



## Chapter 2 The Physical Layer

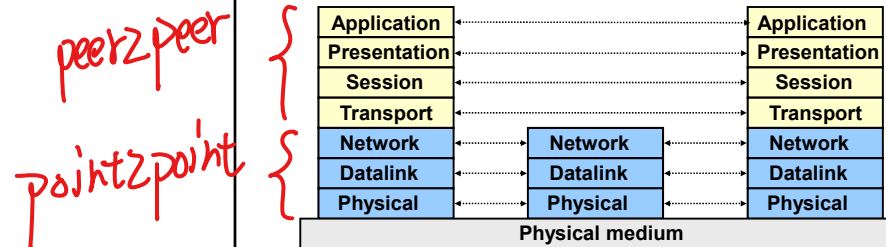
2019 Edition

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## ISO OSI Reference Model

- Seven layers
  - Lower three layers are **point-to-point**
  - Next four layers are **peer-to-peer**



## Physical layer

- Protocols on physical layer specify the mechanical, electrical, functional, procedural and transmission characteristics of the interface.
  - Mechanical characteristics
    - the types of connector and socket
    - the pin functions
    - E.g CCITT X.20,X.21,X.22; ISO 4092
- Mechanical Characteristics*



## Content

- Concept
- The theoretical Basis for Data Communication
- Guided Transmission Media
- Wireless Transmission
- Communication Satellites
- The Public Switched Telephone Network



## Physical Layer

- **Service**: move the information between two systems connected by a physical link
- **Interface**: specifies how to send a bit
- **Protocols**: coding scheme used to represent a bit, voltage levels, duration of a bit
- Examples: coaxial cable, optical fiber links; transmitters, receivers

media

Media is not included in physical layer!



## Limitations on tx rate and distance

- Attenuation
- Distortion
- Dispersion
- Noise

影响  
传输  
速率  
与距离



## Basic Concepts

- **Spectrum**: Range of frequencies of a signal  $[f_{\min}, f_{\max}]$
- **Bandwidth**: Width of the spectrum  $(f_{\max} - f_{\min})$   
(measured in Hz)
- **Capacity**: Rate at which data can be transmitted  
(measured in bits per seconds, bps)
- **Noise**: Random noise which distorts a signal  
(measured as ratio of signal power to noise power, units are decibels (dB))
- ◆ **Signal-to-Noise Ratio**  
S: Signal Power. N: Noise Power  
signal-to-noise ratio (db) =  $10 \log_{10} S/N$

Bandwidth [Hz]  
Bandwidth [bps]



## Bandwidth and Capacity

- **Capacity of a noiseless channel (H. Nyquist, 1924)**

$$\text{Capacity} = 2H \log_2 V \text{ bps}$$

where : H is bandwidth

V is the number of discrete level of a signal

- **Capacity of a noisy channel (C. Shannon, 1948)**

$$\text{Capacity} = H \log_2 (1 + S/N) \text{ bps}$$

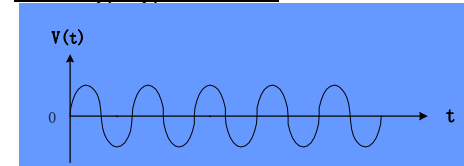
where : S/N is signal-to-noise ratio



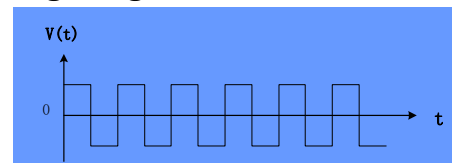
## 消息, 信号, 信道

- 消息是一方发出而另一方能够感受的信息 (Message)
- 信号, 是表达信息的形式; (Signal)  
Analog signal, Digital signal
- 信道, 是传送信号的途径 (Channel)

### • Analog signal wave



### • Digital signal wave

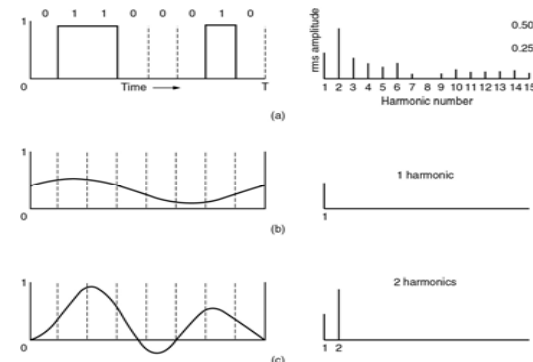


**Data must be converted to signal for transmission on media**

## The Theoretical Basis for Data Communication

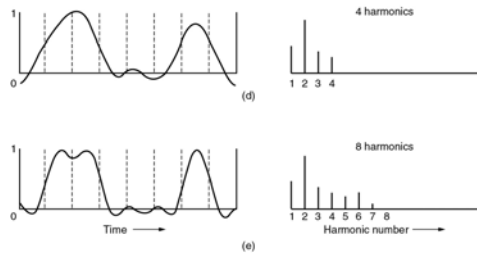
- Fourier Analysis
- Bandwidth-Limited Signals
- Maximum Data Rate of a Channel

### Bandwidth-Limited Signals



- A binary signal and its root-mean-square Fourier amplitudes.
- (b) – (c) Successive approximations to the original signal.

## Bandwidth-Limited Signals (2)



(d) – (e) Successive approximations to the original signal.

## Bandwidth-Limited Signals (3)

Bps	T (msec)	First harmonic (Hz)	# Harmonics sent
300	26.67	37.5	80
600	13.33	75	40
1200	6.67	150	20
2400	3.33	300	10
4800	1.67	600	5
9600	0.83	1200	2
19200	0.42	2400	1
38400	0.21	4800	0

Relation between data rate and harmonics.

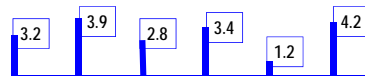


## Nyquist Sampling Theorem example : PCM

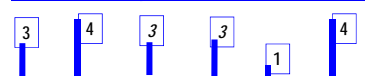
原始信号



PAM脉冲



PCM 脉冲  
有量化差错



PCM 输出

011 100 011 011 001 100



## 调制技术

0 0 1 1 0 1 0 0 0 1 0

ASK

FSK

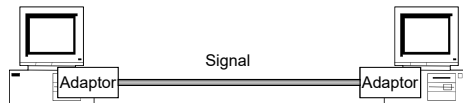
PSK



## Encoding

specify how bits are transmitted on the physical media

- Goal: send bits from one node to other node on the same physical media
  - This service is provided by the **physical** layer
- Problem: specify an **robust** and **efficient** encoding scheme to achieve this goal
- Assumption: we use two discrete signals, high and low, to encode 0 and 1

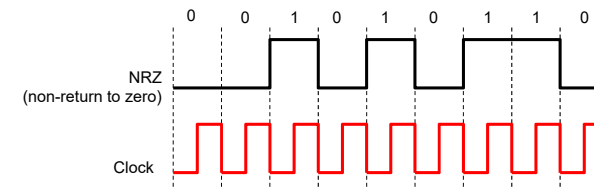


Adaptor: convert bits into physical signal and physical signal back into bits



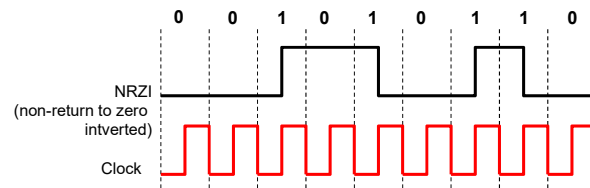
## Encoding : Non-Return to Zero (NRZ)

- 1  $\rightarrow$  high signal; 0  $\rightarrow$  low signal
- Disadvantages: when there is a long sequence of 1's or 0's
  - Sensitive to clock skew, i.e., difficult to do clock recovery
  - Difficult to interpret 0's and 1's (baseline wander)



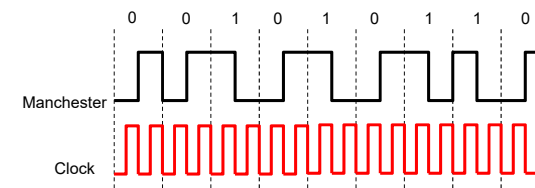
## Encoding : Non-Return to Zero Inverted (NRZI)

- 1  $\rightarrow$  make transition; 0  $\rightarrow$  stay at the same level
- Solve previous problems for long sequences of 1's, but not for 0's



## Manchester

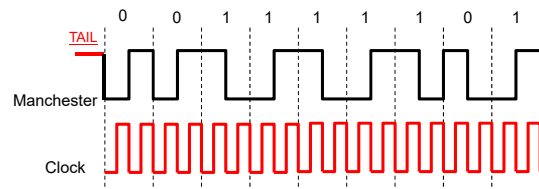
- 1  $\rightarrow$  high-to-low transition; 0  $\rightarrow$  low-to-high transition
- Addresses clock recovery and baseline wander problems
- Disadvantage: needs a clock that is twice as fast as the transmission rate





## Differential Manchester

- 1 → keep level; 0 → transit to opposite level
- Addresses clock recovery and baseline wander problems
- Disadvantage/Advantage



## 4-bit/5-bit

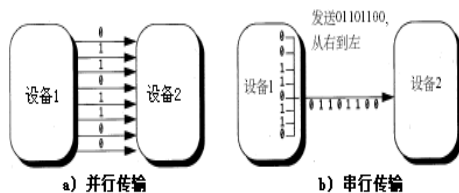
- Goal: address inefficiency of Manchester encoding, while avoiding long periods of low or high signals
- Solution:
  - Use 5 bits to encode every sequence of four bits such that no 5 bit code has more than one leading 0 and two trailing 0's
  - Use NRZI to encode the 5 bit codes

4-bit	5-bit	4-bit	5-bit
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
		1111	11101



## Data Transfer Type

- Parallel
- Serial



## • Examples: EIA RS-232-D

- The RS-232D Serial Interface Standard added the mechanical characteristics to the RS-232C Standard. The RS-232D Standard defines:
  - The mechanical characteristics of the interface
  - The electrical characteristics of the interface
  - The function of each signal
  - Subsets of the signals for certain applications
- The European version of RS-232D is defined in:
  - V.24 - mechanical standard
  - V.28 - electrical standard

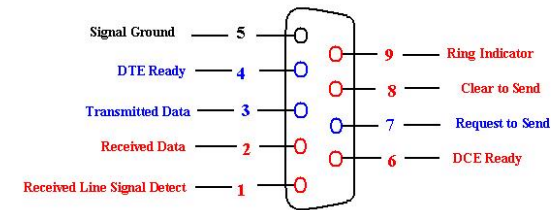


### Mechanical Characteristics of the RS-232D

- The connector is a DB25 connector. DB9 is not universally accepted.
- The connector gender is male at the DTE and female at the DCE.
- The assignments of signals to pins.
- The maximum cable length is 50 ft.
- The maximum cable capacitance = 2500 pF. Typical cable has 50 pF/foot capacitance.



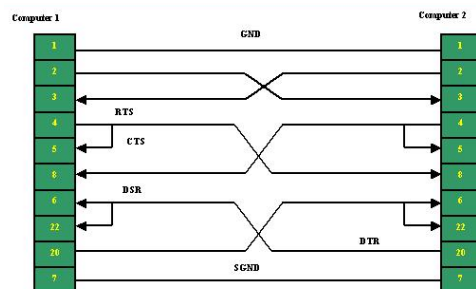
### DB9



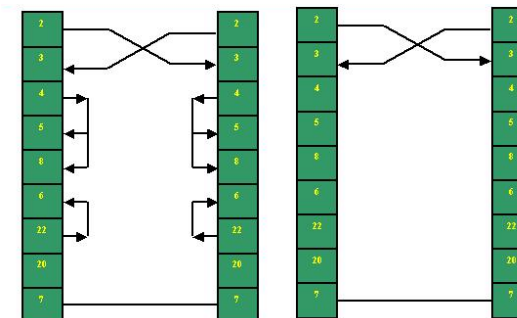
Pin designations for EIA-232 connectors from the DTE side.(DB9)



### Two computers connected using RS-232-C



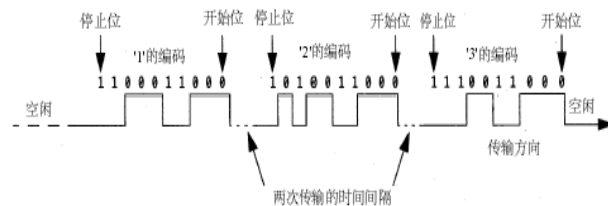
### Two computers simple connected using RS-232-C





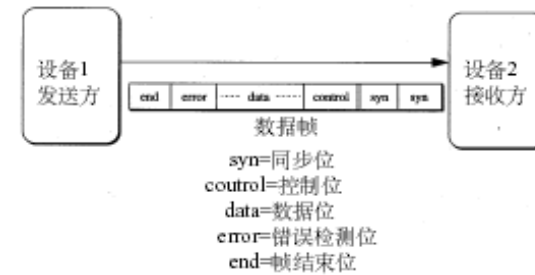
## Serial Transfer

- Asynchronism



## Serial Transfer

- Synchronism



## Transmission Media

- Transmission Medium can be:

- Simplex**
  - Transmission in one direction only.
- Half-duplex**
  - Transmission in both directions; but not at the same time.
- Full-duplex (duplex)**
  - Simultaneous transmission in both directions.





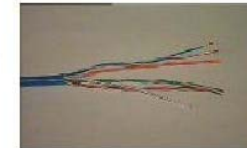
## Guided Transmission Data

- Magnetic Media
- Twisted Pair
- Coaxial Cable
- Fiber Optics



### Twisted Pair

- Two insulated wires are twisted around each other, and combined with others into a cable
- Used to connect telephone subscribers to switching centers and for wiring local area networks
- Different qualities:
  - Two popular varieties:
    - Category 3: 10 Mbps
    - Category 5: 100 Mbps



(a)



(b)

(a) Category 3 UTP.

(b) Category 5 UTP.

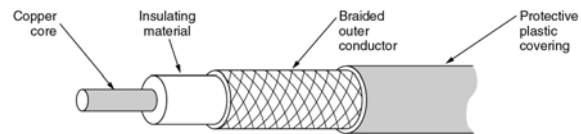


### Coaxial Cable

- Like twisted pair a coaxial cable ("coax") has two conductors that are shielded
- Used for digital transmissions in local area networks (e.g., Ethernet) and analog transmissions for cable television
- Coax used for Cable TV supports a spectrum of 50 - 750 Mhz



## Coaxial Cable



A coaxial cable.

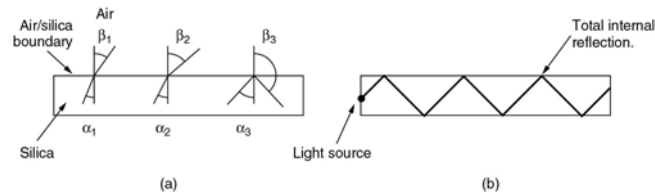


## Optical Fiber

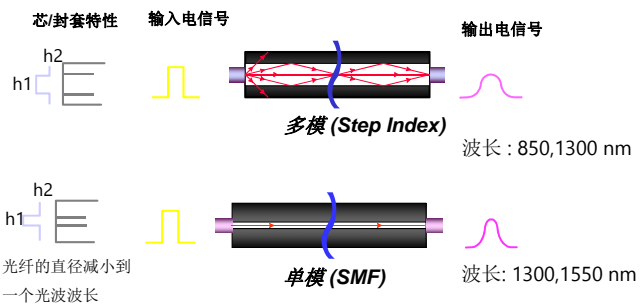
- Optical fiber is a thin, flexible medium capable of conducting an optical ray.
- Fiber is built of various glasses or plastics.
- Very high bandwidth (currently up to 10 Gbps).
- Used for long-distance trunks, local area networks, high-speed transmissions.
- Inherently unidirectional.

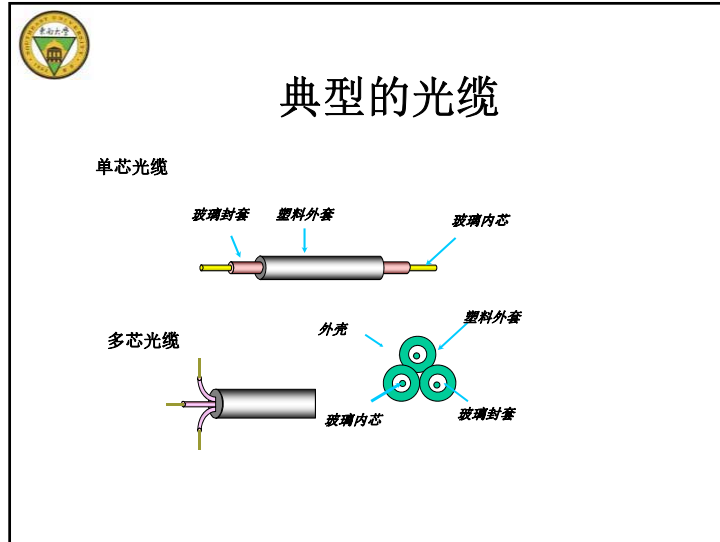


## Fiber Optics

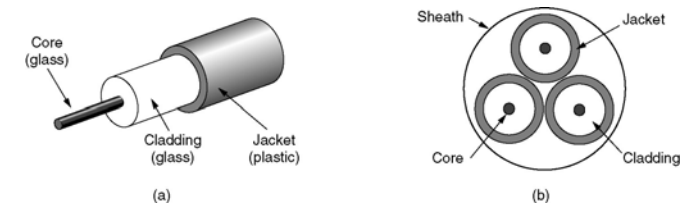


- (a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles.
- (b) Light trapped by total internal reflection.



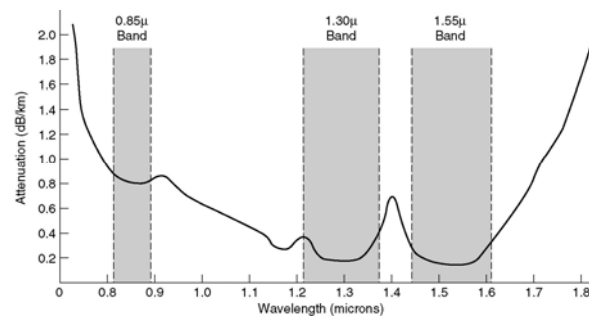


## Fiber Cables



- (a) Side view of a single fiber.
- (b) End view of a sheath with three fibers.

## Transmission of Light through Fiber



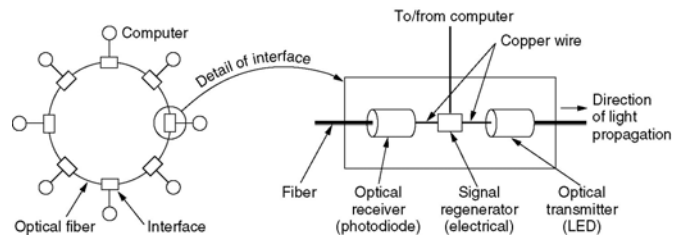
Attenuation of light through fiber in the infrared region.

## Fiber Cables (2)

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

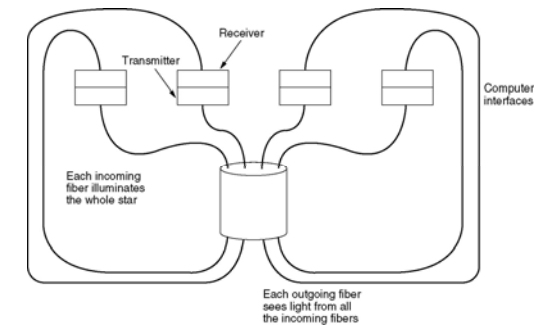
A comparison of semiconductor diodes and LEDs as light sources.

## Fiber Optic Networks



A fiber optic ring with active repeaters.

## Fiber Optic Networks (2)



A passive star connection in a fiber optics network.



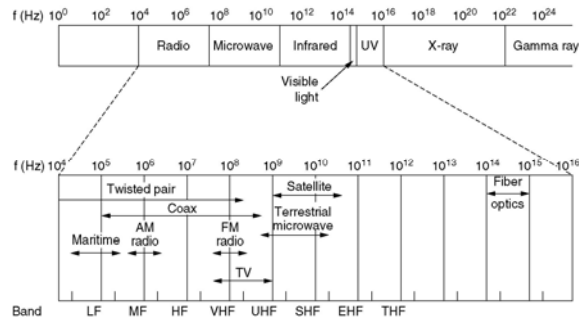
## Wireless Media

- Advantage/Disvantage
- Type
  - normal / microwave / satellite / infrared / laser (unguided) / Cellular networks / Satellite

## Wireless Transmission

- The Electromagnetic Spectrum
- Radio Transmission
- Microwave Transmission
- Infrared and Millimeter Waves
- Lightwave Transmission

## The Electromagnetic Spectrum

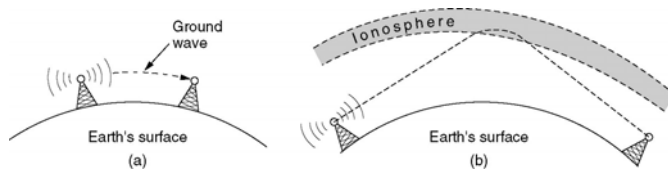


The electromagnetic spectrum and its uses for communication.



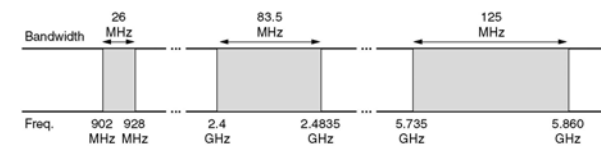
Other Media?

## Radio Transmission



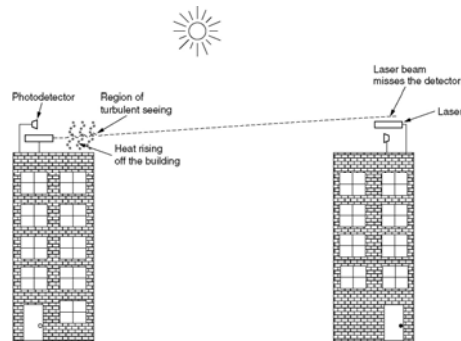
- (a) In the VLF, LF, and MF bands, radio waves follow the curvature of the earth.
- (b) In the HF band, they bounce off the ionosphere.

## Politics of the Electromagnetic Spectrum



The ISM bands in the United States.

## Lightwave Transmission

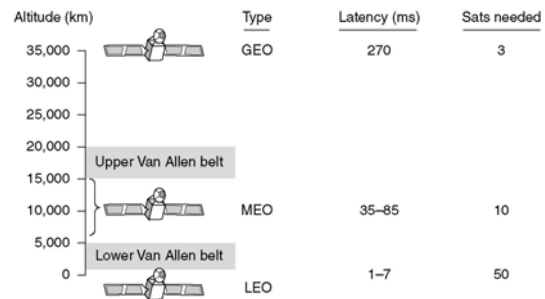


- Convection currents can interfere with laser communication systems.

## Communication Satellites

- Geostationary Satellites
- Medium-Earth Orbit Satellites
- Low-Earth Orbit Satellites
- Satellites versus Fiber

## Communication Satellites



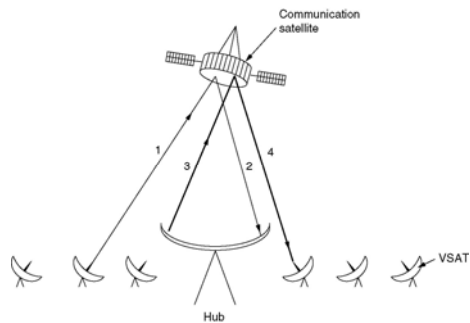
Communication satellites and some of their properties, including altitude above the earth, round-trip delay time and number of

## Communication Satellites (2)

Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

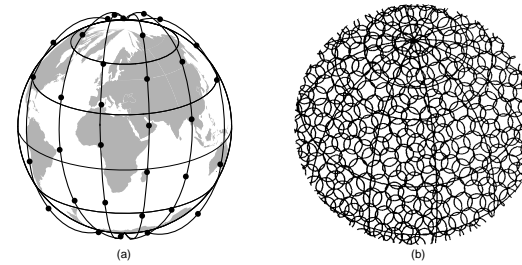
The principal satellite bands.

## Communication Satellites (3)



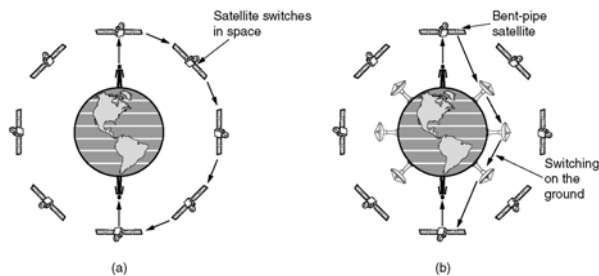
VSATs using a hub.

## Low-Earth Orbit Satellites Iridium



- (a) The Iridium satellites from six necklaces around the earth.
- (b) 1628 moving cells cover the earth.

## Globalstar

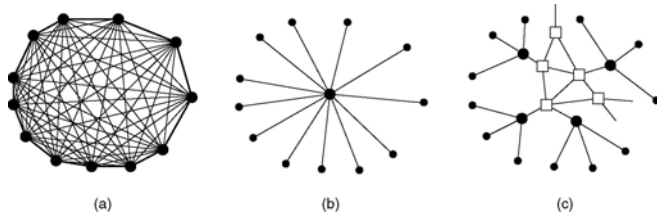


- (a) Relaying in space.
- (b) Relaying on the ground.

## Public Switched Telephone System

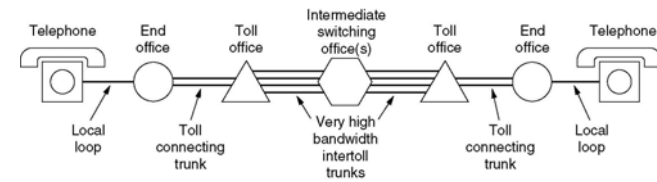
- Structure of the Telephone System
- The Politics of Telephones
- The Local Loop: Modems, ADSL and Wireless
- Trunks and Multiplexing
- Switching

## Structure of the Telephone System



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

## Structure of the Telephone System (2)

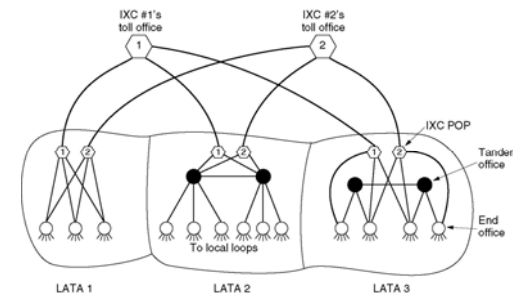


A typical circuit route for a medium-distance call.

## Major Components of the Telephone System

- Local loops
  - Analog twisted pairs going to houses and businesses
- Trunks
  - Digital fiber optics connecting the switching offices
- Switching offices
  - Where calls are moved from one trunk to another

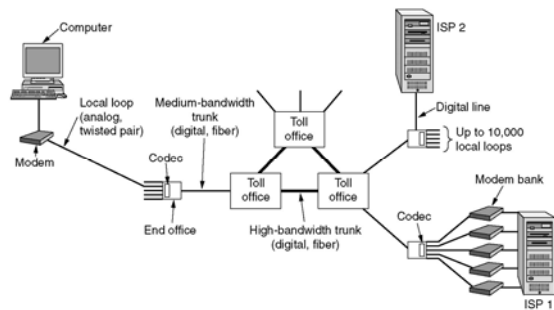
## The Politics of Telephones



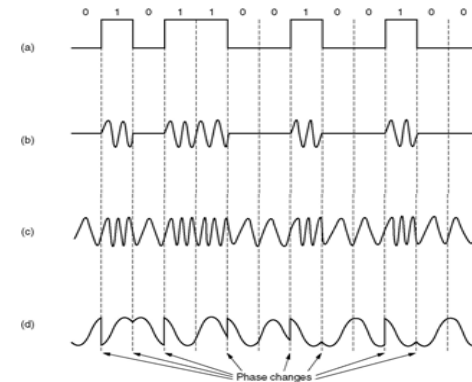
The relationship of LATAs, LECs, and IXCs. All the circles are LEC switching offices. Each hexagon belongs to the IXC whose number is on it.



## The Local Loop: Modems, ADSL, and Wireless

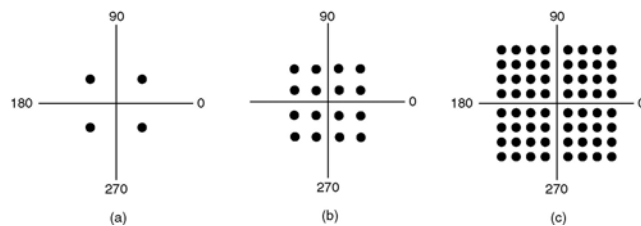


The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modems and codecs.



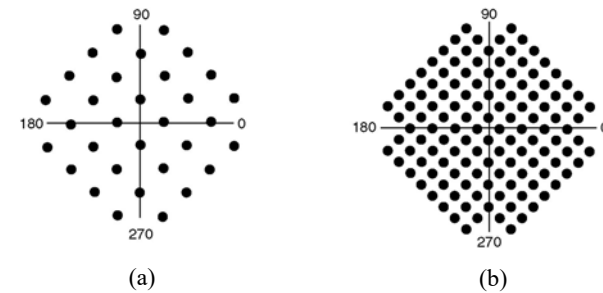
(a) A binary signal  
(b) Amplitude modulation  
(c) Frequency modulation  
(d) Phase modulation

## Modems (2)



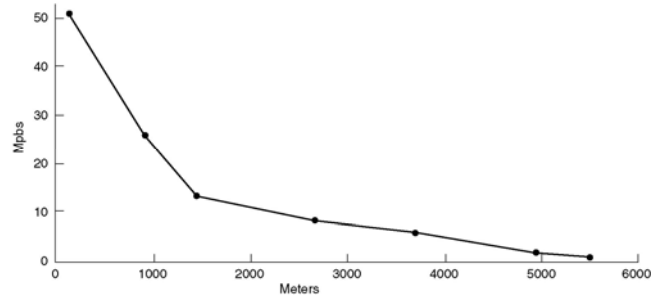
(a) QPSK.  
(b) QAM-16.  
(c) QAM-64.

## Modems (3)

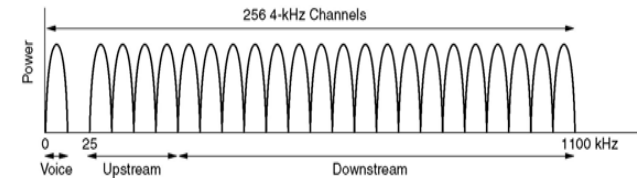


(a) V.32 for 9600 bps.  
(b) V.32 bis for 14,400 bps.

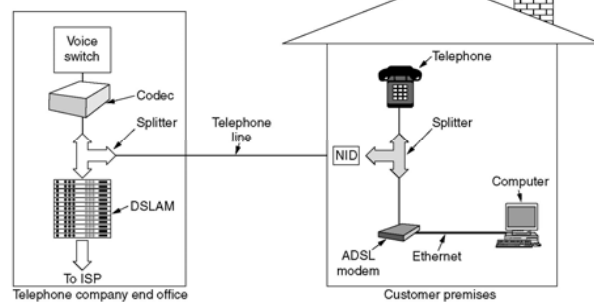
### Digital Subscriber Lines



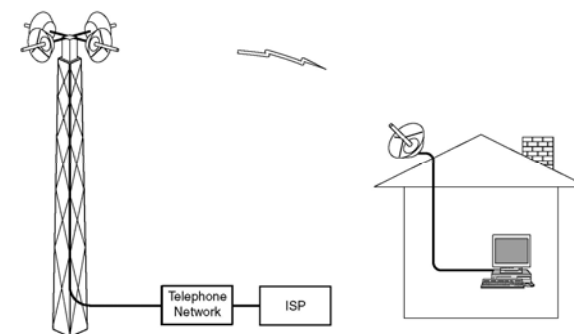
### Digital Subscriber Lines (2)



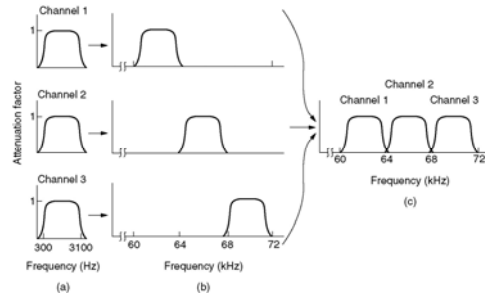
### Digital Subscriber Lines (3)



### Wireless Local Loops

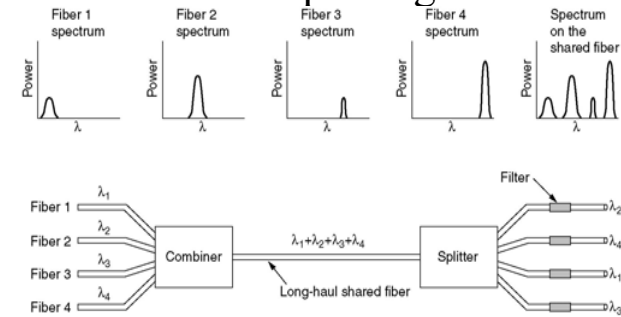


## Frequency Division Multiplexing

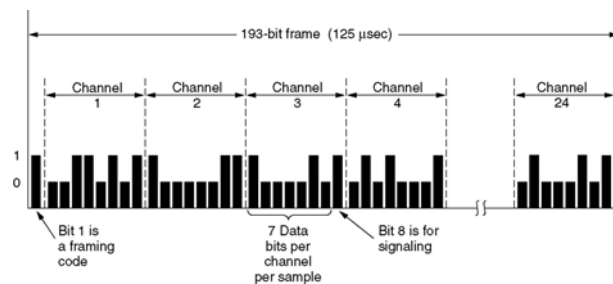


- (a) The original bandwidths.
- (b) The bandwidths raised in frequency.
- (c) The multiplexed channel.

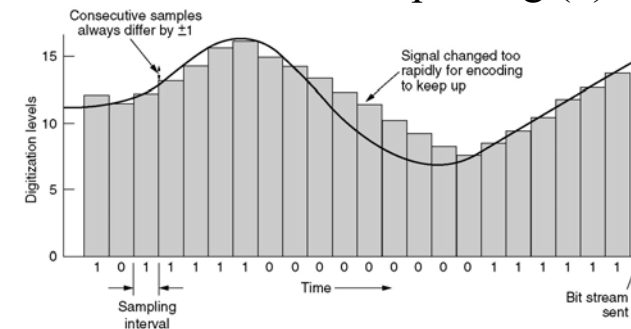
## Wavelength Division Multiplexing



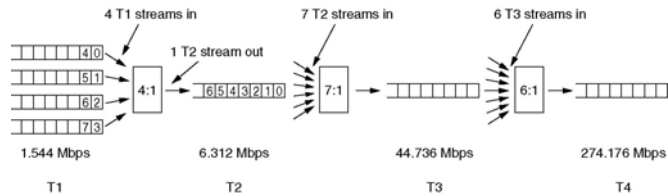
## Time Division Multiplexing



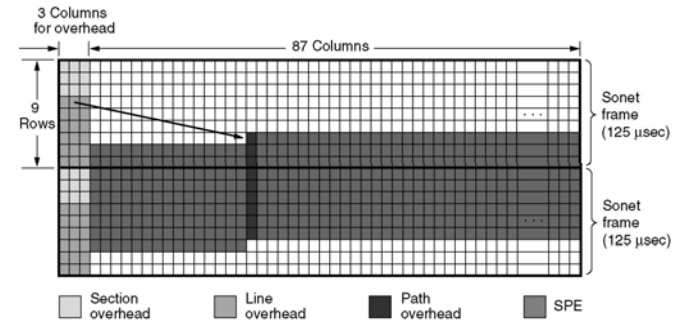
## Time Division Multiplexing (2)



### Time Division Multiplexing (3)



### Time Division Multiplexing (4)

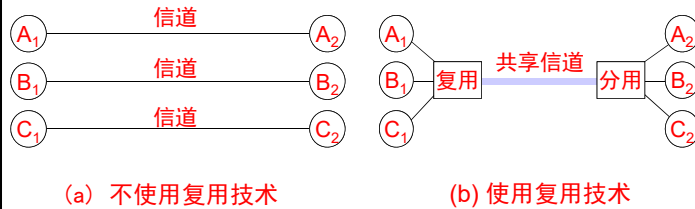


### Time Division Multiplexing (5)

SONET		SDH	Data rate (Mbps)		
Electrical	Optical	Optical	Gross	SPE	User
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-9	OC-9	STM-3	466.56	451.008	445.824
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-18	OC-18	STM-6	933.12	902.016	891.648
STS-24	OC-24	STM-8	1244.16	1202.688	1188.864
STS-36	OC-36	STM-12	1866.24	1804.032	1783.296
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28	9621.504	9510.912

Supplement

## 信道复用技术



- **复用(multiplexing)**是将多个信源的彼此无关的信号，组合在一条物理信道上进行传送的技术。
- 多路复用的**目的**：充分利用昂贵的通信线路，尽可能地容纳较多的用户传输较多的信息。

## 多路复用技术分类

1. **频分多路复用** (FDM, Frequency Division Multiplexing)
2. **时分多路复用** (TDM, Time Division Multiplexing) --同步STDM、异步ATDM
3. **波分多路复用** (WDM, Wavelength Division Multiplexing)
4. **码分多路复用** (CDM, Code Division Multiple)
5. **空分复用** (PDM, sSpace Division Multiplexing)

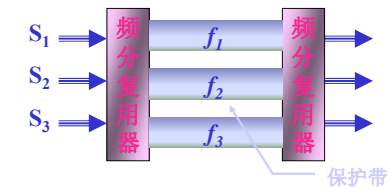
## 频分复用 FDM

- 按照**频率**区分信号的方法，把传输频带分为若干个**较窄的频带**，每个频带构成一个**子信道**，独立地传输信息。用户在分配到一定的频带后，在通信过程中自始至终都占用这个频带。
- 频分复用的所有用户在同样的时间占用不同的**带宽资源**（请注意，这里的“带宽”是频率带宽而不是数据的发送速率）。



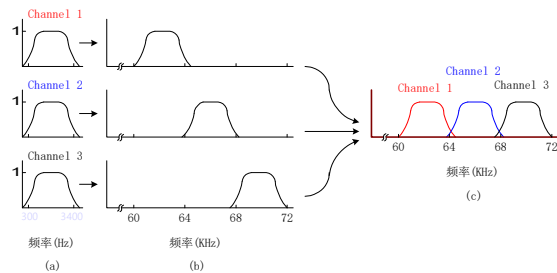
## 频分多路复用的实现过程

- 频分多路复用技术对整个物理信道的可用带宽进行**分割**，并利用**载波调制技术**，实现原始信号的**频谱迁移**，使得**多路信号**在整个物理信道带宽允许的范围内实现**频谱上的不重叠**。
- 为了避免两个**相邻频段**的信号互相干扰，频段之间要保留一定的**隔离频带**，称为**保护带**。



## 频分多路复用技术示例

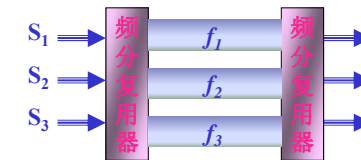
三路音频模拟信号复用在一个带宽为12KHz的物理信道：



## 频分多路复用技术的特点

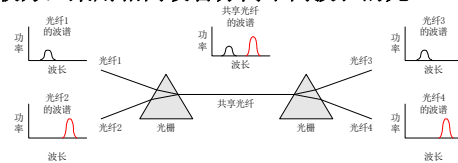
- 频分多路复用使信道在同一时刻能**同时独立传送多路信号**，每路信号占用不同的频带；
- 在线路上传输的是各路信号经过调制后的叠加在一起的复合信号。
- 频分多路复用技术适用于**宽带网络**。要求传输介质的**可用带宽**超过各路信源所需带宽的总和：  

$$B > \sum f_i$$



## 波分复用 WDM

- 波分复用就是光的**频分复用**，它利用了光具有不同的波长的特征。
- 原理：**  
将**不同信道**的信号调制**成不同波长的光**，利用波分复用设备（如衍射光栅）复用到光纤信道上。在接收方，采用相同设备分离不同波长的光。



- 在一根光纤上复用**80路**或更多路的光载波信号称为**密集波分复用DWDM**；

## 时分复用TDM

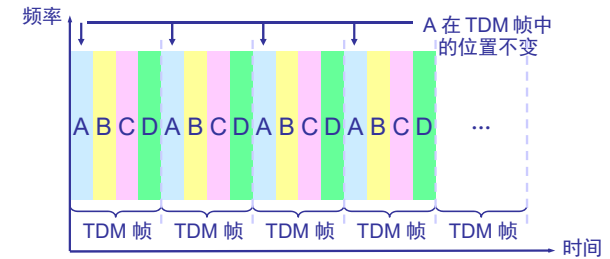
时分复用就是将**提供给整个信道传输信息的时间划分成若干时间片**(简称**时隙**),并将这些时隙分配给每一个信号源使用,每一路信号在自己的时隙内独占信道进行数据传输。

主要用于**数字信道**的复用。

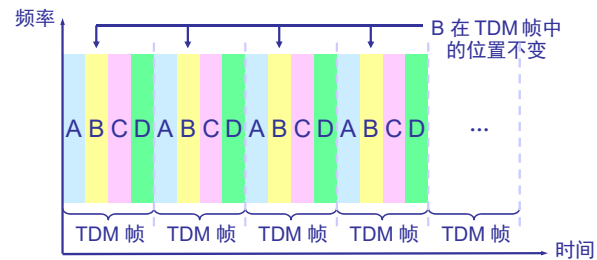
时分复用的所有用户是在**不同的时间**占用**同样的频带宽度**(整个信道的带宽)。

时分多路复用可分为:同步时分复用和异步时分复用(统计时分多路复用)

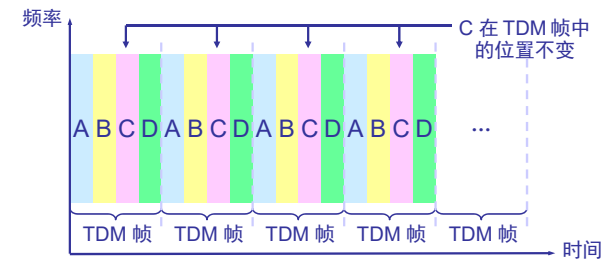
同步时分复用:时隙事先规划分配好且固定不变



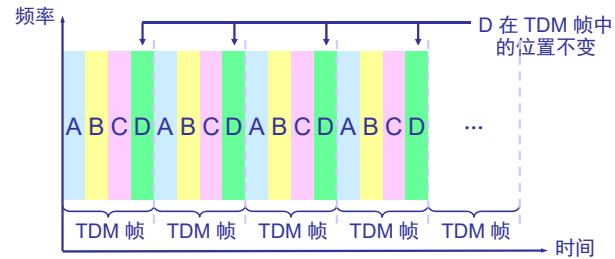
## 同步时分复用



## 同步时分复用



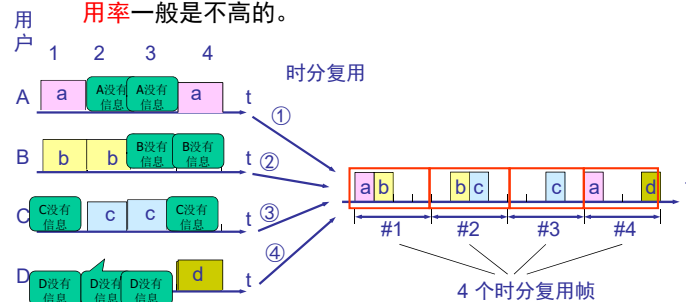
## 同步时分复用



## 同步时分复用特点

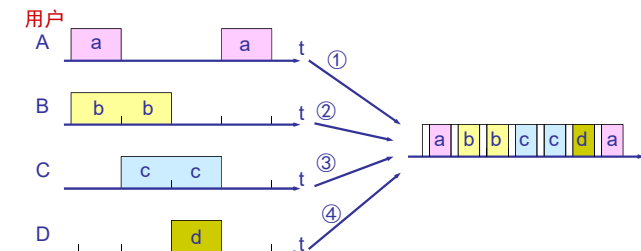
- **优点:** 时隙分配固定, 便于调节控制, 适于数字信息的传输;
- **缺点:** 当某信号源没有数据传输时, 它所对应的信道会出现空闲, 而其他繁忙的信道无法占用这个空闲的信道, 因此会降低线路的利用率。

使用**同步时分复用**系统传送计算机数据时, 由于计算机数据的**突发性**性质, 用户对分配到的子信道的**利用率**一般是不高的。



## 统计时分复用 STDM

**统计时分复用**又称为**异步时分多路复用**, 允许**动态**地分配时间片。根据用户对时间片的需求来分配时间片, 没有数据传输的用户不分配时间片。同时对每个时间片加上**用户标识**, 以区别该时间片属于该用户。





### 码分复用 CDM

- CDM是靠不同的编码来区分各路原始信号的一种复用方式。CDM应用于多址技术即CDMA。
- 各用户使用经过特殊挑选的**不同码型**，因此彼此不会造成干扰。每个用户可以在**同样的时间**使用**同样的频带**进行通信。
- 这种系统发送的信号有很强的**抗干扰能力**，其频谱类似于白噪声，不易被敌人发现。
- 采用CDMA可提高通信的**语音质量**和数据**传输的可靠性**，减少干扰对通信的影响，降低手机的平均发射功率等等。
- 多址访问分类
  - 码分多址：CDMA (Coding Division Multiplexing Access) (联通)
  - 频分多址：FDMA
  - 时分多址：TDMA
    - 联通、移动的GSM移动电话网采用FDMA和TDMA两种方式的结合
  - 同步码分多址：SCDMA (G3移动通信网)
  - 宽带码分多址：WCDMA

### 几种复用技术的简单对比

- 例：假设现在在开会  
**TDM(时分复用)**如在同一个房间轮流发言的方式，但一次只能一个人说，一个说完，另一个继续。  
**FDM(频分复用)**则先将大房间隔成若干个小房间，每个小房间里的人互相交流。  
**CDMA(码分多路复用)**则是把所有的人放在一个大房间里，他们说着不同的语言。这样他要交流只要找自己的语言的那个，而不用担心别的语言的噪声。

### 3.7 同步光纤网 SONET 和同步数字系列 SDH

- 旧的数字传输系统存在着许多缺点。其中最主要的是以下两个方面：
- **速率标准不统一。**
  - 北美和日本是T1：1.544Mbps (24个话路)
  - 欧洲是E1：2.048Mbps (30个话路)
- 如果不对高次群的数字传输速率进行标准化，国际范围的高速数据传输就很难实现。
- **不是同步传输。**
  - 在过去相当长的时间，为了节约经费，各国的数字网主要是采用**准同步方式**。

### 同步光纤网 SONET

- 美国1988年提出了名为**同步光纤网 SONET** (Synchronous Optical Network) 的标准，同步光纤网的各级时钟都来自一个非常精确的主时钟，并且以**51.84 Mb/s**为基础定义了同步传输的线路速率等级。
- 第1级**同步传送信号** STS-1 (Synchronous Transport Signal)的传输速率是 51.84 Mb/s (使用的帧称为**STS-1 帧**)。更高的等级是用N个STS-1帧组成**STS-N帧**。
- 与第1级同步传输信号对应的光信号则称为第1级**光载波** OC-1，OC 表示Optical Carrier。

## 同步数字系列 SDH

- ITU-T（国际电信联盟的电信标准化部门）以美国标准 SONET 为基础，制订出国际标准同步数字系列 SDH (Synchronous Digital Hierarchy)。
- 一般可认为 SDH 与 SONET 是同义词。
- SDH 的基本速率为 155.52 Mb/s，称为第 1 级同步传递模块 (Synchronous Transfer Module)，即 STM-1，相当于 SONET 体系中的 OC-3 速率。更高的等级是用 N 个 STM-1 组成 STM-N。

## 常用 SONET/SDH 数据传输率

SONET 信号	比特率 (Mbps)	SDH 信号	表示线路速率的常用近似值
STS-1 / OC-1	51.840	STM-0	
STS-3 / OC-3	155.520	STM-1	155Mbps
STS-12 / OC-12	622.080	STM-4	622Mbps
STS-48 / OC-48	2,488.320	STM-16	2.5Gbps
STS-192 / OC-192	9,953.280	STM-64	10Gbps
STS-768 / OC-768	39,813,120	STM-256	40Gbps

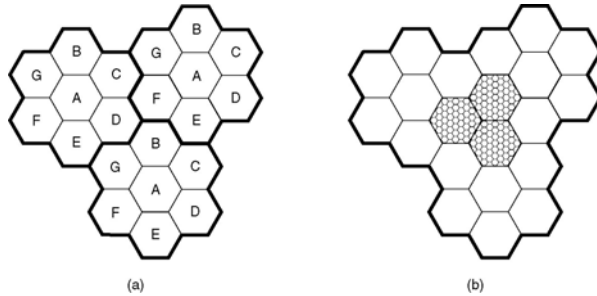
## 其它说明

- SONET速率标准是以 STS-1 速率 51.840Mbps 为基础的，而 SDH 速率标准是以 STM-1 速率 155.520Mb/s 为基础的；
- 更高等级的速率标准 STM-N 是将 STM-1 同步复用而成；
- 4 个 STM-1 构成 STM-4（622.080Mbps）
- 16 个 STM-1 构成 STM-16（2448.320Mbps，即 2.5Gb/s）
- 64 个 STM-1 构成 STM-64（约 10Gbps）

## The Mobile Telephone System

- First-Generation Mobile Phones:  
Analog Voice
- Second-Generation Mobile Phones:  
Digital Voice
- Third-Generation Mobile Phones:  
Digital Voice and Data

## Advanced Mobile Phone System



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

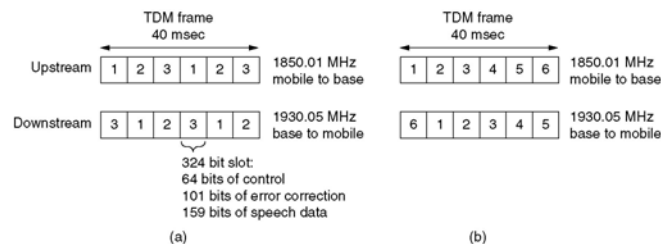
## Channel Categories

The 832 channels are divided into four categories:

- Control (base to mobile) to manage the system
- Paging (base to mobile) to alert users to calls for them
- Access (bidirectional) for call setup and channel assignment
- Data (bidirectional) for voice, fax, or data

## D-AMPS

### Digital Advanced Mobile Phone System

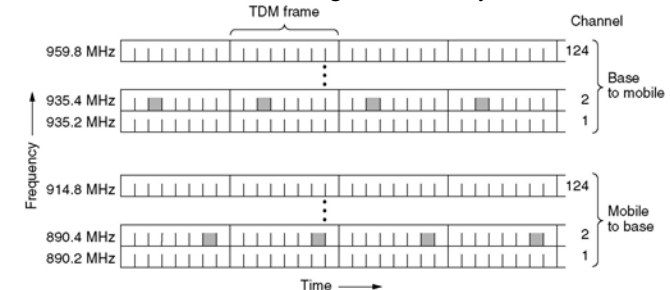


- (a) A D-AMPS channel with three users.  
 (b) A D-AMPS channel with six users.

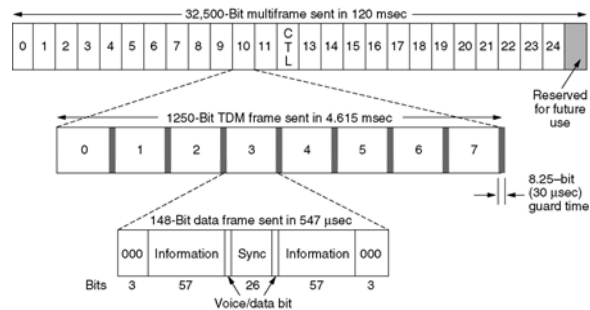
## GSM

### Global System for Mobile Communications

GSM uses 124 frequency channels, each of which uses an eight-slot TDM system



## GSM (2)



## CDMA – Code Division Multiple

A: 0 0 0 1 1 0 1 1  
 B: 0 0 1 0 1 1 1 0  
 C: 0 1 0 1 1 1 0 0  
 D: 0 1 0 0 0 0 1 0

(a)

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)

(b)

Six examples:

-- 1 - C  
 - 1 1 - B + C  
 1 0 - A + B  
 1 0 1 - A + B + C  
 1 1 1 A + B + C + D  
 1 1 0 1 A + B + C + D

(c)

$S_1 = C = (1 + 1 + 1 + 1 + 1 + 1 + 1 + 1)/8 = 1$   
 $S_2 = C = (2 + 0 + 0 + 0 + 2 + 0 + 2)/8 = 1$   
 $S_3 = C = (0 + 0 + 2 + 2 + 0 - 2 + 0 - 2)/8 = 0$   
 $S_4 = C = (1 + 1 + 3 + 3 + 1 - 1 + 1 - 1)/8 = 1$   
 $S_5 = C = (4 + 0 + 2 + 0 + 2 + 0 - 2 + 2)/8 = 1$   
 $S_6 = C = (2 - 2 + 0 - 2 + 0 - 2 - 4 + 0)/8 = -1$

(d)

- (a) Binary chip sequences for four stations
- (b) Bipolar chip sequences
- (c) Six examples of transmissions
- (d) Recovery of station C's signal

## Third-Generation Mobile Phones: Digital Voice and Data

Basic services an IMT-2000 network should provide

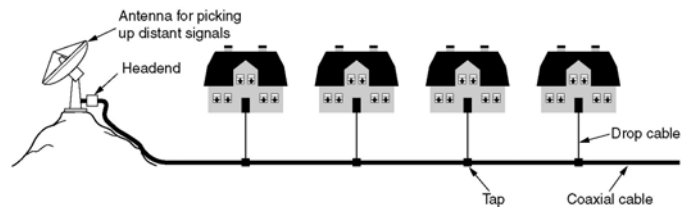
- High-quality voice transmission
- Messaging (replace e-mail, fax, SMS, chat, etc.)
- Multimedia (music, videos, films, TV, etc.)
- Internet access (web surfing, w/multimedia.)

## Cable Television

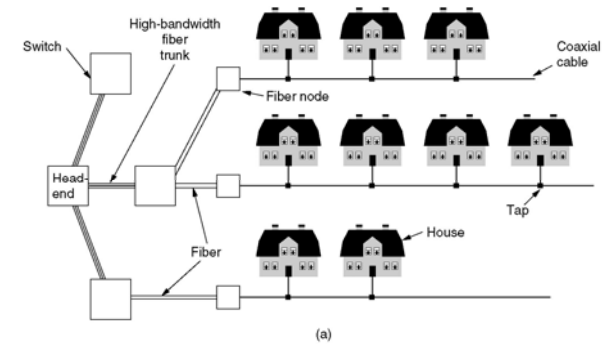
- Community Antenna Television
- Internet over Cable
- Spectrum Allocation
- Cable Modems
- ADSL versus Cable

## Community Antenna Television

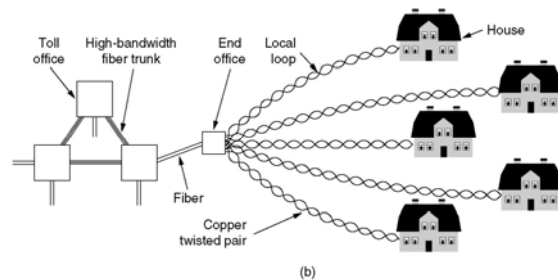
An early cable television system.



## Internet over Cable

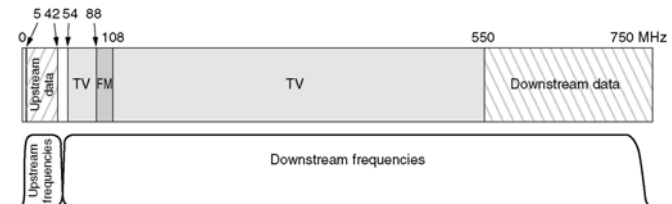


## Internet over Cable (2)



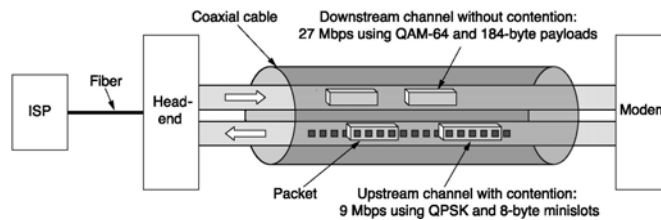
## Spectrum Allocation

Frequency allocation in a typical cable TV system used for



## Cable Modems

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



## 常用传输媒体的比较

传输媒体	速率	传输距离	性能(抗干扰性)	价格	应用	示例
双绞线	模拟 300-3400Hz ; 数字: 10-100Mbps	几十公里	可以	低	模拟传输 数字传输	用户环线 LAN
50Ω 同轴电缆	10M	1公里内	较好	略高于TP	基带数字信号	LAN
75Ω 同轴电缆	300-450MHz	100公里	较好	较高	模拟传输, 可分多信道混合传输电视、数据及CD音频	CATV
光纤	100M-几千Mbps	30公里	很好	较高	远距离传输	长话线路, 主干网
短波	几十-几百bps	全球	一般, 通信质量差	较低	远程低速通信	广播
地面微波接力	4-6GHz	几百公里	很好	低于同容量和长度的电缆	远程通信	电视
卫星	500MHz	一万八千多公里	很好	费用与距离无关	远程通信	电视、电话、数据



## Examples

- RS-232-C RS-422A RS-485 etc
- Dial up modem
- TV set remote control
- Assignment 3 p177 2 4 7 32