南京大学 软件学院
NANJING UNIVERSITY · SOFTWARE INSTITUTE

OSI Layer 1: Physical Layer

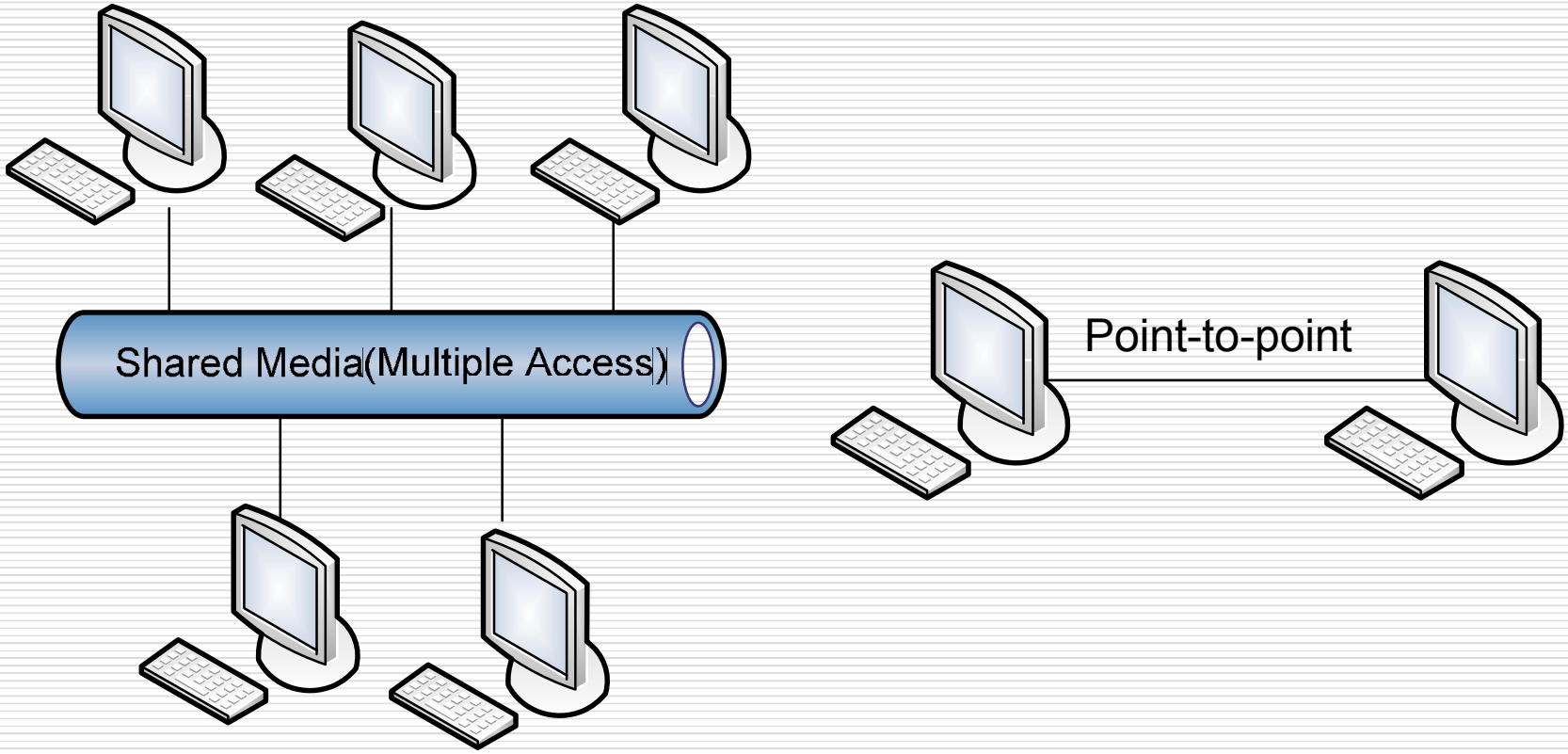
Media, Connections, and Collisions

CISCO SYSTEMS
EMPOWERING THE INTERNET GENERATION℠

OSI Layer1: Physical Layer

- Type of Network
- LAN Media
- UTP for Ethernet
- Media and signal Problems
- Basic Knowledge of Data Communication

Type of Networks



Type of Networks

- Shared media environment
  - Multiple hosts can access the same medium.
  - It means that they all share the same media - even though the "wire" might be UTP, which has four pairs of wire
- Point-to-point network environment
  - One device is connected to the other one via a link
  - Most widely used in dial-up network connections, and is the one with which you are most likely familiar.

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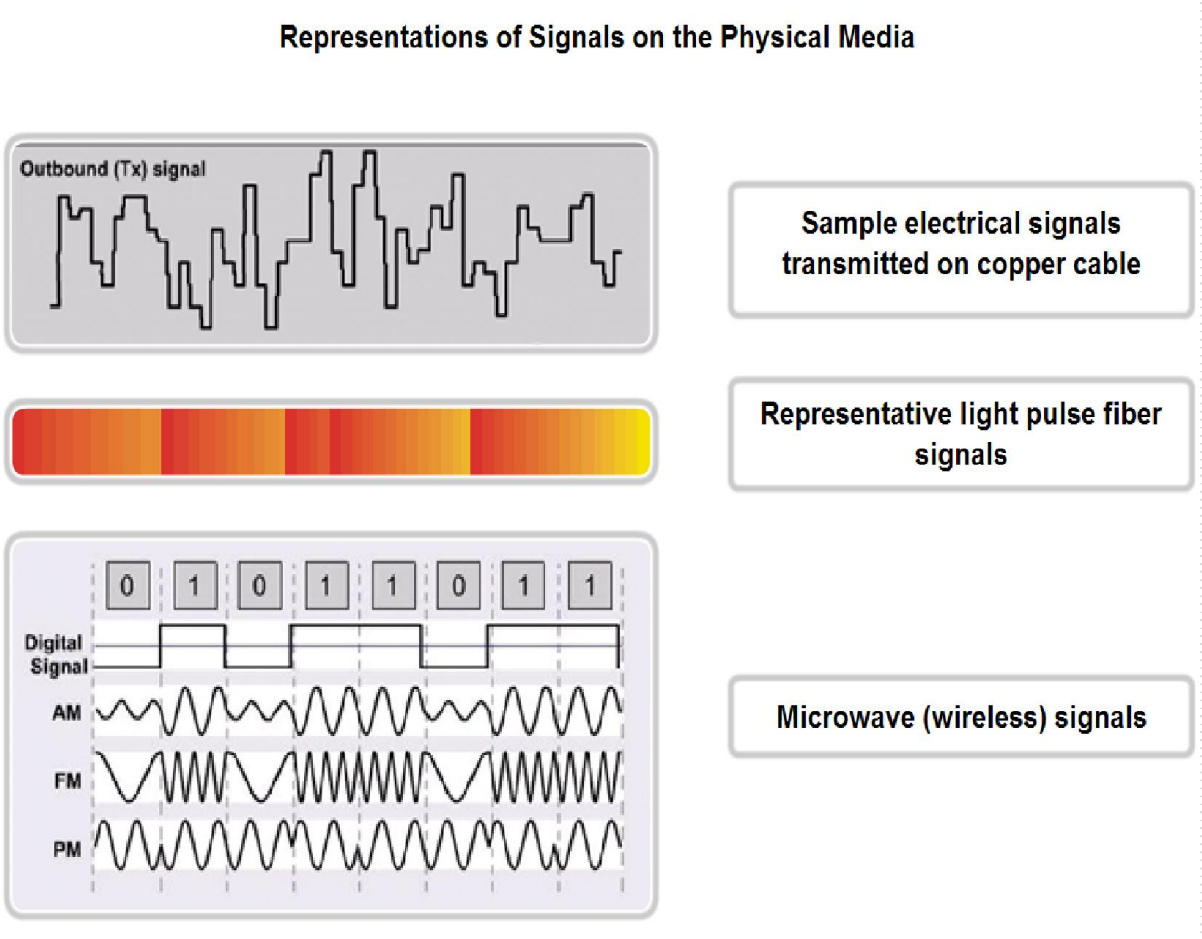
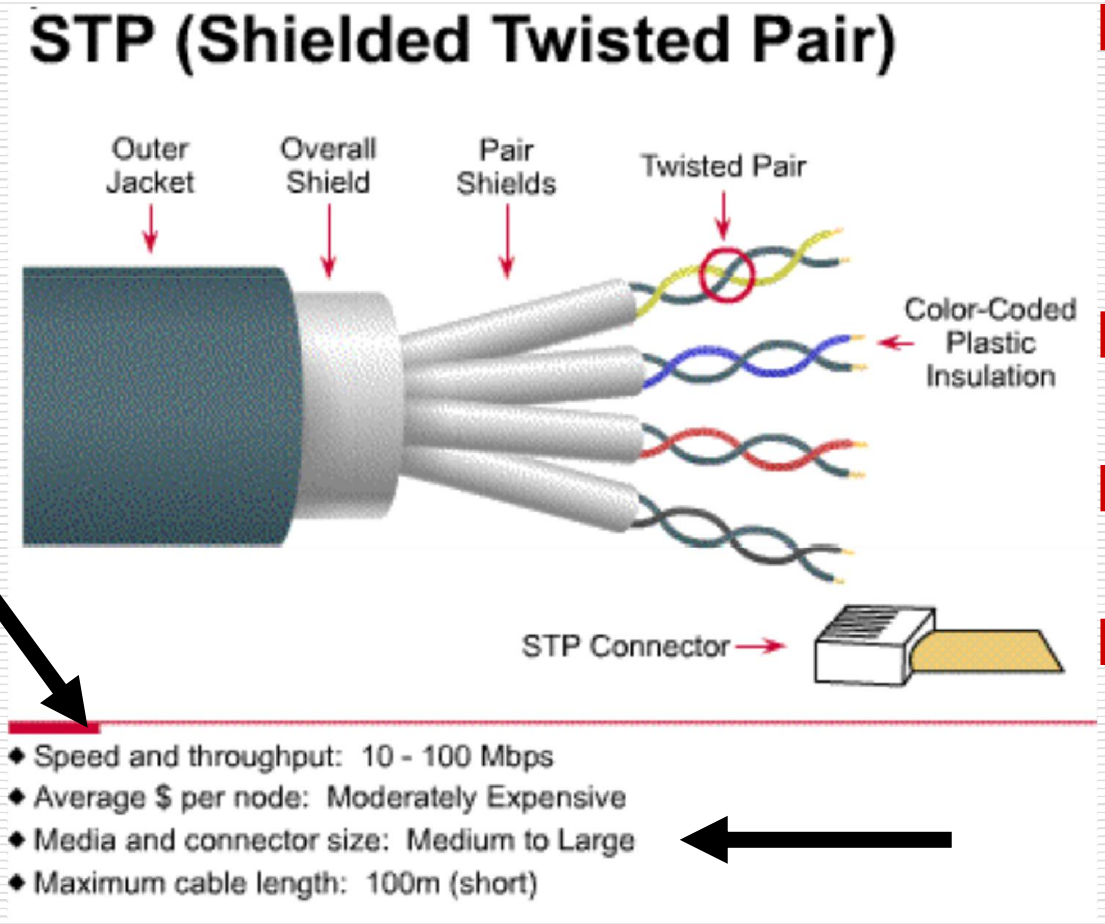
LAN Media

- Function is to transmit data
- Transmission process is referred to as *encoding*
- Cable types include STP, UTP, coaxial, fiber-optics

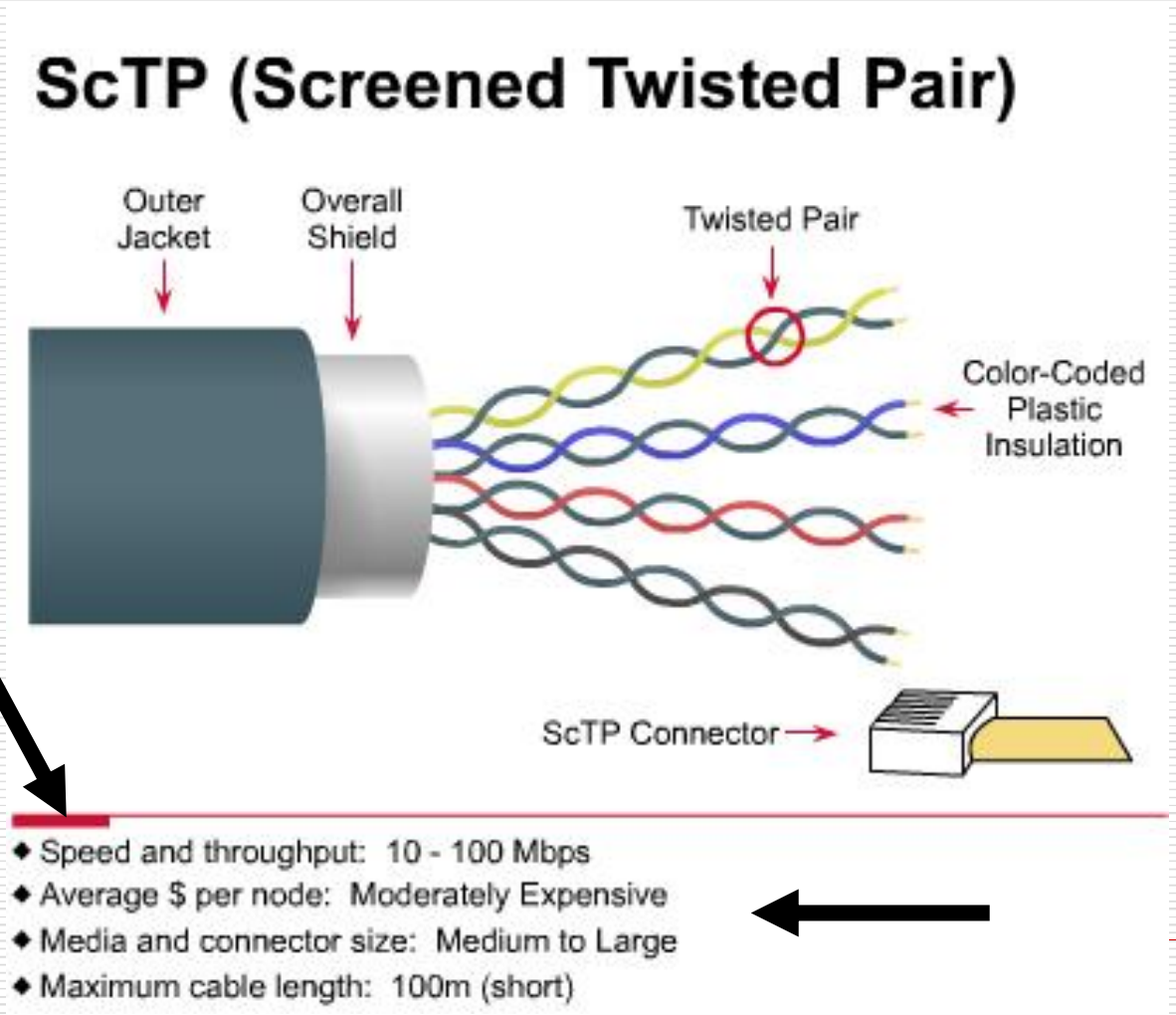


LAN Media--STP



- 4-pair wiring combines shielding and cancellation via twisting of wires
- normally a 150-Ohm cable
- reduces crosstalk EMI, RFI
- affords greater protection against all types of external interference than UTP

LAN Media--ScTP

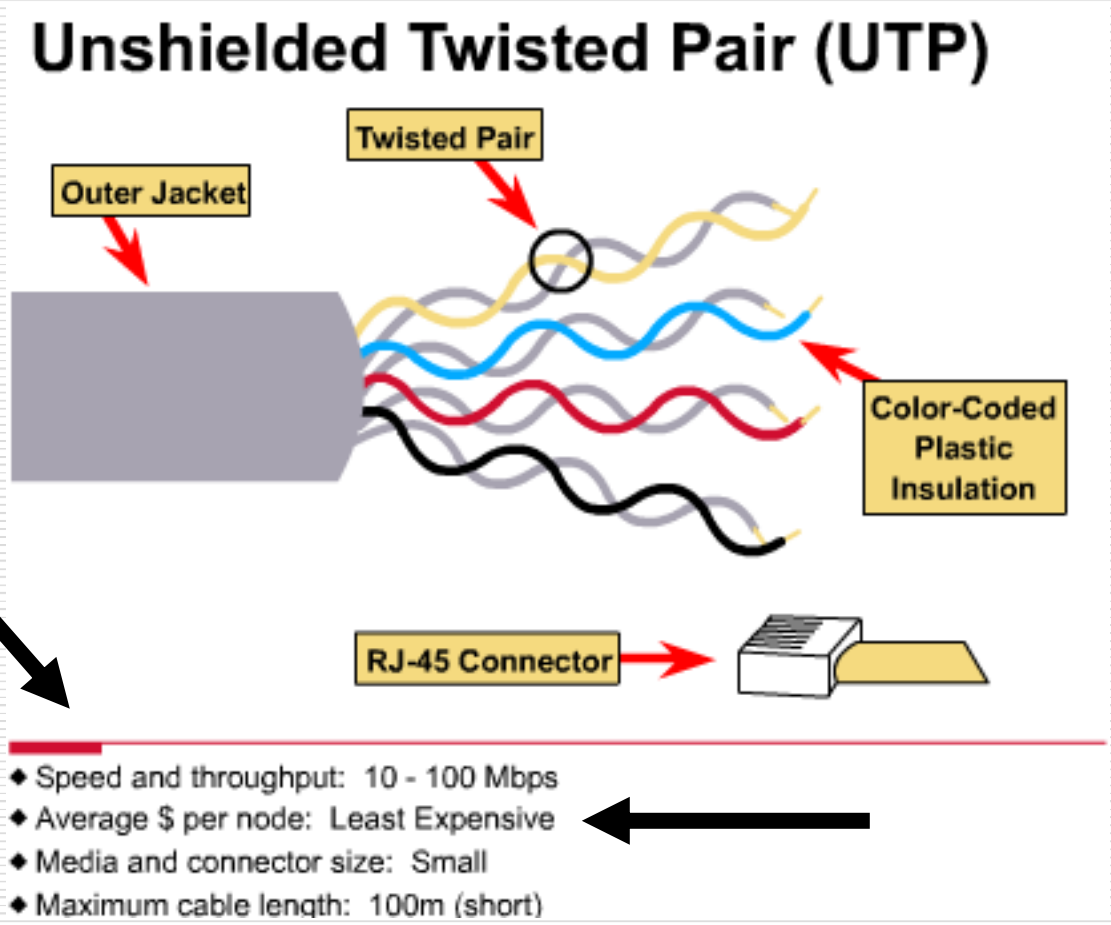


- wrapped in a metallic foil shield or screen
- usually 100 or 120 Ohm cable
- Both STP and ScTP prevent incoming electromagnetic waves from causing noise on data wires and also minimizes outgoing radiated electromagnetic waves

LAN Media—Disadvantages of STP and ScTP

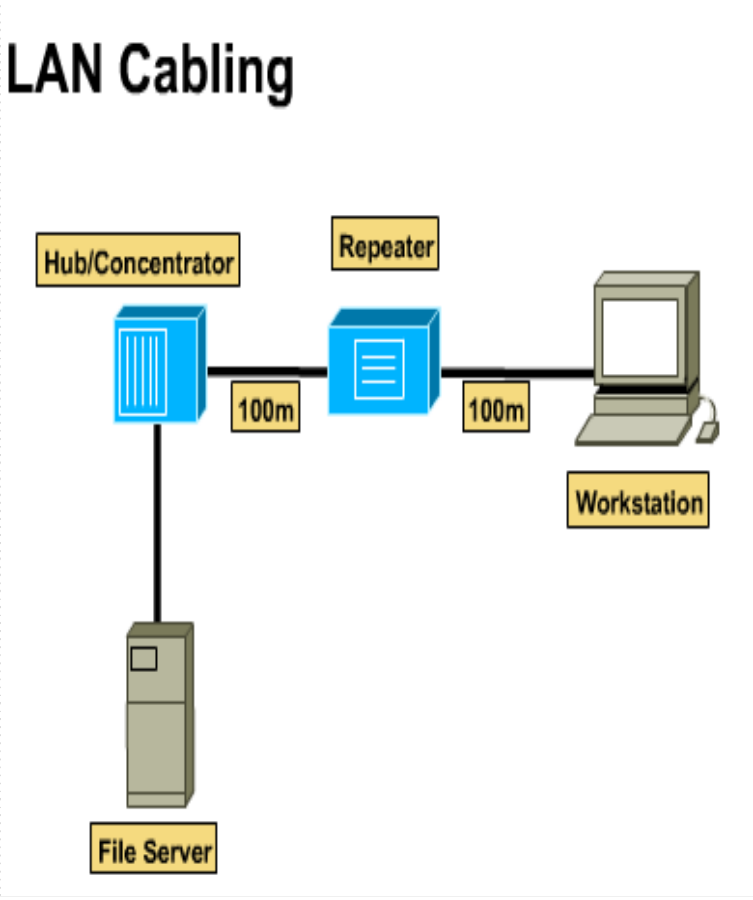
- cannot run cable as far as some other types of networking media without signal being repeated
- insulation adds considerably to size, weight, and cost of cable
- shielding materials make terminations more difficult and susceptible to poor workmanship

LAN Media--UTP



- relies solely on the cancellation effect, produced by twisted wire pairs to limit signal degradation caused by EMI and RFI
- has four pairs of copper wire
- has impedance of 100 Ohms

LAN Media—Advantages of UTP

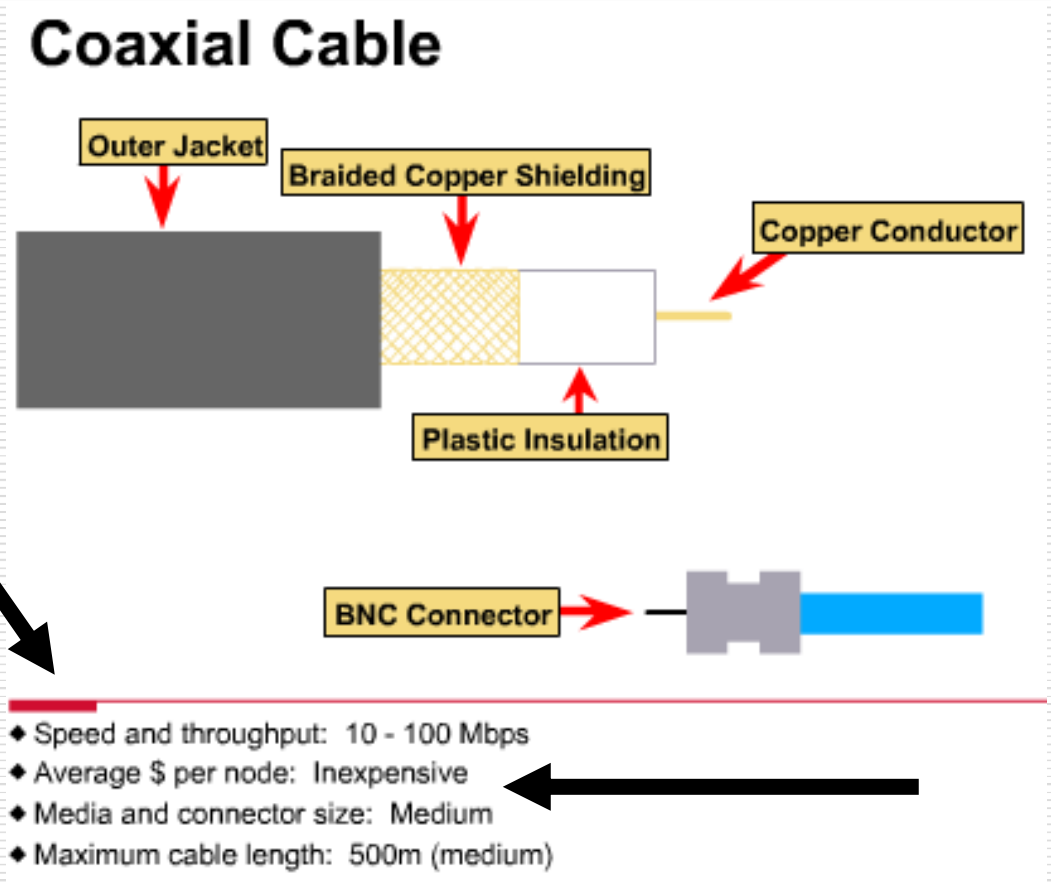


- easy to install and is less expensive
- costs less per meter than any other type of LAN cabling
- small external diameter does not fill up wiring ducts as rapidly as other types of cable
- is installed using an RJ connector so potential sources of network noise are greatly reduced and a good solid connection is practically guaranteed

LAN Media—Disadvantages of UTP

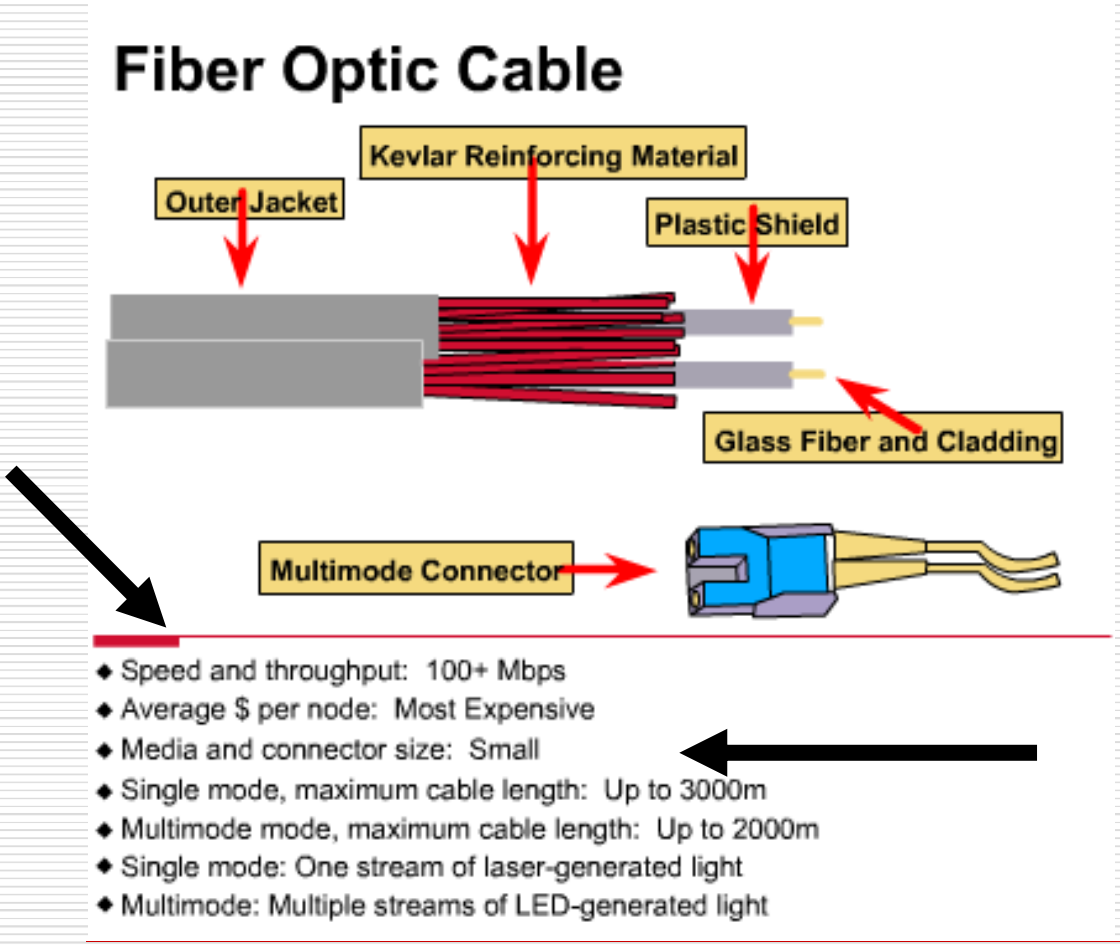
- cable is more prone to electrical noise and interference than other types of networking media
- distance between signal boosts is shorter for twisted-pair than for coaxial and fiber-optics

LAN Media--Coaxial



- *Thinnet/thicknet*
- longer network runs without using repeaters than twisted-pair
- less expensive than fiber but more expensive than twisted-pair

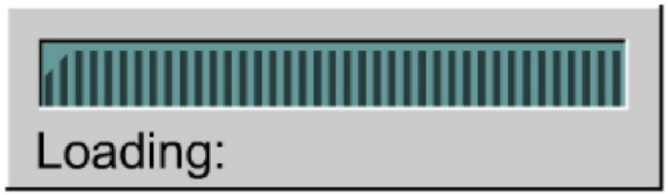
LAN Media—Fiber-Optic



- conducts modulated light transmission
- not susceptible to EMI or RFI and is capable of higher data rates than other networking media
- electromagnetic waves are guided through optical fiber

Fiber-Optic Mode Types

- **Single Mode**
  - also called *axial* : light travels down the *axis* of the cable
  - faster than multimode (up to 10 Gbps) because of the dispersion in multimode
  - typically used for WANS
  - smaller in diameter than multimode (less dispersion)
  - uses ILD most often but also LED
- **Multimode**
  - light enters the glass pipe at different angles and travels nonaxially, which means it bounces back and forth off the walls of the glass tube
  - larger than single mode, used most often in LANS
  - susceptible to greater dispersion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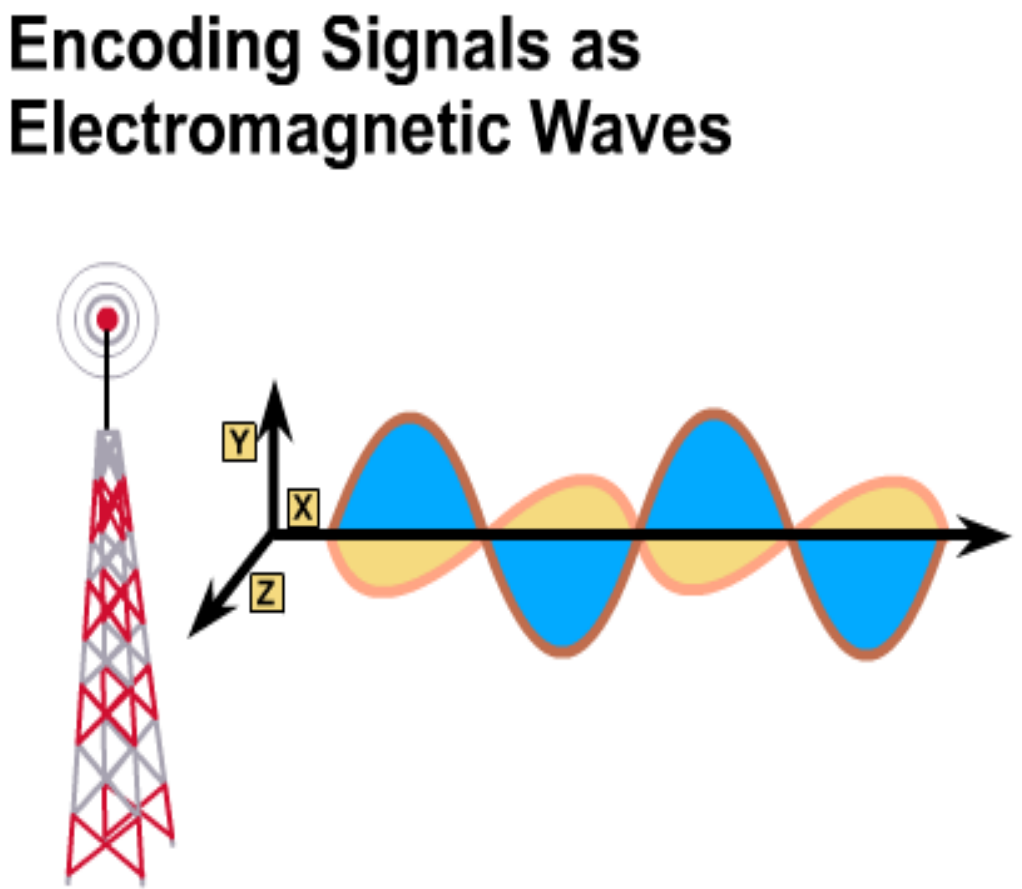
Wireless Communication



- The primary way of distinguishing between different electromagnetic waves is by their frequency.(frequency multiplexing)

Wireless Transmission Methods

- **Lasers**
  - output a coherent electromagnetic field in which all waves are at the same frequency and are aligned in a phase
- **Infrared**
  - normally a line-of-sight technology but can be bounced or redirected
  - cannot go through opaque objects
- **Radio**
  - carry data signals that can pass through walls
  - both terrestrial and satellite radio technologies

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Cable Specification and Termination

- The standards for networking media were developed and issued by the following groups:
  - IEEE—Institute of Electrical and Electronics Engineers
  - UL—Underwriters Laboratories
  - EIA—Electronic Industries Alliance
  - TIA—Telecommunications Industry Association
  - ANSI—American National Standards Institute

TIA/EIA Standards

TIA/EIA-568A	Commercial Building Telecommunications Cabling Standard
TIA/EIA-569A	Commercial Building Standard for Telecommunications Pathways and Spaces
TIA/EIA-570A	Residential and Light Commercial Telecommunications Wiring Standard
TIA/EIA-606	Administration Standard for the Telecommunications Infrastructure of Commercial Buildings
TIA/EIA-607	Commercial Building Grounding and Bonding Requirements for Telecommunications

Category of UTP

- 一类线：主要用于语音传输，不用于数据传输
- 二类线：传输频率1MHz，用于语音和最高4Mbps的数据传输，常见于令牌网
- **三类线**：EIA/TIA568标准指定电缆，传输频率16MHz，用于语音传输及最高传输速率为10Mbps的数据传输，主要用于10BASE-T
- 四类线：传输频率为20MHz，用于语音传输和最高传输速率16Mbps的数据传输，主要用于令牌网和 10BASE-T/100BASE-T
- **五类线**：增加了绕线密度，外套高质量绝缘材料，用于语音和数据传输(主要为100/1000BASE-T)，是最常用的以太网电缆
- **超五类线**：衰减小，串扰少，具有更高的衰减/串扰比和信噪比、更小的时延误差，主要用于1000BASE-T
- **六类线**：传输频率为1MHz～250MHz，性能远高于超五类标准，适用于高于1Gbps的应用
- 七类线：带宽为600MHz，可能用于今后的10G比特以太网。

Type of Cable

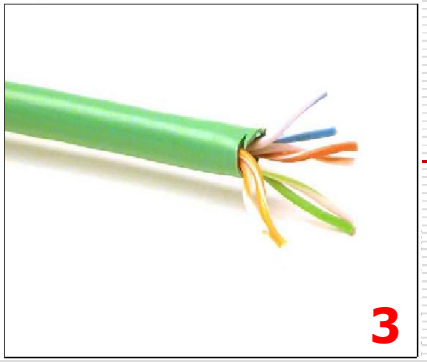
- Straight Cable
- Rollover Cable
- Crossover Cable

Creating a Straight-Through Cable

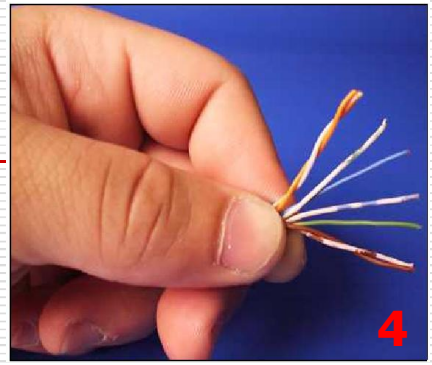
Cut a Length of Cable

Strip off the Jacket

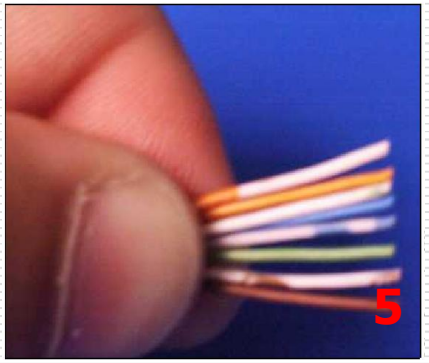
Separate the Wires



Untwist the Wires

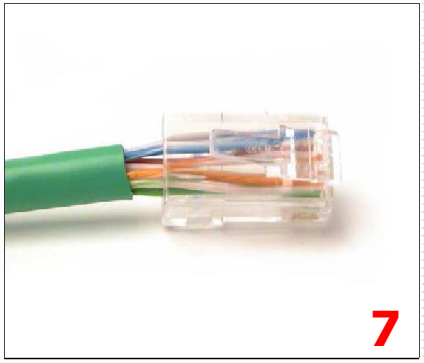


Organize and Flatten Wires

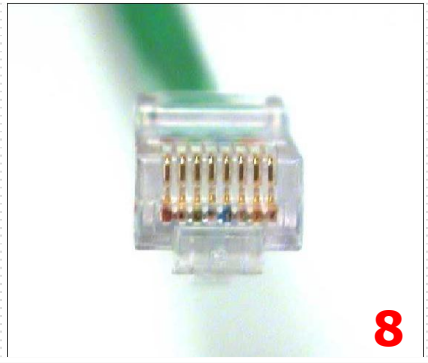


Clip the Wires

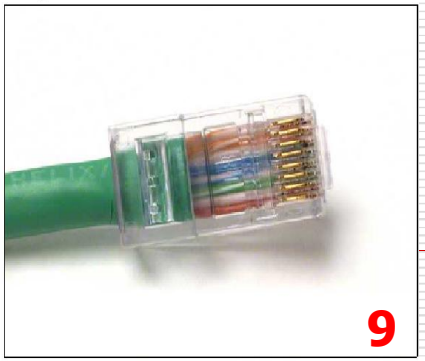
Insert Wires into RJ-45 Plug



Push the Wires in



Inspect the Color Code



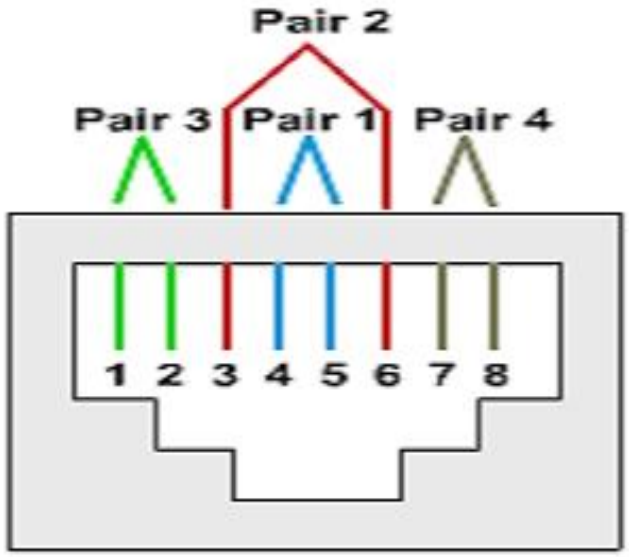
Crimp down the Wires

Inspect Both Ends

Test the Quality of Cable

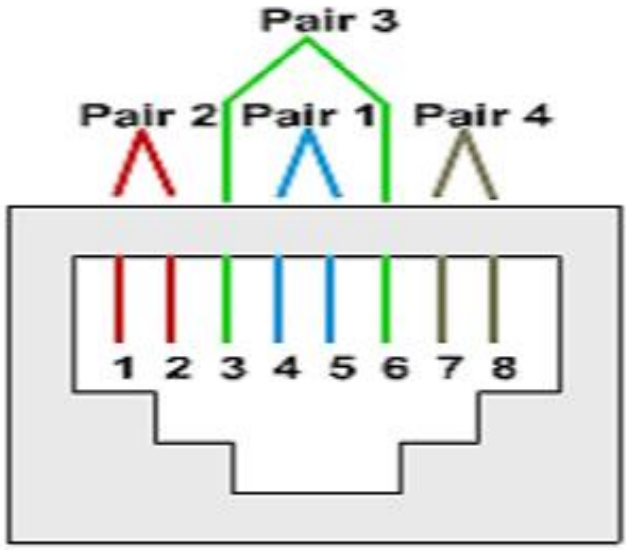
Straight Cable

100-Ohm balanced twisted-pair telecommunication outlet/connector



T568A

W-G G W-O Bl W-Bl O W-Br Br



T568B

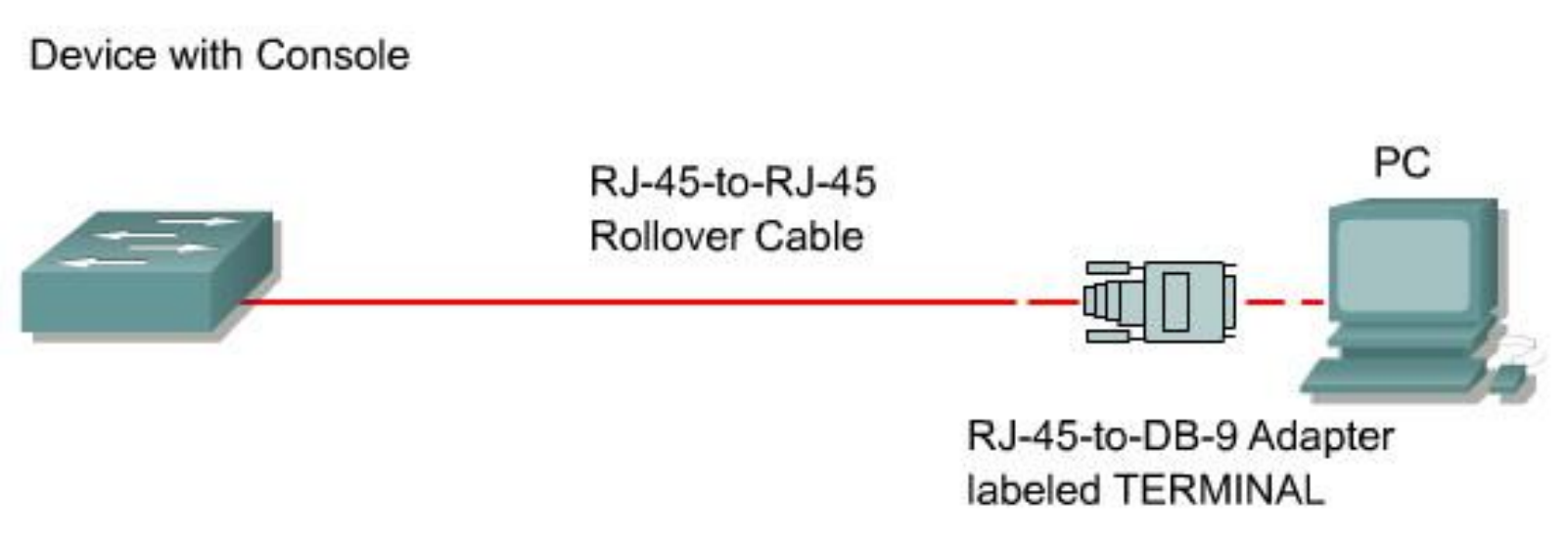
W-O O W-G Bl W-Bl G W-Br Br

Straight cable: *use T568A on both ends or T568B on both ends*

Rollover Cable

- Alias: console cable
- is used to connect a workstation or terminal to the console port of a router/switch to configure it
- Pin 1 on one end connects to Pin 8 on the other end; then Pin 2 connects to Pin 7, Pin 3 to Pin 6 and so on

Configuring Devices with Console



- Connect the serial port (com) of computer by using RJ-45-to-DB-9 adapter
- Start up “super terminal”
- Use “default configurations”

Crossover Cable

- pairs 2 and 3 on one end of the cable will be reversed on the other end
  - T568-A on one end and T568-B on the other
- is considered to be part of the “vertical” cabling/ backbone
- can be used to
  - connect two or more hubs or switches
  - connect two isolated workstations to create a mini-LAN

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Signaling and Communications Problems

- Propagation
  - travel time; speed depends upon medium
  - As data transmission rates increase, you must sometimes take into account the amount of time it takes the signal to travel.
- Attenuation
  - loss of signal over distance due to surroundings
  - can affect a network because it limits the length of network cabling over which you can send a message

Signaling and Communications Problems

- Reflection
  - Caused by discontinuities in the medium
  - Occurs in electrical signals; can be a result of kinks in cable or poorly terminated cables
  - Networks should have a specific impedance to match the electrical components in the NICs
  - The result of *impedance mismatch* is reflected energy.

Signaling and Communications Problems

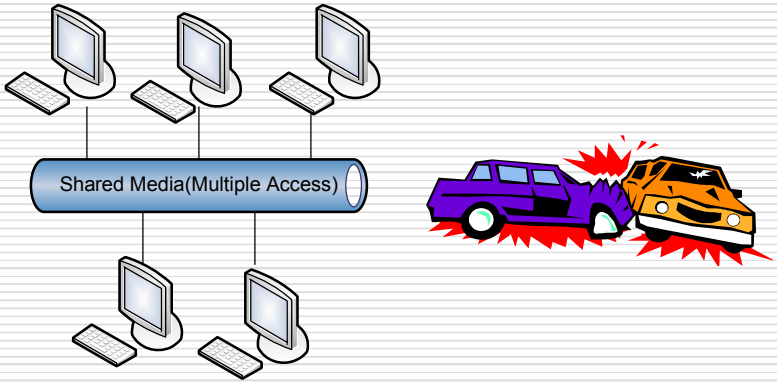
- Noise
  - unwanted additions to optical/electromagnetic signals
  - Crosstalk—electrical noise from other wires in a cable
  - EMI (electromagnetic interference) can be caused by electric motors.
  - Cancellation of signals can be avoided through the twisting of wire pairs to provide self-shielding within the network media.

Signaling and Communications Problems

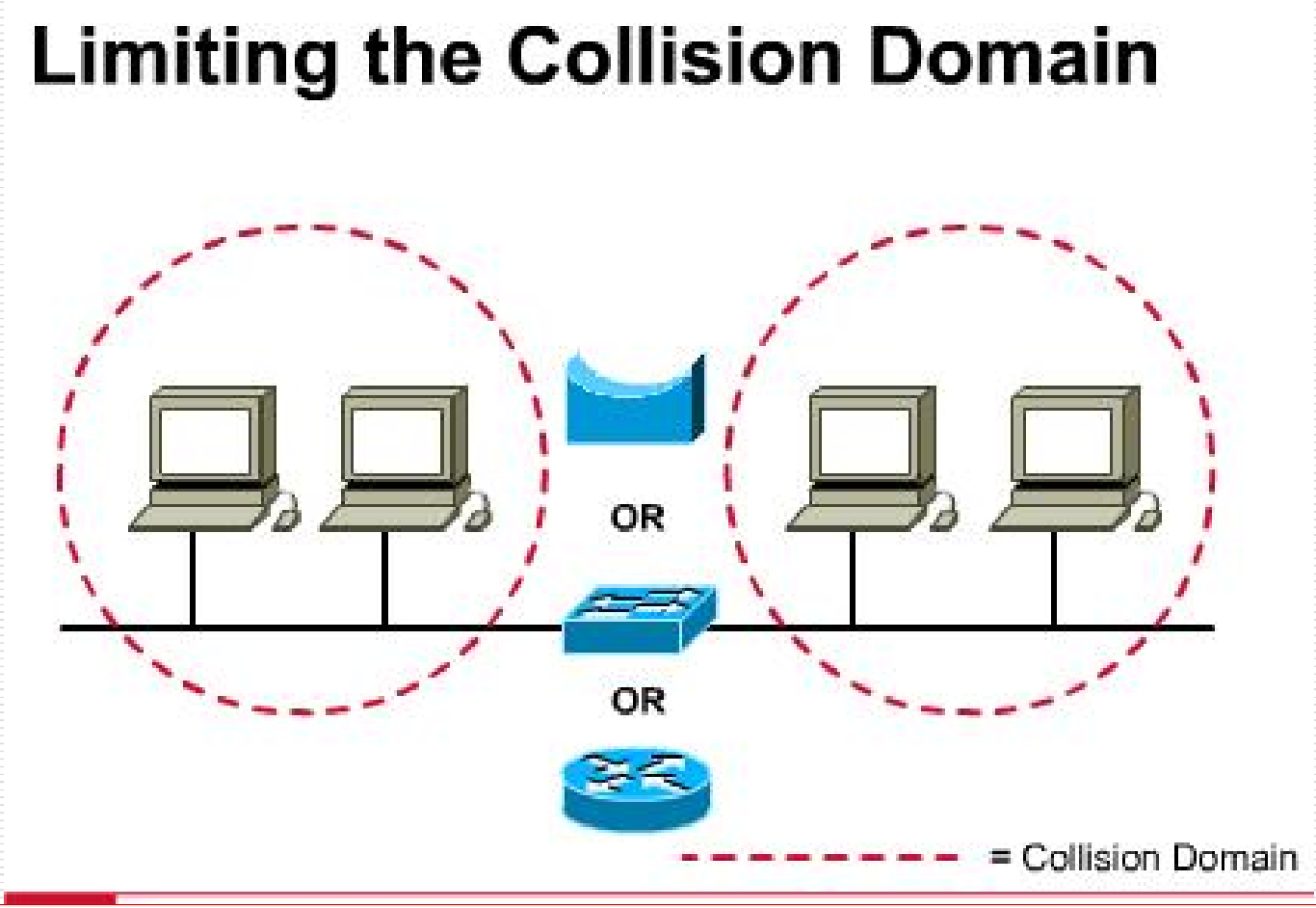
- Timing problem
  - Dispersion—signal broadens in time
    - can be fixed by proper cable design, limiting cable lengths, and finding the proper impedance
  - Jitter—source and destination not synchronized
    - can be fixed through hardware and software including protocols
  - Latency—delay of network signal

Collisions and Collision Domains

- A **collision** occurs when two bits propagate at the same time on the same network.
- Collision domains are extended by adding repeaters and hubs.
- Networks can be *segmented* by adding intelligent devices such as bridges, switches, and routers.



Segmenting Collision Domains

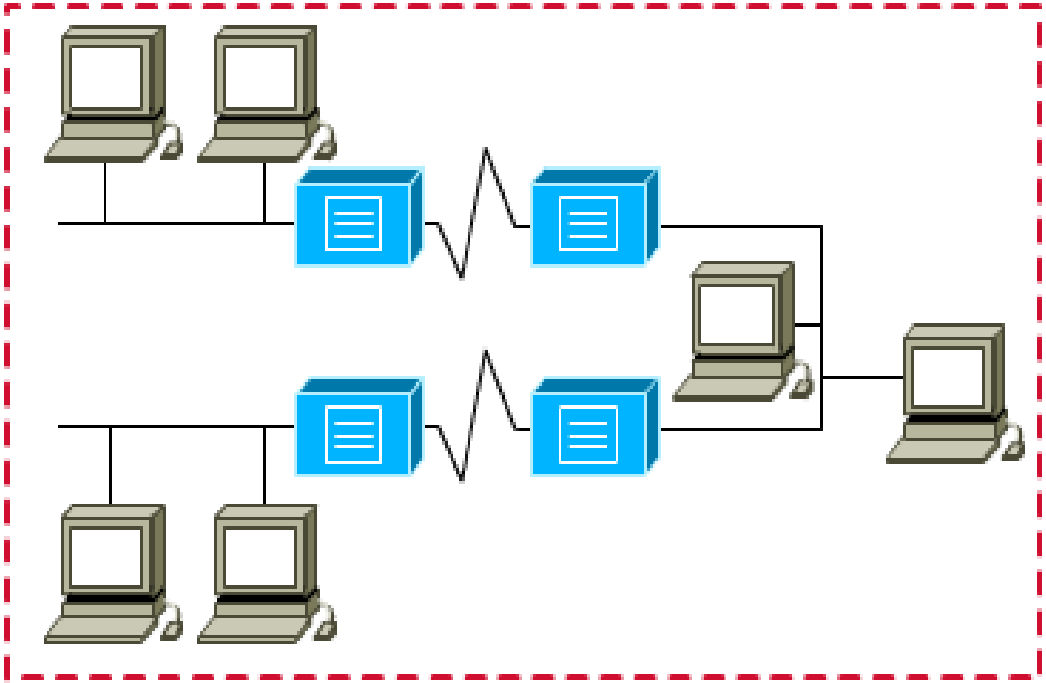


Collisions and Collision Domains

- When this delay limit is exceeded, the number of *late collisions* dramatically increase.
- A *late collision* is when a collision happens after the first 64 bytes of the frame are transmitted
- These late collision frames add delay referred to as *consumption delay*.
- As consumption delay and latency increase, network performance decreases

5-4-3-2-1 Rule

Collision Domain: 4 Repeater Rule



= Collision Domain

Five sections of the network, four repeaters or hubs, three sections of the network are "mixing" sections (with hosts), two sections are link sections (for link purposes), and one large collision domain.

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数据通信基本知识

- 数据通信的理论基础
  - 基本术语
  - 信号处理
  - 波特率与比特率
- 数据通信技术
  - 数据通信系统基本结构
  - 数据表示和传输方式
  - 信号的传输
  - 数字信号编码
  - 多路复用
  - 通信方式

基本术语

- 信号(signal)——数据的电气的或电磁的表现。
  - “模拟的”(analogous)——消息的参数的取值是连续的
    - 模拟信号是随时间变化而平稳变化的连续波形式
  - “数字的”(digital)——消息的参数的取值是离散的
    - 数字信号是离散信号，可能包含有限的几个预定值
- 码元(code)——在使用时间域（或简称为时域）的波形表示数字信号时，代表不同离散数值的基本波形。

理论基础:信号处理

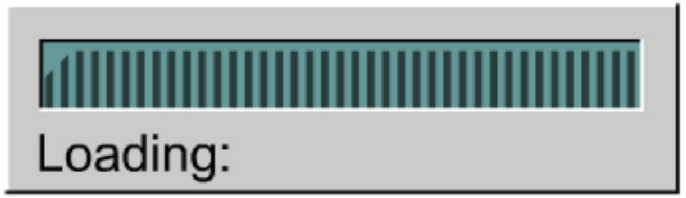
- 模拟信号可以被分为简单信号和复合信号
  - 简单信号（正弦波）不能被分解为更简单的模拟信号
  - 复合信号可以被分解为多个正弦波
- 复合模拟信号的分解：**傅立叶分析**
  - 任何一个周期为T的有理周期性函数 g(t)可分解为若干项（可能无限多项）正弦和余弦函数之和：

$$g(t) = \frac{1}{2}\, c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

f = 1/T 基本频率； a_n, b_n : n次谐波项的正弦和余弦振幅值

理论基础:信号处理

- 数字信号一般是非周期性的，通常在传输介质上表现为方波
- 一个数字信号可以分解为无穷多个被称为谐波的简单正弦波，每个谐波都具有不同的频率与相位
- 在介质上发送数字信号时，其实质是在发送无穷多的简单谐波，如果某些分量未能忠实地通过介质传输，则在接收端将产生信号畸变
- 由于介质本身的限制，信号畸变是难以完全避免的
- 任何实际的信道都不是理想的，在传输信号时会产生各种失真以及带来多种干扰。
- 码元传输的速率越高，或信号传输的距离越远，在信道的输出端的波形的失真就越严重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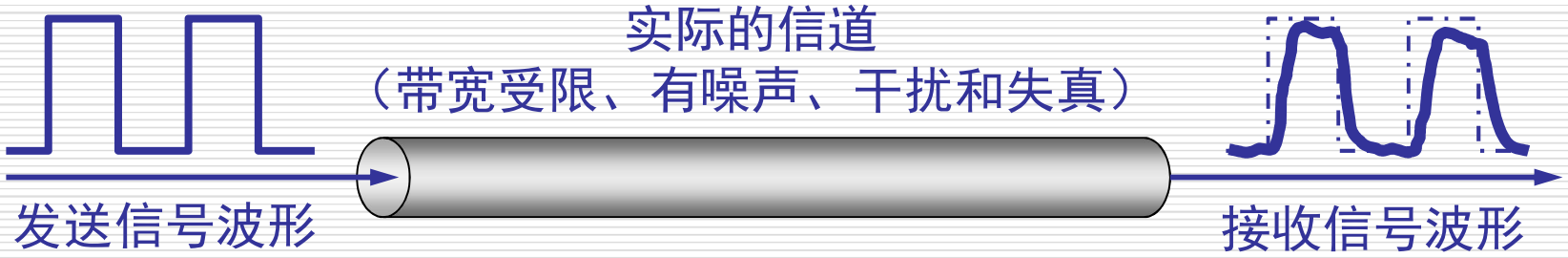
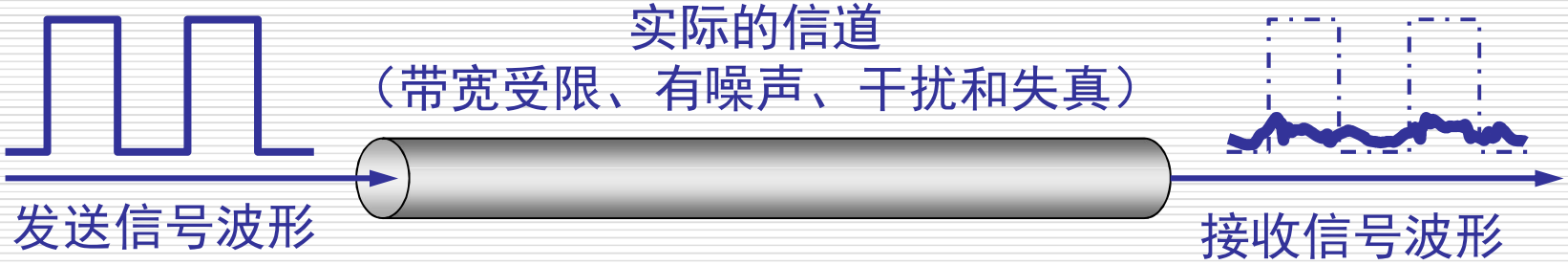
数字信号通过实际的信道

- 有失真，但可识别



- 失真大，无法识别



无噪声信道的最高传输速率

- 1924 年，奈奎斯特(Nyquist) 指出在假定无噪声的信道上，为避免码间串扰，传输比特率的上限值为：

$$C = W \log_2 L \text{ bps}$$

  - *W* 为信道的带宽（以 Hz 为单位）
  - L 为表示数据的信号电平的数量
- 在任何信道中，码元传输的速率是有上限的，否则就会出现码间串扰的问题，使接收端对码元的判决（即识别）成为不可能。
- 如果信道的频带越宽，也就是能够通过的信号高频分量越多，那么就可以用更高的速率传送码元而不出现码间串扰

噪声信道的最高传输速率

- 香农(Shannon)用信息论的理论推导出了带宽受限且有高斯白噪声干扰的信道的极限、无差错的信息传输速率
- 信道的极限信息传输速率 C 可表达为

$$C = W \log_2(1+S/N) \quad \text{bps}$$

  - W 为信道的带宽（以 Hz 为单位）；
  - S 为信道内所传信号的平均功率；
  - N 为信道内部的高斯噪声功率
  - S/N称为信噪比

香农公式的含义

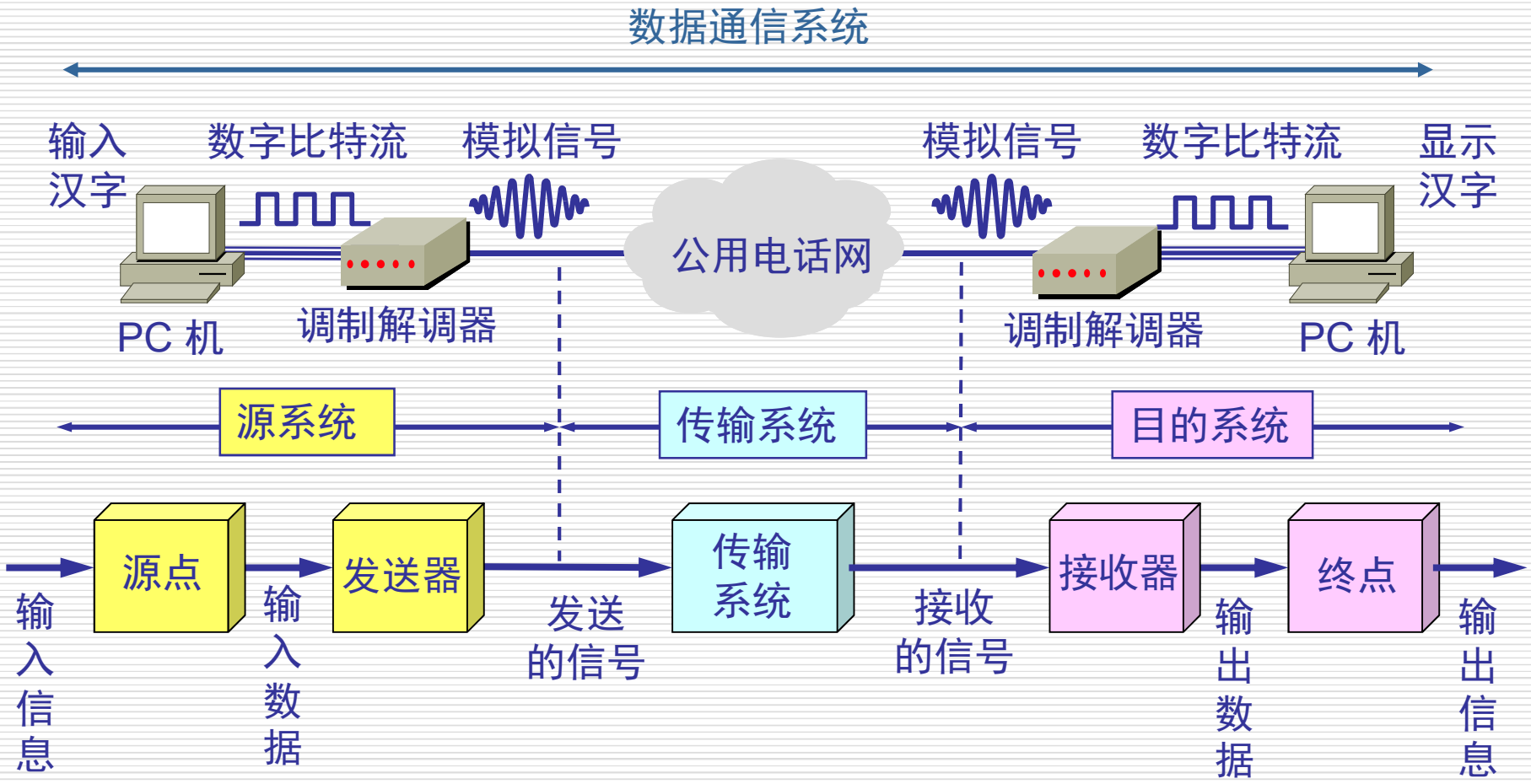
- 信道带宽或信道的信噪比越大，极限传输速率越高
- 只要信息传输速率低于信道的极限信息传输速率，就一定有办法实现无差错的传输
- 若信道的带宽 W 或信噪比 S/N 没有上限（实际不可能），则其极限信息传输速率 C 也没有上限
- 实际能够达到的传输速率比香农极限传输速率低不少
- 请注意：对于频带宽度已确定的信道，即使信噪比不能再提高，且码元速率已达上限，也有办法提高传输速率。这就是用编码的方法让每个码元携带更多比特的信息量

理论基础:波特率和比特率

- 波特率（baud）和比特率（bit）
  - 波特率（调制速率）：信号每秒钟变化的次数
  - 比特率：每秒钟传送的二进制位数。
- 波特率与比特率的关系取决于信号值与比特位的关系
  - 例：每个信号值表示为 3 位，则比特率是波特率的 3 倍；每个信号值表示为 1 位，则比特率和波特率相同
  - 对于比特率为a bps的信道，发送 8 位所需的时间为 8/a秒，若 8 位为一个周期 T，则一次谐波的频率是：

$$f = a/8 \text{ Hz}$$

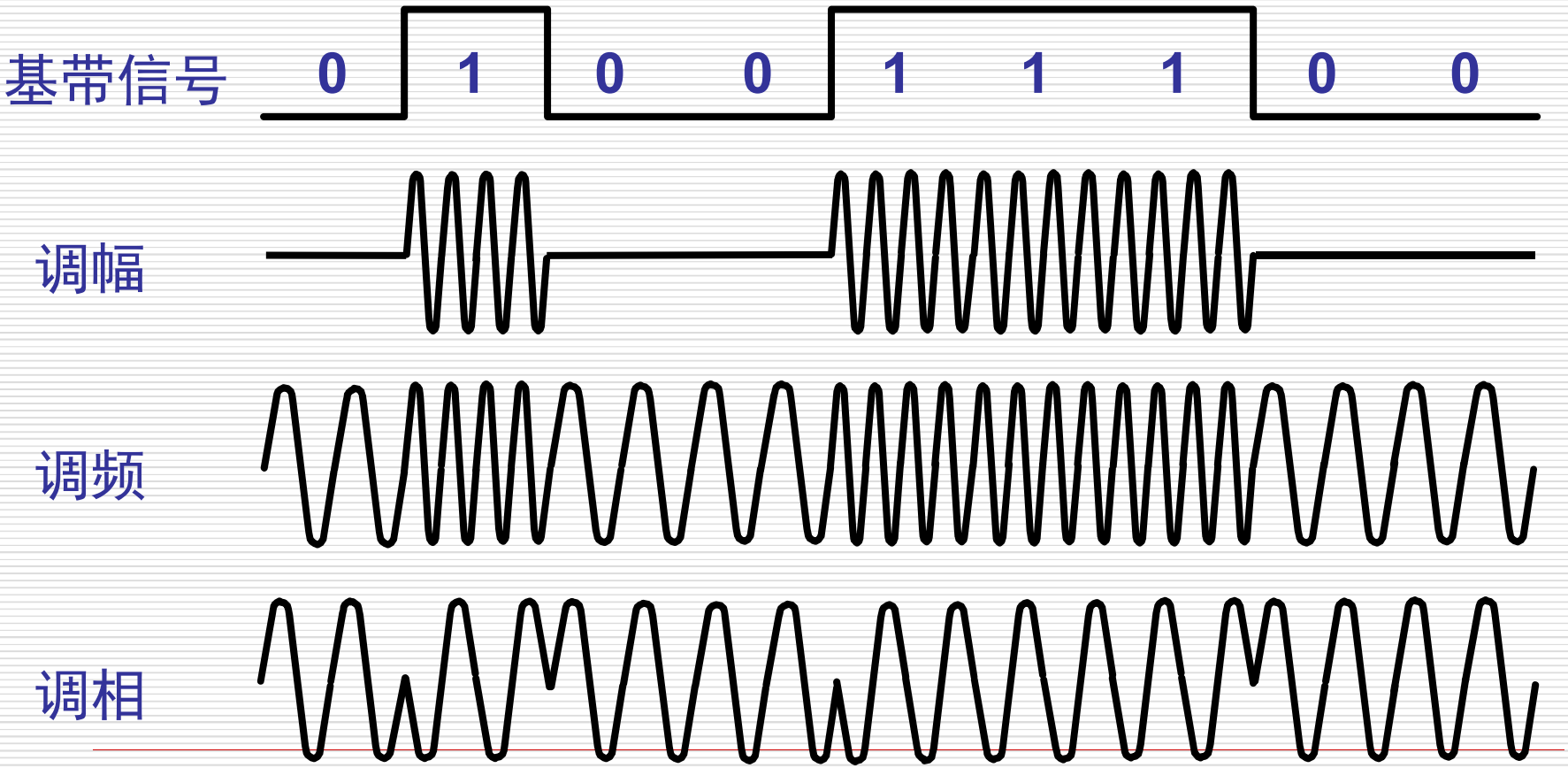
数据通信系统的模型


数据通信系统
输入汉字
数字比特流
模拟信号
公用电话网
模拟信号
数字比特流
显示汉字
PC 机
调制解调器
调制解调器
PC 机
源系统
传输系统
目的系统
源点
发送器
传输系统
接收器
终点
输入信息
输入数据
发送的信号
接收的信号
输出数据
输出信息

数据通信技术：数字数据编码

- 基带：基本频带，指传输变换前所占用的频带，是原始信号所固有的频带
- 基带传输:在传输时直接使用基带数字信号(不转换为模拟信号，即不调制)
  - 基带传输是一种最简单最基本的传输方式，一般用低电平表示“0”，高电平表示“1”
  - 适用范围：低速和高速的各种情况。
  - 限制：因基带信号所带的频率成分很宽，所以对传输线有一定的要求

将数字数据转换到模拟信号：调制



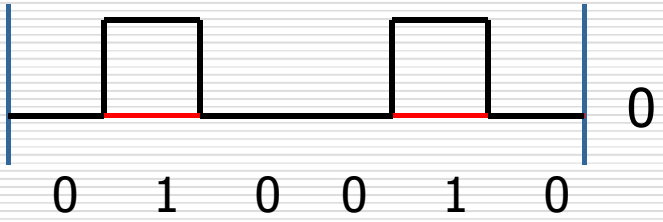
将数字数据转换到数字信号：线路编码

- ***Line coding*** means to convert the binary data into a form that can travel on a physical communications link such as an electrical pulse on a wire, a light pulse on an optical fiber, or an electromagnetic wave in space

数据通信技术：编码方式

- 编码方式可分为三类：
  - 单极性编码
  - 极化编码
    - **NRZ(Non-Return to Zero，不归零制码)**
    - **RZ(Return to Zero，归零制码)**
    - 双相位编码
      - 曼彻斯特码
      - 差分曼彻斯特码
  - 双极性编码
    - **传号交替反转码(AMI)**
    - 双极性8连0替换码(B8ZS)
    - 3阶高密度双极性码(HDB3)

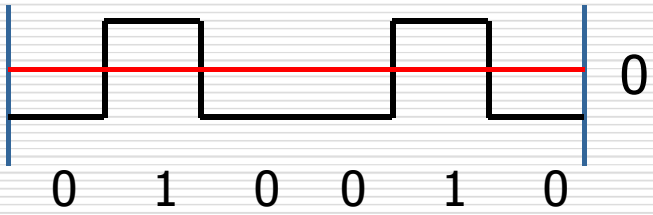
单极性编码



- 原理：
  - 用0电平表示“0”，正电平表示“1”
- 缺点：
  - 难以分辨一位的结束和另一位的开始
  - 发送方和接收方必须有时钟同步
  - 若信号中“0”或“1”连续出现，信号直流分量将累加，单极性编码的直流分量问题严重
- 结论：容易产生传播错误

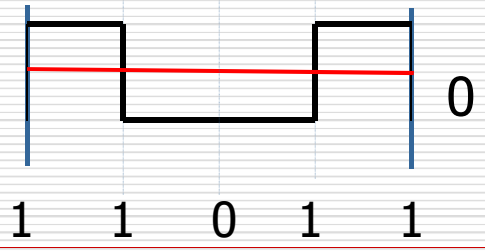
极化编码
——不归零制码(NRZ: Non-Return to Zero)

- 不归零电平编码
  - 原理：用负电平表示“0”，正电平表示“1”（或相反）
  - 缺点：
    - 难以分辨一位的结束和另一位的开始
    - 发送方和接收方必须有时钟同步
    - 尽管不会如单极性编码严重，但若信号中“0”或“1”连续出现，信号直流分量仍将累加



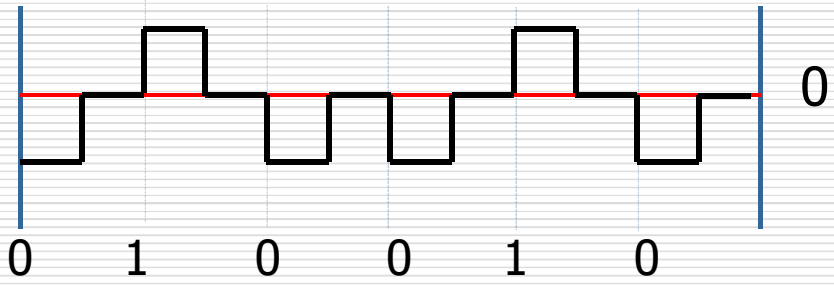
极化编码
——不归零制码(NRZ: Non-Return to Zero)

- 不归零反相编码
  - 原理：信号电平的一次翻转代表比特1，无电平变化代表0
  - 不归零反相编码优于不归零电平编码：由于每次遇到“1”（或“0”）都要发生跃迁，因此可以根据电平跃迁进行有限的同步



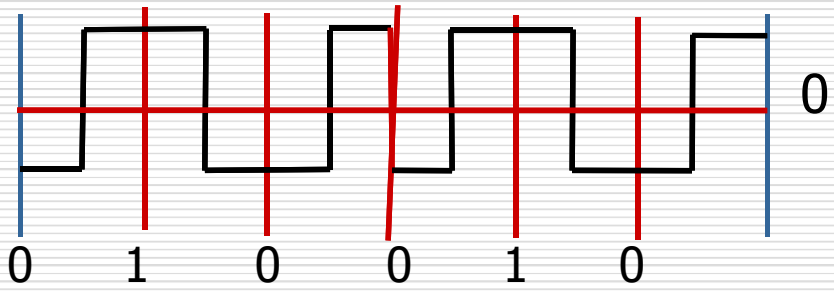
极化编码：
——归零制码（RZ: Return to Zero）

- 原理：用负电平表示“0”，正电平表示“1”（或相反），比特中位跳变到零电平，从而提供同步
- 优点：信号本身带有同步信息，经济性好，且不易出错
- 缺点：需要采用三个不同电平，两次信号变化来编码1比特，因此增加了占用的带宽



极化编码：
——曼彻斯特码（Manchester）

- 原理：每一位中间都有一个跳变，从低跳到高表示“0”，从高跳到低表示“1”
  - 请思考：“00” “01”曼彻斯特编码下应怎样表示？
  - 优点：克服了NRZ码的不足。每位中间的跳变既可作为数据，又可作为时钟，能够自同步；同时只采用两个电平，跳变减少，比RZ码效率更高



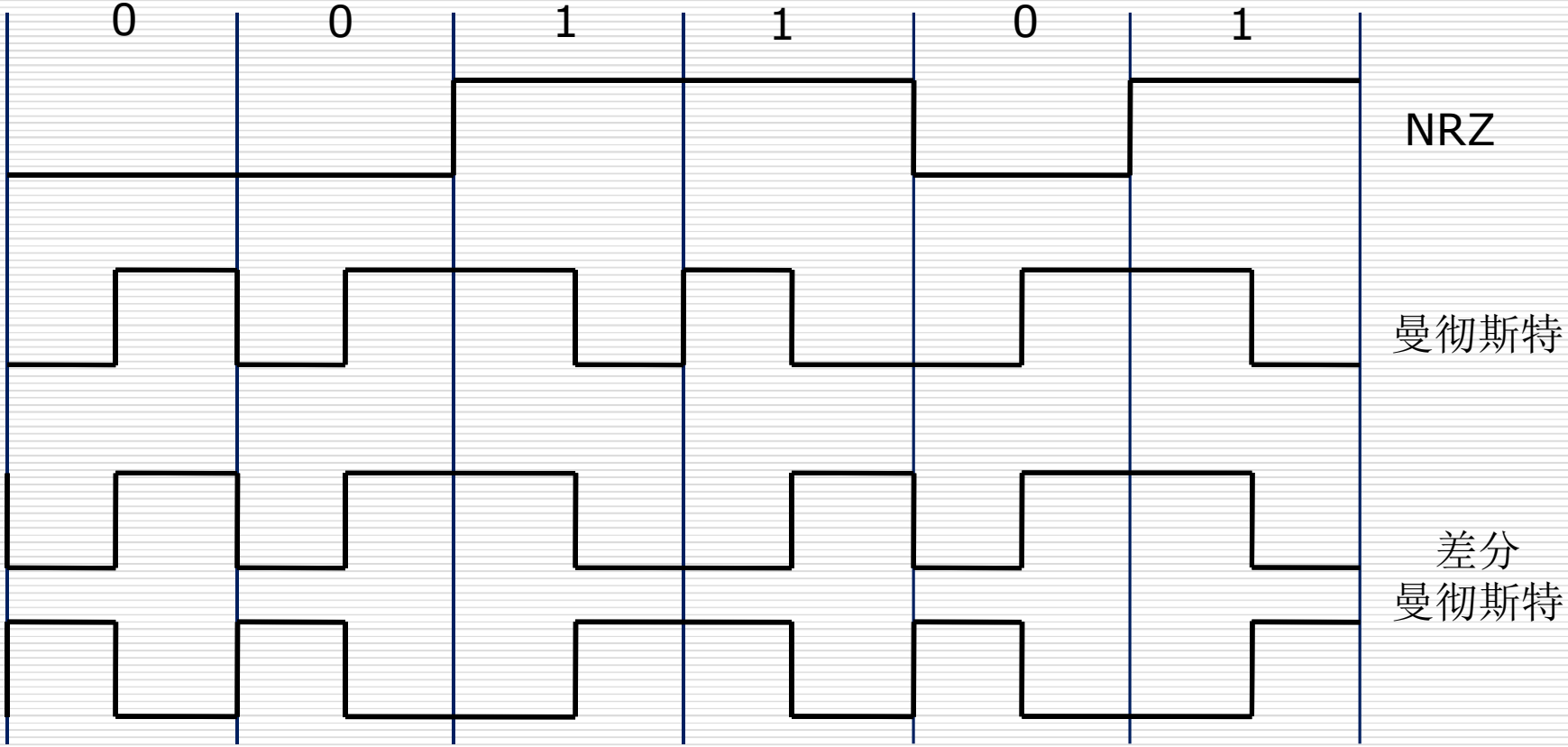
极化编码：

——差分曼彻斯特码（Differential Manchester）

- 原理：
  - 每一位中间跳变：表示时钟
  - 每一位位前跳变：表示数据
    - 有跳变表示“0”，无跳变表示“1”
- 优点：时钟、数据分离，便于提取

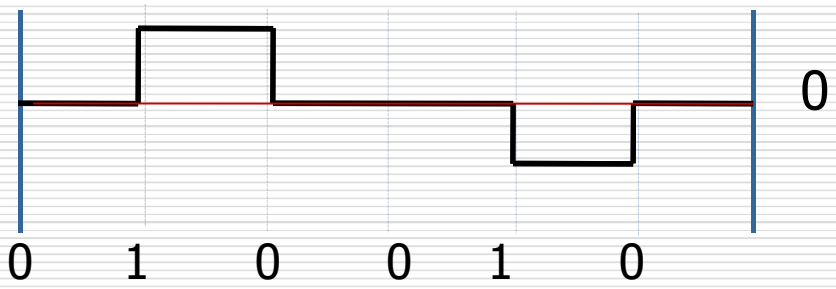
极化编码：

——差分曼彻斯特码（Differential Manchester）



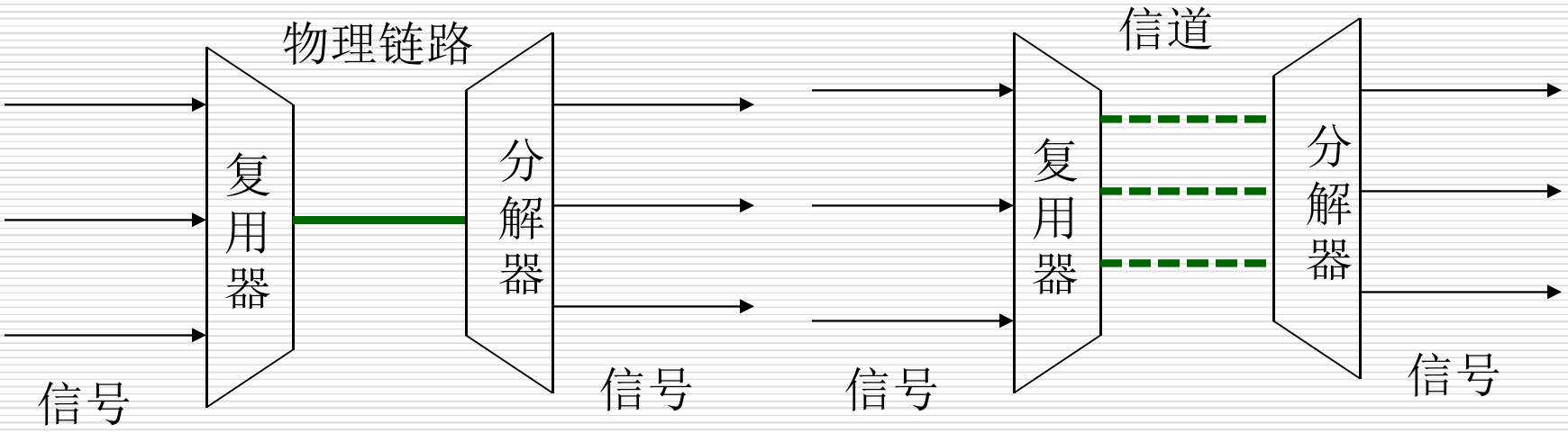
双极性编码：
——双极性传号交替反转码（AMI）

- 与RZ相同的是：采用三个电平：正、负与零
- 与RZ不同的是：零电平表示“0”，正负电平的跃迁表示“1”，实现对“1”电平的交替反转。
- 优点：
  - 对每次出现的“1”交替反转，使直流分量为0
  - 尽管连续“0”不能同步，但连续“1”可以同步



数据通信技术：多路复用

- 多路复用技术
  - 由于一条传输线路的能力远远超过传输一个用户信号所需的能力，为了提高线路利用率，经常让多个信号共用一条物理线路



多路复用

时分复用

TDM (Time Division Multiplexing）

频分复用

FDM (Frequency Division Multiplexing)

波分复用

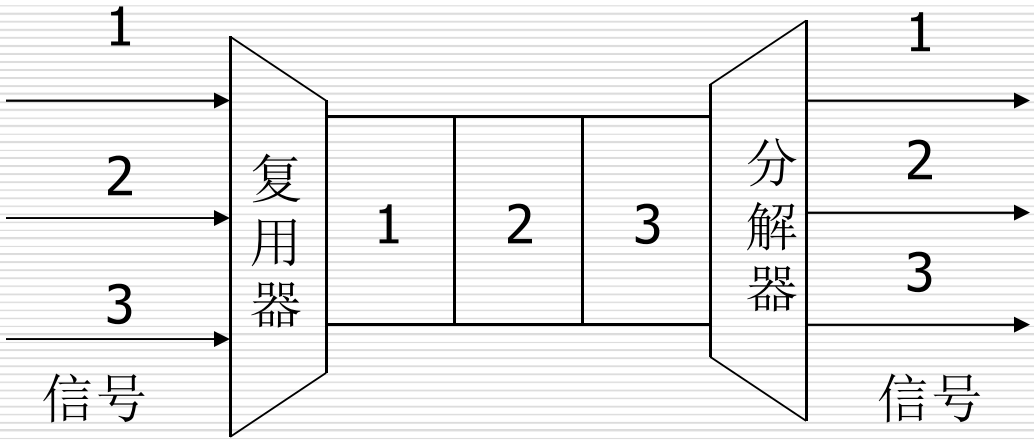
WDM (Wavelength Division Multiplexing)

码分复用

CDM (Code Division Multiplexing)

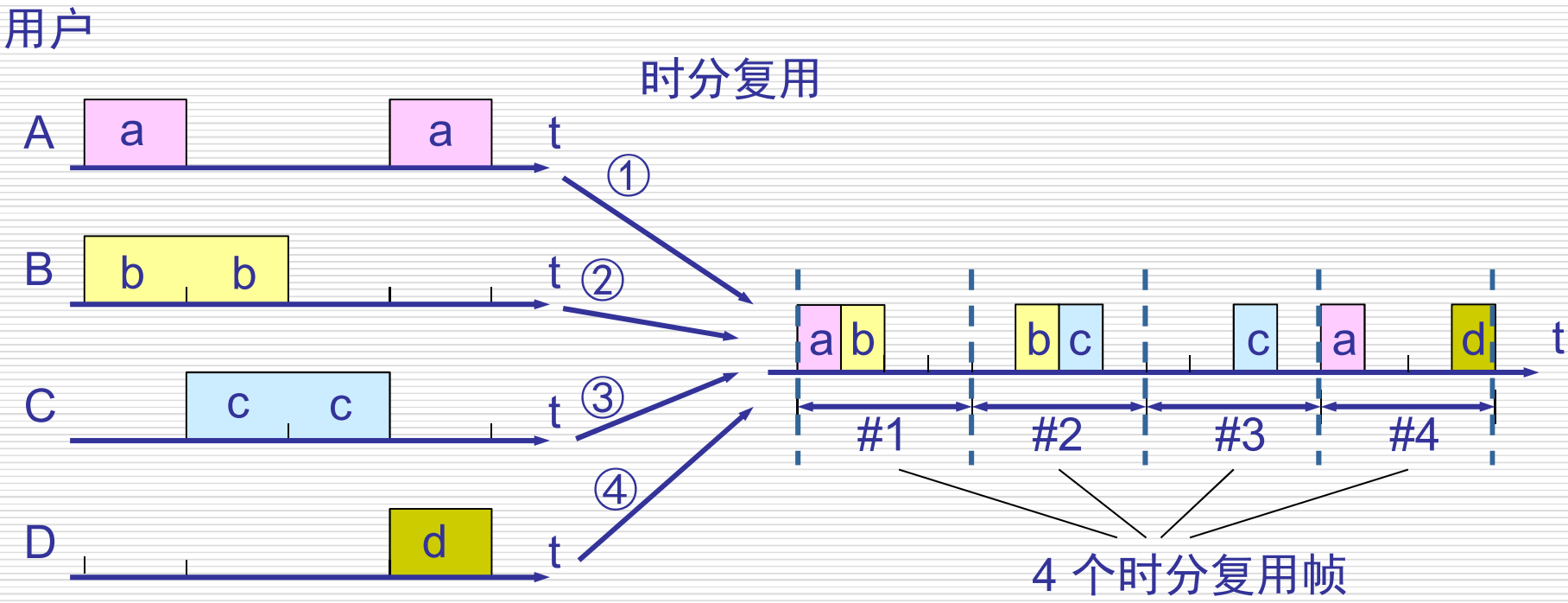
时分复用TDM (Time Division Multiplexing)

- 时分复用是将时间划分为一段段等长的时分复用（TDM ）帧，每个时分复用的用户在每个 TDM 帧中占用固定序号的时隙。
- 每一个用户所占用的时隙是周期性地出现
- TDM 信号也称为等时(isochronous)信号。
- 时分复用的所有用户在不同的时间占用同样的频带宽度

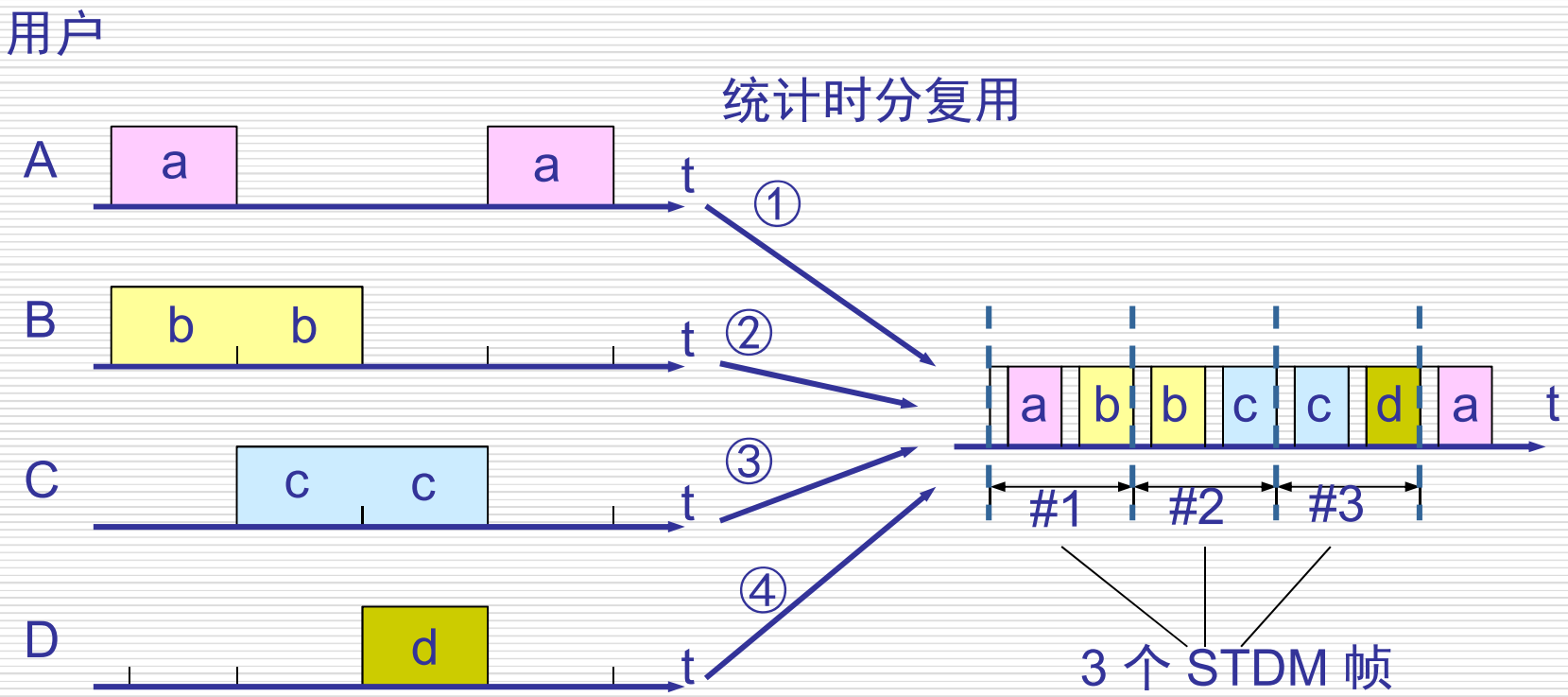


时分复用可能会造成线路资源的浪费

使用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质，用户对分配到的子信道的利用率一般不高。

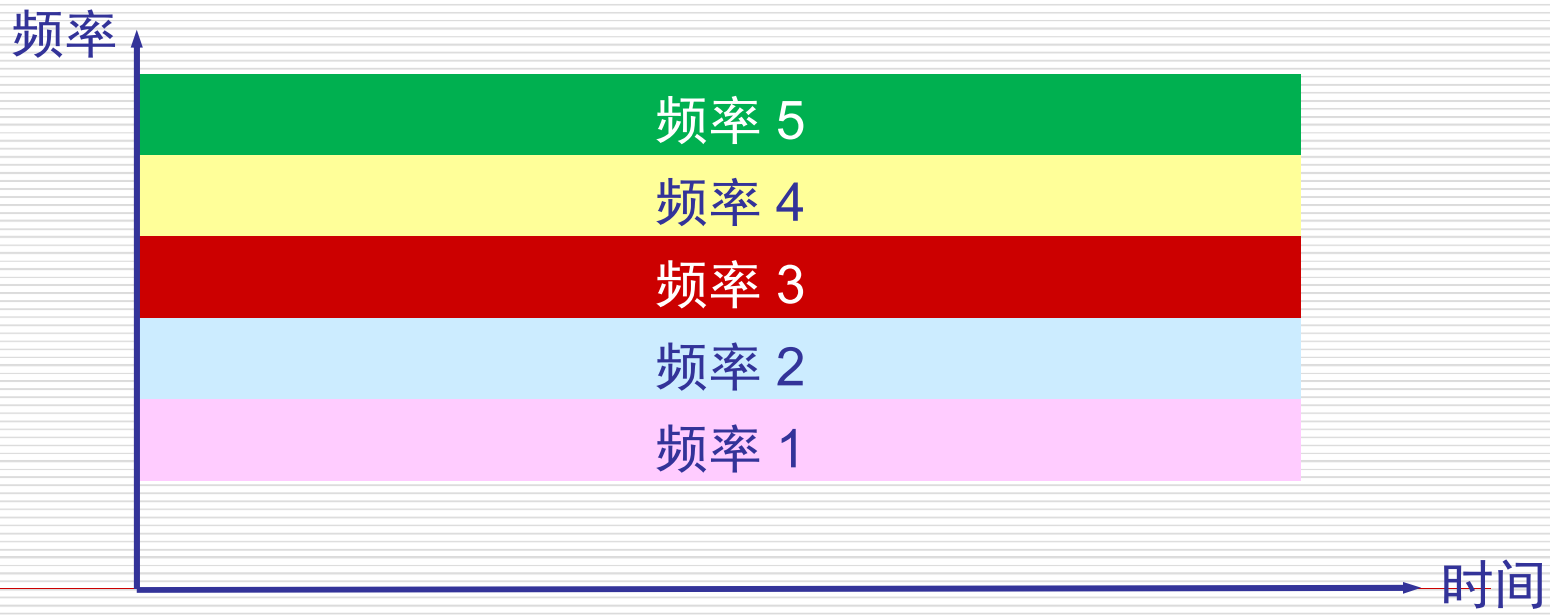


统计时分复用 STDM (Statistic TDM)



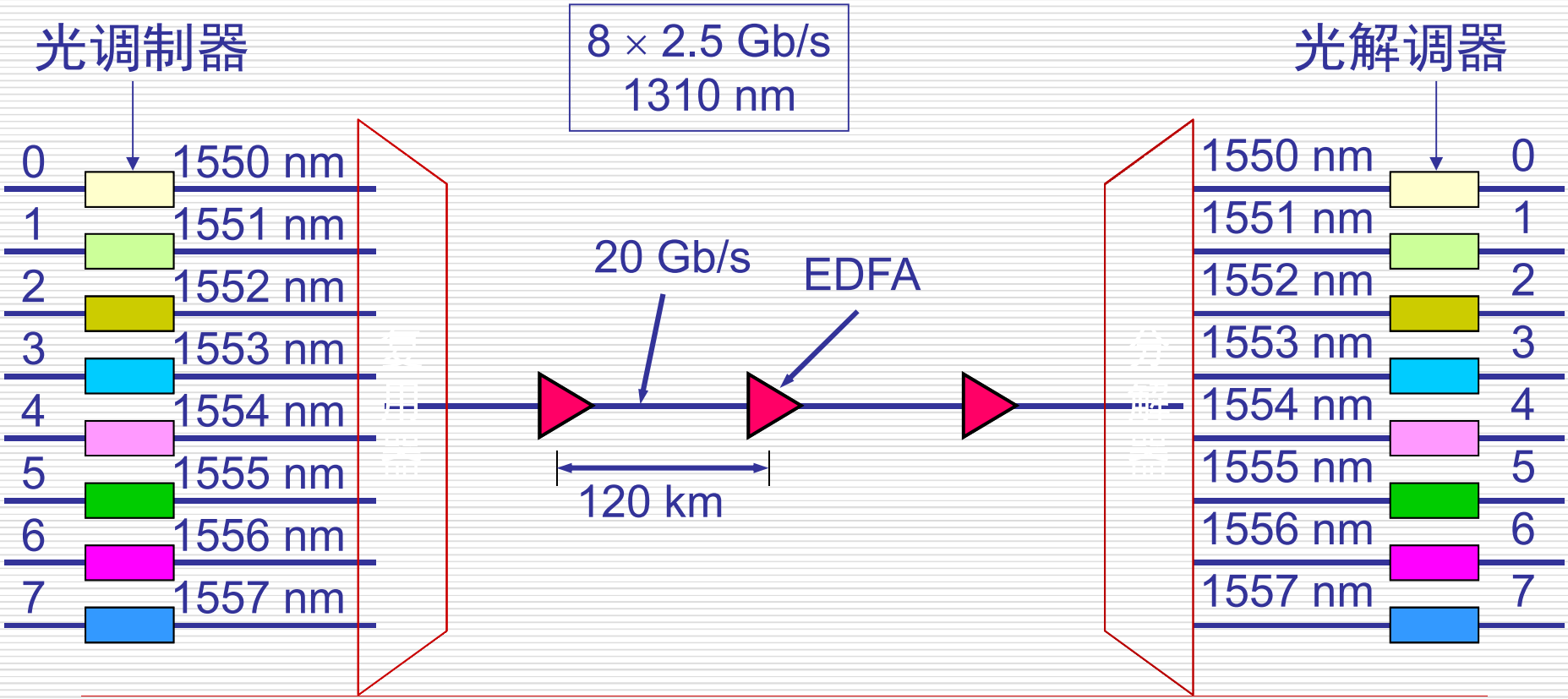
频分复用 FDM (Frequency Division Multiplexing)

- 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。
- 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）



波分复用 WDM (Wavelength Division Multiplexing)

- 波分复用就是光的频分复用。



码分复用 CDM (Code Division Multiplexing)

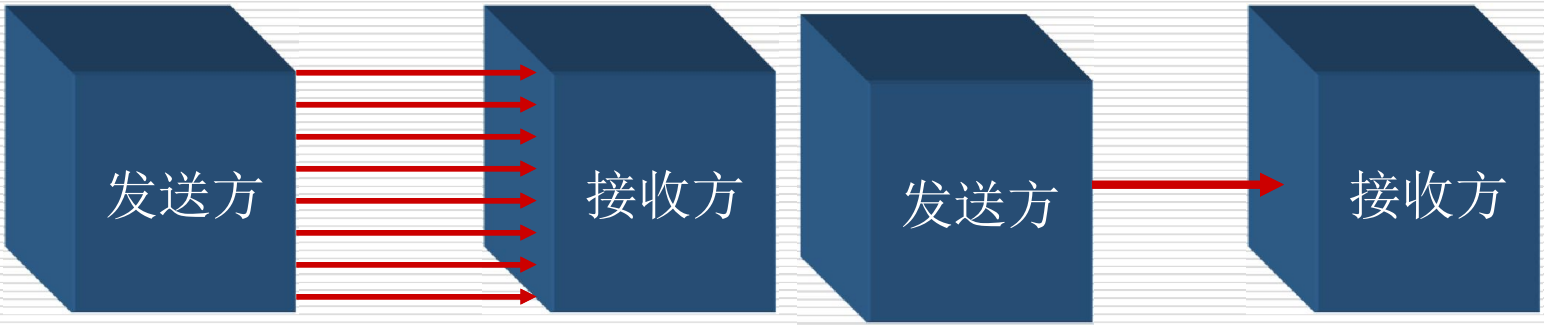
- 常用的名词是码分多址 CDMA(Code Division Multiple Access)
- 各用户使用经过特殊挑选的不同码型，因此彼此不会造成干扰。
- 这种系统发送的信号有很强的抗干扰能力，其频谱类似于白噪声，不易被敌人发现

数据通信技术：通信方式

- Simplex Transmission(单工)
  - Unidirectional—signal travels in only one direction
  - Television is an example.
- Half-Duplex Transmission（半双工）
  - Signal can travel in both directions but not at the same time.
- Full-Duplex Transmission（全双工）
  - Signal can travel in both directions at the same time.

数据通信技术：通信方式

- 并行传输与串行传输
  - 并行传输：由0和1组成的二进制数据可以组成每组n比特的位组，并行传输同时发送这种位组而非单独的比特
  - 串行传输：每次传输1位比特



并行：8根线一次发送01001010　串行：1根线分8次发送01001010

习 题

- 请写出下列两个比特串编码后的结果（所有编码方式）：
  - 010001101111
  - 100011110001

谢 谢！