

Chapter 2 The Physical Layer

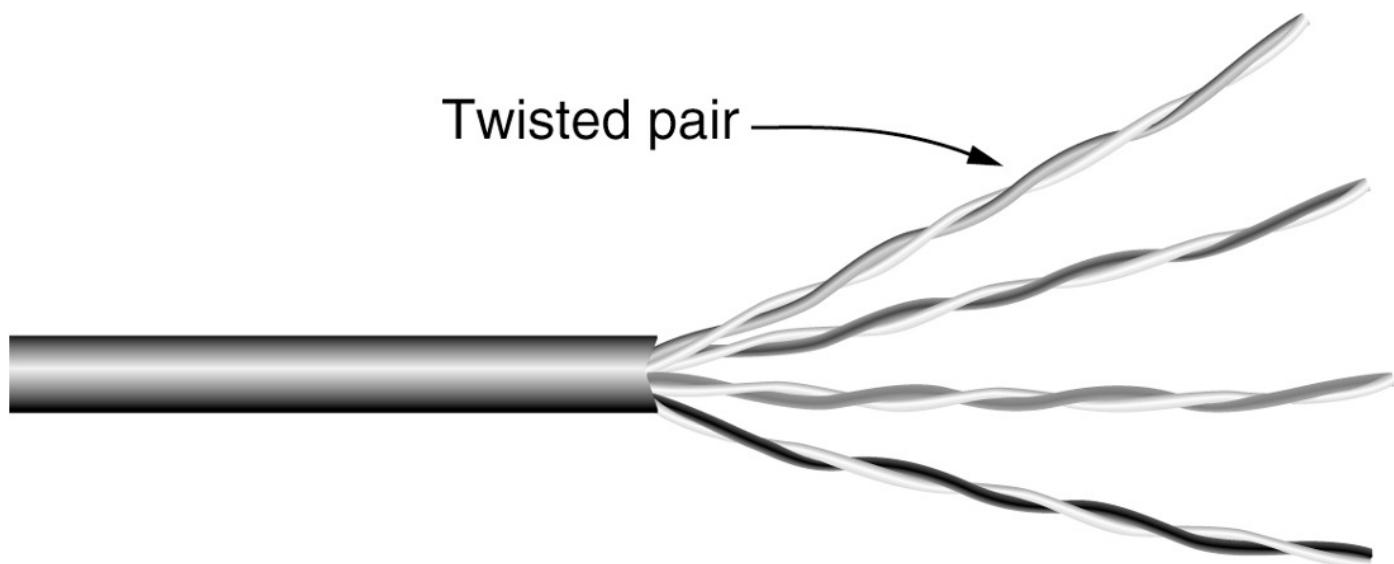
Chapter 2 The Physical Layer

2.1 Persistent storage, twisted pairs, Coaxial cable, Power lines, Fiber optics, Comparison of fiber optics with copper wire

2.1.1 Persistent Storage

- Consists of magnetic or solid-state storage
由磁性或固态存储器组成
- Common way to transport data
传输数据的常用方法
 - Write to persistent storage
写入持久存储
 - Physically transport the tape or disks to the destination machine
物理地将磁带或磁盘传输到目标机器
 - Read data back again
再次读取数据
- Cost effective for applications where a high data rate or cost per bit transported is the key factor
对于高数据速率或每比特传输成本是关键因素的应用程序而言，成本效益是关键
- Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway
永远不要低估一辆满载磁带的旅行车在高速公路上飞驰的带宽

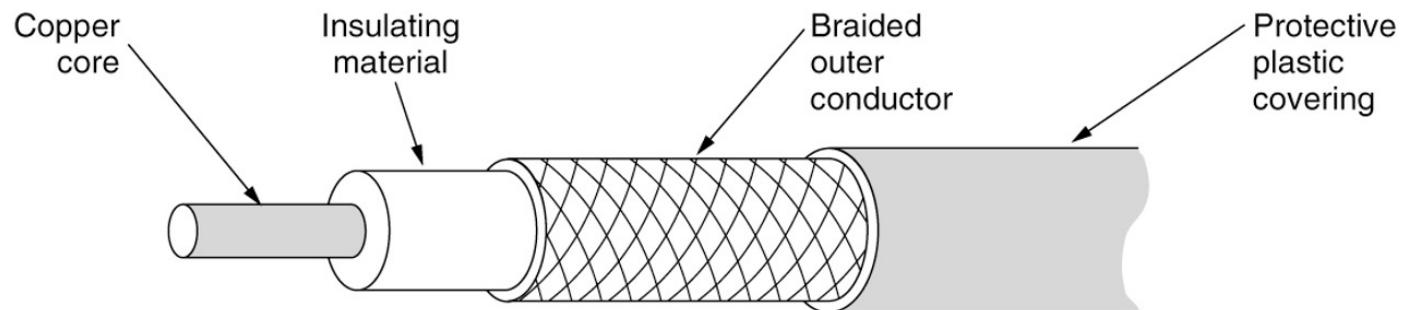
2.1.2 Twisted Pairs



A category 5e twisted pair consists of two insulated wires gently twisted together. Four such pairs are typically grouped in a plastic sheath to protect the wires and keep them together.

5e类双绞线由两根绝缘电线轻轻绞合而成。四对这样的电线通常被组合在一个塑料护套中，以保护电线并使它们保持在一起。

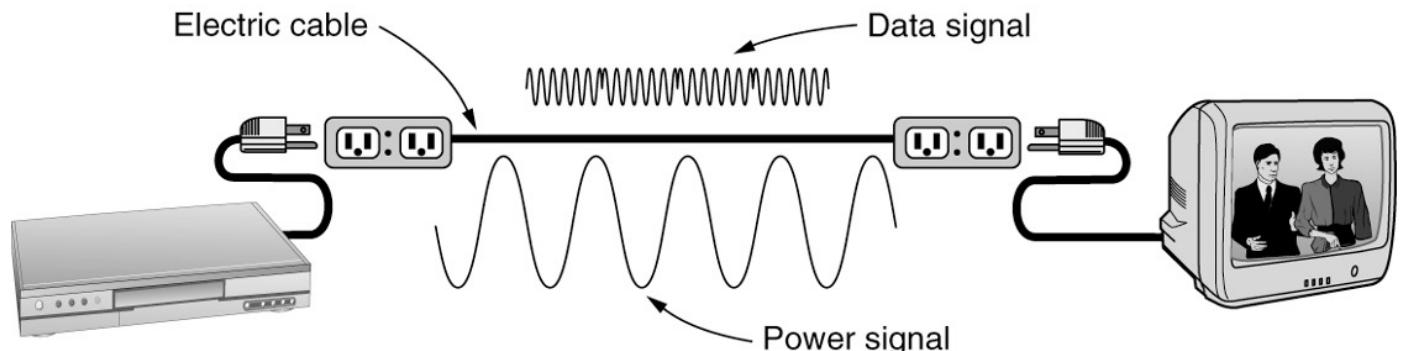
2.1.3 Coaxial cable



A coaxial cable consists of a stiff copper wire as the core, surrounded by an insulating material. The insulator is encased by a cylindrical conductor, often as a closely woven braided mesh. The outer conductor is covered in a protective plastic sheath.

同轴电缆由一根硬铜线作为芯线，周围环绕一层绝缘材料。绝缘体由圆柱形导体包裹，通常是紧密编织的编织网。外导体被一层塑料护套所覆盖。

2.1.4 Power lines



Using power lines for networking is simple. In this case, a TV and a receiver are plugged into the wall, which must be done anyway because they need power. Then they can send and receive movies over the electrical wiring.

使用电力线进行网络连接很简单。在这种情况下，电视和接收器插在墙上，无论如何都必须这样做，因为它们需要电力。然后他们可以通过电线发送和接收电影。

2.1.5 Fiber optics

- Allows essentially infinite bandwidth
允许无限带宽
- Must consider costs

必须考虑成本

- For installation over the last mile and to move bits

用于安装最后一英里和移动位

- Uses

- Long-haul transmission in network backbones

网络骨干网中的长距离传输

- High-speed LANs

高速局域网

- High-speed Internet access

高速互联网接入

- Key components

关键部件

- Light source, transmission medium, and detector

光源、传输介质和探测器

- Transmission system uses physics

传输系统使用物理原理

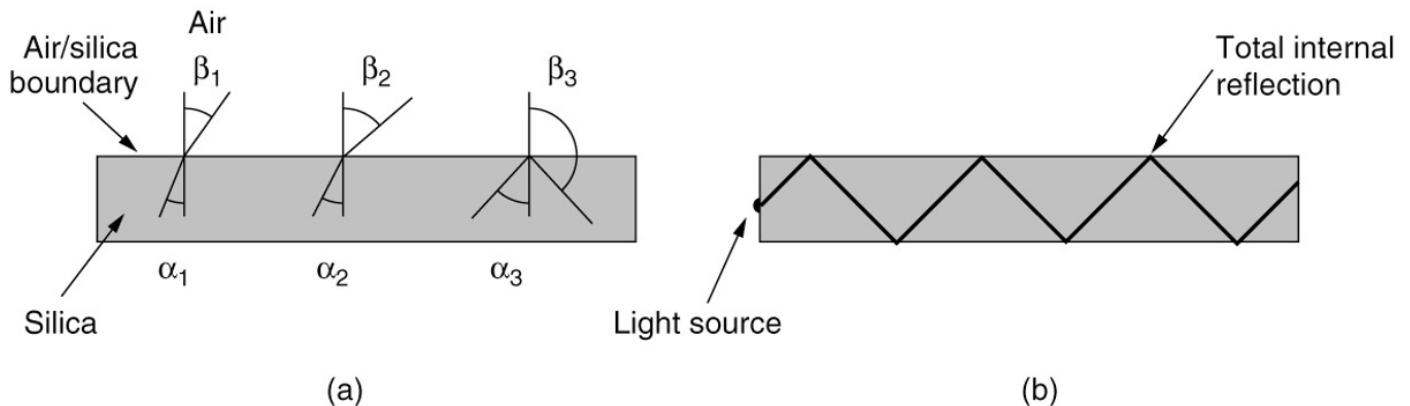


Figure (a) illustrates a light ray inside a silica fiber impinging on the air/silica boundary at different angles. Figure (b) illustrates light trapped by total internal reflection.

图(a)说明了硅光纤内的光线以不同角度撞击空气/硅边界。图(b)说明了被全内反射捕获的光。

- Transmission of light through fiber

通过光纤传输光

- Attenuation of light through glass

光通过玻璃的衰减

- Dependent on the wavelength of the light

依赖于光的波长

- Defined as the ratio of input to output signal power

定义为输入输出信号功率之比

- Fiber cables
- 光纤
- Similar to coax, except without the braid
- 类似于coax, 只是没有辫子

- Two kinds of signaling light sources

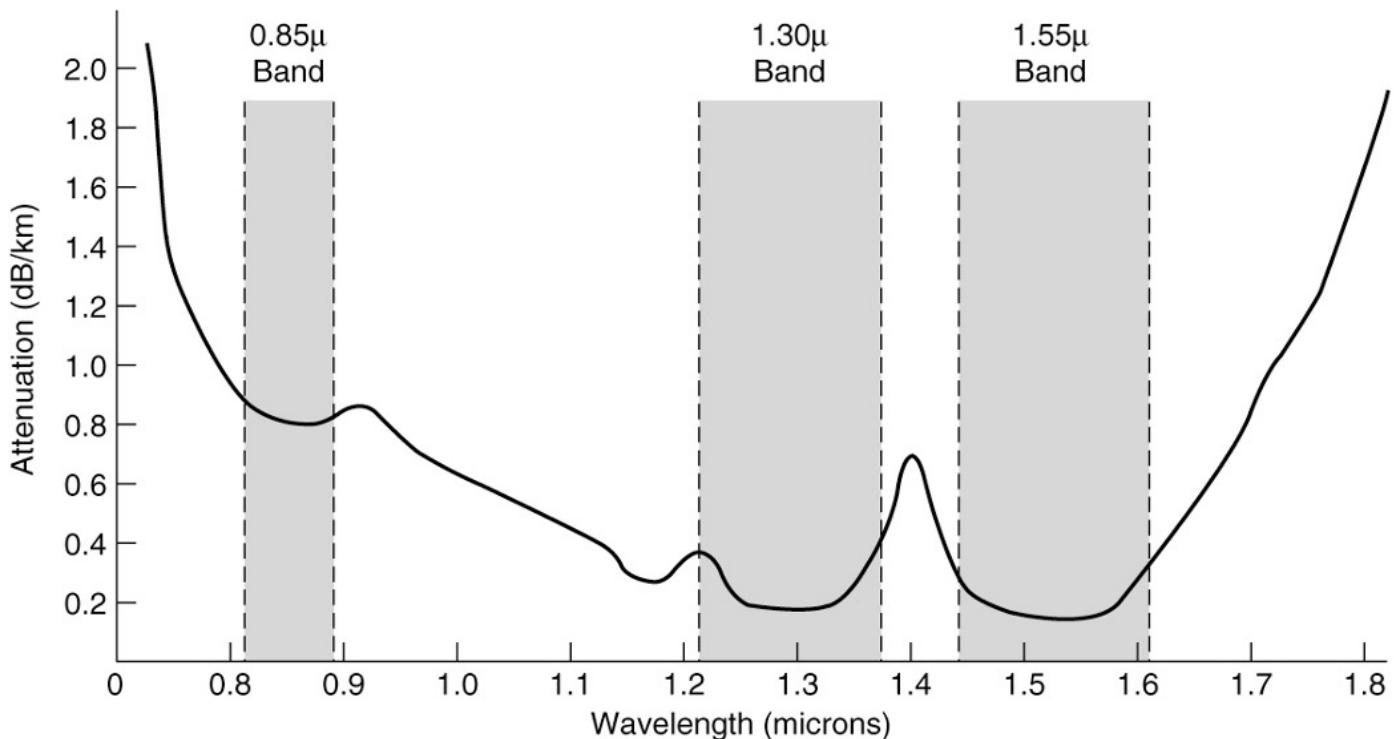
两种信号光源

- LEDs (Light Emitting Diodes)

led(发光二极管)

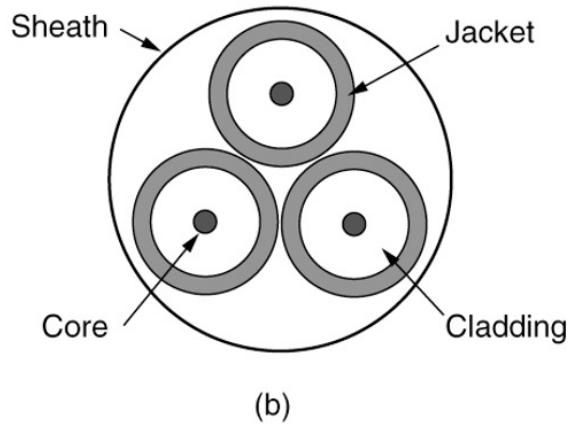
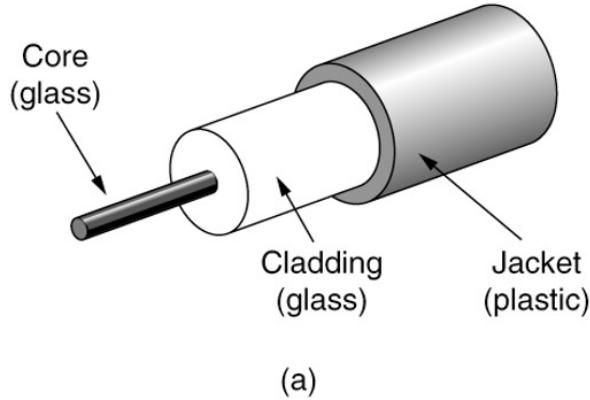
- Semiconductor lasers

半导体激光器



Attenuation of light through fiber in the infrared region is measured in units of decibels (dB) per linear kilometer of fiber.

光在红外区域通过光纤的衰减是以每直线千米光纤的分贝(dB)为单位来测量的。



Views of a fiber cable

光纤的外观

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multi-mode	Multi-mode or single-mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

A comparison of semiconductor diodes and LEDs as light sources.

半导体二极管和发光二极管作为光源的比较。

2.1.6 Comparison of fiber optics with copper wire

- Fiber advantages over copper

光纤优于铜

- Handles higher bandwidth
处理更高的带宽
- Not affected by power surges, electromagnetic interference, power failures, corrosive chemicals
不受电涌、电磁干扰、电源故障、腐蚀性化学品影响
- Thin and lightweight
轻薄
- Do not leak light
不要漏光
- Difficult to tap
难以点击

- Fiber disadvantage

纤维的缺点

- Less familiar technology that requires specific engineering skills
不太熟悉的技术，需要特定的工程技能
- Fibers damaged easily by being bent too much
过度弯曲容易损坏纤维

2.2: Electromagnetic spectrum, Frequency hopping spread spectrum, direct sequence spread spectrum

Wireless Transmission:

- The electromagnetic spectrum

电磁频谱

- Modulate wave amplitude, frequency, or phase

调制波的振幅、频率或相位

- Frequency hopping spread spectrum

跳频扩频

- Transmitter hops from frequency to frequency hundreds of times per second

发射机每秒从一个频率跳到另一个频率数百次

- Direct sequence spread spectrum

直接序列扩频

- Code sequence spreads data signal over wider frequency band

码序列将数据信号扩展到更宽的频带

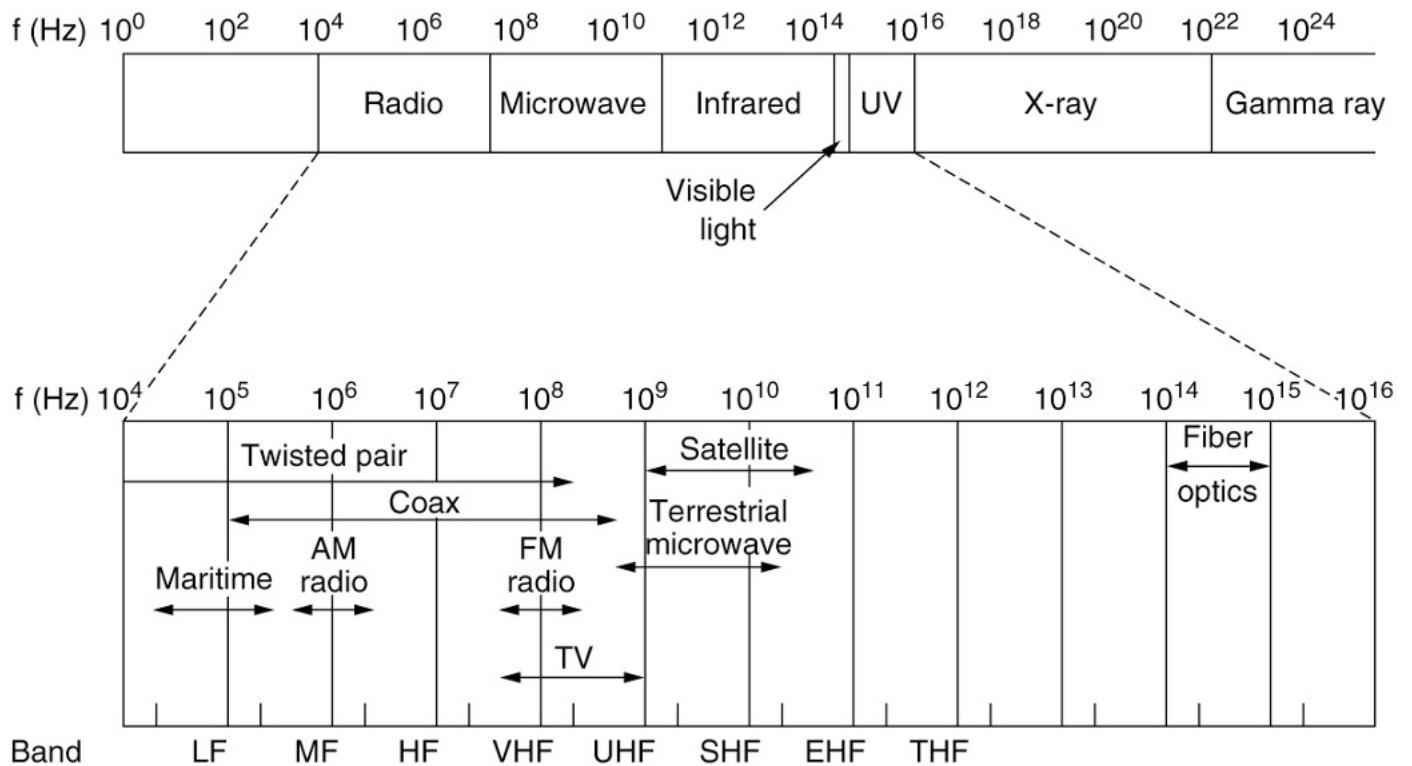
- Ultra-wideband communication

超宽频通讯

- Communication sends a series of low-energy rapid pulses, varying their carrier frequencies to communicate information

通信发送一系列低能量的快速脉冲，改变它们的载波频率来通信信息

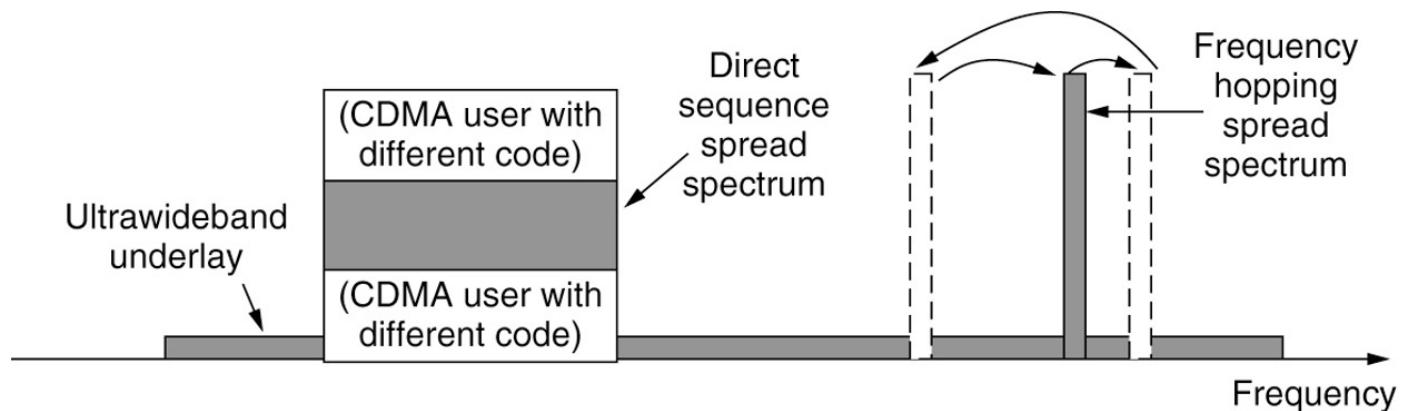
2.2.1 The Electromagnetic Spectrum



The electromagnetic spectrum and its uses for communication.

电磁频谱及其通信用途

2.2.2 Direct Sequence Spread Spectrum



Direct sequence spread spectrum uses a code sequence to spread the data signal over a wider frequency band.

直接序列扩频使用码序列将数据信号扩展到更宽的频带。

2.3: Radio transmission, Light transmission

- Radio transmission

无线电传输

- Omnidirectional waves, easy to generate, travel long distances, penetrate buildings

全向波，容易产生，传播距离远，穿透建筑物

- Microwave transmission

微波传输

- Directional waves requiring repeaters, do not penetrate buildings

定向波需要中继器，不能穿透建筑物

- Infrared transmission

红外传输

- Unguided waves used for short-range communication, relatively directional, cheap, easy to build, do not penetrate solid walls

非导波用于短程通信，相对定向，便宜，易于建造，不穿透坚固的墙壁

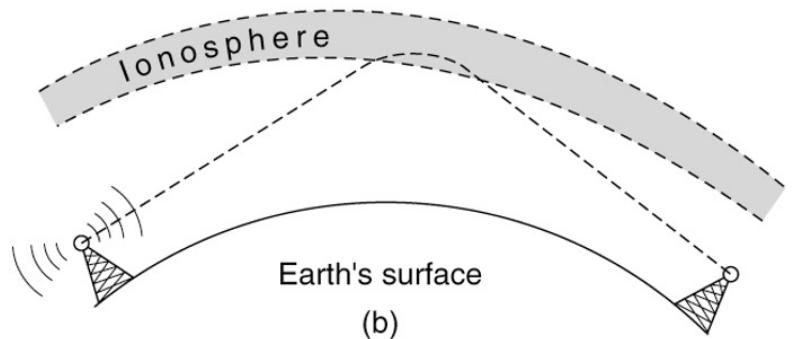
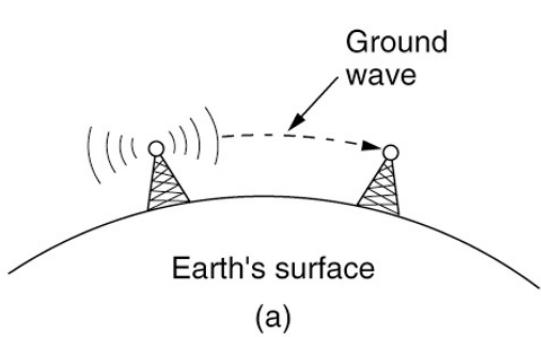
- Light transmission

光传输

- Unguided optical communication

无制导光通信

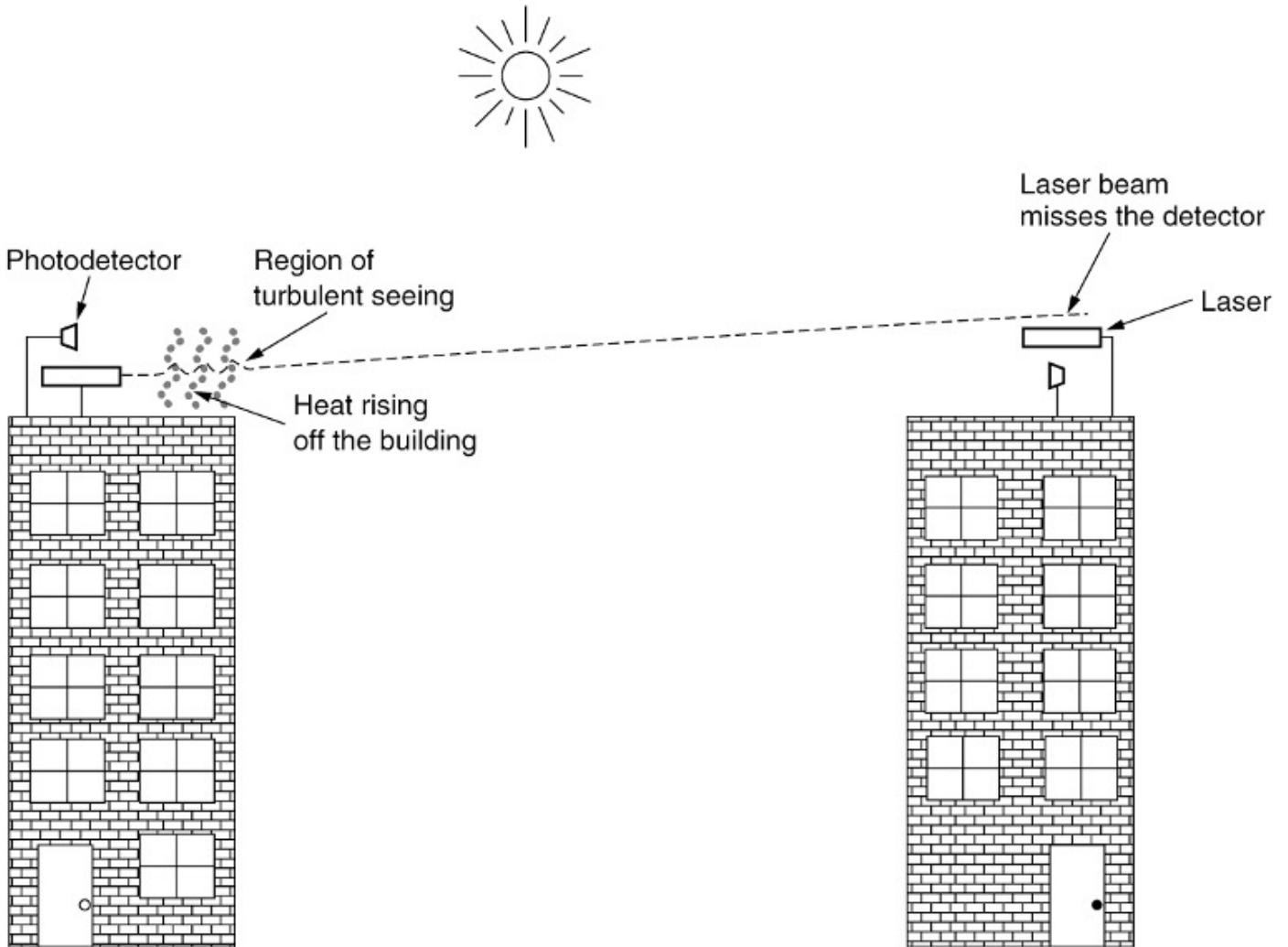
2.3.1 Radio transmission



In the VLF, LF, and MF bands, radio waves follow the curvature of the earth. In the HF band, they bounce off the ionosphere.

在VLF、LF和MF波段，无线电波沿着地球的曲率运动。在高频波段，它们在电离层反弹。

2.3.2 Light transmission



Convection currents can interfere with laser communication systems. A bidirectional system with two lasers is pictured here.

对流会干扰激光通信系统。一个双向系统有两个激光器在这里被描绘。

2.4: Bandwidth, Baseband transmission, Passband transmission, FDM, TDM, CDM, WDM

2.4.1 Bandwidth

- Bandwidth means different things to electrical engineers and to computer scientists.
带宽对于电子工程师和计算机科学家来说意味着不同的东西。
- To electrical engineers, (analog) bandwidth is a quantity measured in Hz. The hertz is equivalent to one cycle per second.
对电气工程师来说, (模拟)带宽是一个以Hz测量的量。赫兹等于每秒一个周期。
- To computer scientists, (digital) bandwidth is the maximum data rate of a channel, a quantity measured in bits/sec.
对计算机科学家来说, (数字)带宽是信道的最大数据速率, 以比特/秒来衡量。

- That data rate is the end result of using the analog bandwidth of a physical channel for digital transmission, and the two are related

数据速率是使用物理信道的模拟带宽进行数字传输的最终结果，两者是相关的

- Bandwidth is often a limited resource

带宽通常是一种有限的资源

- Solution

- Use more than two signaling levels

使用两个以上的信号级别

- By using four voltages we can send 2 bits at once as a single symbol

通过使用四种电压，我们可以一次发送两个比特作为一个符号

- Design works as long as the signal at the receiver is sufficiently strong to distinguish the four levels

只要接收器的信号足够强，可以区分这四个等级，设计就可以工作

- Signal rate change is half the bit rate, so the needed bandwidth has been reduced

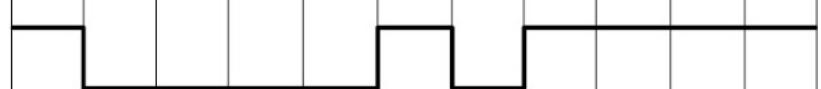
信号速率的变化是比特率的一半，因此所需的带宽也减少了

2.4.2 Baseband transmission

(a) Bit stream



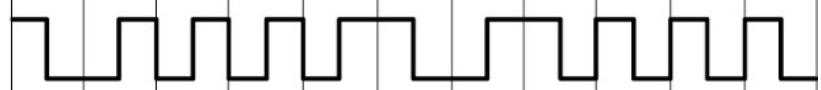
(b) Non-Return to Zero (NRZ)



(c) NRZ Invert (NRZI)



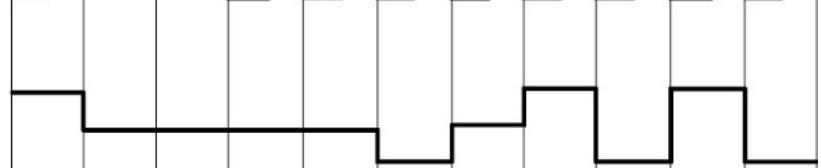
(d) Manchester



(Clock that is XORed with bits)



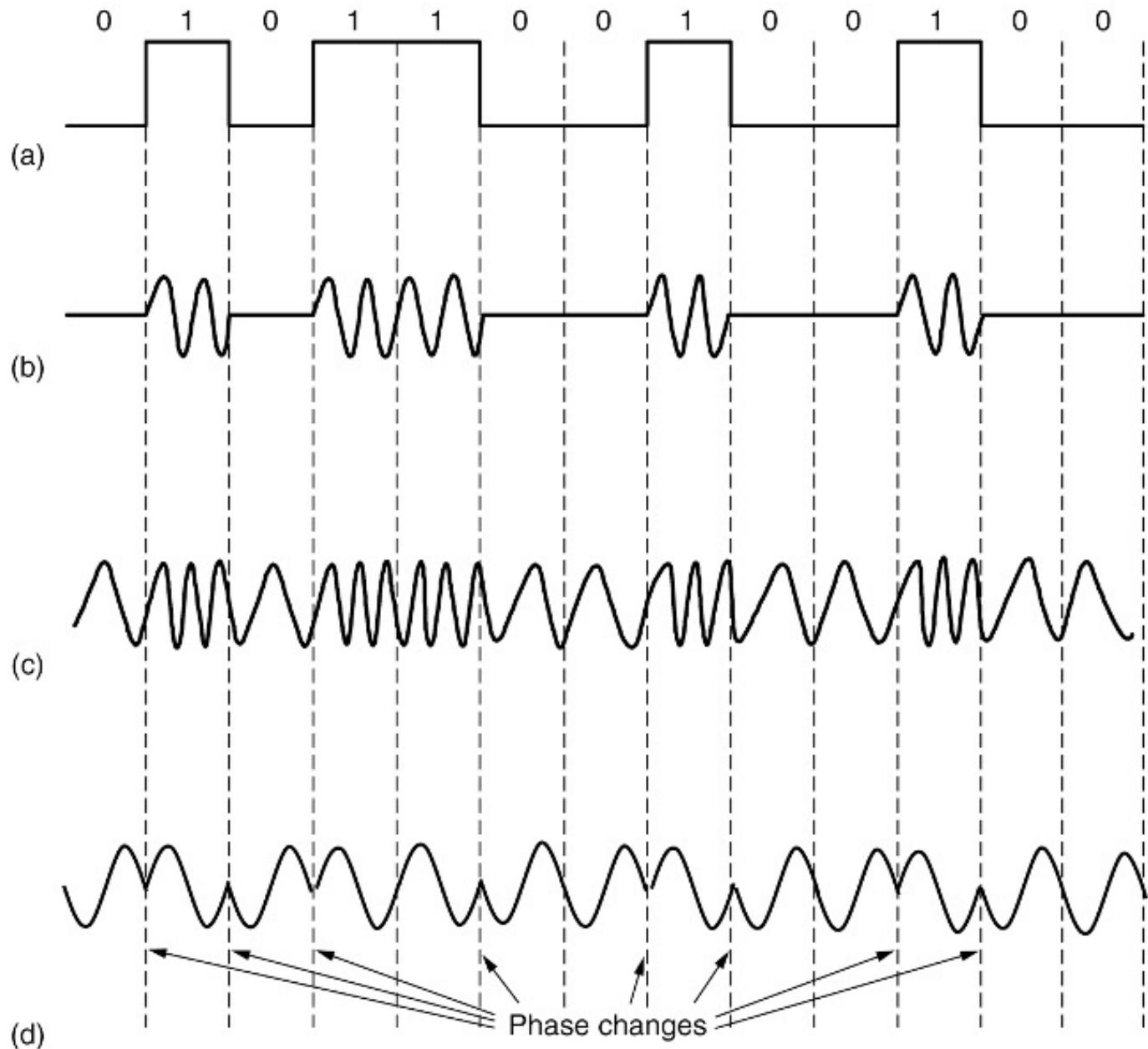
(e) Bipolar encoding
(also Alternate Mark
Inversion, AMI)



Line codes: (a) Bits, (b) NRZ, (c) NRZI, (d) Manchester, (e) Bipolar or AMI.

线路码:(a)比特, (b) NRZ, (c) NRZI, (d)曼彻斯特, (e)双极或AMI。

2.4.3 Passband Transmission



(a) A binary signal. (b) Amplitude shift keying. (c) Frequency shift keying. (d) Phase shift keying.

(a)二进制信号。(b)幅度键控。(c)频移键控。(d)相移键控。

2.4.4 Multiplexing

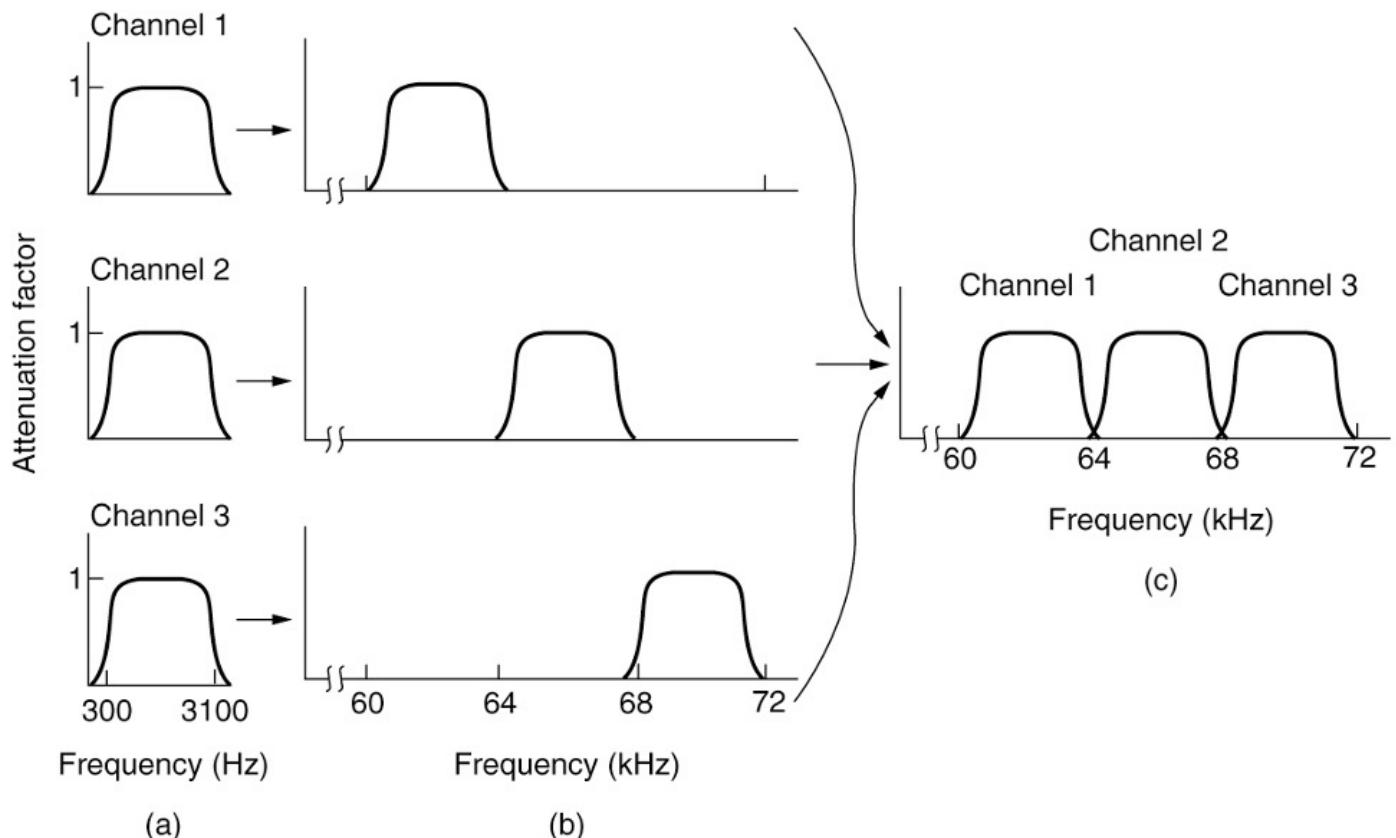
复用

- Frequency Division Multiplexing
频分复用
- Time Division Multiplexing

时分多路复用

- Code Division Multiplexing
代码分复用
- Wavelength Division Multiplexing
波分复用

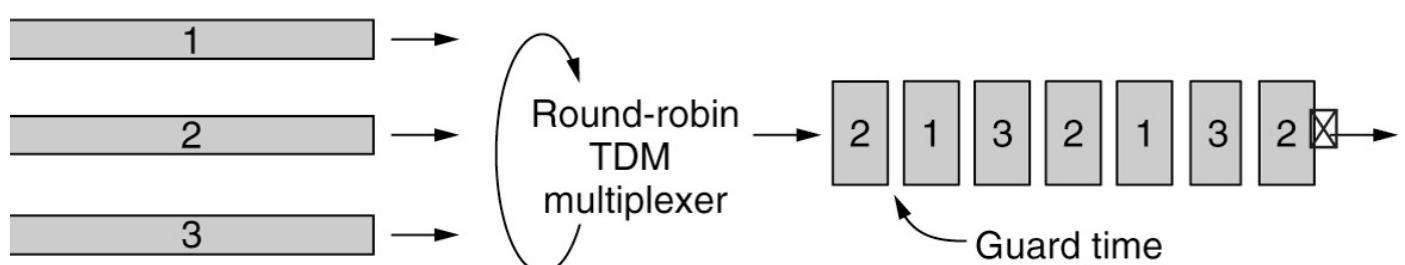
2.4.4.1 Frequency Division Multiplexing



(a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

(a)原始带宽。 (b)频带增加。 (c)多路复用信道。

2.4.4.2 Time Division Multiplexing



Time Division Multiplexing (TDM)

时分复用

2.4.4.3 Code Division Multiplexing

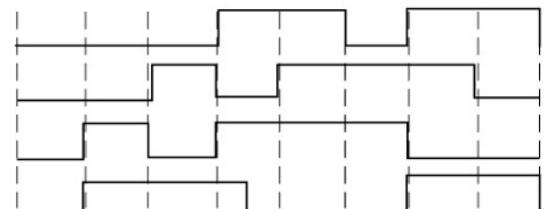
$$A = (-1 -1 -1 +1 +1 -1 +1 +1)$$

$$B = (-1 -1 +1 -1 +1 +1 +1 -1)$$

$$C = (-1 +1 -1 +1 +1 +1 -1 -1)$$

$$D = (-1 +1 -1 -1 -1 -1 +1 -1)$$

(a)



(b)

$$\begin{aligned} S_1 \cdot C &= (-1 +1 -1 +1 +1 +1 -1 -1) \\ S_2 \cdot C &= (-2 0 0 0 +2 +2 0 -2) \\ S_3 \cdot C &= (0 0 -2 +2 0 -2 0 +2) \\ S_4 \cdot C &= (-1 +1 -3 +3 +1 -1 -1 +1) \\ S_5 \cdot C &= (-4 0 -2 0 +2 0 +2 -2) \\ S_6 \cdot C &= (-2 -2 0 -2 0 -2 +4 0) \end{aligned}$$

$$\begin{aligned} S_1 \cdot C &= [1+1+1+1+1+1+1]/8 = 1 \\ S_2 \cdot C &= [2+0+0+0+2+2+0+2]/8 = 1 \\ S_3 \cdot C &= [0+0+2+2+0-2+0-2]/8 = 0 \\ S_4 \cdot C &= [1+1+3+3+1-1+1-1]/8 = 1 \\ S_5 \cdot C &= [4+0+2+0+2+0-2+2]/8 = 1 \\ S_6 \cdot C &= [2-2+0-2+0-2-4+0]/8 = -1 \end{aligned}$$

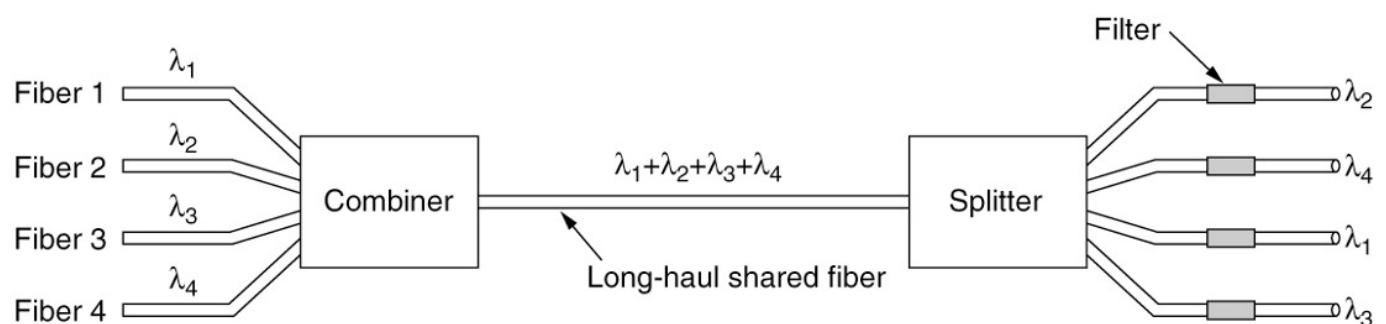
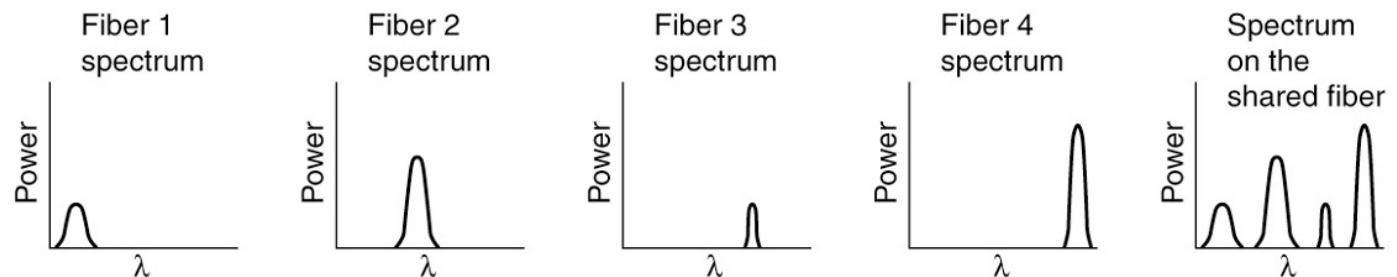
(c)

(d)

(a) Chip sequences for four stations. (b) Signals the sequences represent. (c) Six examples of transmissions. (d) Recovery of station C's signal.

(a)四个台站的芯片序列。(b)表示序列。(c)六个传输实例。(d)恢复C站的信号。

2.4.4.4 Wavelength Division Multiplexing



Wavelength division multiplexing

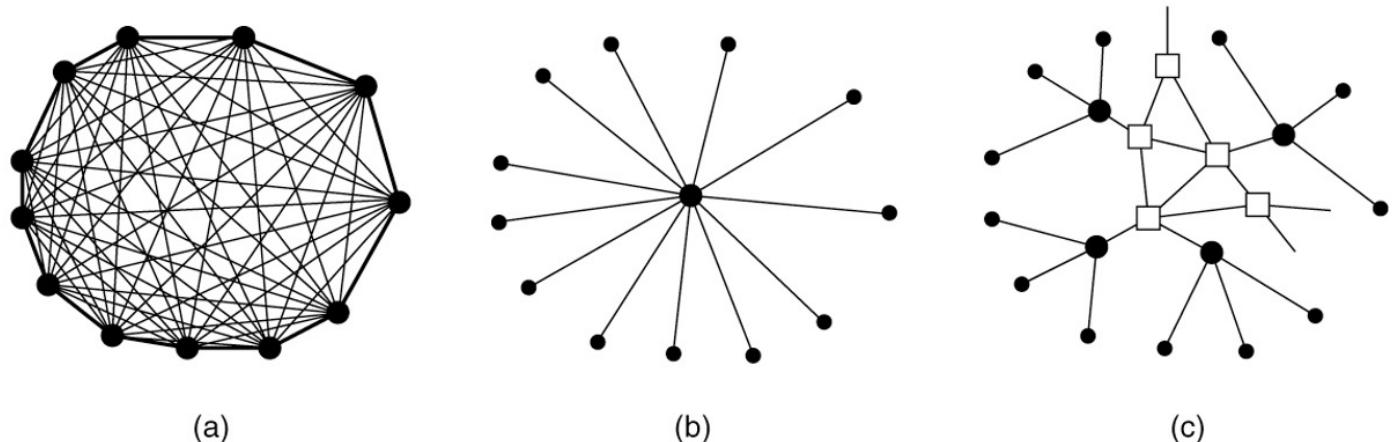
波分复用

2.5 Structure of the telephone system, Telephone modem, DSL, FTTX, Circuit switching, packet switching

The public Switched Telephone Network

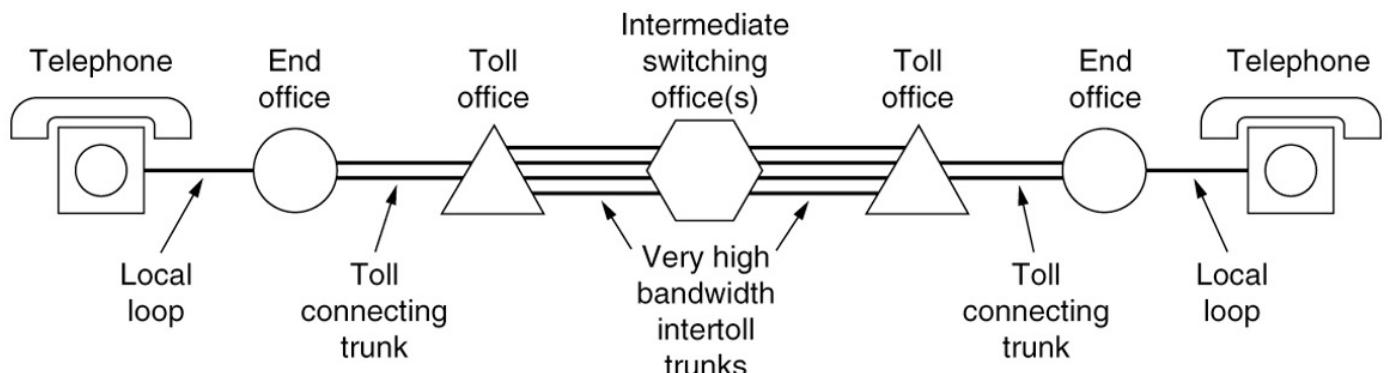
- Structure of the Telephone System
- The Local Loop: Telephone Modems, ADSL, and Fiber
 - Telephone modems

2.5.1 Structure of the telephone system



(a) Fully interconnected network. (b) Centralized switch. (c) Two-level hierarchy.

(a)全互联网络。(b)集中式切换。(c)两级等级。



A typical circuit route for a long-distance call

长途电话的典型线路

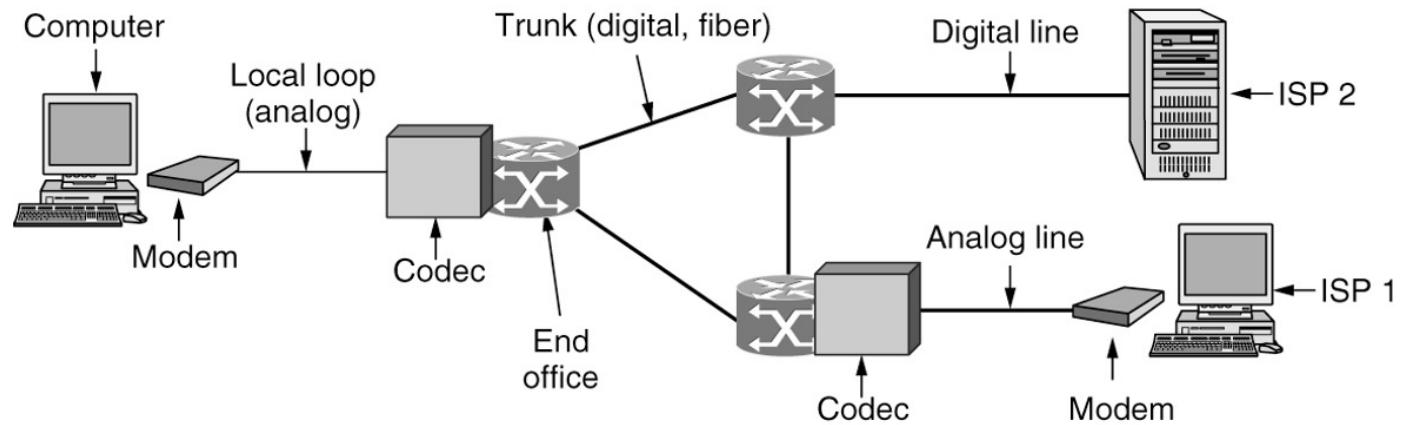
Telephone System components:

- Local loops (analog twisted pairs between end offices and local houses and businesses).
本地环路(末端办公室与本地房屋和企业之间的模拟双绞线)
- Trunks (very high-bandwidth digital fiber-optic links connecting the switching offices).
中继(连接交换局的高带宽数字光纤链路)。
- Switching offices (where calls are moved from one trunk to another either electrically or optically).

交换局(将呼叫从一个干线转移到另一个干线，无论是电还是光)。

The local loop: Local Telephone Modems, ADSL, and Fiber

2.5.1.1 Telephone Modems



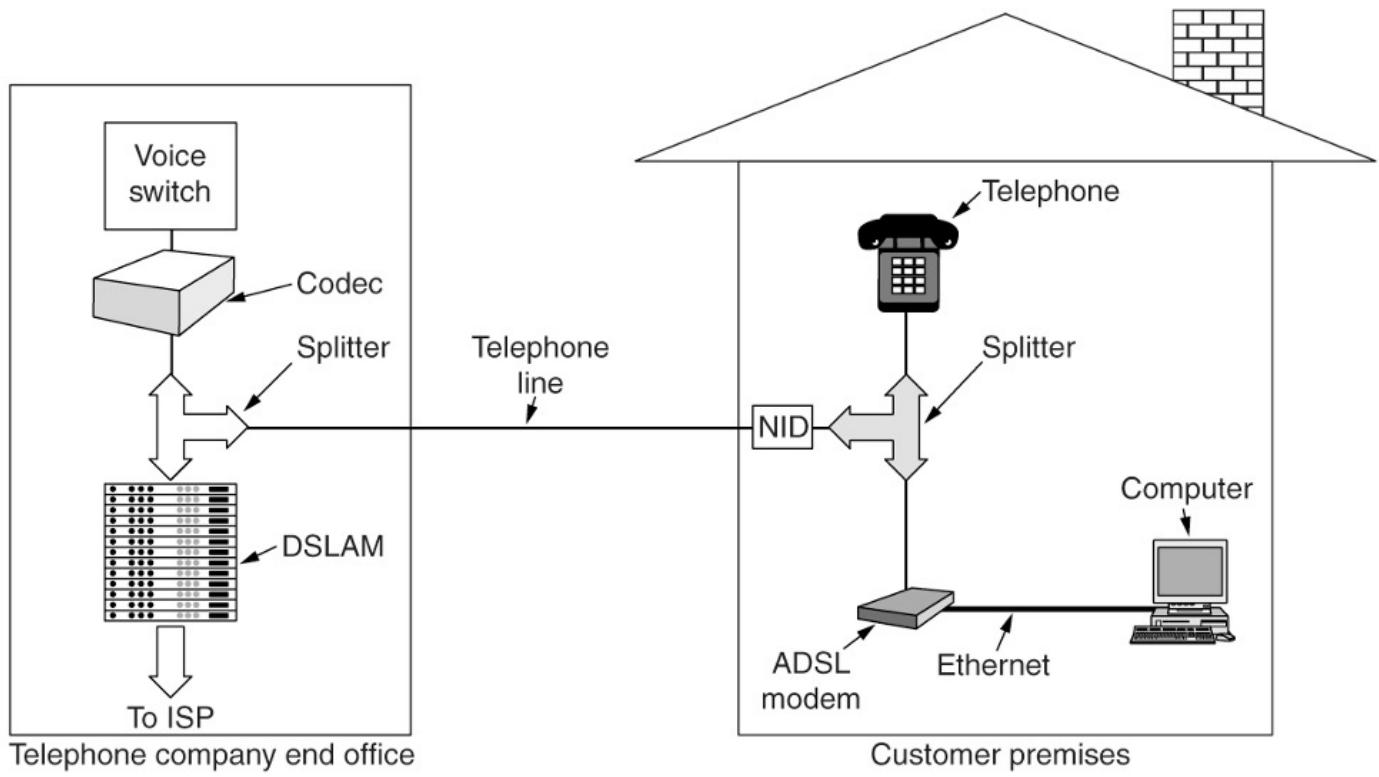
A device that converts between a stream of digital bits and an analog signal that represents the bits is called a **modem**.

The use of both analog and digital transmission for a computer-to-computer call. Conversion is done by the modems and codecs.

在数字比特流和表示比特流的模拟信号之间进行转换的设备称为调制解调器。

使用模拟和数字两种传输方式进行计算机对计算机的呼叫。转换由调制解调器和编解码器完成。

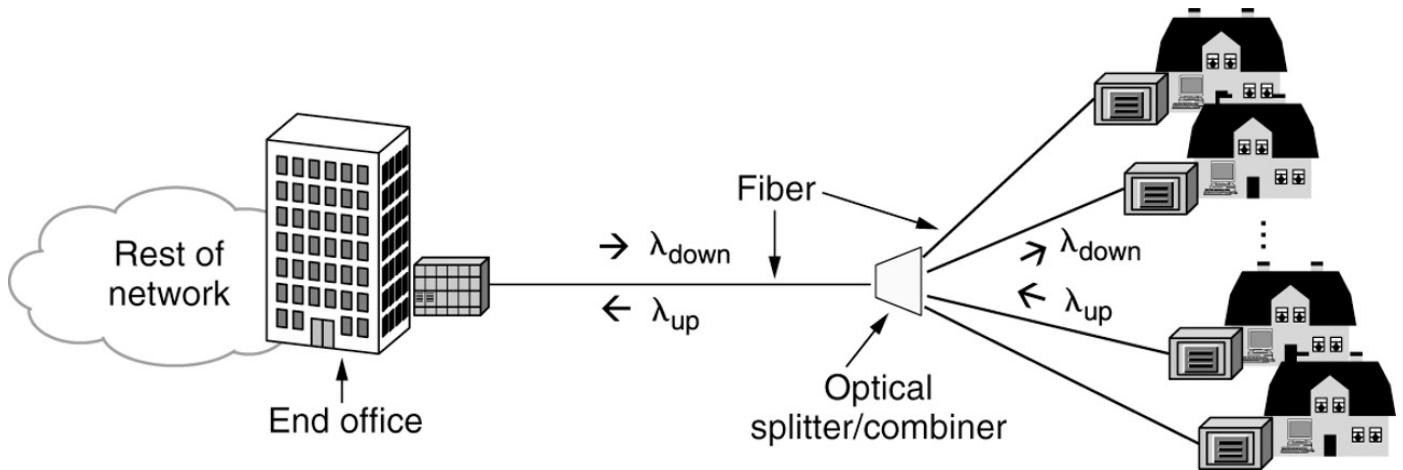
2.5.1.2 Digital Subscriber Lines (DSL)



A typical ADSL equipment configuration.

典型的ADSL设备配置。

2.5.1.3 Fiber To The X (FTTX)



Passive optical network for Fiber To The Home.

无源光网络用于光纤到家庭。

2.5.2 Switching

- Phone system principal parts
 - Outside plant (outside switching offices)

工厂外(交换室外)

- Inside plant (inside switching offices)

厂房内(开关室内)

- Two different switching techniques

两种不同的切换技术

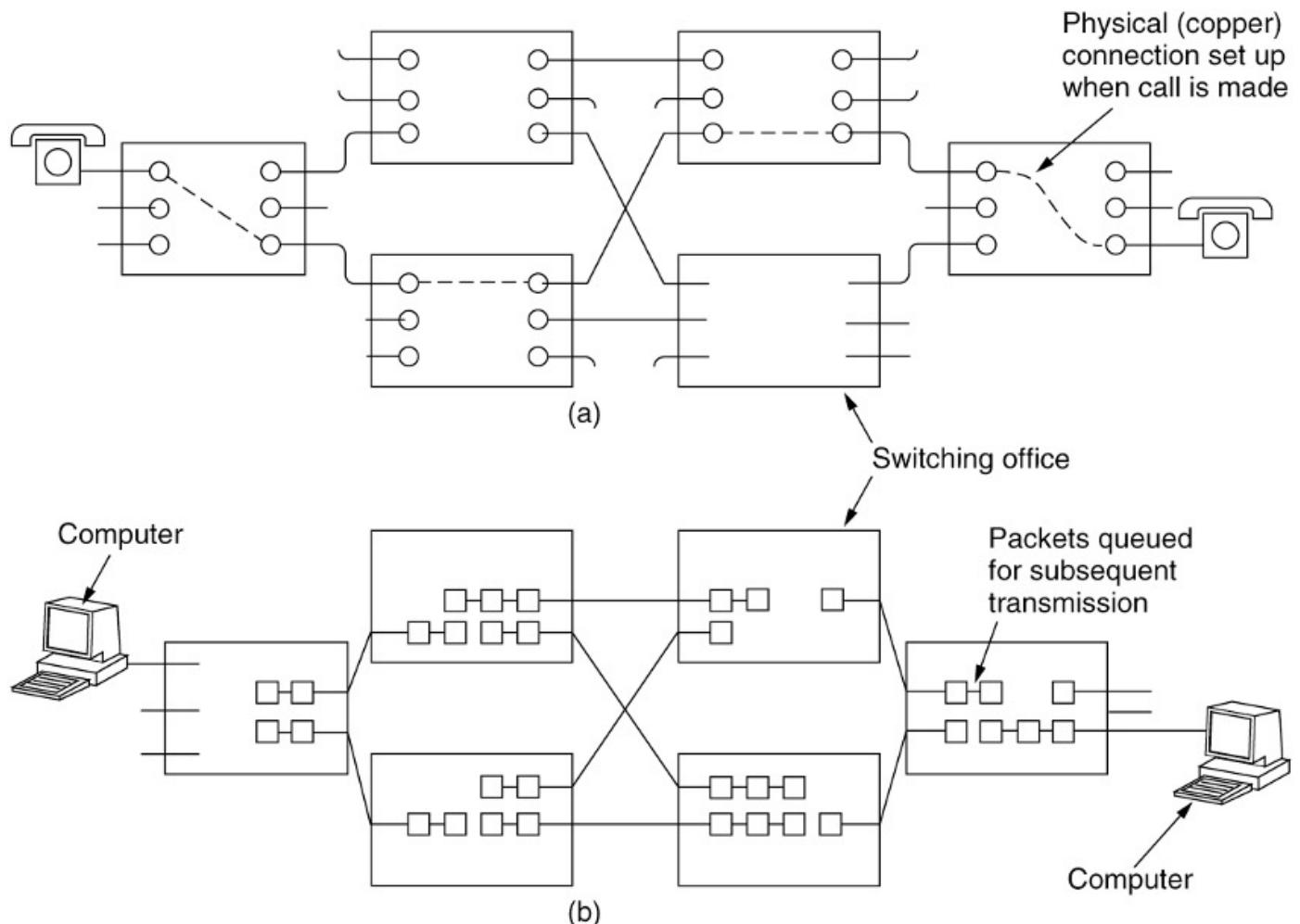
- Circuit switching: traditional telephone system

电路交换:传统的电话系统

- Packet switching: voice over IP technology

分组交换:voip技术

2.5.2.1 Circuit switching



(a) Circuit switching. (b) Packet switching.

(a) 电路切换。 (b) 分组交换。

2.5.2.2 Packet switching

Item	Circuit switched	Packet switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
Time of possible congestion	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Charging	Per minute	Per byte

A comparison of circuit-switched and packet-switched networks.

电路交换和分组交换网络的比较。

2.6: Cellular network concept, 1G, 2G, 3G, 4G, 5G

2.6.1 Cellular networks

- Mobile phone distinct generations
手机有不同的世代
- The initial three generations: 1G, 2G, 3G
最初的三代:1G、2G、3G
 - Provided **analog** voice, **digital** voice, and **both** digital voice and data (Internet, email, etc.) respectively
提供模拟语音，数字语音，以及同时提供数字语音和数据(互联网，电子邮件等)
- 4G technology adds capabilities
4G技术增加了功能
 - Physical layer transmission techniques and IP-based femtocells
物理层传输技术和基于ip的家庭基站
 - 4G is based on **packet switching** only (no circuit switching)
4G仅基于分组交换(没有电路交换)
- 5G being rolled out now
5G正在推出
 - Supports up to 20 Gbps transmissions and denser deployments

支持高达20 Gbps的传输和更密集的部署

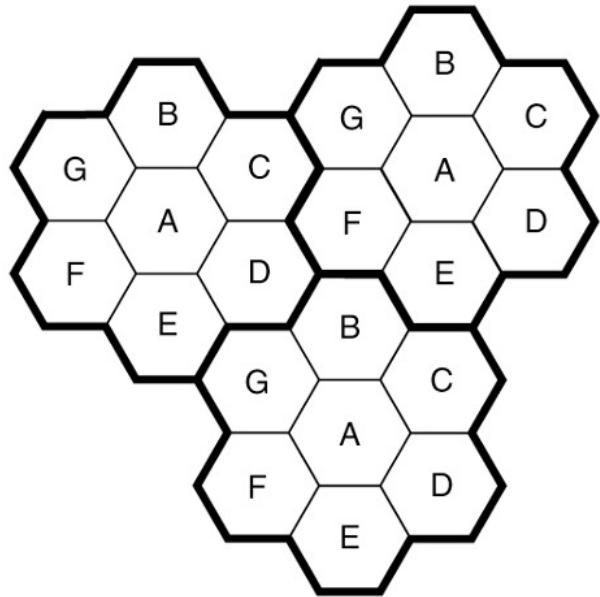
- Focus on reducing network latency

专注于减少网络延迟

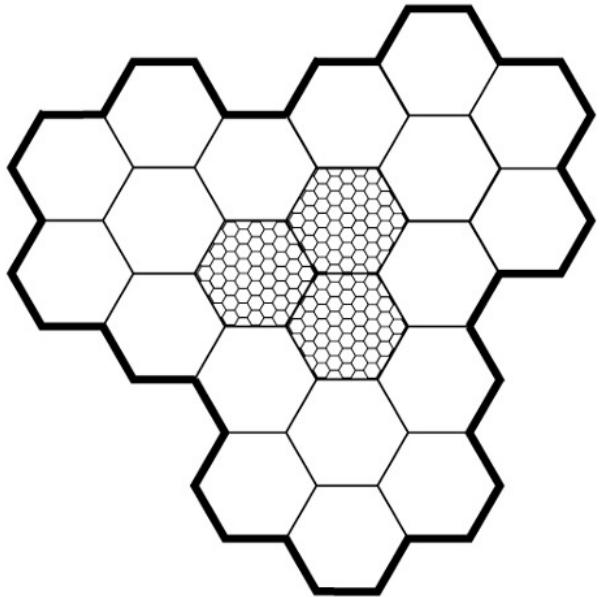
Common Concepts: Cells

A geographic region is divided up into **cells**, allowing for frequency reuse

一个地理区域被划分为单元格，允许频率重用



(a)



(b)

(a) Frequencies are not reused in adjacent cells. (b) To add more users, smaller cells can be used.

(a) 相邻小区不重复使用频率。 (b) 为了增加更多的用户，可以使用更小的小区。

Common Concepts: Cells

常见概念:单元格

At the center of each cell is a base station to which all the telephones in the cell transmit.

在每个小区的中心是一个基站，小区里所有的电话都向它传输。

The base station consists of a computer and transmitter/receiver connected to an antenna.

基站由一台计算机和连接到天线的发射机/接收机组成。

In a small system, all the base stations are connected to a single device called an **MSC (Mobile Switching Center)** or **MTSO (Mobile Telephone Switching Office)**.

在一个小型系统中，所有基站都连接到一个叫做**MSC(移动交换中心)**或**MTSO(移动电话交换办公室)**的设备上。

In a larger one, several MSCs may be needed, all of which are connected to a second-level MSC, and so on.

在一个更大的系统中，可能需要多个MSC，所有这些MSC都连接到一个二级MSC，以此类推。

First-Generation (1G) Technology: Analog Voice

- 1946 push to talk systems
1946 push to talk系统
- 1960 IMTS (Improved Mobile Telephone System)
1960年IMTS(改进的移动电话系统)
 - Two frequencies: one for sending, one for receiving
两个频率:一个用于发送, 一个用于接收
- 1983 AMPS (Advanced Mobile Phone System)
1983 AMPS(高级移动电话系统)
 - Analog mobile phone system
模拟手机系统
 - Cells are typically 10 to 20 km across
电池的直径通常为10到20公里
 - Used FDM to separate channels
使用FDM分离通道

Call Management

- Outgoing calls
呼出电话
 - Phone switched on, number entered, CALL button hit
手机开机, 号码输入, 呼叫按钮按下
 - Phone transmits called number and its own identity on the access channel
手机在接入信道上传输被叫号码和自己的身份
 - Base informs the MSC and MSC looks for a channel for the call
Base通知MSC, MSC寻找呼叫的通道 MSC(Mobile Switching Center)
- Incoming calls
来电
 - Idle phones continuously listen to the paging channel to detect messages directed at them
闲置的电话会持续监听寻呼频道, 以侦测发给他们的讯息
 - Packet sent to base station in the current cell as a broadcast on the paging channel
通过寻呼信道以广播形式发送到当前小区基站的数据包
 - The called phone responds on the access channel
被呼叫的电话在接入通道上响应
 - Called phone switches to channel and starts ringing sound

被呼叫的电话切换到频道并开始响起铃声

Second-Generation (2G) Technology: Digital Voice

第二代(2G)技术:数字语音

- Digital advantages

数字优势

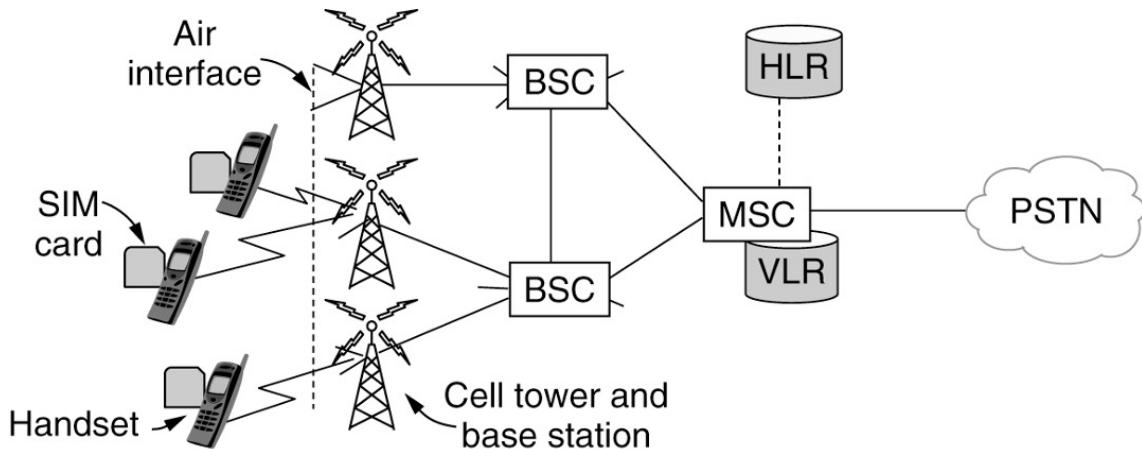
- Provides capacity gains by allowing voice signals to be digitized and compressed
通过允许语音信号被数字化和压缩来提供容量增益
- Improves security by allowing voice and control signals to be encrypted
通过允许语音和控制信号加密来提高安全性
- Deters fraud and eavesdropping
阻止欺诈和窃听
- Enables new services such as text messaging
启用新的服务，如短信

- Three systems developed

开发了三个系统

- D-AMPS (Digital Advanced Mobile Phone System)
D-AMPS(数字先进移动电话系统)
- GSM (Global System for Mobile communications)
GSM(全球移动通信系统)
- CDMA (Code Division Multiple Access)
CDMA(码分多址)

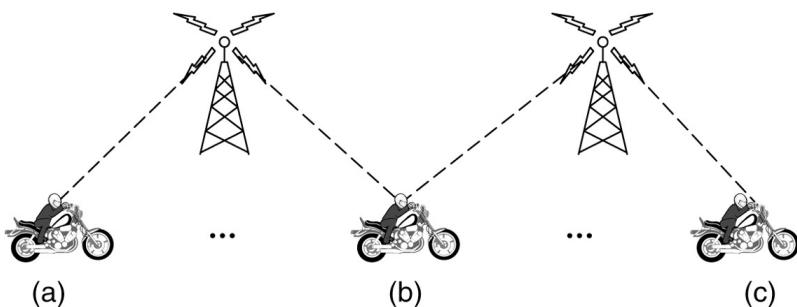
GSM: The Global System for Mobile Communications (1 of 3)



GSM mobile network architecture.

GSM移动网络体系结构

Third-Generation (3G) Technology: Digital Voice and Data



Soft handoff (a) before, (b) during, and (c) after.

软切换(a)前, (b)中, (c)后。

Fourth-Generation (4G) Technology: Packet Switching

第四代(4G)技术:分组交换

- Also called IMT Advanced
也叫IMT Advanced
- Based completely on packet-switched technology
完全基于分组交换技术
- EPC (Evolved Packet Core) allows packet switching
EPC(演化包核心)允许分组交换
 - Carries both voice and data in IP packets
在IP包中携带语音和数据
 - Voice over IP (VoIP) network with resources allocated using the statistical multiplexing approaches
VoIP (voice over IP)网络, 使用统计复用方法进行资源分配
 - The EPC must manage resources in such a way that voice quality remains high in the face of network resources that are shared among many users
EPC必须以这样一种方式管理资源, 即在面对许多用户共享的网络资源时, 语音质量仍然很高

Fifth-Generation (5G) Technology

- Two main factors
两个主要因素
 - Higher data rates and lower latency than 4G technologies
比4G技术更高的数据速率和更低的延迟
- Technology used to increase network capacity
用于增加网络容量的技术
 - Ultra-densification and offloading

- 超致密和卸载
 - Increased bandwidth
增加带宽
 - Increased spectral efficiency through advances in massive MIMO (Multiple-Input Multiple-Output) technology
通过大规模MIMO(多输入多输出)技术的进步提高频谱效率
- Network slicing feature
网络切片特性
 - Lets cellular carriers create multiple virtual networks on top of the same shared physical infrastructure
让蜂窝运营商在相同的共享物理基础设施之上创建多个虚拟网络
 - Can devote network portions to specific customer use cases
能否将网络部分用于特定的客户用例

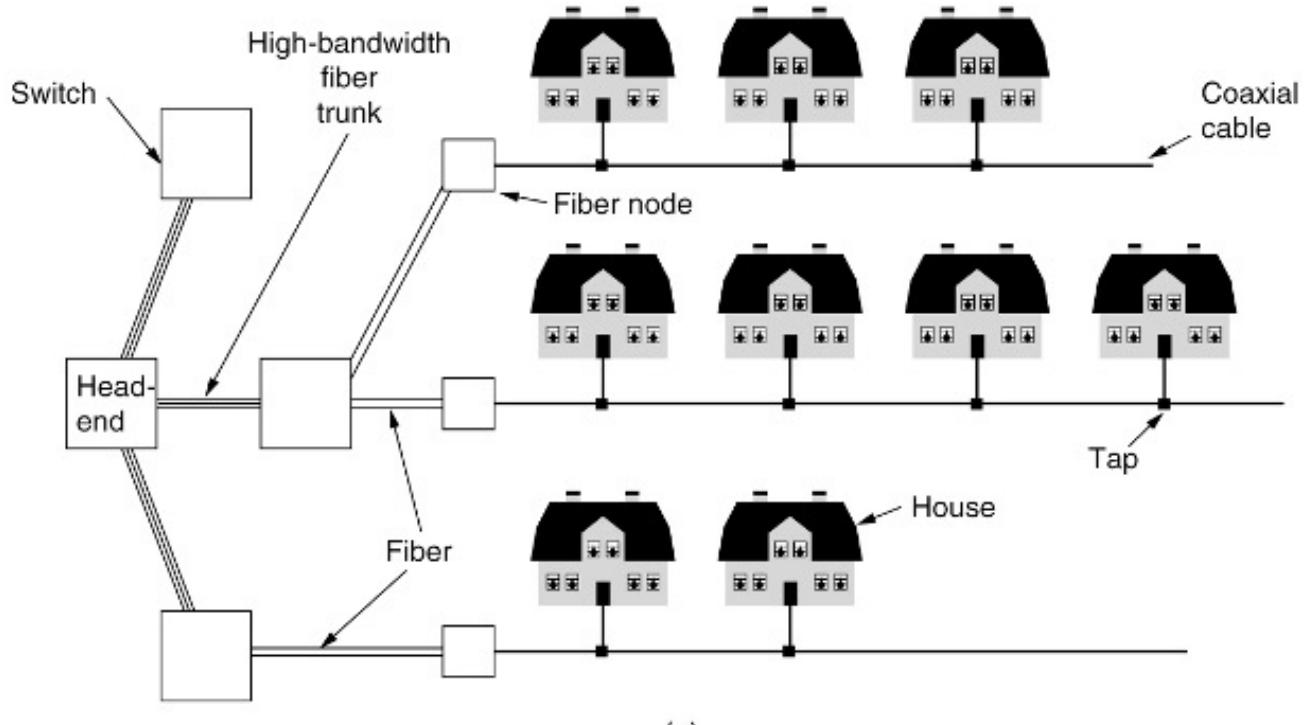
2.7: Broadband Internet access over cable, Docsis

Cable Networks

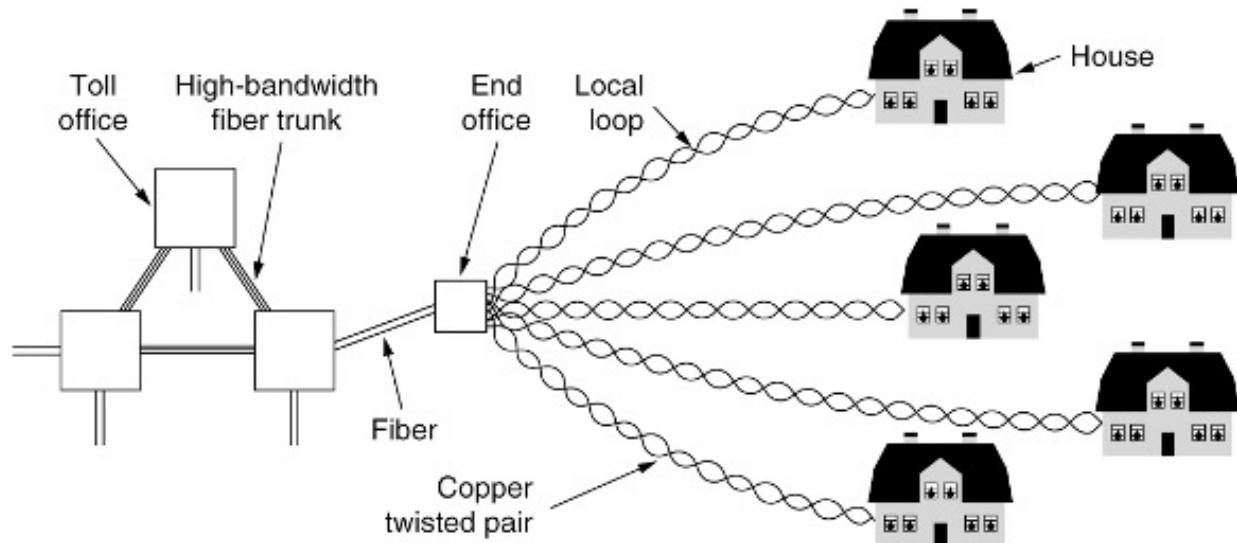
- Cable networks
有线网络
 - Will factor heavily into future broadband access networks
将严重影响未来的宽带接入网络
- Many people nowadays get their television, telephone, and Internet service over cable
现在许多人通过有线电视、电话和互联网服务
- 2018 DOCSIS standard
2018年DOCSIS标准
 - Provides information related to modern cable network architectures
提供与现代电缆网络架构相关的信息

Broadband Internet Access Over Cable: HFC Networks

通过有线宽带互联网接入:HFC网络



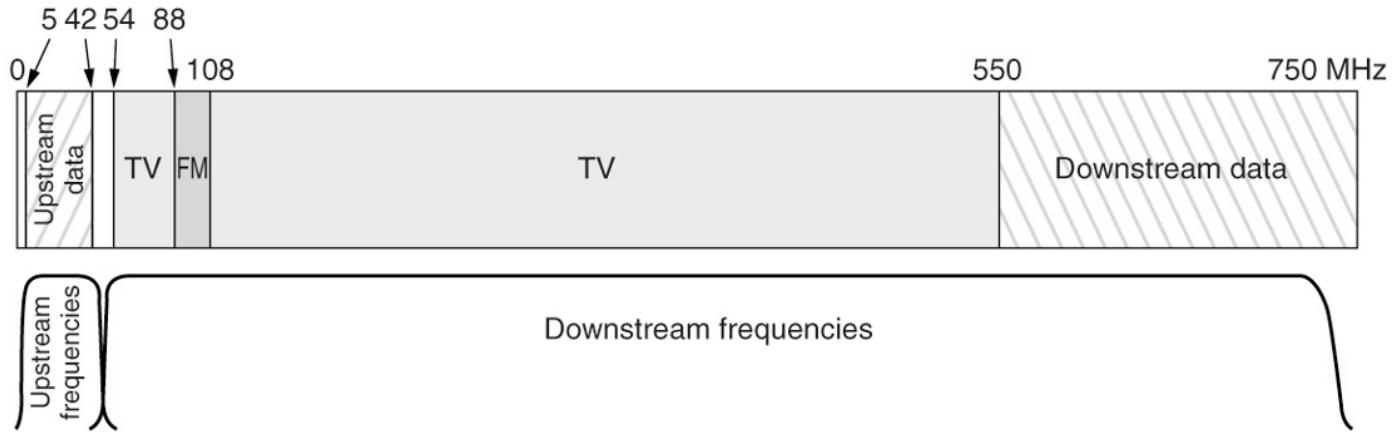
(a)



(b)

(a) Hybrid Fiber-Coax cable network. (b) The fixed phone system.

(a)光纤-同轴电缆混合网络。(b)固定电话系统。



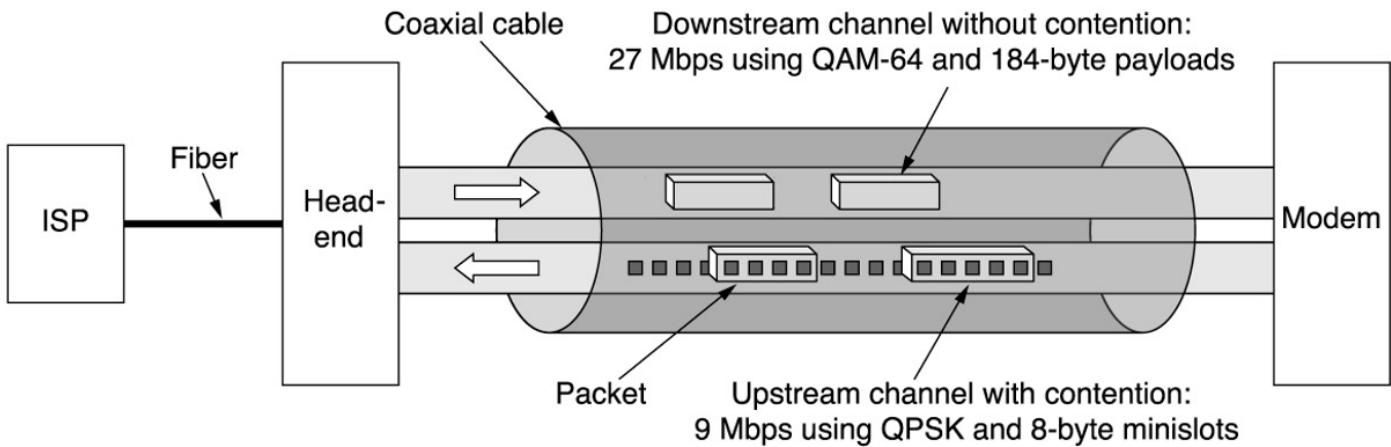
Frequency allocation in a typical cable TV system used for Internet access

用于因特网接入的典型有线电视系统中的频率分配

DOCSIS

- DOCSIS (Data Over Cable Service Interface Specification) 3.1 latest version
DOCSIS(电缆数据服务接口规范)3.1最新版本
 - Introduced Orthogonal Frequency Division Multiplexing (OFDM)
引入正交频分复用(OFDM)
 - Introduced wider channel bandwidth and higher efficiency
引入更宽的信道带宽和更高的效率
 - Enabled over 1 Gbps of downstream capacity per home
每个家庭的下行容量超过1gbps
- Extensions to DOCSIS 3.1
扩展到DOCSIS 3.1
 - Full Duplex operation (2017) and DOCSIS Low Latency (2018)
全双工操作(2017)和DOCSIS低延迟(2018)
- Cable Internet subscribers require a DOCSIS cable modem
有线互联网用户需要DOCSIS电缆调制解调器
- Modem-to-home network interface: Ethernet connection
调制解调器到家庭网络接口:以太网连接

Resource Sharing in DOCSIS Networks



Typical details of the upstream and downstream channels in North America.

北美上游和下游河道的典型细节

2.8: GEO, MEO, LEO

Communication Satellites

Altitude (km)	Type	Latency (ms)	Sats needed
35,000	GEO	270	3
10,000	MEO	35–85	10
0	LEO	1–7	50

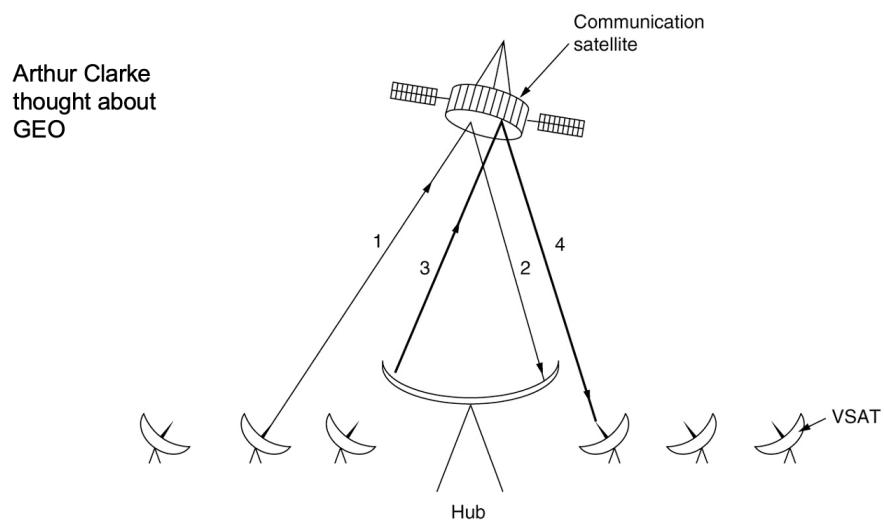
Upper Van Allen belt

Lower Van Allen belt

Communication satellites and some of their properties, including altitude above the earth, round-trip delay time, and number of satellites needed for global coverage.

通信卫星及其一些特性，包括离地球的高度、往返延迟时间和全球覆盖所需的卫星数量。

2.8.1 Geostationary Satellites



VSATs using a hub.

使用集线器的VSATs. 小型卫星地面站 (Very Small Aperture Terminal)

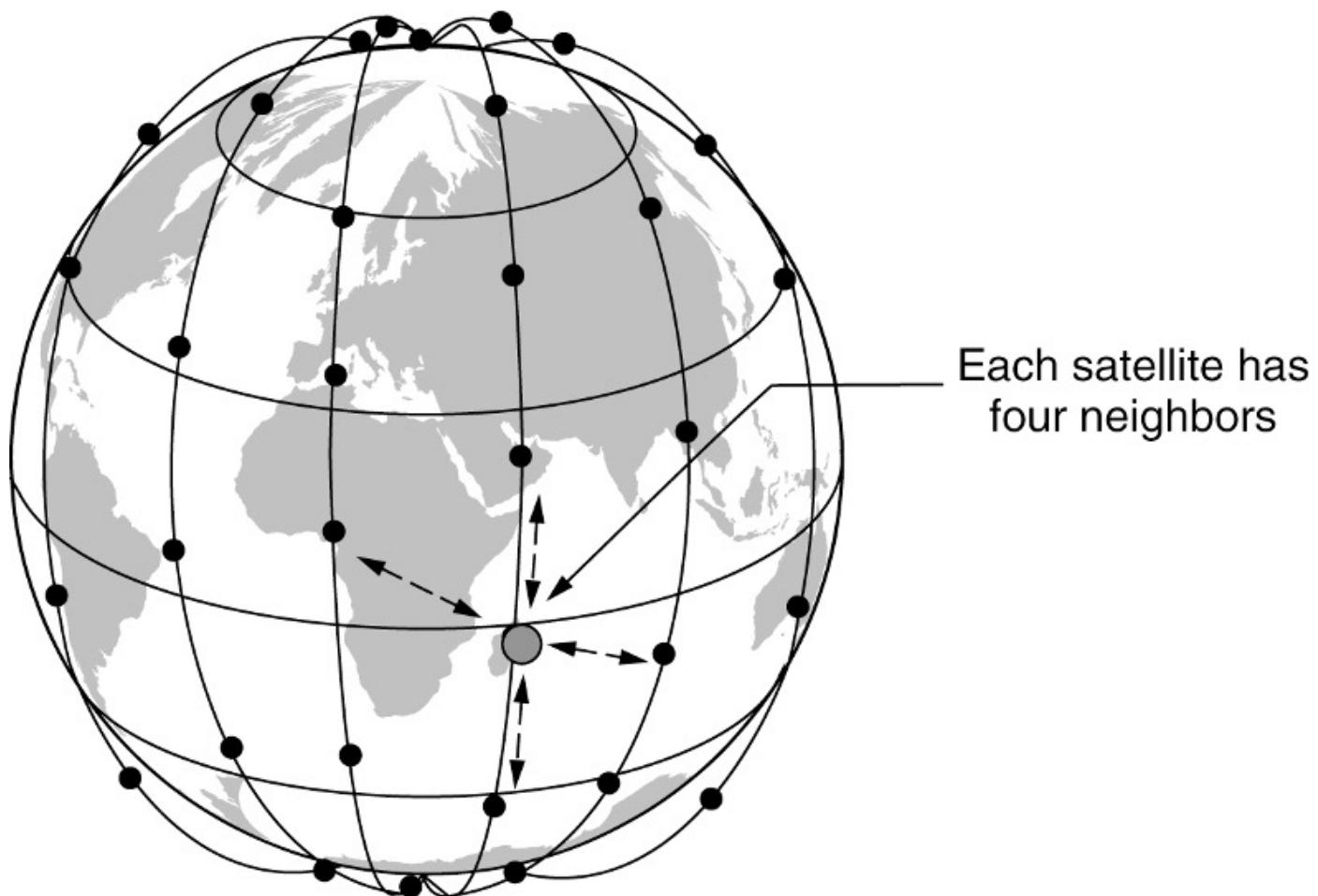
2.8.2 Medium-Earth Orbit Satellites

中地球轨道卫星

- MEO (Medium-Earth Orbit) satellites
 - Found at lower altitudes - between the two Van Allen belts
发现于较低的海拔——两个范艾伦辐射带之间
 - Drift slowly in longitude (6 hours to circle the earth)
沿经度缓慢漂移(绕地球6小时)
 - Must be tracked as they move through the sky
当它们在天空中移动时必须被追踪
 - Have a smaller footprint on the ground
在地面上的足迹更小
 - Require less powerful transmitters to reach them
不需要太强大的发射器就能找到他们
- Used for navigation systems
用于导航系统

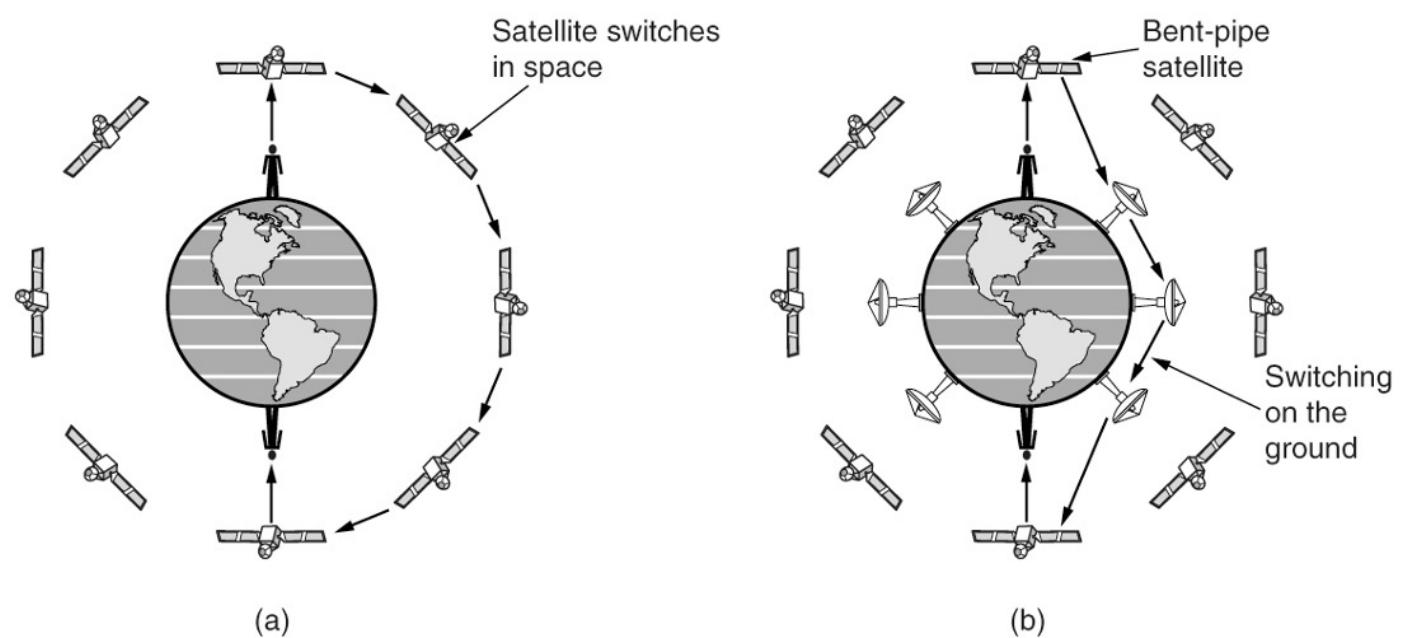
2.8.3 Low-Earth Orbit Satellites

低地球轨道卫星



The Iridium satellites form six necklaces around the earth.

铱卫星围绕地球形成六条项链。



(a) Relaying in space. (b) Relaying on the ground.

(a)空间中继。(b)地面转播。

Terrestrial Access Networks: Cable, Fiber, and ADSL

- Similarities
 - Comparable service and comparable prices
同类服务和同类价格
 - Use fiber in the backbone
在backbone中使用fiber
- Differences
 - Last-mile access technology at the physical and link layers
物理和链路层的最后一公里访问技术
 - Bandwidth consistency
带宽一致性
 - Cable subscribers share the capacity of a single node
电缆用户共享单个节点的容量
 - Maximum speeds
最大速度
 - Availability
可用性
 - Security
安全

Satellites Versus Terrestrial Networks

卫星与地面网络

- Communication satellites niche markets
通信卫星利基市场
 - Rapid deployments
快速部署
 - Places where the terrestrial infrastructure is poorly developed
地面基础设施欠发达的地方
 - When broadcasting is essential
当广播很重要的时候
- United States has some competing satellite-based Internet providers
美国有一些与之竞争的卫星网络提供商
- Satellite Internet access seeing a growing interest
卫星互联网接入的兴趣越来越大

- In-flight Internet access

机上上网