计算机网络

6. LAN & Wireless Technologies, Network Topology

厦门大学软件学院

黄炜 助理教授

第1课 传输介质	第2课 局域通信	第3课 远程通信	第4课 差错控制	第5-7课 局域网
第8-9课 广域网 技术	第10课 协议分层	第11课 互联网络 协议	第12课 支持协议 技术	第13课 可靠与不 可靠传输
第14课 Internet 路由	第15课 客户端与 服务器	第16课 套接字	第17-19课 应用层协 议	

第5课
分组、交换、网卡、编址、广(多)播

第6课
以太网帧格式、网络拓扑、无线网络

第7课
布线、拓扑、接口硬件

PART II Packet Transmission

Ch 8 LAN Technologies and Network Topology

局域网技术与网络拓扑

拓扑

Topology

8.2 Direct Point-to-Point Communication

- **Point-to-point network or mesh network (网状网络).**
  - **Each communication channel (e.g., a leased data circuit) connected exactly two computers, and was available to those computers exclusively.**
- **Advantages**
  - 独立安装、独占访问
  - 安全稳定
- **Disadvantages**

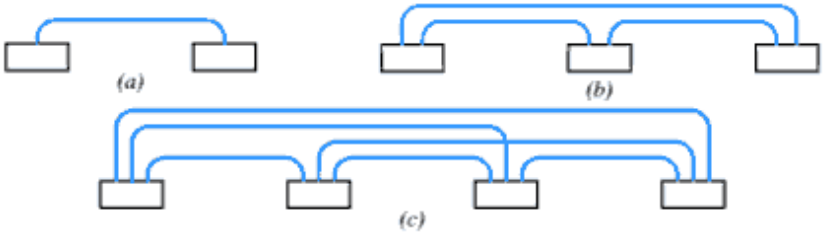


Figure 8.1 The independent point-to-point connections required for (a) two, (b) three, and (c) four computers. The number of connections grows rapidly as the number of computers increases.

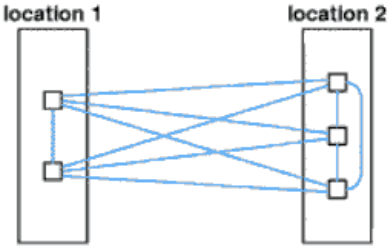


Figure 8.2 The disadvantage of a point-to-point network that requires a dedicated connection for each pair of computers: the total number of connections passing between two locations can exceed the total number of computers being connected.

- **Disadvantage:**
  - **The total number of connections grows more rapidly than the total number of computers.**
  - **The number of connections needed for n computers is proportional to the square of n :**
  - **Direct connections required: $\left(n^2 - n\right)/2$**
  - **The expense is especially high because many connections follow the same physical path.**

8.3 Shared Communication Channels

- Each LAN consists of a single shared medium, usually a cable (电缆), to which many computers attach.
  - Computers take turns using the medium to send packets.
  - Networks that allow computers to share a communication medium are used for local communication (本地通信).
    - Because coordination requires communication and the time required to communication depends on distance.
- Point-to-point connections are used for long-distance networks (远程通信) and a few other special cases.

8.4 Significance of LANs and Locality of Reference

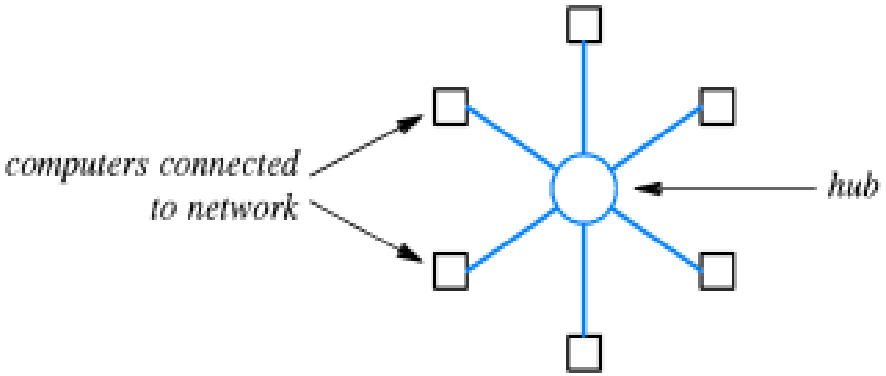
- LAN technologies are both inexpensive (便宜) and widely available (广泛使用).
- The locality of reference principle (参考原则):
  - 找邻居：A computer is more likely to communicate with computers that are physically nearby than with computers that are far away.
  - 找主顾：A computer is more likely to communicate with the same set of computers repeatedly.

8.5 LAN Topologies 局域网拓扑结构

- 为何学习拓扑结构
  - **Because many LAN technologies have been invented, it is important to know how specific technologies are similar and how they differ.**
  - **To help understand similarities, each network is classified into a category according to its topology or general shape.**
- 注意：拓扑图不是风水图，只表示连接性，不表示方位。

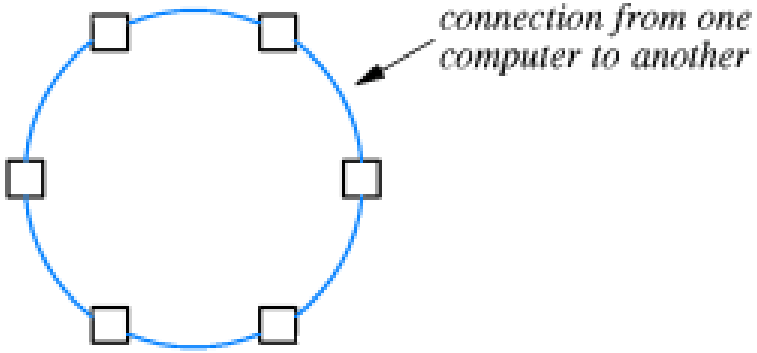
8.5.1 Star Topology

- **A network uses a star topology if all computers attach to a central point.**
- **Star networks seldom have a symmetric shape in which the hub is located an equal distance from all computers.**
- 星型结构
  - 一个中心节点
  - 一组计算机通过中心节点实现信息传输
  - 各节点和中心节点之间通过点到点的链路进行连接



8.5.2 Ring Topology

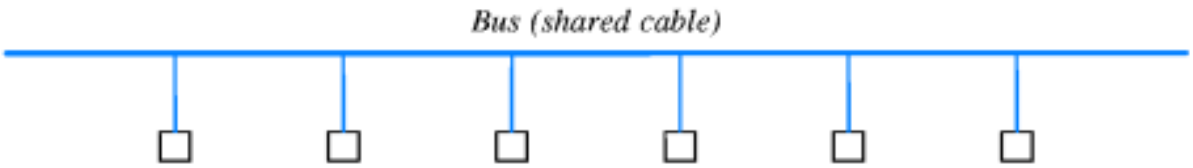
- **A network that uses a ring topology arranges for computers to be connected in a closed loop.**
  - **The computers and connections in a ring network need not be arranged in a circle.**



- 环型结构
  - 各节点通过通信介质连成一个封闭的环形
  - 两个邻接的节点之间通过点到点连接
  - 非邻接节点之间通信要经过路径上的其它节点

8.5.3 Bus Topology

- A network that uses a bus topology usually consists of a single, long cable to which computers attach.
  - Any computer attached to a bus can send a signal down the cable, and all computers receive the signal.
  - The computers attached to a bus network must coordinate to ensure that only one computer sends a signal at any time or chaos results.



- 总线型结构
  - 网络中所有的站点共享一条数据通道
  - 任何节点只需发送一个数据包到总线中，其它节点会接收，从而完成数据通信

8.5.4 The Reason for Multiple Topology

- **Each topology has advantages and disadvantages.**
  - **Star topology**
  - **Ring topology**
  - **Bus topology**
  - **Mesh topology**

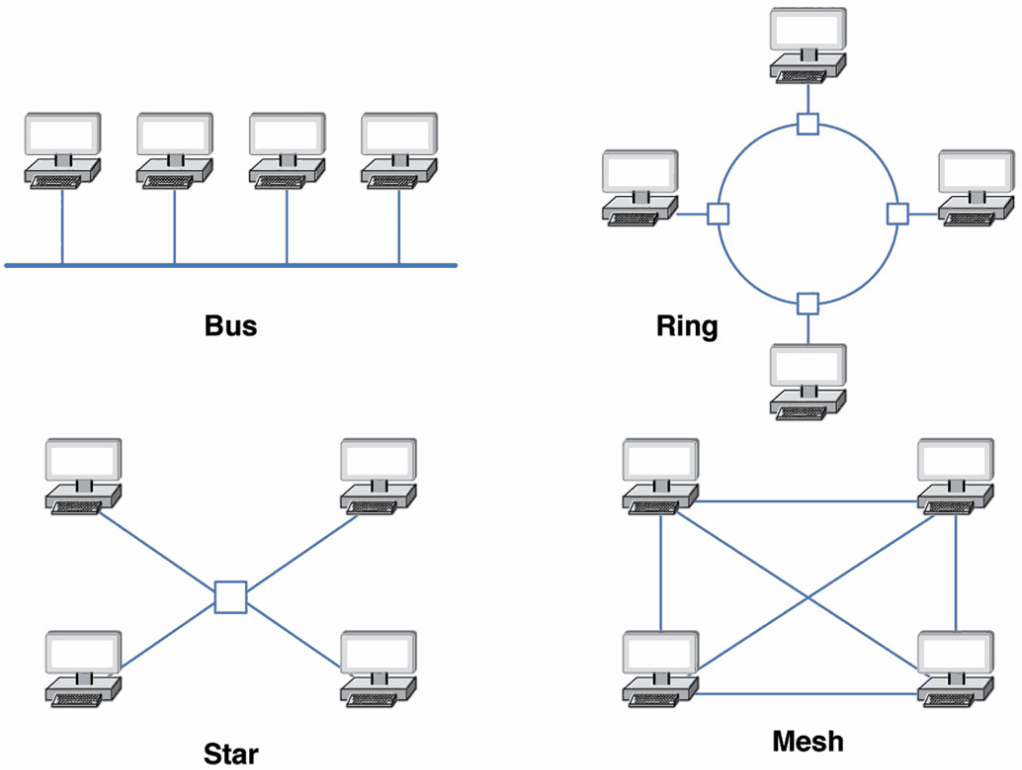


Figure 13.7 Four network topologies used with LANs.

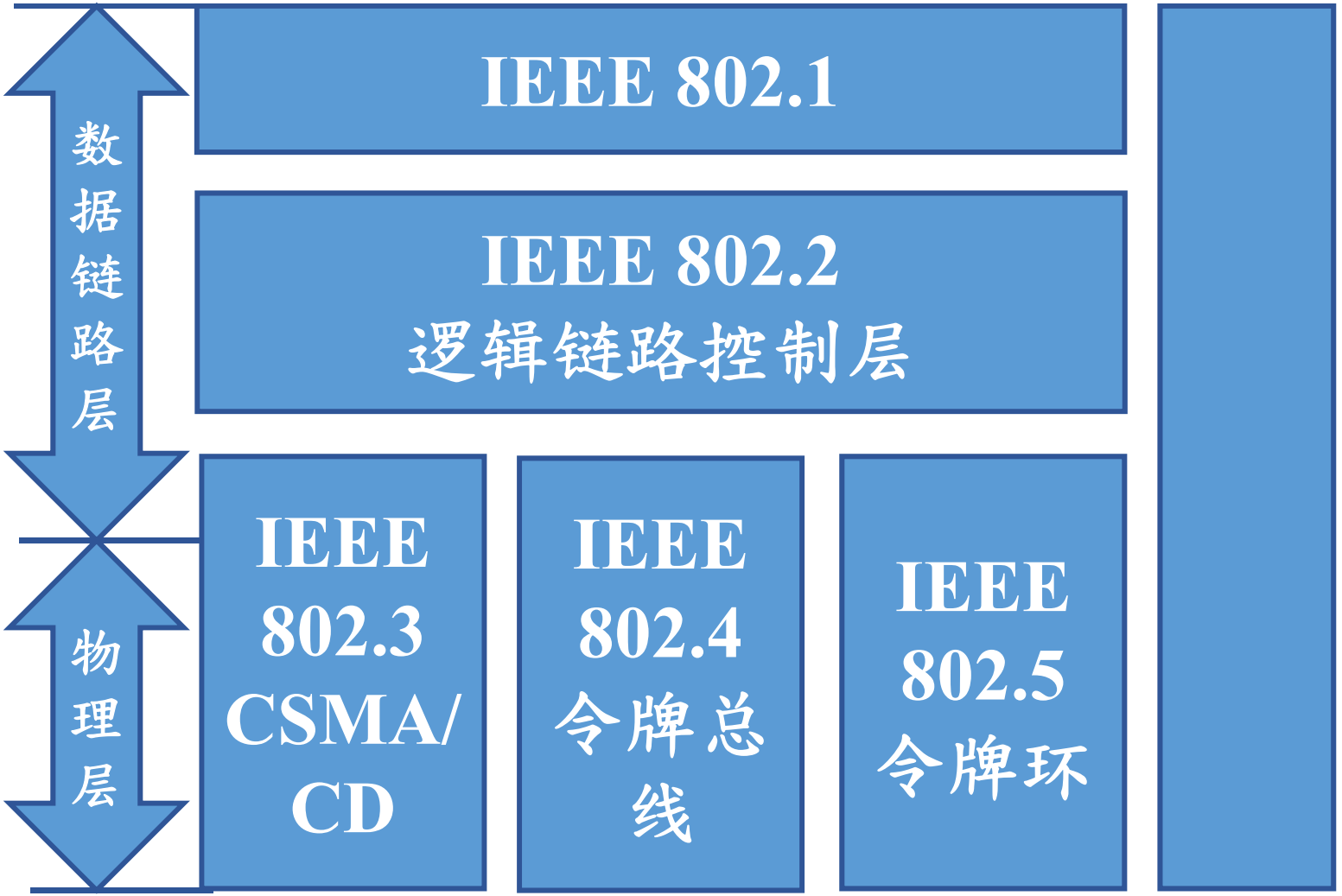
三种拓扑的优缺点

拓扑	优点	缺点
Star	容易在网络中增加新的站点 一个节点断掉不会影响其它节点 数据的安全性和优先级容易控制 易实现网络监控	中心节点的故障会引起整个网络瘫痪
Ring	结构简单，容易安装 容易监控通/断情况 节省资源	容量有限 网络建成后，难以增加新的站点 一个节点产生异常情况，会影响其它节点通信
Bus	安装简单方便 需要铺设的电缆最短，成本低 某个站点的故障一般不会影响整个网络	介质的故障会导致网络瘫痪 线网安全性低 监控比较困难 增加新站点也不如星型网容易

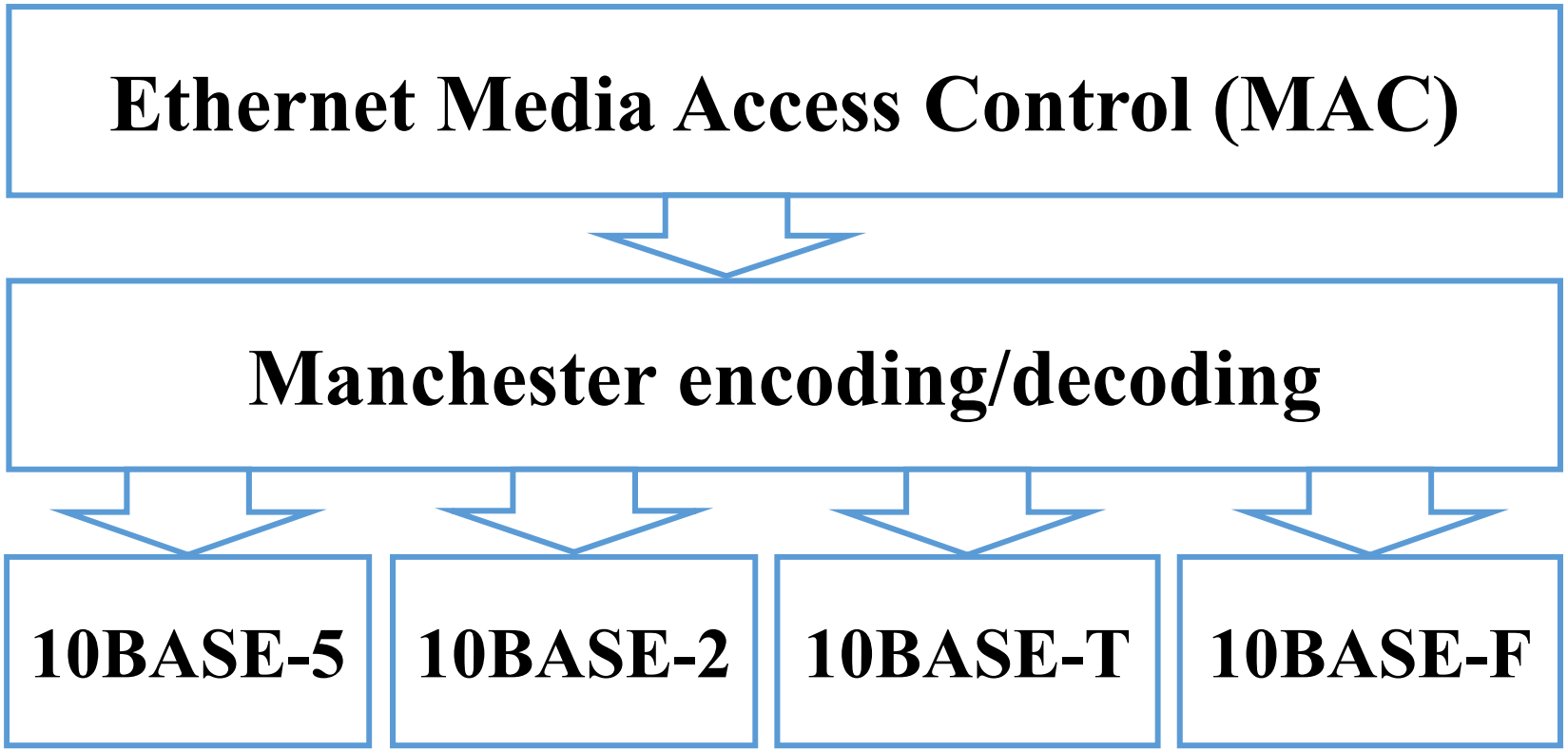
8.6 Example Bus Network: Ethernet

- History of The Ethernet
  - 以太网是由Xerox公司在70年代早期发明的。
  - 以太网的标准: 现在由IEEE制订并维护
- 带宽容量
  - 传统：10M bps；快速：100M bps；千兆：1G bps
- 以太网发展历史
  - IEEE 802.3 标准（1985）
  - IEEE 802.3u Fast Ethernet 标准（1995）
  - IEEE 802.3z Gigabit Ethernet 标准（1998）
  - IEEE 802.3ab Gigabit Ethernet 标准（1999）

IEEE 802.x


数据链路层
物理层
IEEE 802.1
IEEE 802.2
逻辑链路控制层
IEEE 802.3 CSMA/CD
IEEE 802.4 令牌总线
IEEE 802.5 令牌环

IEEE802.3的组成示意图



曼彻斯特编码

Manchester Encoding

不同于RS-232编码

8.6.2 Ethernet Transmission And Manchester Encoding

- Manchester (曼彻斯特) Encoding uses rising and falling edges to encode data.
- The sender transmits a falling edge (下降边缘) to encode a 0 and a rising edge (上升边缘) to encode a 1.
- The hardware is said to be edge triggered (触发), and the change are known as rising or falling edge.

- **The Ethernet standard specifies that frames are sent using the Manchester (曼彻斯特) Encoding.**

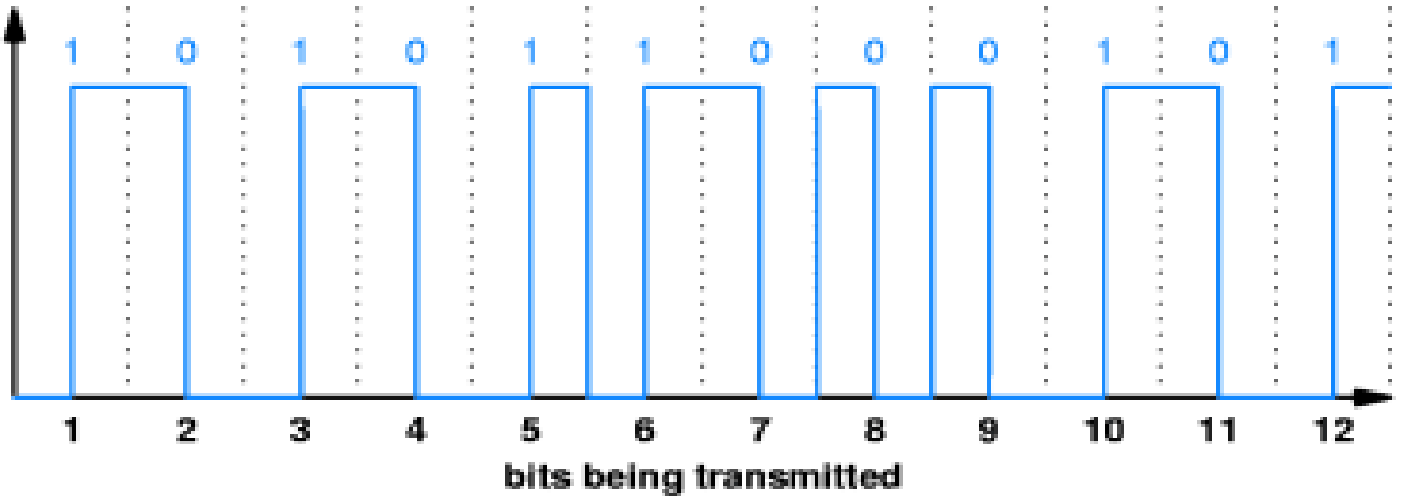


Figure 8.6 Illustration of Manchester Encoding used with Ethernet. A change from positive voltage to zero encodes a 0 bit, and a change from zero to positive voltage encodes a 1 bit.

- **To make sense (检测) of the incoming signal, a receiver must know exactly when each time slot (时间间隙、时隙) begins and ends.**
- **The Manchester Encoding uses a preamble (前同步) to allow such synchronization.**
- **The preamble consists of sixty-four alternating 1's and 0's sent before the frame.**

8.6.3 Sharing on An Ethernet

- A sender transmits a signal, which propagates(传播) from the sender toward both ends of the shared cable.
  - Multiple computers share a single transmission medium.
  - Multiple frames are not being sent at the same time.
  - While one computer transmits a frame to another, all other computers must wait.

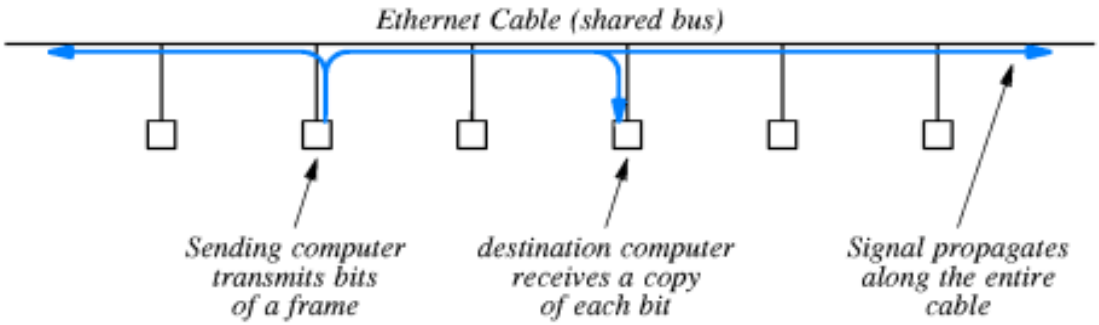


Figure 8.7 Conceptual flow of bits across an Ethernet. While transmitting a frame, a computer has exclusive use of the cable.

8.7 Carrier Sense on Multi-Access Networks (CSMA)

- During frame transmission, a sender transmits electrical signals used to encode bits.
- When no computer is sending a frame, the ether (以太) does not contain electrical signals.
- To determine whether the cable is currently being used, a computer can check for a carrier.

8.7 Carrier Sense on Multi-Access Networks (CSMA)

- Checking for a carrier wave is called carrier sense (载波侦听).
- The idea of using the presence of a signal to determine when to transmit is called carrier sense multiple access (CSMA，载波侦听多路访问)

8.8 Collision Detection and Backoff with CSMA/CD

- When the signals transmitted by two computers reach the same point on the cable, they interfere with each other.
- The interference between two signals is called a collision (冲突).
- Monitoring a cable during transmission is known as collision detect (CD，冲突检测).
- The Ethernet mechanism is known as Carrier Sense Multiple Access with Collision Detect (CSMA/CD)

14.6 Random Access Protocols (CSMA/CD)

- Xerox PARC created a random access protocol (1973)
  - Ethernet: DIX standard was created by Digital Equipment Corporation, Intel, and Xerox (1978)
- It uses cable as a shared medium
  - instead of broadcasting radio frequency transmissions through the atmosphere
- Ethernet uses 3 mechanisms to handle collisions:
  - Carrier sense (载波侦听)
  - Collision detection (碰撞检测)
  - Binary exponential back off (二进制指数退避)

14.6.2 CSMA/CD

- **Carrier sense**
  - **Ethernet requires each station to monitor (监视) the cable (电缆) to detect whether another transmission is already in progress (已经在进行中)**
    - **prevents the most obvious collision problems (最明显的碰撞问题)**
    - **substantially (充分) improves (提高) network utilization (利用率)**
  - 如果双方都检测到空闲、准备传输，怎么办？

14.6.2 CSMA/CD

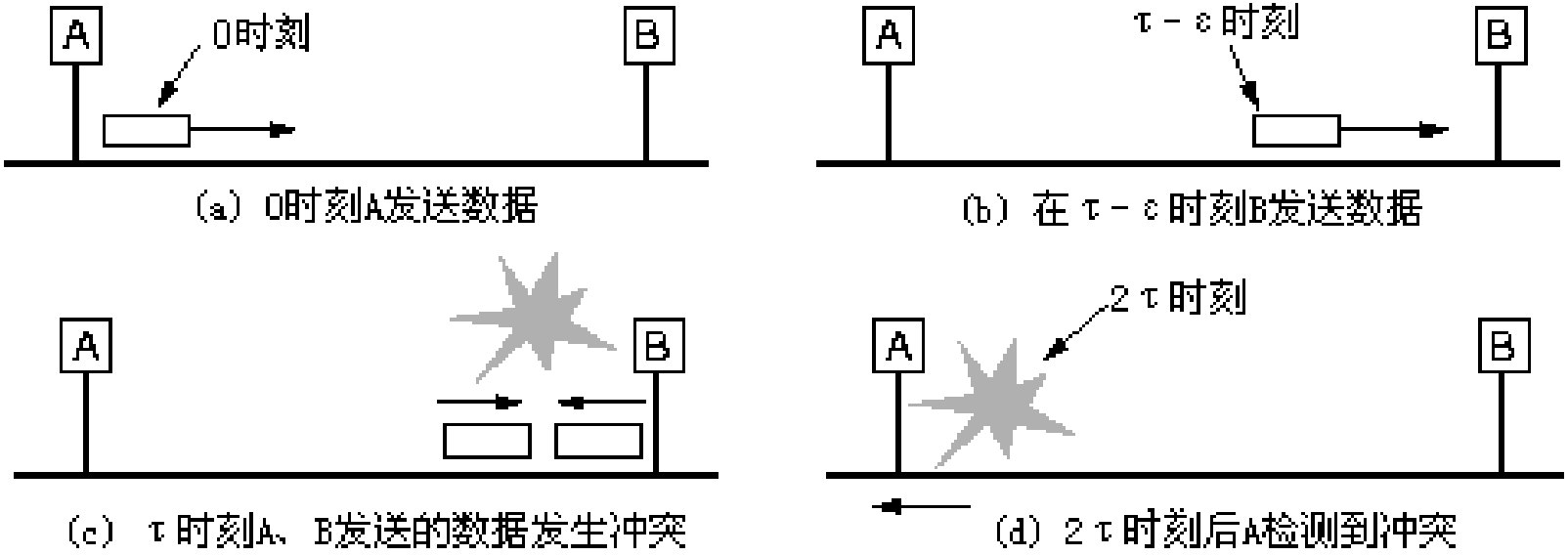
- **Collision detection**
  - 双方都发现信道空闲
  - **each station monitors (监视) the cable during transmission**
    - **If the signal on the cable differs from (不同于) the signal that the station is sending, it means that a collision has occurred (发生)**
    - **when a collision is detected, the sending station aborts (停止) transmission**
  - 以太网技术设计仔细
    - 一旦冲突，不马上停止，保证信号传递到所有站点
    - 传输后必须等待一定的间隙(10Mbps以太网为9.6μs)确保所有站点感觉到信道空闲

14.6.2 CSMA/CD

- **Binary Exponential Back off**
  - 发生冲突后，应等信道空闲再发送
  - 规定最大延迟为d，双方随机选择小于d的时间发送
  - 如果还是碰撞了，则定义新的最大延迟$2d$。
    - 如果还是碰撞了，则定义新的最大延迟$4d$。以此类推。
    - 范围越大，再次冲突的几率越小
  - 意味着以太网能在冲突后迅速恢复，降低竞争性

CSMA/CD

- 在时刻τ处发生冲突，B站将检测到回收的能量大于发出的能量，因此知道发生了冲突，于是放弃发送，并产生一个48比特的噪声帧以警告其他站。大约在2τ时，A看到了噪声帧，知道了冲突，放弃发送。



CSMA/CD

- After a collision occurs, a computer must wait for the cable to become idle again before transmitting a frame.
- To avoid multiple collisions, Ethernet requires each computer to delay after a collision before attempting to retransmit.
- Doubling the range of the random delay after each collision is known as binary exponential backoff (二进制指数后退算法：一般地，第i次冲突后，等待时隙数就从0到$2i-1$中随机选出）

CSMA/CD

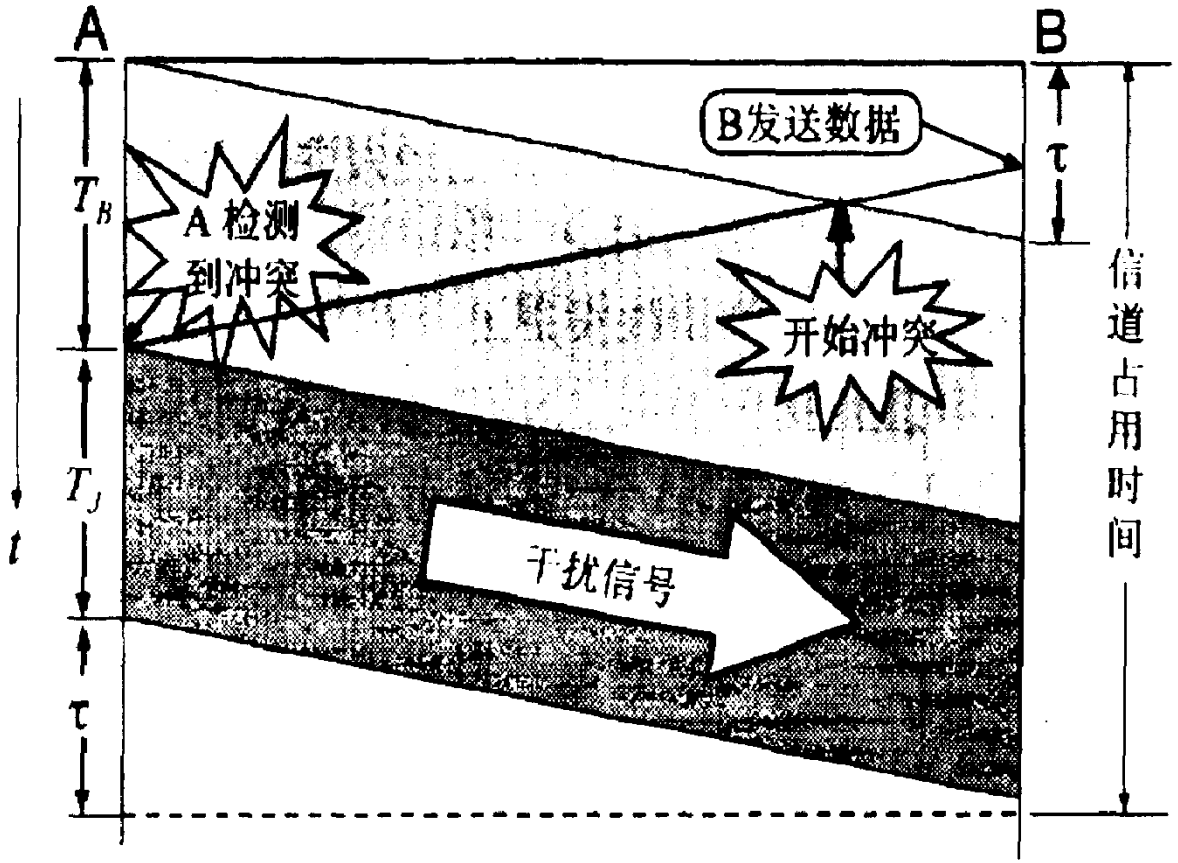


图 5-13　CSMA/CD 产生冲突对信道占用时间的影响

- 总线争用期：$T_B + T_J + \tau$

14.6.2 CSMA/CD

Algorithm 14.4

Purpose:

Use CSMA/CD to send a packet

Method:

```
Wait for a packet to be ready;
Wait for the medium to be idle (carrier sense);
Delay for the interpacket gap;
Set variable x to the standard backoff range, d ;
Attempt to transmit the packet (collision detection);
While (a collision occurred during previous transmission) {
    Choose q to be a random delay between 0 and x ;
    Delay for q microseconds;
    Double x in case needed for the next round;
    Attempt to retransmit the packet (collision detection);
}
```

Algorithm 14.4 Packet transmission using CSMA/CD.

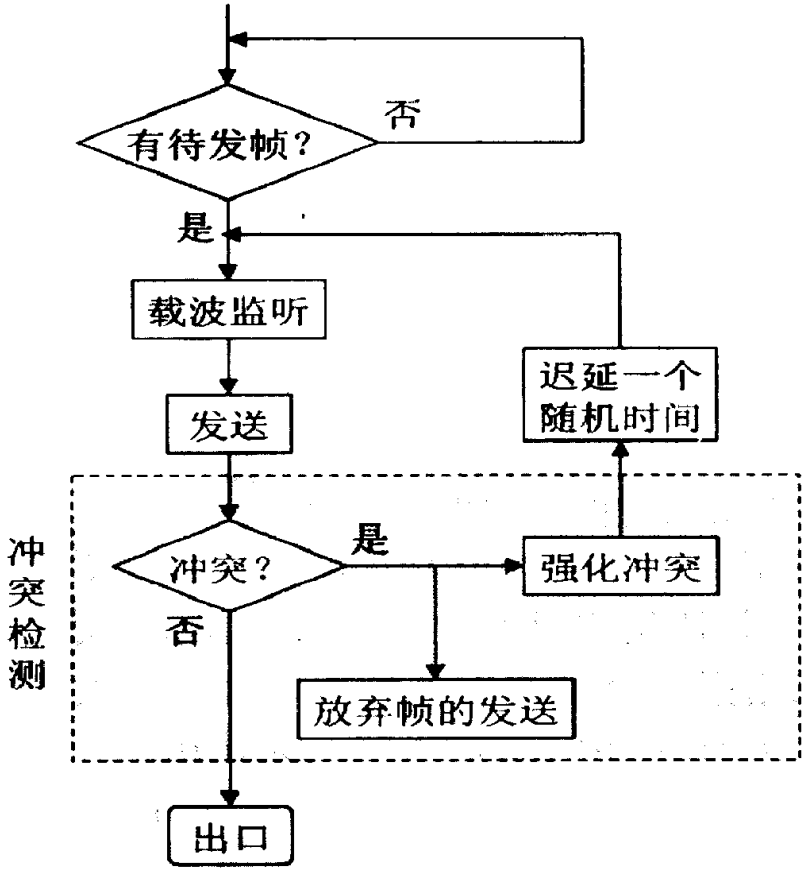


图 5-12 CSMA/CD 的流程图

以太网工作原理特点

- 采用曼彻斯特编码格式
  - 载波形式：直方波
  - 通过载波中心的波形变化表示信号值：电压上升表示“1”，下降表示“0”
- 是分组交换网，每个主机有一个全球唯一的物理地址
- 通过CSMA/CD技术实现局域网总线上的数据监听和冲突检测
- 需要通过网桥或交换机实现对网络的分段，以减少主机增多时冲突发生次数

CSMA/CD特点

- 载波侦听多路访问
  - 站点传送数据时，首先侦听信道是否空闲
  - 空闲则发送，非空闲则等待，重新侦听
  - 侦听等待的时间
    - 始终侦听，直到没有冲突，开始发送
    - 冲突后，等待一个随机时间，再重新开始侦听
    - 如果不冲突，按照一个特定概率p决定当前是否发送
- 冲突检测
  - 多个站点同时侦听到空闲，发送数据时进行冲突检测
  - 检测到冲突，立刻停止，等待一定的时间后，再重新开始CSMA/CD过程

其它网络

LocalTalk, Token Ring, FDDI, ATM

8.10 Another Example Bus Network: LocalTalk

- Apple公司的总线网
- 应用了CSMA/CA技术处理介质访问冲突
- 成本低，安装简单，适合苹果机的局域网
- 带宽受限（230.4kbps），距离受限，不适合其它品牌设备互联
- AppleTalk became unsupported as of the release of Mac OS X v10.6 in 2009

8.11 Example Ring Network: IBM Token Ring

- A LAN using ring topology connects computers in a loop.
- An access mechanism known as token passing (令牌传递).
- The networks using token passing are known as token passing ring networks, or token ring.
- 优点：实时性。
- 在LAN中过时，用于光缆骨干网高可靠性环境。

- When a computer needs to send data , the computer must wait for permission before it can access the network.
- A token ring transmission does not rely on CSMA/CD, the token ring hardware coordinates among all connected computers to ensure that permission is passed to each computer in turn.
- The coordination uses a special ,reserved message called a token (令牌), it is a bit pattern that differs from normal data frame.

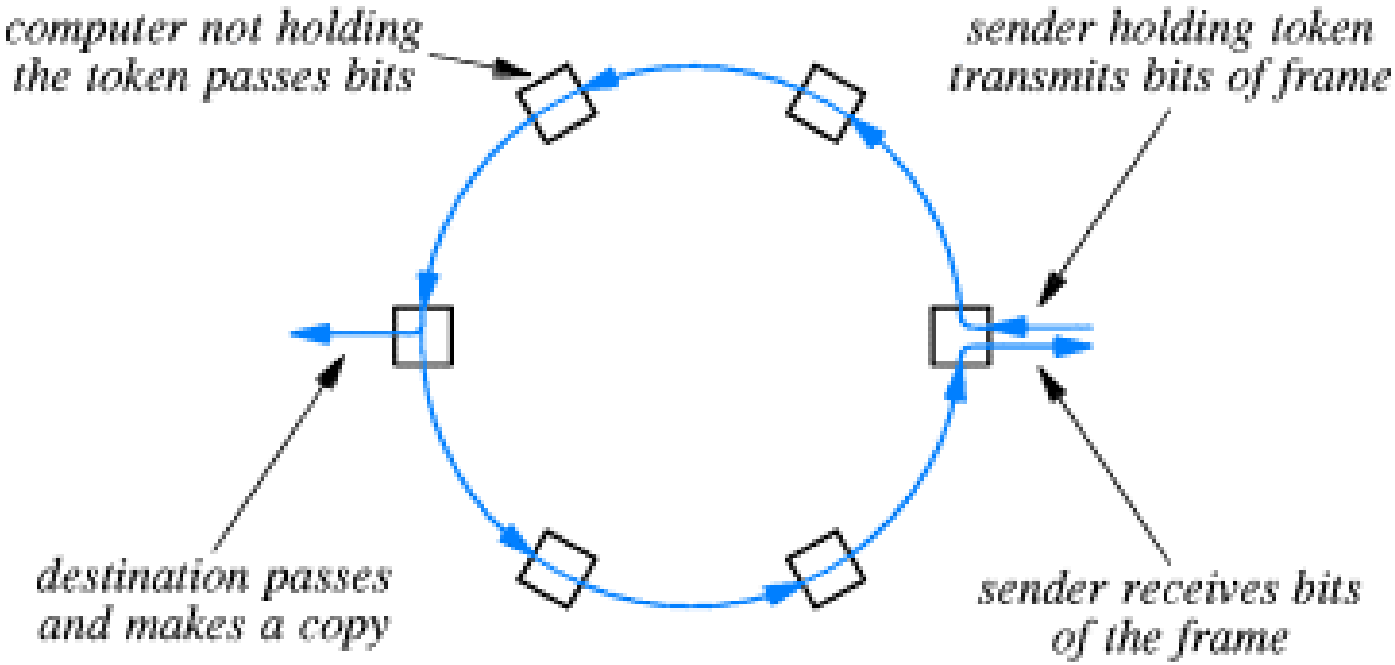


Figure 8.9 The conceptual flow of bits during a transmission on a token ring network. Except for the sender, computers on the network pass bits of the frame to the next station. The destination makes a copy.

IBM 令牌环网特点

- 单向环网，相邻节点是点到点连接
- 环中接口采用三种工作方式之一
  - 拷贝：普通的环中节点
  - 传输：和其它环的邻接节点
  - 恢复：恢复已经丢失的令牌的节点
- 对令牌集中管理，避免了冲突的发生
- 单点出现故障，可造成环网瘫痪

8.12 Another Example Ring Network: FDDI

- **Fiber Distributed Data Interconnect (FDDI光纤分布数据互连) is a token ring technology that can transmit data at a rate of 100 million bits per second.**
- **FDDI uses optical fiber to interconnect computers.**
- **An FDDI network contains two complete rings.**

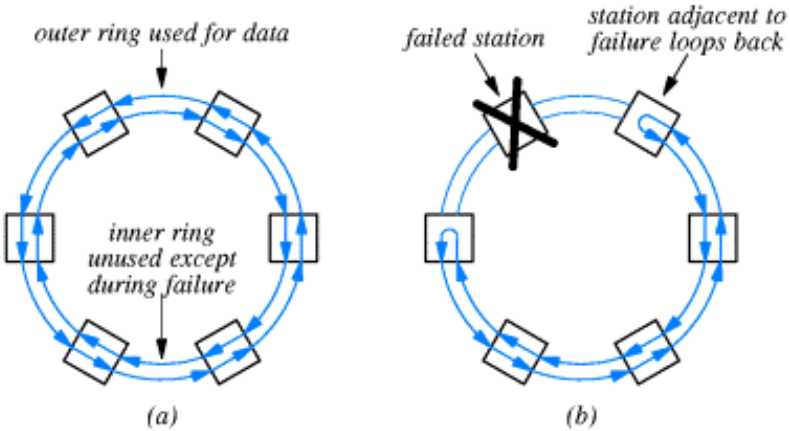


Figure 8.10 (a) An FDDI network with arrows showing the directions that data flows, and (b) the same network after a station has failed. Normally, data travels in one direction. After a station fails, adjacent stations use the reverse path to form a closed ring.

- **An FDDI network is called self-healing (自恢复) because the hardware can detect a catastrophic (灾难的) failure and recover automatically. To do so, FDDI uses a pair of counter rotating rings (反旋转环). One ring is used to transmit data. When a failure occurs that breaks the ring, stations adjacent to the failure automatically reconfigure, using the second ring to bypass (旁路) the failure.**

FDDI特点

- 双向环网，保证了单点故障对网络的影响，具有自愈合能力
- 是一个开放式网络，网桥连接的两个局域网可以基于同一种标准，也可以基于两种不同类型的标准
- 转发速度快，传输速率较高（100Mbps）
- 成本较高，越来越少用。

8.13 Example Star Network: ATM

- ATM (Asynchronous Transfer Mode，异步传输模式)
- The basic element of an ATM network is an electronic switch (电子交换机) to which several computers can connect.
- An ATM network is a star topology.
- An ATM switch operates at a speed of 155Mbps or faster.
- An ATM switch usually uses optical fiber.

ATM特点

- 通过ATM交换机进行互连，典型的星型结构
- 异步传输模式，两条传输线缆
- 数据包分组发送
- 速度快（155Mbps）
- 成本相对较高

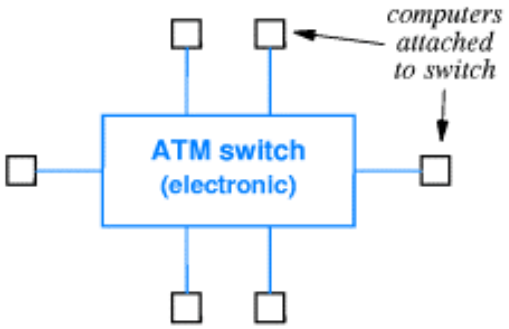


Figure 8.11 An ATM switch with six computers attached, and the star topology that results.

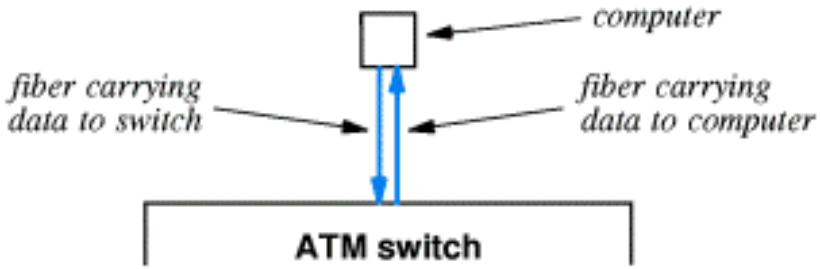


Figure 8.12 Details of a connection between an ATM switch and a computer. Each connection consists of a pair of optical fibers. One fiber carries data to the switch, and the other carries data to the computer.

Ch 16 Wireless Networking Technologies

无线联网技术

无线网络分类

- 无线网络
  - 旧时王谢堂前燕，飞入寻常百姓家

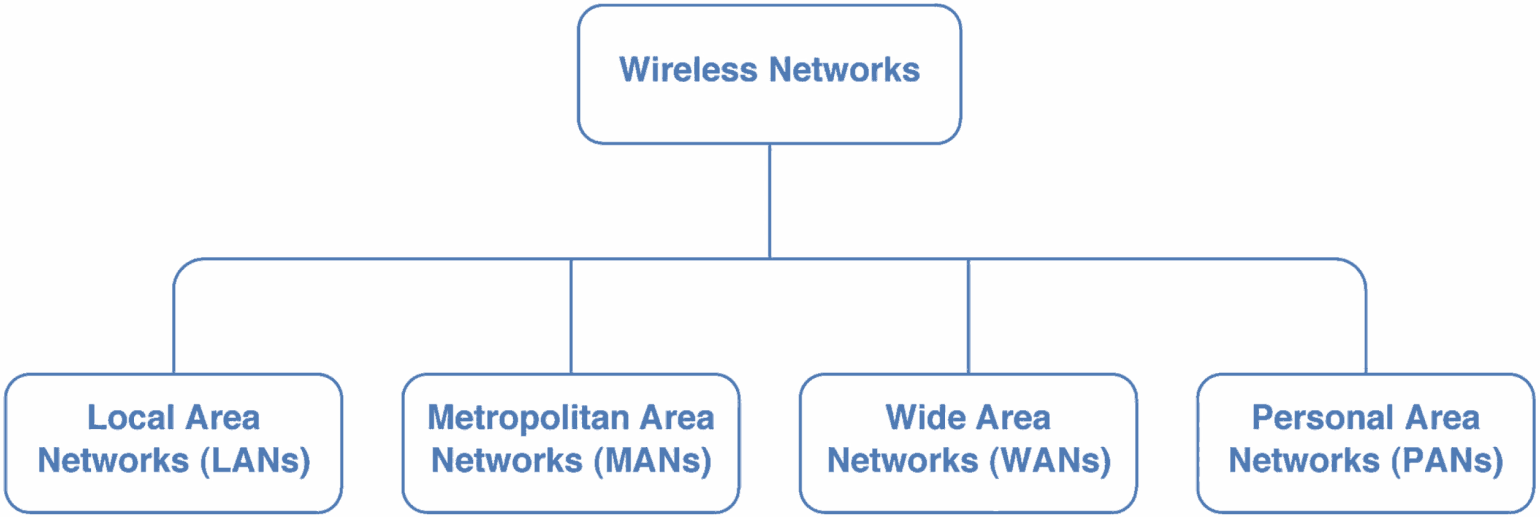


Figure 16.1 A taxonomy of wireless networking technologies.

无线LAN与Wi-Fi：802.11abgn

- Wi Fi：Wireless Fidelity（无线保真度）？？
  - 802.11 bg：室内50平方米，室外140平方米。802.11n两倍。

IEEE Standard	Frequency Band	Data Rate	Modulation Technique	Multiplexing Technique
original 802.11	2.4 GHz	1 or 2 Mbps	FSK	DSSS
	2.4 GHz	1 or 2 Mbps	FSK	FHSS
	InfraRed	1 or 2 Mbps	PPM	±none±
802.11a	5.725 GHz	6 to 54 Mbps	PSK or QAM	OFDM
802.11b	2.4 GHz	5.5 and 11 Mbps	PSK	DSSS
802.11g	2.4 GHz	22 and 54 Mbps	various	OFDM

Figure 16.4 Key wireless standards certified by the Wi-Fi Alliance.

无线LAN组成

- 无线网的3个构件
  - 接入点（基站）
  - 互联机构（如：交换机、路由器）
  - 无线主机（无线节点或无线站点）
- 两种接入类型
  - 点对点模式（Ad hoc）
  - 基础结构型（infrastructure）

802.11帧格式与协调

- 有线和无线的区别：盲区、重叠区域

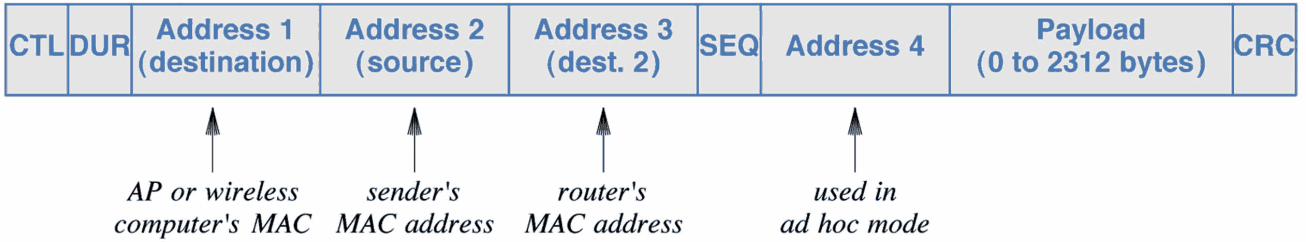


Figure 16.9 The frame format used with an 802.11 wireless LAN.

- 接入点之间需要协调，以保证无缝移动。
  - 接入点负责
  - 无线计算机负责（成本低）

无线网络技术

- PAN技术
  - 蓝牙（1Mbps，2.4GHz）
- WAN
  - 蜂窝系统、基站集群
- 更新换代
  - 1G：模拟信号语音
  - 2G：数字信号语音、2.5G：部分3G业务
  - 3G、3.5G：高速数据服务
  - 4G：实时多媒体业务的支持、含WiFi和卫星

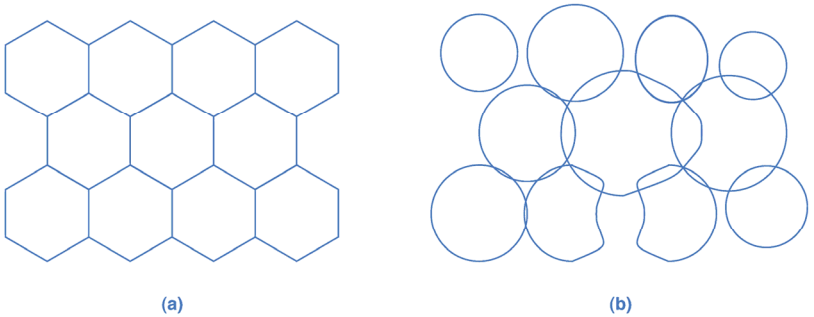


Figure 16.15 Illustration of (a) an idealized cellular coverage, and (b) a realistic version with overlaps and gaps.

无线网络技术

- 卫星通信
- **GPS卫星(Global Positioning System，全球定位系统)**
  - 精确度：2~20m（军用更高）
  - 24颗卫星绕行地球轨道
  - 6个轨道平面
  - 网络时间同步
  - 美军的产品、中国北斗
  - 国内地图定位不准确？

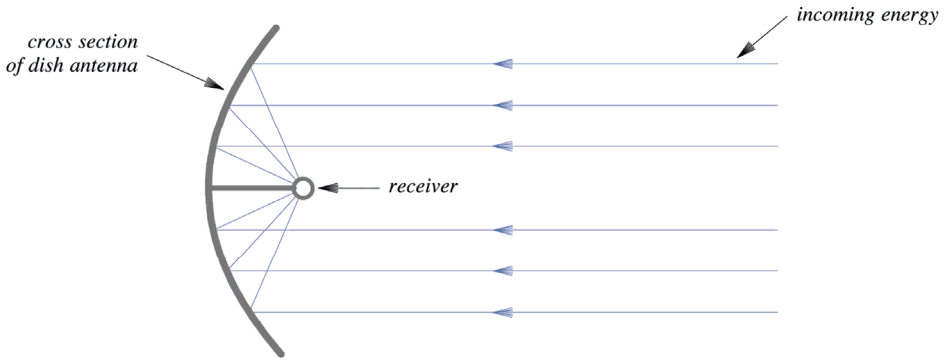


Figure 16.20 Illustration of reflection by a parabolic dish antenna.

8.9 802.11 Wireless LANs And CSMA/CA

- IEEE standard 802.11 defines wireless LANs that operate at 11Mbps using a frequency in the 2.4 GHz range.
- A standard known as bluetooth specifies a wireless LAN technology designed for short distances.
- Wireless LAN hardware uses antennas to broadcast RF signals through the air, which other computers receive.

14.6.3 CSMA/CA

- **CSMA/CD does not work as well in wireless LANs**
  - **a transmitter used in a wireless LAN has a limited range**
- **A receiver more than δ away from the transmitter**
  - **won't receive a signal, and won't be able to detect a carrier**

Figure 14.6 Three computers with wireless LAN hardware at maximal distance.

14.6.3 CSMA/CA

- In Figure 14.6, computer1 can communicate with c2, but cannot receive the signal from c3
  - Thus, if c3 is transmitting a packet to c2, c1's carrier sense mechanism will not detect the transmission
  - Similarly, if c1 and c3 simultaneously transmit, only c2 will detect a collision
  - The problem is sometimes called the hidden station problem
    - because some stations are not visible to others
- Wireless LANs use a modified access protocol
  - known as CSMA with Collision Avoidance (CSMA/CA)
  - The CSMA/CA triggers a brief transmission from the intended receiver before transmitting a packet

14.6.3 CSMA/CA

- **The idea is that if both the sender and receiver transmit a message**
  - **all computers within range of either will know a packet transmission is beginning**

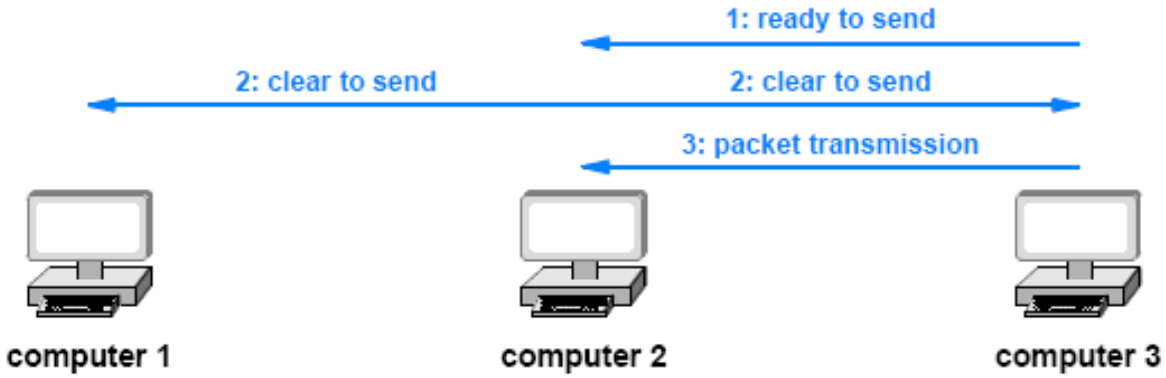


Figure 14.7 A sequence of messages sent when computer 3 transmits a packet to computer 2.

14.6.3 CSMA/CA

- In Figure 14.7
  - c3 sends a short message to announce that it is ready to transmit a packet to c2
  - and c2 responds by sending a short message announcing that it is ready to receive the packet
  - all comp's in range of c3 receive the initial announcement
  - all comp's in the range of computer2 receive the response
  - as a result, even though it can't receive the signal or sense a carrier, c1 knows that a packet transmission is taking place

14.6.3 CSMA/CA

- Collisions of control messages can occur when using CSMA/CA, but they can be handled easily
- For example, if c1 and c3 each attempt to transmit a packet to c2 at exactly the same time
  - their control messages will collide
  - When a collision occurs, the sending stations apply random backoff before resending the control messages.
- Because control messages are much shorter than a packet, the probability of a second collision is low.

CSMA/CA

- **Wireless LANs use a modified scheme known as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA，载波侦听多路访问/冲突避免)**
- **The CSMA/CA triggers a brief transmission from the intended receiver before transmitting a packet.**
- **Collisions of control messages can occur.**
- **The sending stations apply random backoff before resending the control messages.**

无线局域网技术特点

- 基本技术特点
  - 通过一台PC机器加上一块无线网络接口卡构成将多个无线的接入站聚合到有线的网络上
  - 采用了新的协议CSMA/CA进行冲突避免
    - 只有当客户端收到网络上返回的ACK信号后才确认送出的数据已经正确到达目的
  - 两个节点通过中间节点进行数据通信，要由中间节点通过控制命令进行统一调度控制，增加了额外的网络负担

6. THANK YOU.

厦门大学软件学院

黄炜 助理教授