Computer Networks

Chapter 4: The Medium Access Control Sublayer

(Version March 29, 2023)

Xiao Mingzhong

CIST, Beijing Normal University

Outline

- 共享介质访问控制协议
  - ALOHA、CSMA、无冲突的协议、有限竞争协议、波分多路访问协议、无线LAN协议
- 网络实例
  - 以太网、无线LAN、宽带无线*、蓝牙*和RFID*
- 数据链路层交换
  - 网桥和交换机
  - VLAN

媒体访问控制子层(1/3)

- So far: We have discussed the Data Link Layer's functionality and some protocols related to point-to-point communication.
- A large class of networks is built on top of broadcast channels: a number of stations that share same "wire." if one station sends, all the others get to hear it.
- What's the problem: if you're sharing a channel, then two stations may decide to start frame transmission at the same time → frame collision, which means rubbish on the wire.
- Solution: allocate the channel to one of the competing stations.
- Problem: you'll have to use that same channel to figure out the competition and the allocation.

媒体访问控制子层(2/3)

- Static Channel Allocation
  - FDM and TDM
  - 信道利用率不高，大多数时候大多信道是空闲的
    - 占有信道不使用 vs 想收发数据但却没有信道可用
    - 原因：流量的突发性
  - In principle, CDMA could be used but there are a number constraints which makes it difficult to apply in the general case
    - e.g., senders and receivers must know the chip sequence beforehand
    - Requires high synchronization

媒体访问控制子层(3/3)

- Three strategies for channel dynamic allocation:
  - no control at all: simply let a station try to use the channel, and do something when a collision happens. Applied in contention systems.
  - Employ a round-robin technique: each station in turn is allowed to use the channel. Applied in token-based systems – the station that has the token may use the channel.
  - Let a station place a reservation for the channel. Used in slotted systems. The problem is how to make a reservation.

Contention systems: ALOHA(1/2)

- Principle: 如果想发就发好了。If a collision occurs, finish your current transmission and retry later (clearly a random waiting time is needed otherwise we would have periodic collisions).
- Note: it's pretty hard to do any worse than this, but efficiency is not really that bad:
  - 假定G是平均要提交传输的新旧帧数during a frame time (time needed to transmit a full frame). 有K帧要传输Poisson distributed.

$$\mathcal{P}[k \text{ frames submitted}] = \frac{G^k \cdot e^{-G}}{k!}$$

  - 假定P_0是帧不会遭受冲突的概率，即成功传送的概率，那么：(average throughput) $S=G*P_0$.
  - 当一个帧正发送时，它不应该跟前面的帧冲突，后面的帧也不应该跟它冲突。前面的帧要求T_{frame}时间, and this frame as well

Contention systems: ALOHA(2/2)

  - Probability that a test frame will not be damaged is

$$P_0 = e^{-2G}$$ 在2倍T_{frame}时间内,帧平均数是2G

$$S = G \cdot e^{-2G}$$ 纯ALOHA协议吞吐率

- We can improve a bit by removing some randomness. In Slotted ALOHA 帧传输仅发生在固定的时刻点上。两个相邻时刻点时间差等于一个帧时。

CSMA Protocols

- Carrier Sense Multiple Access Protocols do better than ALOHA: you monitor the channel before transmission.
  - *1-persistent:* listen whether the channel is free before transmitting. 当信道忙的时候，持续监听直到空闲便开始发送。
  - *Nopersistent:* Less greedy – 当信道忙的时候，等待随机时间再来尝试. If you wait to long, the channel utilization drops.
  - *P-Persistent:* 用于分(时)槽系统. 若发现当前时槽信道空闲，以概率p使用之。p=1 is not really good, p=0 makes you really polite.

Protocol Comparison

- Question: Should the conclusion be that p-persistent protocols are really good with p=0?

CSMA/Collision Detection (1/2)

- Improvement: sense the channel, but immediately stop transmission when you detect a collision.
  - Listen to see whether the channel is free. Transmission is delayed until the channel is no longer used.
  - During transmission, keep listening in order to detect a collision. If a collision occurs, transmission immediately stops.
  - If a collision occurred, wait a random period of time, and proceed with the first step again.

CSMA/Collision Detection(2/2)

- Problem: 发出帧的第1位多久才知道有没有冲突？
  - $2T_{prop}$-ε，若$2T_{prop}$没有检测到冲突则抢占成功(frame已开始传送)
  - 从而在CSMA/CD系统中竞争期
    - 可按相距最远两站的$2T_{prop}$建模成分槽系统

Collision Free Protocols(1/2)

- 前述若电缆很长，而帧的长度又很短的话，how to do？
  - 填充（要求最小帧长度），否则还以为已经成功传送帧了。
  - 无冲突协议, and so on.
- Bit-map: let the contention period contains N slots. If station k wants to transmit a frame, it transmits a '1' during the kth slot. (reservation protocol)

  - 低负载（1站传送）信道利用率:d/(N+d)
  - 高负载（都有传送）信道利用率:d/(d+1),帧平均传输等待时间(N-1)d+N
  - 扩展性问题

Collision Free Protocols(2/2)

- Binary Countdown: (二进制倒计数)in the contention period a total of $\log_2 N$ bits can be transmitted. Each station transmits its number (bit by bit), and stops as soon as it detects a higher-numbered contender:

信道利用率：d/（d+$\log_2$N），
可以做到100%
//发送方的地址正好是帧的第一个域
//d数据长度,N节点数

Limited-contention protocols(1/3)

- Principle
  - Contention systems are good when there's not much going on – a station can immediately transmit a frame. We do some repairing when things go wrong.
  - Collision-free systems are good when there's generally a lot of traffic – a station first has to get the channel explicitly before frame transmission. We do a lot of work avoiding collisions.

What we really want is the contention strategy during light loads, and collision-free strategy during rush hours.

Limited-Contention Protocols(2/3)

- A solution: Dynamically regulate the number of competing stations during a contention period. If there's a collision during the kth slot, divide the contenders into two groups.
  - The first group gets to try it again during the next slot (k+1). If no collisions occur then, the second group gets a try during the slot after that (k+2). Otherwise, the first group is split up again.
- Note: if there's not much traffic, the first station will be immediately allowed to transmit a frame. With a lot of traffic, the strategy reduces to the bit-map protocol.

Limited-Contention Protocols(3/3)

- 自适应树搜索协议
  - 某个竞争时槽，发生冲突，则缩小下一个时槽参与竞争的站点数目；
  - 不发生冲突，那么下一个时槽应该让另一半节点来竞争；
  - 当负载较重，显然不应该从树根节点开始尝试
    - 负载越重，越应该从树的下面节点开始搜索
    - 假设估计会有均匀分布的q个站要发送帧，则搜索起始级数i=$\log_2$q可以保证每个时槽中，参与竞争的站的平均数为1。证明见P222。

The tree for eight stations.

Wavelength Division Multiple Access Protocols(1/3)

- 从任何一个站输出的光都会被其他的站检测到

A passive star connection in a fiber optics network.

Wavelength Division Multiple Access Protocols(2/3)

- Principle: 划分出若干子信道，然后动态分配。
  - 每个站有two channels: 控制信道处理incoming requests, 另一个用于实际的(向外)数据传输data transfer.
  - 每个信道repeatedly carries a fixed series of slots. 数据信道里的status slot给出其控制信道的free slots状况

Wavelength division Multiple Access Protocols(3/3)

- In order to contact a station A, you first read its status slot from the data channel to see which control slot is unused. You then put a transmission request in a free control slot.
- If the transmission request is accepted, you can send data on your own data channel that will be picked up by A. you put the data in a specific slot, and tell A which slot that is.

- Note: there's still a lot of competition. If two senders say that there's data in slot #4 for station A, one of the slots will not be read – A can only read from one channel at a time.

Wireless Networks

- Problem: 隐藏站点和暴露站点问题

- Issue (a): How can C be prevented from trying to transmit sth to B? in that case it will ruin any receipt by B (hidden station problem)
- Issue (b): How can we tell C that it is allowed to transmit to D, because this will not interfere with the communication from B to A? (exposed station problem)

- Solution: before starting a transmission, a station (the sender) knows whether there is activity around the receiver ! //看接收方是否可以接收
  - How to know? 询问。

Multiple Access with Collision Avoidance

- A first sends a Request to Send (RTS) //内含数据帧长度
- B answers with a Clear to Send (CTS) //内含数据帧长度
- C hears only RTS and can freely transmit, knowing it should not interfere with A's reception (CTS).
- D hears only the CTS and keeps still for otherwise it would interfere with B's reception (frame).
- E ?

Ethernet

- Physical Layer
  - Ethernet Cabling
  - Manchester Encoding
- Data Link Layer
  - The Ethernet MAC Sublayer Protocol---CSMA/CD
    - The Binary Exponential Backoff Algorithm
  - IEEE 802.2: Logical Link Control Sublayer
- Ethernet Performance
- Other Ethernets
  - Switched Ethernet
  - Fast Ethernet
  - Gigabit Ethernet

Ethernet Cabling (1/3)

- Ethernet stands for a near implementation of the IEEE 802.3 protocol. It is CSMA/CD based (sense the channel, wait until idle, and backoff when you detect a collision) //1-持续的CSMA
- The most common kinds of Ethernet cabling

Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

- Note:10Base-T is popular as it can make use of telephone lines, and is easy to maintain when it comes to cable breaks (cables go to hubs). Detecting cable: time domain reflectometry

Ethernet Cabling (2/3)

- Three kinds of Ethernet cabling

<50m,5对双绞线,8机器>

- a)收发器含载波和冲突检测的电路，控制器负责收、发及管理数据帧
- b)收发器电路位于控制器卡上，每个站有自己独立的收发器
- c)检测维护容易，最大线缆长度100m，5UTP→200m
- d)10Base-F,光纤连接方式昂贵，抗噪声能力强，安全性高

Ethernet Cabling (3/3)

- 电缆拓扑结构（布线方案）

- 在每一种版本的以太网中，每段电缆的长度都有最大值限制
- 中继器是物理层设备，在两个方向上接收、放大和重传信号
- 多根电缆段、中继器扩展LAN，但任两个收发器之间不能超过2.5km，任两个收发器之间的路径上不得跨越多于4个中继器

Manchester Encoding（1/2）

- Problem: we can't just send straight binary codes across the wire(物理层例子：0伪代表0，5伪代表1), because stations can't distinguish a 0 from an idle line.
  - +-1伪方案：
    - 信号发送和接收频率一致难
    - 收发双方时钟速度同步困难
  - 理想方案：
    - 接收方在没有外部时钟参考的情况下，可以毫无歧义地确定每一位的起始、结束或者中间位置
    - 曼切斯特编码和差分曼切斯特编码
  - 以太网：三信号方案（+-0.85v，0v）+曼切斯特编码

Manchester Encoding（2/2）

- Solution: use an encoding scheme in which a voltage transition occurs during every bit time (Manchester Encoding):

- 每一个位中间的电压变化，使得接收方容易与发送方实现同步
- 信号改变频率20M，方可达到10Mbps的传输速率，“改变2次为1位”

802.3 Frame Layout

- Preamble: seven times 10101010 is used to synchronize the receiver's clock with that of the sender. //10Mbps，持续5.6us的方波
- Start of Frame: 10101011,标志帧的开始
- Address: generally 48-bit fields. Leftmost bit indicates ordinary or group addresses. Second bit indicates global or local address.
- Length: ranges from 0~1500. Frames should always be at least 64 bytes. Can also indicate type(>1500): what to do with this frame? 即将此帧交给哪个进程。因接收方能同时有多个网络层协议在使用。
- Pad: you got it…
- Checksum: Calculated over the data field. CRC-based.

一些数字限制

- 为何1500？
  - 1978年制定标准出于对RAM价格的考虑 //收发器用来缓存帧。
- 为何46？

所以，所有的帧至少需要2t时间发送

  - 2.5km/（2/3*C）*2+8个中继器处理时延=51.2us
  - 51.2us是10Mbps以太网发送64字节的时间
  - 其次，区分有效帧和垃圾数据的需要（检测到冲突，会停止后续发送）
  - 网速越高，最小帧长及电缆长度需要相应调整

二进制指数回退算法

- 冲突发生，如何确定随机等待的时间？
  - 时槽长度51.2us
  - 随机等待时槽数：0~2^i-1个，i表示第几次冲突。
  - 最大值1023(i=10)
  - 连续16次冲突，放弃。
- 关于确认问题(研究路子...)
  - 确认帧是可靠通信需要
  - 看作是普通帧即可，也要竞争信道
    - 如何加速回帧确认？
      - 接收方无条件使用成功传输后的第一个竞争时槽
      - …

802.2：逻辑链路控制协议

- 可以运行在以太网和其他的802协议之上，向网络层提供统一接口。

- LLC三种服务类型：不可靠的数据包服务，有确认的数据包服务，面向连接的可靠服务
  - 以HDLC协议为基础

以太网的性能分析

- 恒定负载情况
  - 假设总是有k个站点准备发送，每个站点在一个竞争时槽的发送概率为p，则某站获得信道概率A=kp(1-p)$^{k-1}$
    - p=1/k,A取最大值；k→无穷，A→1/e。
  - 竞争间隔(/时间)刚好等于j个时槽的概率A(1-A)$^{j-1}$，每次竞争的平均时槽数（数学期望）：1/A。
    - 由于每个时槽是2t，故平均竞争间隔(/时间)2t/A，最大值2te。
  - 若传送一帧平均时间S，则信道利用率=S/(S+2t/A)
  - 电缆越长,竞争时间（2t/A）越长.所以，规定<2.5km，4个中继器>将2t限制在51.2us
- 重负载情况
  - See book for detail.
  - 解释流量自相似特征 //p237

Switched 802.3 LANs（交换式以太网）

- Problem: 随着站点数的增加，流量将上升，冲突的可能性加大→the network will saturate.
- Solution: 将网络分化成隔离的sub-LANs and connect them through a switch:

  - 思想：冲突域分划开来，并行通信可能
- Note: 交换机将维护一个表格，用于 to see how it should forward incoming frames from one port to another (HOW?)

Fast Ethernet(802.3u)快速以太网 （1/2）

- Problem: Ethernet太慢了，而new alternatives (optics) were just too expensive (主要用于骨干网，but not for basic LAN segments)
- Solution: 升级Ethernets，保持接口不变，but the capacity goes up → 100Mbps Ethernet
  - Data formats, interfaces, and protocols are all the same.
  - That means that we can only drop the bit time from 100 nsec to 10 nsec.
    - Just telling everyone to shorten their wires won't really do.//技术可行，但因10Base-T连线方式的优势。
    - The solution is still to use only hubs (10Base-T) and combine it with switching technology. (10Base-T can make use of telephone lines, and is easy to maintain when it comes to cable breaks.)
    - How to do？

Fast Ethernet(802.3u)快速以太网 （2/2）

Name	Cable	Max. segment	Advantages
100Base-T4	3 Twisted pair	2 100 m	1 Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

- 100Base-T4
  - 8B/6T编码，非曼切斯特编码(3类线不能承载200MHz的信号频率)
  - 信号速度25MHz（标准以太网20MHz），4对双绞线；
  - 3对线同一方向传输，3态信号，27种可能，所以每次(/个)信号可传输4位（2^4<27），4*25=100Mbps。同时反向信道33.3Mbps。
- 100Base-Tx
  - 5类双绞线，信号速度125MHz，2对双绞线；
  - 4B/5B编码：5个时钟周期为一组，32种组合，其中16个被用来代表4位组(5个时钟周期传4位)，其余可用于控制，如帧边界标示。
  - 双向均100Mbps。 //125*4/5=100

Gigabit Ethernet (802.3z)千兆以太网 (1/2)

- Because Fast Ethernet may not always be fast enough, we simply move the decimal point one position and get Gigabit Ethernet: transfer Ethernet frames at 1000Mbps.

Name	Cable	Max. range
1000BASE-SX	Fiber	550 m
1000BASE-LX	Fiber	5000 m
1000BASE-CX	Copper	25 m
1000BASE-T	Twisted pair	100 m

- Note: 千兆以太网仅工作于point-to-point mode，支持全双工或半双工传输. Full duplex 要求 a switch (cache); half duplex 可以是 hubs (no cache).
- 10 Gbit: another step further: pint-to-point over fiber, with copper specs being developed.

Gigabit Ethernet千兆以太网 (2/2)

- Note: 有了交换机，CSMA/CD就没有存在的必要了！最大电缆长度也改由 signal strength决定了.
- Note: 使用hub的话，the maximal cable length is restricted to 25m (2500m,10 Mbps→25m,1000Mbps). 想电缆更长的话，技巧有:
  - Carrier extension(负荷扩充): let the hardware extend a frame to 512 bytes.
  - Frame bursting(串帧): let the hardware put several frames into 512-byte frame.

Wireless LANs

- Observation: Wireless LANs need to apply special techniques to achieve high bandwidth. In brief:
  - Infrared: Applicable for 1-2 Mbps. Not very popular, also because sunlight degrades performance.
  - Frequency hopping: Use 79 channels, each 1 MHz wide in an unregistered band (i.e., free to be used by anyone). In effect frames are sent at different frequencies each time. Low bandwidth, but good resistance against security attacks and interference from another devices.
  - High rate direct sequencing: Akin to CDMA – use 11 million chip sequences to get to 11 Mbps (802.11b).

802.11: Channel Allocation

- Problem: How to we solve the hidden/exposed station problem: one way or the other, stations should not be allowed to continuously interfere with each other's transmissions.

  - Distributed coordination: let the stations figure it out by using a collision avoidance protocol (CSMA/CA)
  - Point coordination: there's central base station that controls who goes first.

CSMA/CA

- Ethernet-like: Sense the channel and send only if it's free. Don't sense the channel during transmission: if a collision occurred, wait a random time and try again later.
- MACAW: Multiple Access w/Collision Avoidance Wireless:
  - Send RTS/CTS packets to see where you are and whether you should defer transmission to avoid interference with a transmission between two other stations:

  - Network Allocation Vector: it's a virtual channel that a station assigns to itself telling it to shut up.

Point Coordination

- Essence: let a single base station control who gets to send a frame.
- Approach: Send a beacon frame（信标帧）once every 10 or 100ms. This frame carries information on frequencies and such, and invites stations to sign up for transmission.

802.11: Frame Structure(1/3)

- Type: Data, control, or management frame
- Subtype: Are we dealing with RTS,CTS, an ACK, etc.
- DS: Is the frame entering/leaving the current cell?
- MF: Frames are allowed to be fragmented to increase reliability. This bit tells whether more fragments are on their way.

802.11: Frame Structure(2/3)

- Retry: Is this a retransmission?
- Power: Used by a base station to activate/passive a station (important in view of power saving)
- More: Additional frames can be expected.
- W: Data is encrypted using the Wired Equivalence Privacy algorithm.
- O: Stick to ordered delivery of frames.

802.11: Frame Structure(3/3)

- Duration: tells how long the transmission of this frame will take, allowing other stations to set their NAV accordingly.
- Addresses: Source/destination in a cell; and those of base stations outside the cell when dealing with inter cell traffic.
- Sequence: Sequence number of this frame. 4 bits are used to identify a fragment of a frame.

Broadband Wireless（无线本地回路）

- Goal: Use wireless connection between buildings (e.g., avoiding the use of the local loop).
- Observation: 802.11 is great for indoor networking, but is not that good for wireless communication between buildings:
  - Buildings do not move, so much of the mobility stuff from 802.11 is not need
  - Several computers should be able to make use of the same "connection" (i.e., it should be broadband). 802.11 is intended to support one transmission at a time.
  - Broadband connections can be supported by powerful radios (money is less of a problem), making power management less of an issue.
  - We may need to cross longer distances, up to several kilometers.

802.16: The Basics (1/2)

- Note: At the physical layer, different modulation techniques are used, each leading to different transmission rates. Typically, 70 Mbps channels can be allocated under ideal circumstances.

802.16: The Basics (2/2)

- Observation: We need a flexible way to allocate bandwidth for downstream and upstream data. It can be expected that, just as in ADSL, an asymmetric approach works best.
- Solutions: Let the base station sent out frames containing time slots:

- Guard time: time used for stations to switch transmission direction. Number of upstream and downstream slots can be changes dynamically.
- Practice: Users get 10Mbps upload/download at 10km distance.

802.16: Frame Structure

- Some observations:
  - 802.16 offers connection-oriented services, very unlike other MAC protocols
  - Checksumming the data is optional: the physical layer uses error correction techniques and there are no facilities for retransmissions.

Bluetooth

- Essence: Bluetooth is to allow very different (portable and fixed) devices located in each other's proximity to exchange information:
  - Let very different portable devices (PDA, cellular phone, notebook) set up connections
  - Replace many of the existing cables (headset, keyboard, mouse, printer)
  - Provide better wireless connection (hands free solutions)
  - Provide wireless access to Internet entry points
  - Relatively high bandwidth: 1 Mbps

Bluetooth Architecture

- Piconet微微网: Group of devices with one master and multiple slaves. There can as much as 7 active slaves, but a total of 255 parked ones (i.e., in a power-saving state).
- Scatternet分散网: An interconnected collection of piconets.

DLL Switching(1/2)

- Basic idea: we want to interconnect a number of LANs, rather than having one big one. Two LANs are connected through a bridge.
  - You want to let existing LANs (in departments, buildings, etc.) as they are. On the other hand, you do want to connect them.
  - When an organization is spread over several buildings, it may be cheaper to have a different interconnect (e.g., infrared) than coax cable. You may also have no choice.
  - Splitting this up (rather than just trying thins together) may be good for load balancing. There can be a file server per LAN.

DLL Switching(2/2)

- Physical distance sometimes precludes building one big LAN. For example, UTP 100 Mbps Ethernet can handle cables only up to 100m.
- The reliability can be improved: if one part goes down, the other LAN segments may still operate.
- For security reasons, bridges can check frames, and refuse to forward those that seem suspicious.
- See p267~269

- 交换方式
  - 存储转发和直通型两种

Bridges: Basics

- A packet is passed to the data link layer (LLC part)
- It is then passed to the MAC layer (specific access strategy)
- A bridge converts the stuff above the MAC layer, in the LLC layer

Bridging Problems

- Problem: Really great – committees for 802.x invented different frame formats:

  - We also have the problem of different transmission rates. If a higher speed LAN starts pumping frames on a lower speed one, we've got a problem.
  - What should we do if the target LAN can't accept the frame length of the source LAN? Splitting a frame into pieces is often out of the question(不可能的)! (WHY?要插手净荷)

Transparent Bridges(透明网桥)

- Main issue: Can we develop a bridge that interconnects LANs in a completely transparent way, i.e. seems to turn it into one big LAN?

  - An incoming frame is simply forwarded to all other LAN segments connected to the bridge.
  - Because an incoming frame contains the source address, a bridge can gradually get to know through which interface it can reach a host.
  - Use a timeout mechanism to flush all knowledge a bridge has →it will gradually build up a fresh view again.

Parallel Transparent Bridge(1/2)

- Problem: Sometimes LANs are connected by multiple bridges in such a way that we no longer have a tree, but a graph containing cycles →we can't just forward frames anymore.

- Question: why would we use multiple bridges in such a way that we don't have a tree anymore?

Parallel Transparent Bridges(2/2)

- Solution: let the bridges construct a spanning tree on their own.

  - Each bridge broadcasts its ID across the attached LAN segments. The lowest numbered bridge becomes root for that segment.
  - A root bridge for a segment knows it can never be the root for the tree, if it finds out there's a bridge with a lower number.
  - Bridges advertise their distance to the "real" root →that's how we build a spanning tree.

From Repeater to Switch

- Observation: there's a lot of confusion when it comes to placing "connectors" in reference models:

  - Repeater: amplifies incoming signal,连接两根电缆,物理层设备
  - Hub: Takes an incoming frame and passes it to all other ports,物理层设备,整个集线器构成一个冲突域
  - Bridge: Connects two or more LANs,多个冲突域,网络可异构
  - Switch: Connects several computers (and routes frames between them) //可连接同构网络

From Router to Gateway

- Routers: placed in "classical" networks, and forwards packets to other routers
- Transport gateways: connects two networks at transport layer: go from a TCP connection to an ATM transport connection.
- Application gateway: connects two different application protocols, such as sending SMS messages to a Web server, or connecting an X.400 mail system to an Internet-based mail system.

Virtual LANs(1/2)

- Observation: Many LANs are organized according to a physical division of workstations, possibly having multiple LANs connected by bridges for sake of better management (and security):

- Problem: the physical organization may not correspond at all with what would seem logically the best organization (e.g., based on membership of a department).

Virtual LANs(2/2)

- Solution: adjust the bridges and switches such that an incoming frame is forwarded only to those outgoing ports that connect hosts (or LAN segments) belonging to the same logical group as the sending host:

Identifying a VLAN(1/2)

- Observation: it's not really important that you know to which group the sending host belongs, as long as the frame it is sending has the logical group encoded in it → add a tag to frame headers.
- Problem: you don't want existing networks (Ethernet!) to break down. As a consequence, you need to apply a trick so that non-VLAN aware frames can be adjusted to one in which the VLAN is identified by a tag.
- Basic idea: Let bridges and switches make the adjustment: add the tag when a frame comes in for the first time; remove it when it is sent to a non-VLAN aware host.

Identifying a VLAN(2/2)

802.1Q: VLAN Ethernet

- VLAN protocol ID: value 0x8100, by which it is automatically interpreted as a type (correct according to the 802.3 standard)
- VLAN ID: this is what it is all about
- CFI: Bit indicating that the payload is an 802.5 frame that is being tunneled (token ring protocol)
- PRI: So, finally, we can introduce QoS into Ethernet networks.

Summary

- 多路访问协议/信道分配技术/介质访问控制协议
- 以太网主流的局域网组网技术，主要使用双绞线连接到集线器和交换机组网；
- 802.11无线LAN、802.16无线MAN以及蓝牙无线桌面
- 网桥和交换机用于互联LANs（可异构）；
- VLAN进一步可以把物理拓扑结构和逻辑拓扑结构分离开来，形成虚拟局域网，帧格式定义在802.1Q中。