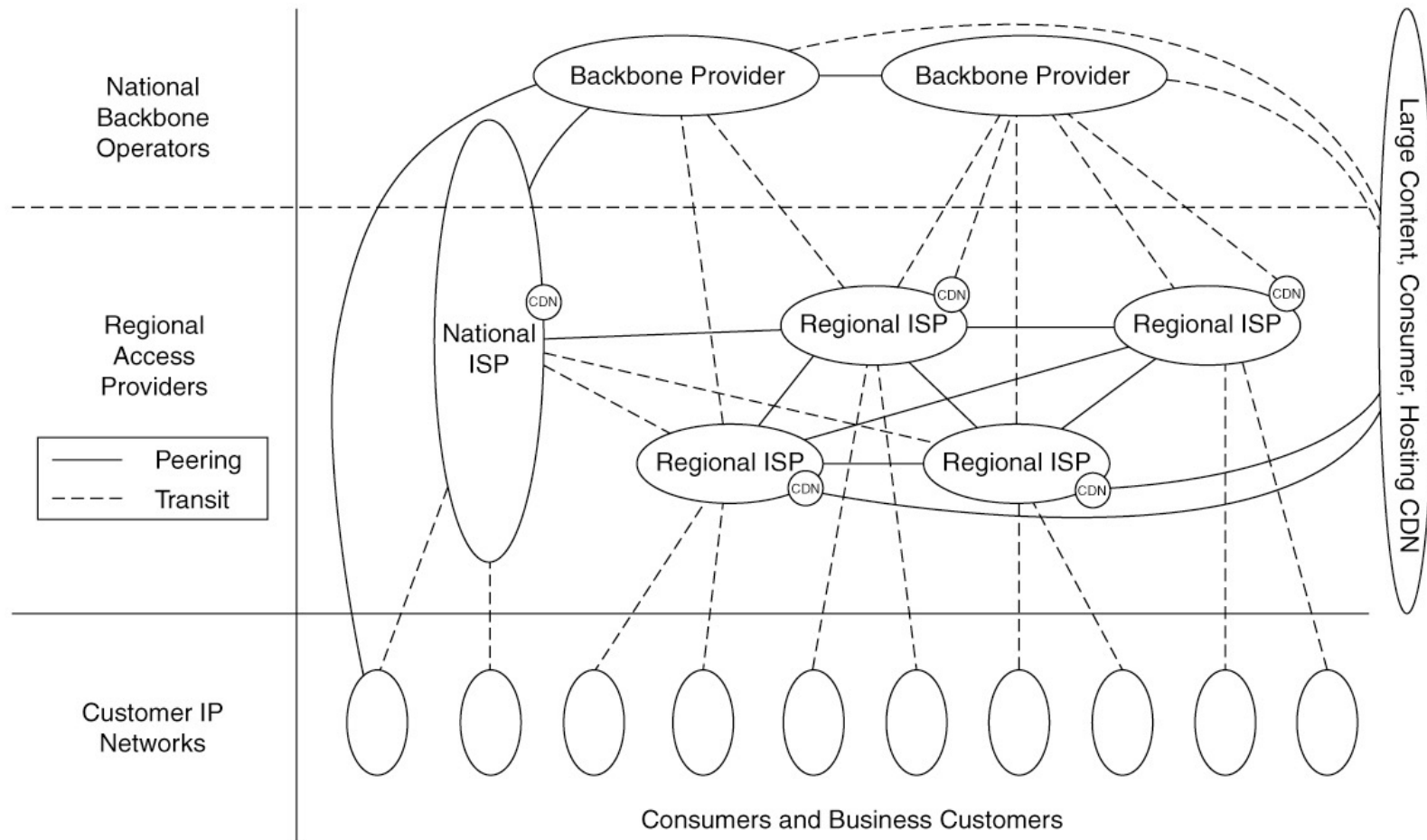
A common method for connecting to the Internet from your home is to send signals over the cable television infrastructure.

# Examples of Networks (8 of 9)



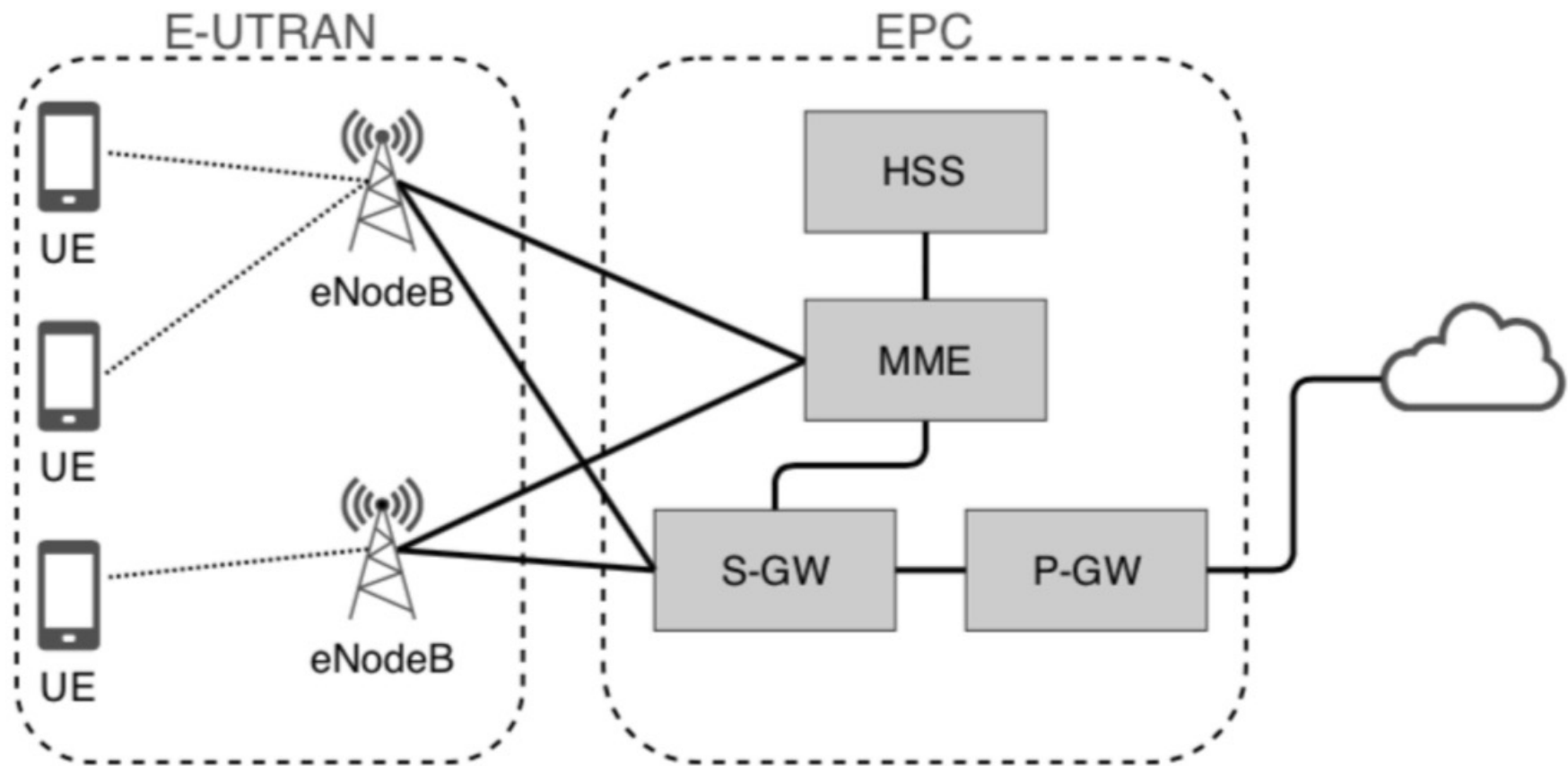
Conventionally, the Internet architecture has been viewed as a hierarchy, with the tier-1 providers at the top of the hierarchy and other networks further down the hierarchy, depending on whether they are large regional networks or smaller access networks.

# Examples of Networks (9 of 9)



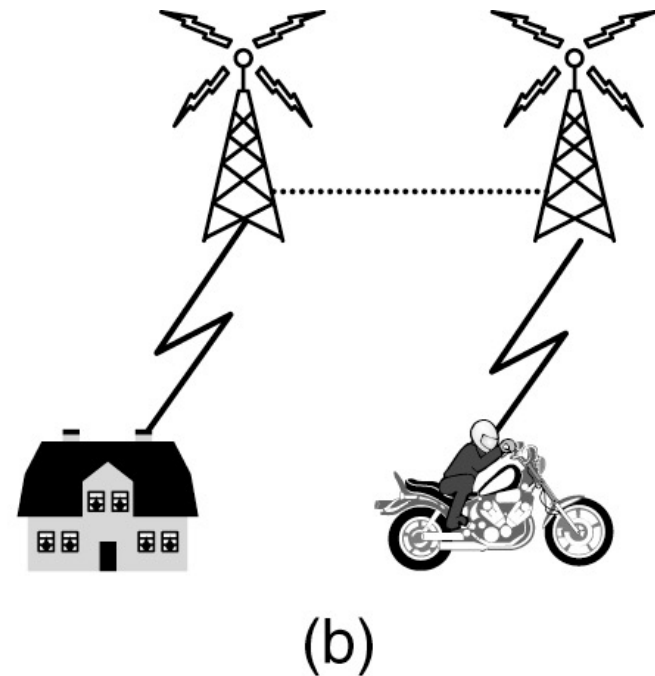
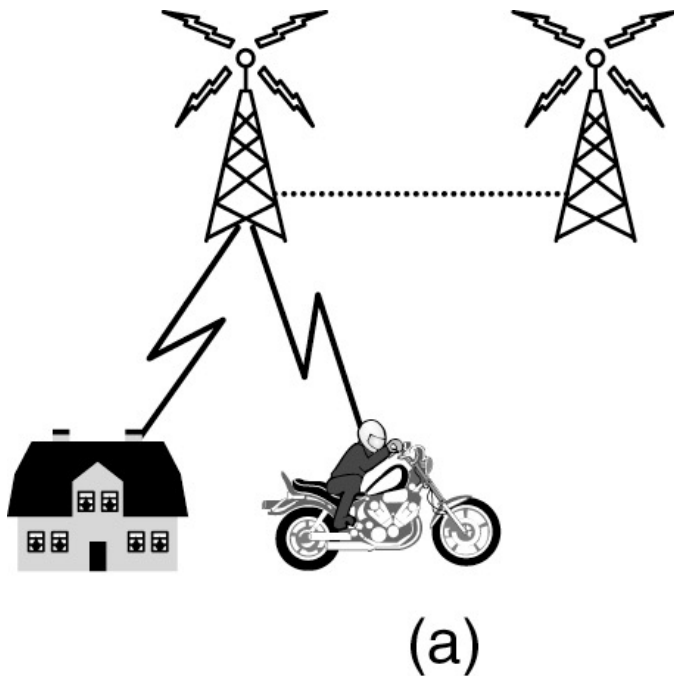
Over the past decade, the conventional hierarchy has evolved and “flattened” dramatically.

# Mobile Networks (1 of 6)



The architecture of the mobile phone network has several parts.

# Mobile Networks (2 of 6)



When a user moves out of the range of one cellular base station and into the range of another one, the flow of data must be re-routed from the old to the new cell base station.

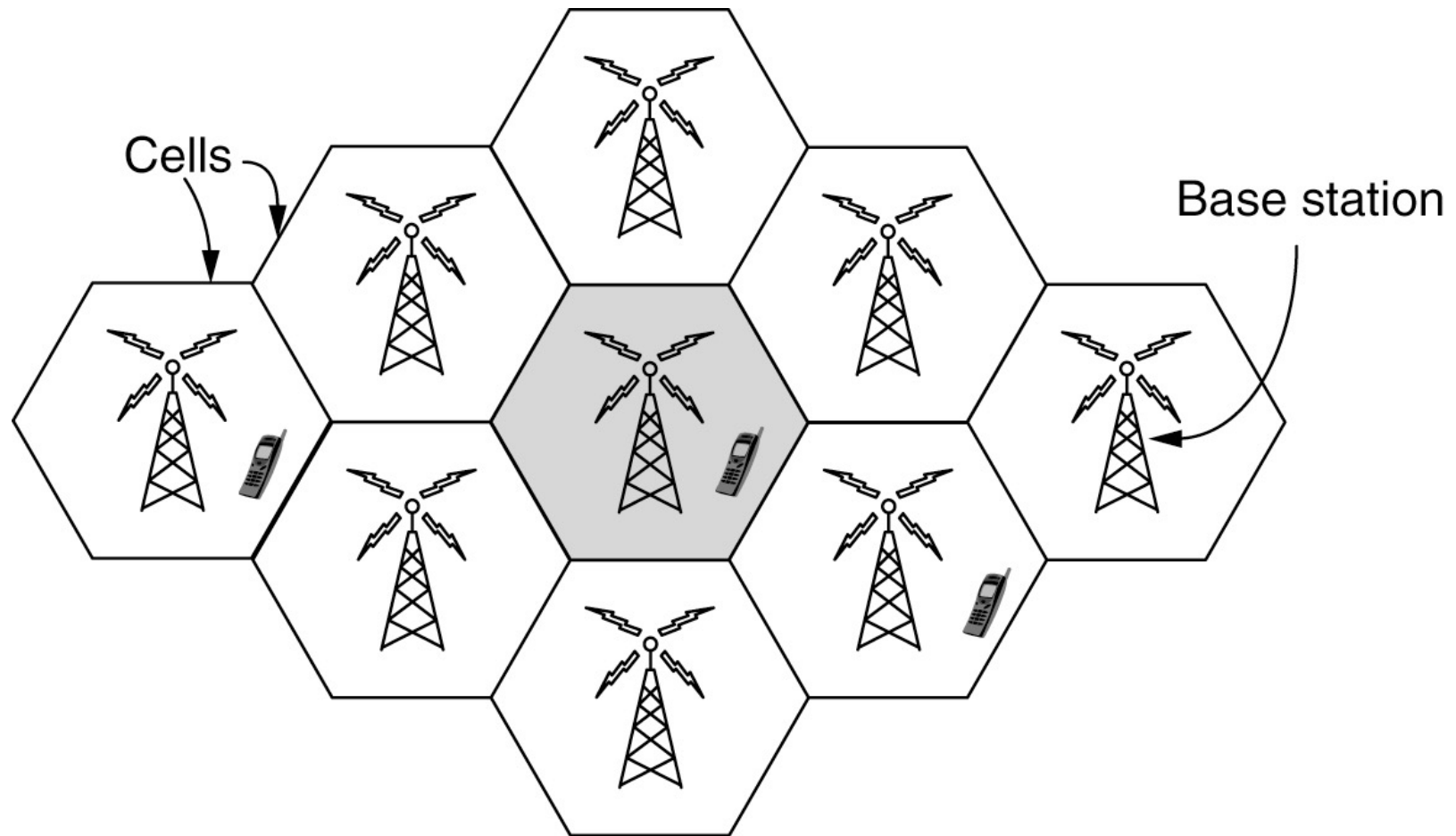
# Mobile Networks (3 of 6)

- Packet switching comes from the Internet community
  - Connectionless networks
  - Every packet is routed independently
  - If some routers go down during a session, no harm will be done as long as the system can dynamically reconfigure itself
- Circuit switching comes from telephone companies
  - Connection-oriented networks
  - Caller must dial the called party's number and wait for a connection before talking or sending data
  - Route maintained until call is terminated
  - Can support quality of service more easily

# Mobile Networks (4 of 6)

- First-generation mobile phone systems
  - Transmitted voice calls as continuously varying (analog) signals
  - AMPS (Advanced Mobile Phone System)
- Second-generation (2G) mobile phone systems
  - Transmitted voice calls in digital form to increase capacity, improve security, and offer text messaging
  - GSM (Global System for Mobile communications)
- Third generation (3G) offer digital voice and broadband digital data services
- Spectrum scarcity led to today's cellular network design

# Mobile Networks (5 of 6)



To manage the radio interference between users, the coverage area is divided into cells.



# Mobile Networks (6 of 6)

- 4G
  - Later 4G known as LTE (Long Term Evolution) technology
  - Offers faster speeds
  - Emerged in the late 2000s
  - Quickly became the predominant mode of mobile Internet access in the late 2000s
  - Outpacing competitors like 802.16 (WiMiMax)
- 5G technologies are promising faster speeds
  - Up to 10 Gbps
  - Set for large-scale deployment in the early 2020s
- Main distinction: frequency spectrum they rely on

# Wireless Networks (WiFi) (1 of 6)

- IEEE created a wireless LAN standard
  - Wireless LAN standard was dubbed 802.11
  - Common slang name for it is WiFi
  - 802.11 systems operate in unlicensed bands
  - Example: ISM (Industrial, Scientific, and Medical) bands defined by ITU-R
  - 802.11 radios compete with cordless phones, garage door openers, and microwave ovens
- 802.11 network modes: Ad hoc and access point (AP)
- Multipath fading causes received signals to fluctuate greatly

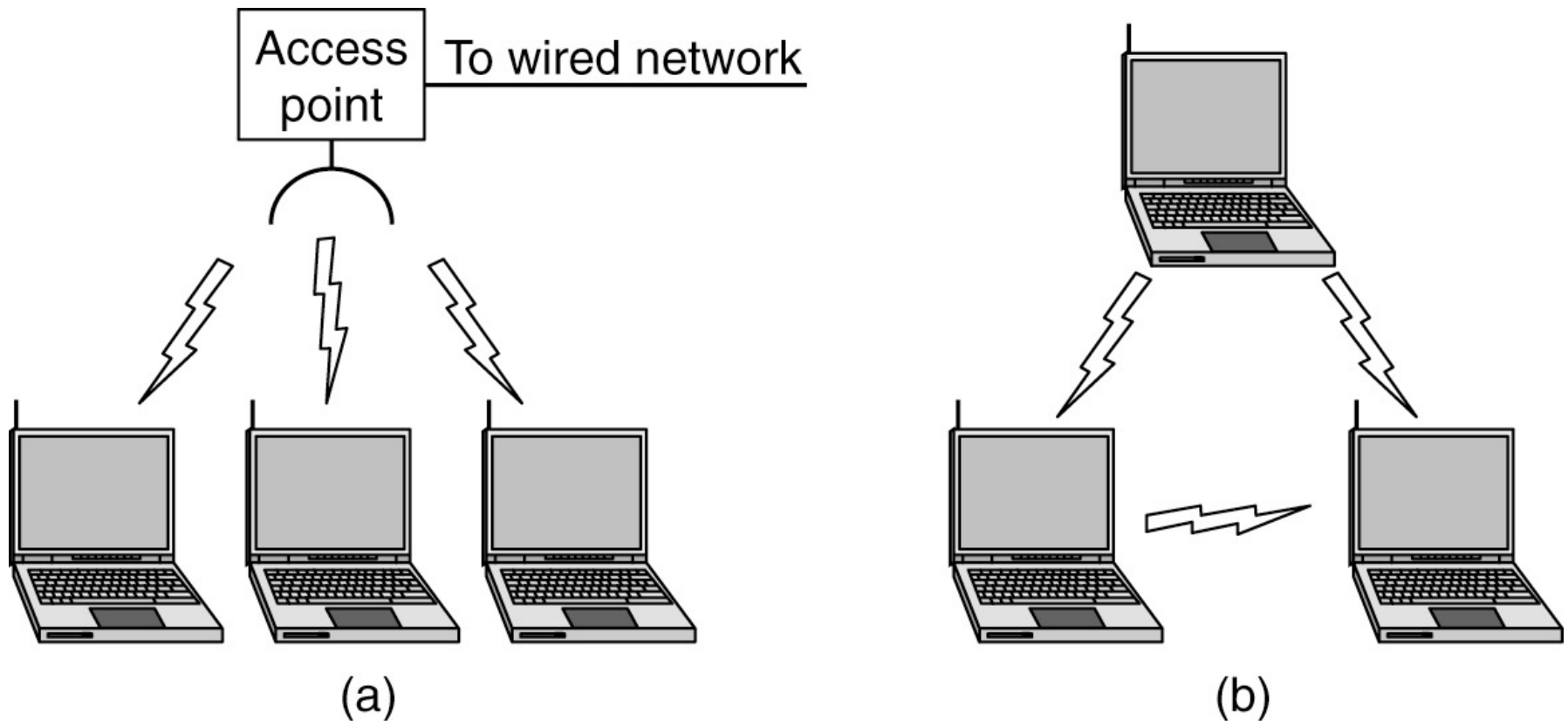
# Wireless Networks (WiFi) (2 of 6)

- Path diversity overcomes variable wireless conditions
- Versions of 802.11
  - Original 802.11 ran at either 1 Mbps or 2 Mbps
  - 802.11b used spread spectrum for rates up to 11 Mbps
  - 802.11a/g rates were boosted to 54 mbps using OFDM (Orthogonal Frequency Division Multiplexing) modulation
  - 802.11ac can run at 3.5 Gbps
  - 802.11ad can run at 7 Gbps (only indoors within a single room)
- CSMA (Carrier Sense Multiple Access) scheme
  - Handles transmission collision

# Wireless Networks (WiFi) (3 of 6)

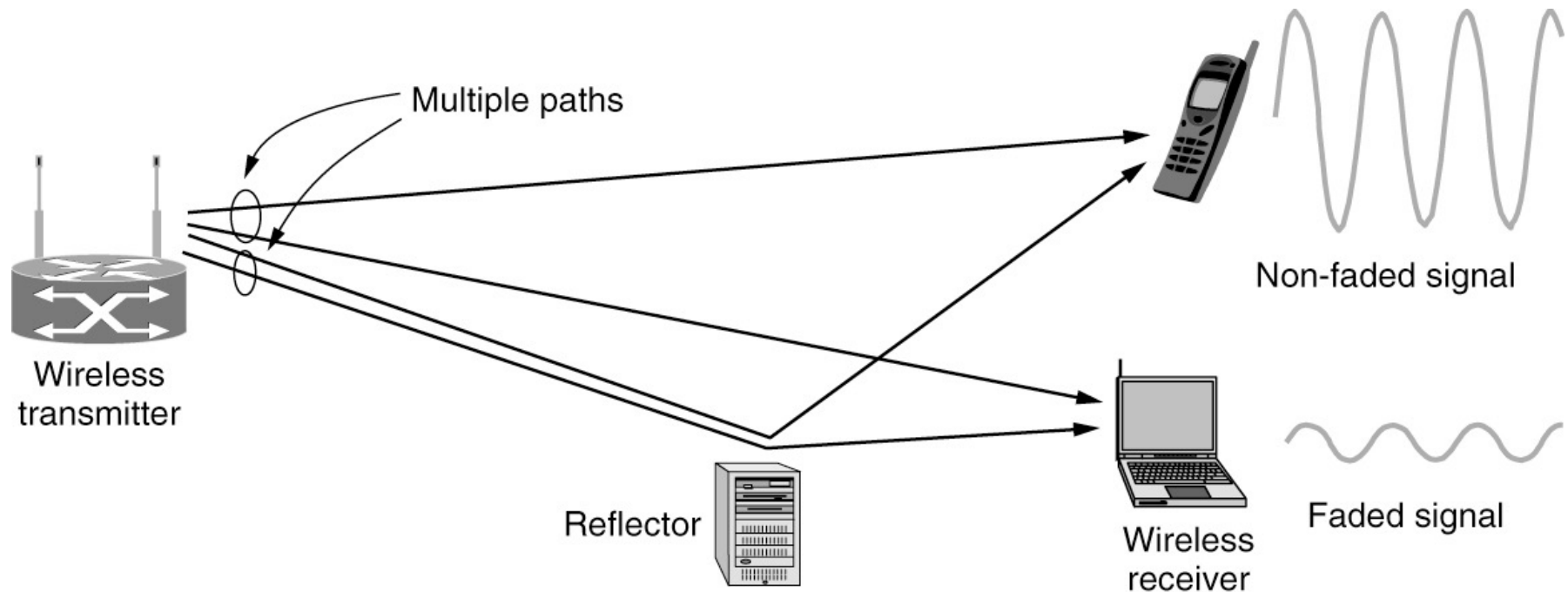
- 802.11 mobility
  - Of limited value compared to mobility in mobile phone networks
- 802.11 security
  - WEP (Wired Equivalent Privacy)
  - WEP replaced by WiFi Protected Access (initially called WPA)
  - WiFi Protected Access (WPA) replaced by WPA2 and 802.1X

# Wireless Networks (WiFi) (4 of 6)



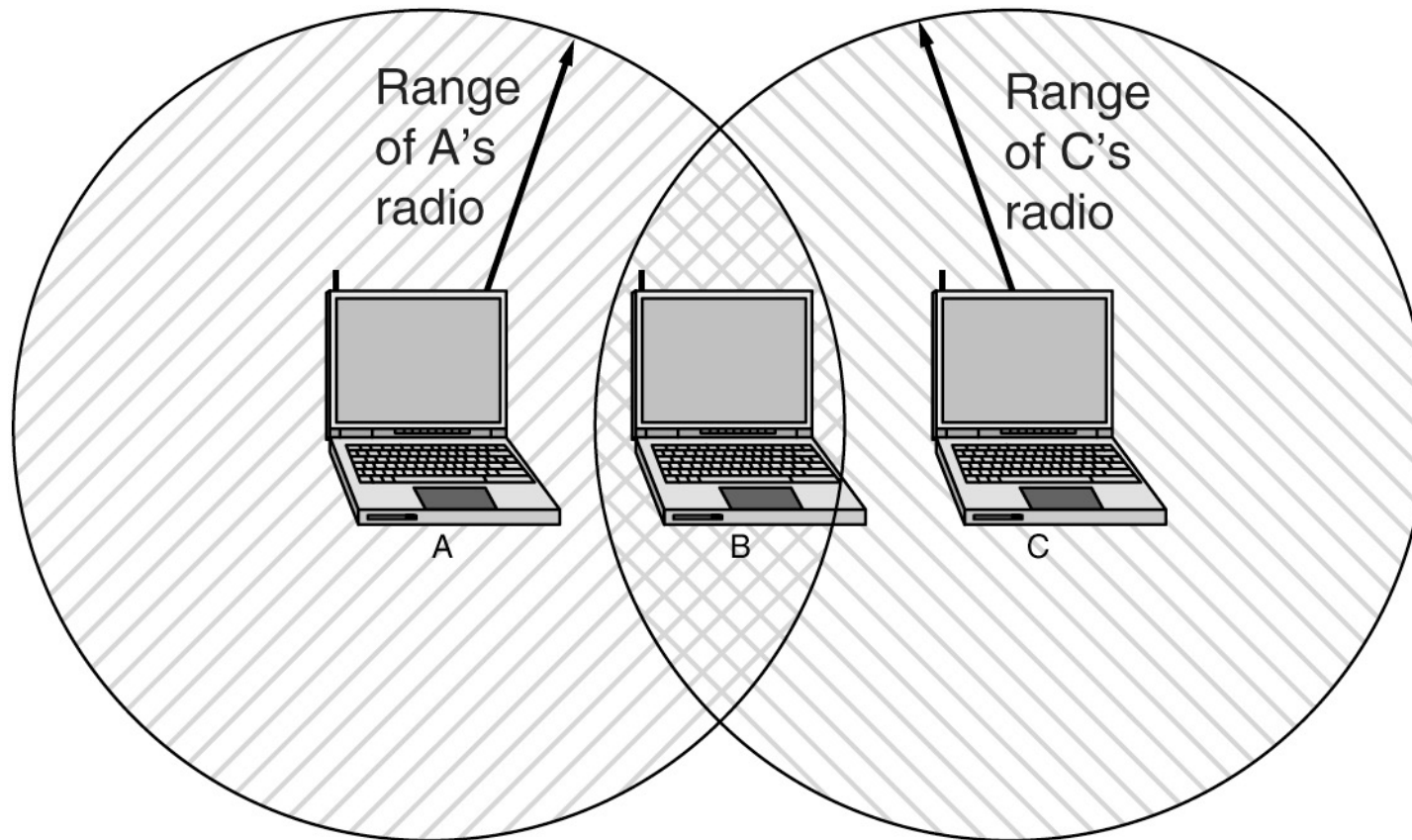
Access points connect to the wired network, and all communication between clients goes through the access point. In an ad hoc network, clients that are in radio range talk directly without an access point.

# Wireless Networks (WiFi) (5 of 6)



At the frequencies used for 802.11, radio signals can be reflected off solid objects so that multiple echoes of a transmission may reach a receiver along different paths. The echoes can cancel or reinforce each other, causing the received signal to fluctuate greatly – a phenomenon known as multipath fading.

# Wireless Networks (WiFi) (6 of 6)



The range of a single radio may not cover the entire system.

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