信道有两种：点到点链路or多点链路（广播式链路为多）

1 The Channel Allocation Problem

- Five Key Assumption
  - Station model
  - Single Chanel model
  - Collision assumption
  - Continuous time (frame transimission can begin at any instant); Slotted time (必须要要在一个时间潮来了，某个时间点上去发送)
  - Carrier sense（每个站可以知道某个信道是否在使用）; No carrier sense.

1.1 Static Channel Allocation in LANs and MANs

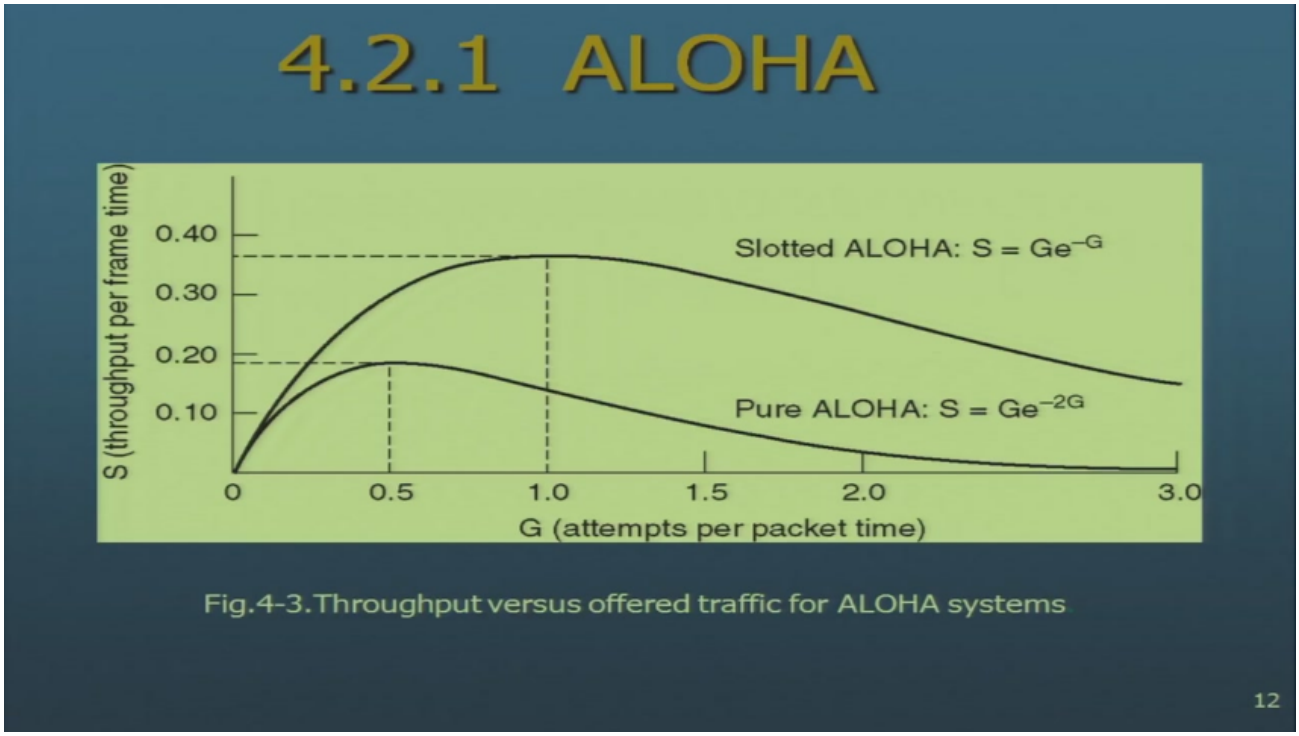
1.2 Dynamic Channel Allocation in LANs and MANs

2 Multiple Access Protocol

2.1 ALOHA

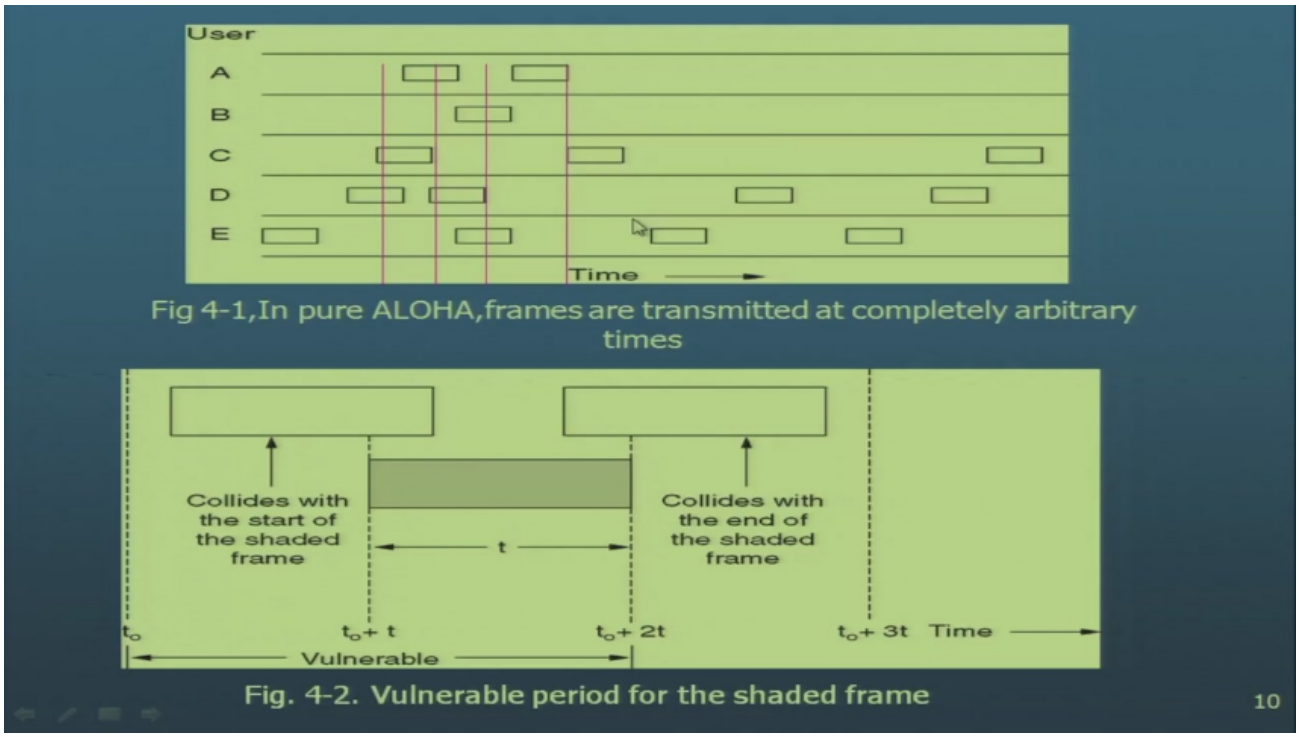
In pure ALOHA, frames are transmitted at completely arbitrary times: 有些帧会重叠，使得会出现错误重发，间隔随机时间再重发，直到不重叠，效率很低。

吞吐量S和负载G（attempts per packet time）：在一定范围内，吞吐量随负载增大；但是负载太多了之后，信道会变的得拥挤，导致吞吐量反而下降。



$$S = Ge^{-G}, Slotted\ ALOHA$$

$$S = Ge^{-2G},\ Pure\ ALOHA \tag{1}$$



Slotted ALOHA 中需要在特定的时间节点发送，因此在某些时刻发送的帧是无效的，只有在特定时间发送的帧会成功，相比于pure ALOHA（上图中三个全失败），这里一个成功，两个失败。

2.2 Carrier Sense Multiple Access Protocols

2.2.1 CSMA

2.2.1.1 1-CSMA

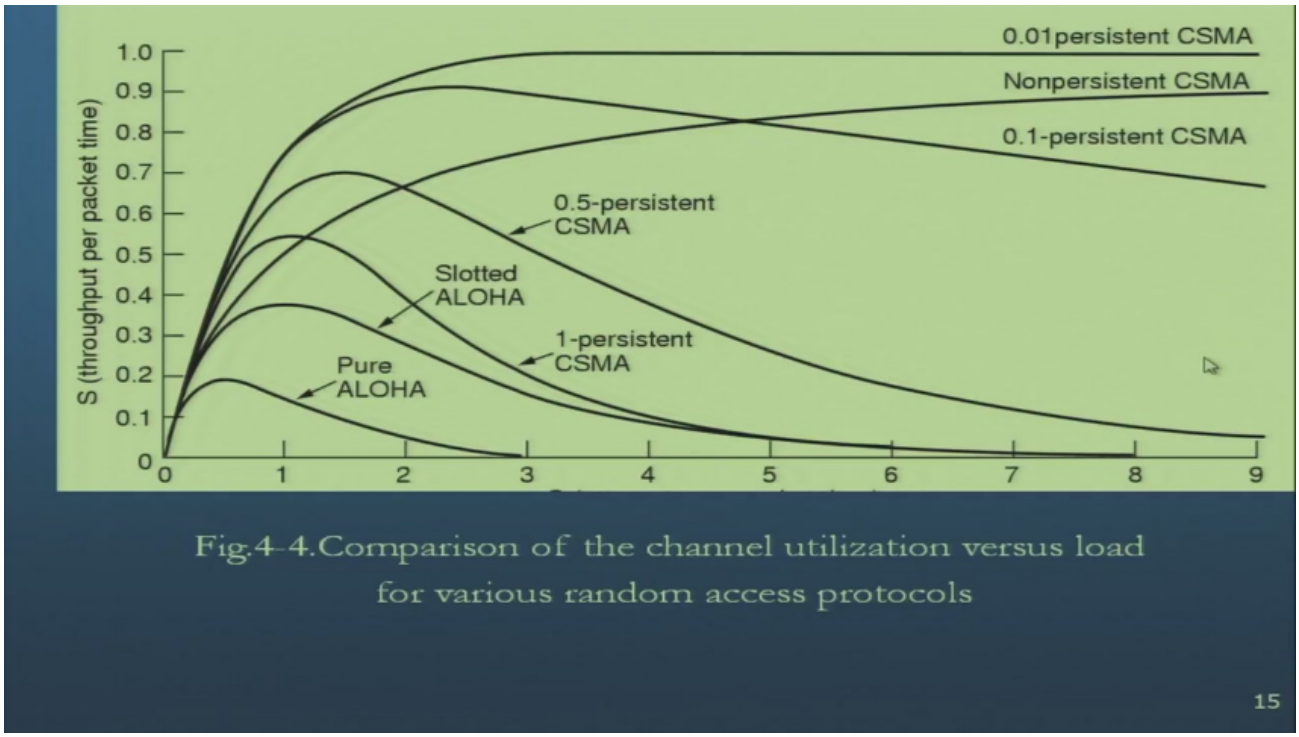
- 如果有帧要发送，那就监听信道，如果信道是空的就发送帧，如果信道繁忙就等待，一直等到变空，再去发送。
- 但也有问题：如果负载正在忙，然后有两个站在监听，信道一空，就马上同时发，会出现冲突。
- 信道很忙的时候效率反而不高。

2.2.1.2 Nonpersistent CSMA

- 可以考虑加一个随机时间，每次检测到信道忙的时候都会延迟一个随机时间，那么两个要发的站发送帧的时间一般来说都会错开，不会打架。
- 会浪费一点点信道（在等随机时间）。

2.2.1.3 p- persistent CSMA

- 增加一个概率p，有p的概率选择发送，1-p的概率选择不发送继续监听。两个站会用概率来选择是否发送。



- 概率p越小，代表站点之间越谦让，吞吐量很高

2.2.2 CSMA/CD

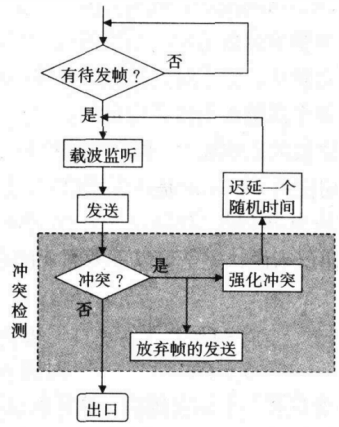


图 4-10　CSMA/CD 的流程图

- 两边的信息是相向而行的
- 有要求最小帧长
- 如果只是一开始几次的发送失败，那就强化冲突，发送一串违规码，告诉所有站发生冲突了。比如说，一列火车头和一列长火车相撞，火车头的那个会重发，但是一列长火车会认为这个相撞是噪声什么的，不管他，导致信息丢失；发了违规码，就会让站点都知道发生冲突，不错发信息。
- 重走监听、发送。如果冲突16次，那就放弃帧的发送。
- 注意：是先发送，再判断冲突。如果有冲突，那就马上刹车。
- 针对会发生冲突的Hub这样的硬件，switch不会发生冲突

2.3 Wireless LAN Protocols - WIFI

- WIFI 工作的载波是2.4GHz，C波段；载波频率越高，覆盖范围越小。

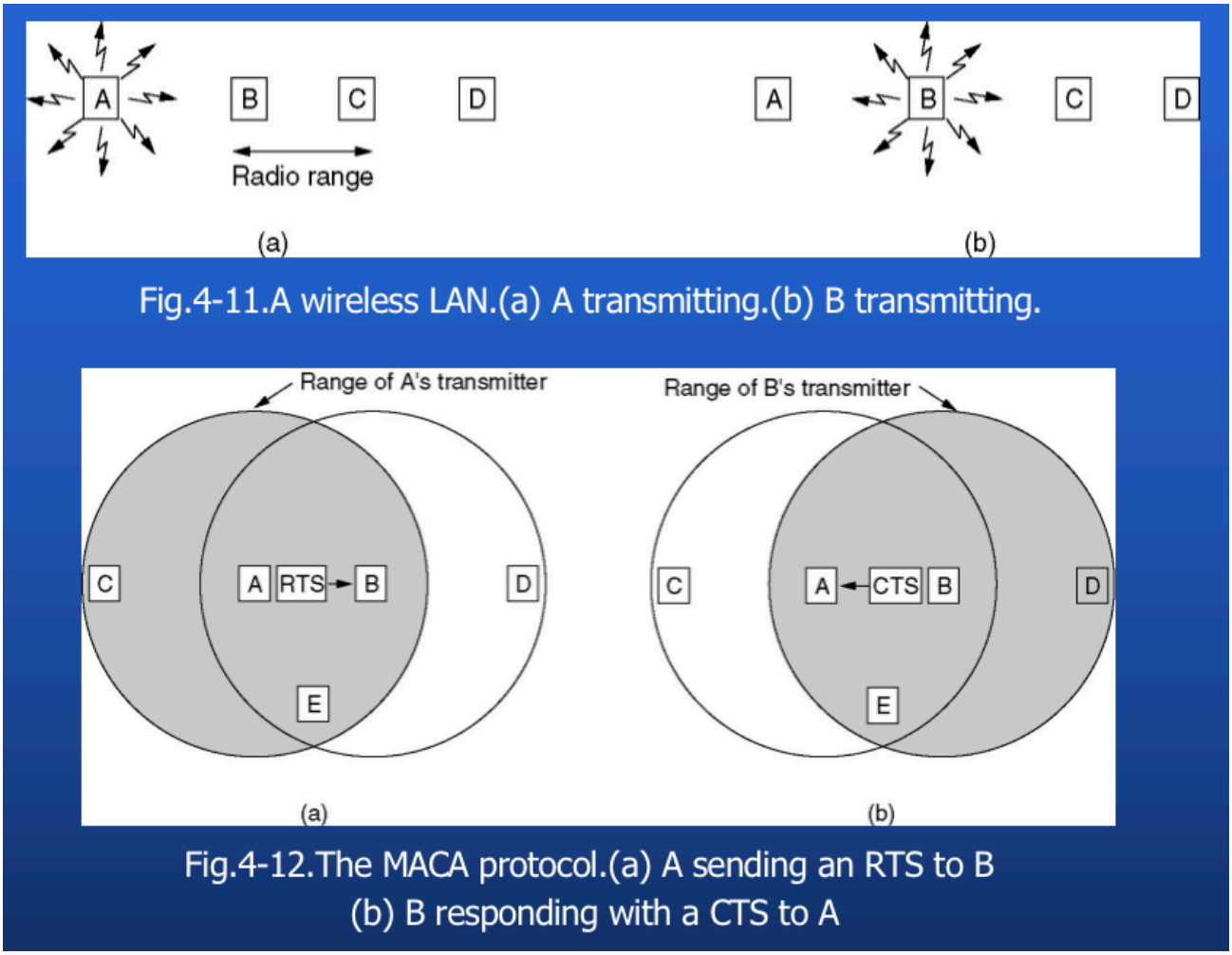


Fig.4-11.A wireless LAN.(a) A transmitting.(b) B transmitting.

Fig.4-12.The MACA protocol.(a) A sending an RTS to B
(b) B responding with a CTS to A

- Hidden station problem-[see fig 4-11(a)]
  - A->B, C will not hear A, thus falsely conclude that C can transmit, collision occur.
- Exposed station problem-[see fig 4-11(b)]
  - B->A, C is listening ,falsely conclude that it may not send to D
- Solution
  - Multiple Access with Collision Avoidance(MACA) - [see fig 4-12]
  - IEEE 802.11
  - The basic idea：the sender stimulate the receiver（RTS），make it send a frame(CTS)，all stations nearby can detect this transmission, avoid collision.
- Conclusion （CSMA / CA Rule）：
  - If station X received RTS of A, X must remain silent for a short time so that X will not interfere with A's receipt of CTS. （C不能影响他）
  - If station X received RTS,but did not receive CTS,then X can transmit its data and will not interfere with other stations.
  - If station X has not received RTS, but received CTS,then X may not transmit its data.
  - If station X has received both RTS and CTS, then X may not transmit its data.

	CTS☑	CTS ✖
RTS☑	E（不要发送数据，会干扰B）	C，说明收信息站离得远，发送数据不干扰B接收
RTS ✖	D（不要发送数据，会干扰B）	None of ur business

- 所以关键是CTS，也就是离接收站的距离决定了某站点能否发数据

3 Ethernet

3.1 Ethernet Cabling

3.2 Manchester Encoding

3.3 The Ethernet MAC Sublayer Protocol

- round trip delay：往返延迟

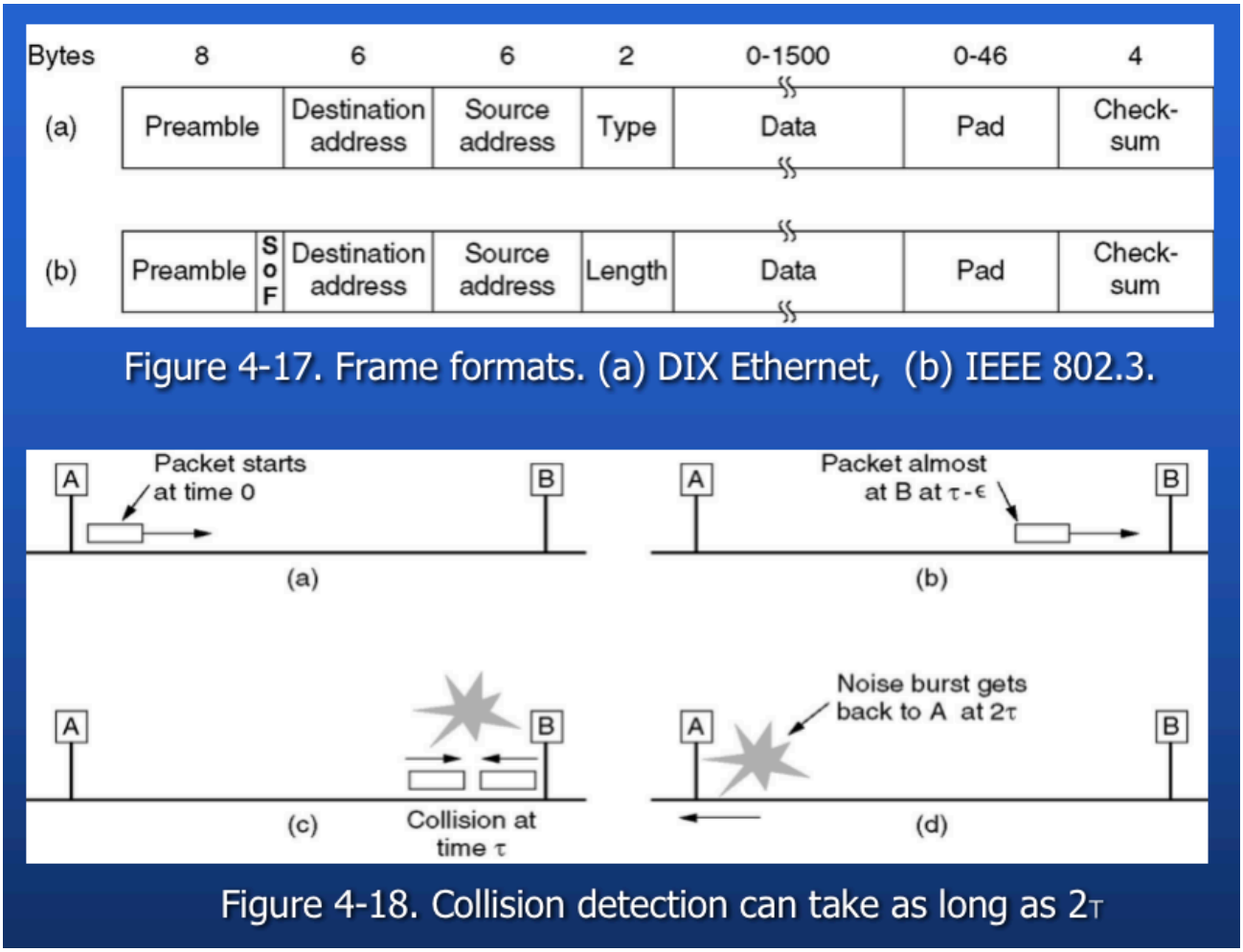


Figure 4-17. Frame formats. (a) DIX Ethernet, (b) IEEE 802.3.

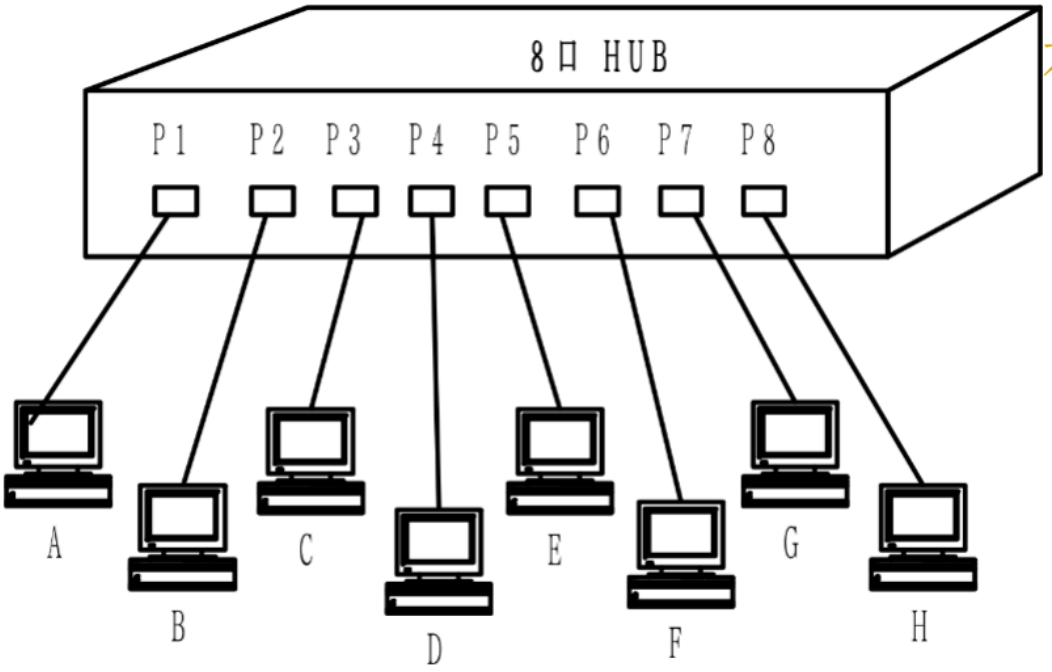
Figure 4-18. Collision detection can take as long as 2T

- 发送时间一定要大于一个来回的时间，那么出现冲突就都能被检测出来
- 如果发送的时间太快，那么还没等冲突回来，那就已经停止接收了，冲突自然也检测和接收不到。

3.4 The Binary Exponential Backoff Algorithm

3.5 Ethernet Performance

3.6 Switched Ethernet

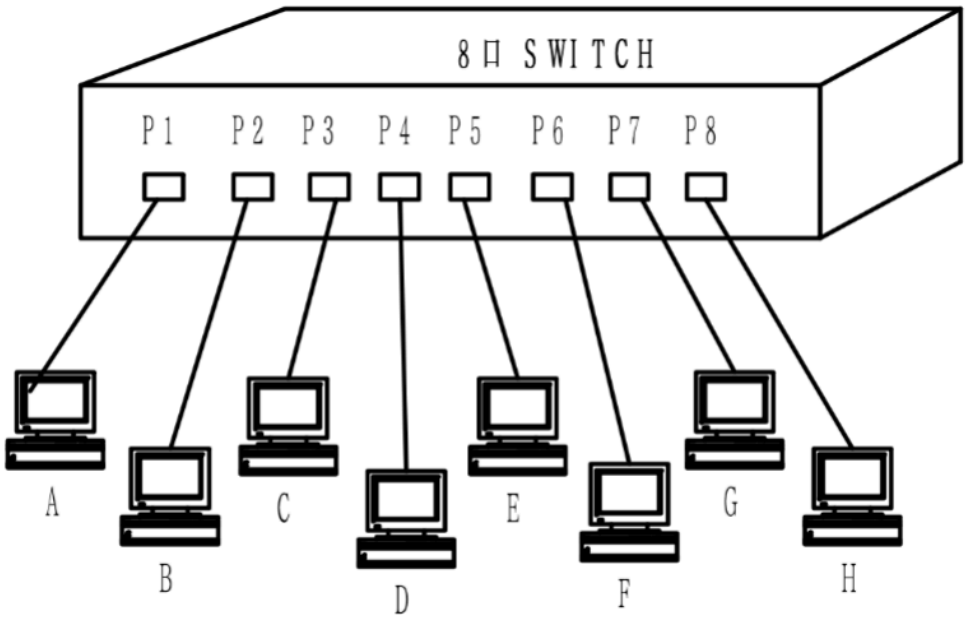


补充

集线器： 当B-->C时，所有其他计算机不能同时发送。网络总带宽为10 Mbps。平均每台节点机的最高带宽为：10/8=1.25 Mbps。

- 非常的底层，不是很智能
- 在某一个端口发送的时候，其他的端口不能发送，会有短暂的信道浪费
- 可能会有冲突，会用CSMA/CD

补充



8口交换机： 当B-->C时，同时可以进行:D-->A，E-->G，H-->F。网络总带宽为10*4=40 Mbps,平均每台节点机的最高带宽为：10/2 = 5 Mbps。

当网卡及交换机都是全双工设备时，平均每台节点机的最高带宽为：5*2 = 10 Mbps。

- 交换机更加智能一点，可以同时发送
- 全双工：网卡可以一边发送一边接收
- 信道分开的，很多条路

3.7 Fast Ethernet 千兆以太网

- 802.3u
- Category 5 twisted pair：100Base-TX （2 twisted pairs)
  - 125 MHZ of clock rate,
  - 4B/5B, 16 of 25 possible combinations are used to transmit 4 bit data（每5个bit传输4bit的数据）

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	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

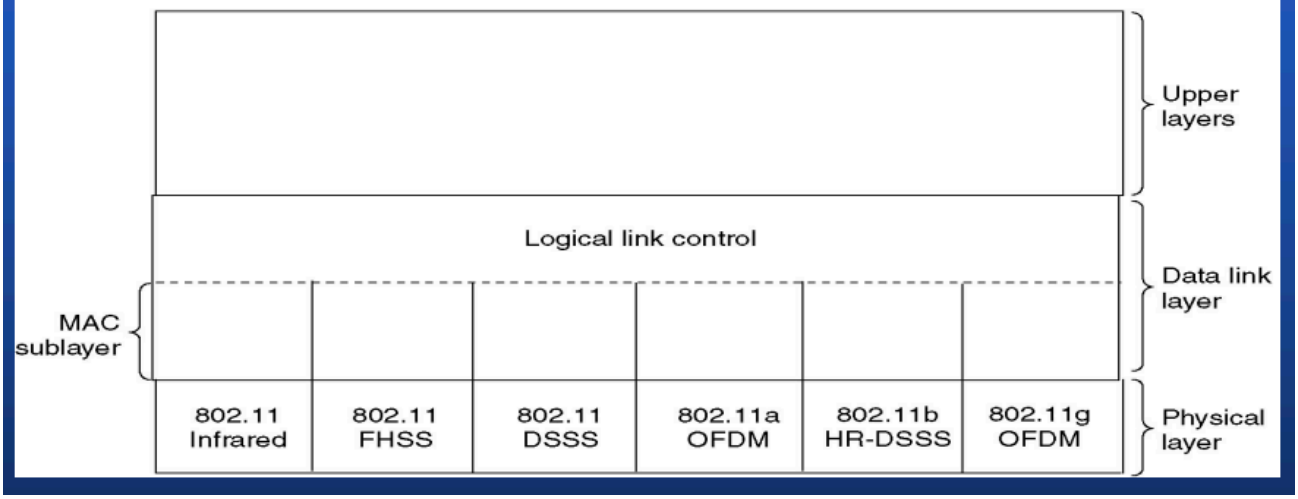
3.8 Gigabit Ethernet

- 802.3z
- Two different modes of operation:
  - Full-duplex mode: “normal” mode. Used in central switch. buffered. No contention, no CSMA/CD
  - Half-duplex mode: used with a hub. A hub does not buffer incoming frames. Collisions are possible, CSMA/CD protocol required. A minimum frame can now be transmitted 100 times faster than in classic Ethernet, and the maximum distance is 100 times less, or 25 meters.
  - 一般来说贵的端口（用光纤的），会用贵的switch，不会用到CSMA/CD
- Two features to the standard to increase the radius (200 meter):
  - Carrier extension: tells the hardware to add its own padding after the normal frame to extend the frame to 512 bytes.
  - Frame bursting: allows a sender to transmit a concatenated sequence of multiple frames in a single transmission.

4 Wireless LANs

4.1 The 802.11 Protocol Stack

- Protocol stack structure [see fig.4-25]
  - MAC sublayer determines how the channel is allocated
  - LLC sublayer hide the difference between 802 variants
  - The first three: 1997; the second two: 1999; the last one: 2001



4.2 The 802.11 Physical Layer

- Infrared: diffused (散射的，扩散的) transmission, 0.85 or 0.95 microns, two speeds:
  - 1 Mbps: a group of 4 bits is encoded as 16-bit codeword containing fifteen 0s and a single 1, Gray code
    - 0000-->0000 0000 0000 0001
    - 0001-->0000 0000 0000 0010
    - 0010-->0000 0000 0000 0100
    - ….
  - 2 Mbps: takes 2 bits and produces a 4-bit codeword, also only a single 1
    - 00-->0001
    - 01-->0010
    - 10-->0100
    - 11-->1000
- FHSS(Frequency Hopping Spread Spectrum): uses 79 channels, each 1 MHz wide, starting at the low end of the 2.4-GHz ISM band.
  - Pseudo random number generator, dwell time<=400 ms
  - All station using the same Pseudo random number will hop to the same next frequency. 2.401 GHz-->2.408-->2.403-->
  - 1 Mbps or 2 Mbps

- 跳频技术：我方的信号传输不停地在不同的频率跳变

- DSSS(Direct Sequence Spread Spectrum): Each bit is encoded as 11 chips (similar to CDMA), using Barker sequence,
  - phase shift modulation
  - 1 Mbps or 2 Mbps, 2.4 GHZ ISM band.
- OFDM(Orthogonal Frequency Division Multiplexing): 802.11a
  - up to 54 Mbps, wider 5 GHZ ISM band.
  - 52 frequencies: 48 for data and 4 for synchronization
- HR-DSSS (High Rate Direct Sequence Spread Spectrum): 802.11b
  - Uses 11 million chips/sec to achieve 11 Mbps in the 2.4-GHz band
  - Data rates supported: 1, 2, 5.5, and 11 Mbps.
- 802.11g, uses OFDM modulation method of 802.11a but operates in the narrow 2.4-GHz ISM band along with 802.11b

4.3 The 802.11 MAC Sublayer Protocol

- Two modes of opertion:
  - DCF(Distributed Coordination Function): not use central control
  - PCF(Point Coordination Function): uses the base station to control all activity in its cell.
  - All must support DCF, but PCF is optional.
- CSMA/CA(CSMA with Collision Avoidence): employs DCF, uses both physical and virtual channel sensing
  - method 1: senses channel:
    - if idle, just starts transmitting. Does not sense channel while transmitting.
    - If collision occurs, wait random time, using Ethernet binary exponential backoff algorithm
    - Be used to transmit RTS frame.
  - method 2: based on MACAW, uses virtual channel sensing[see Fig.4-27]

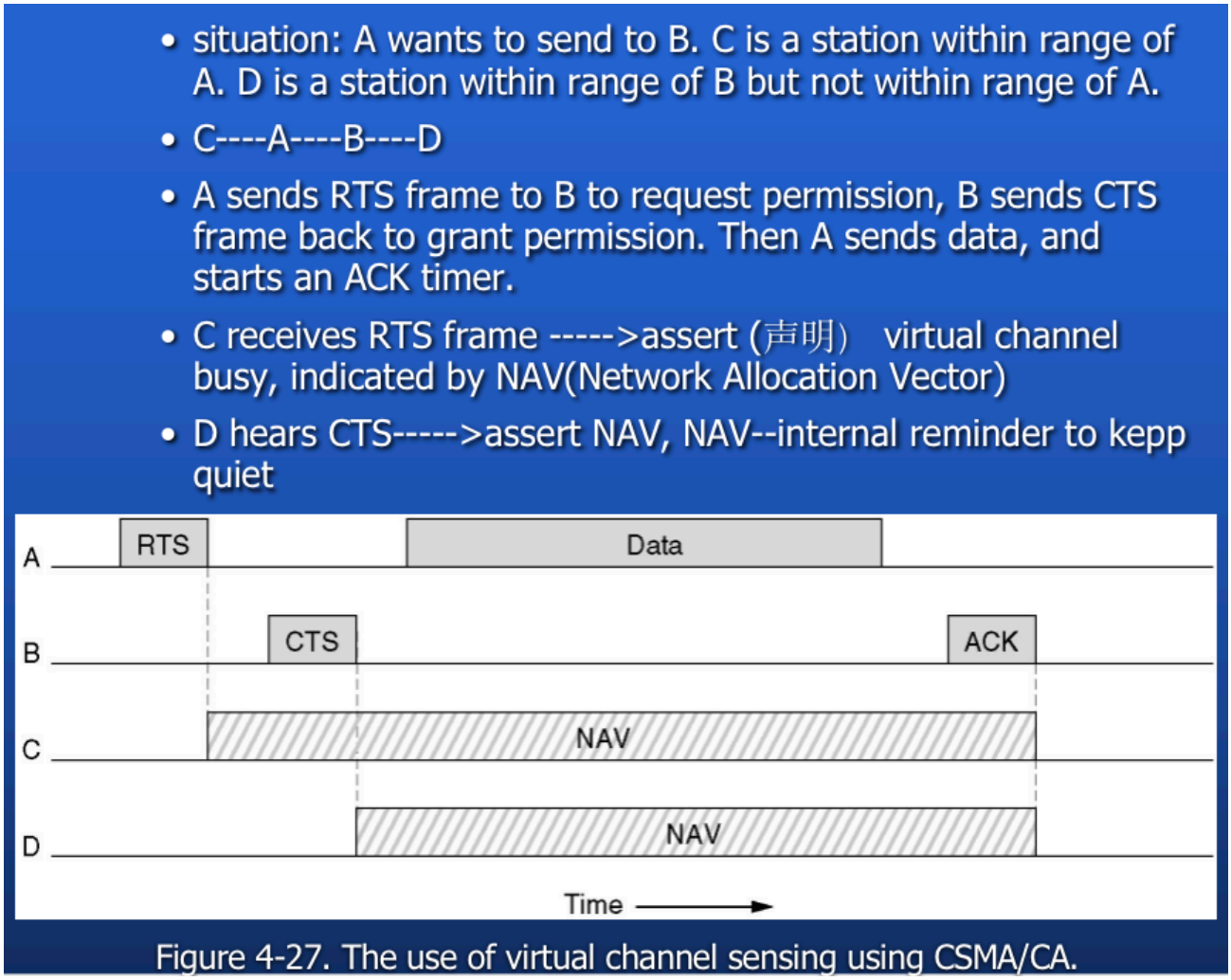


Figure 4-27. The use of virtual channel sensing using CSMA/CA.

- 自由空间存在很多的干扰，data数据很容易被破坏

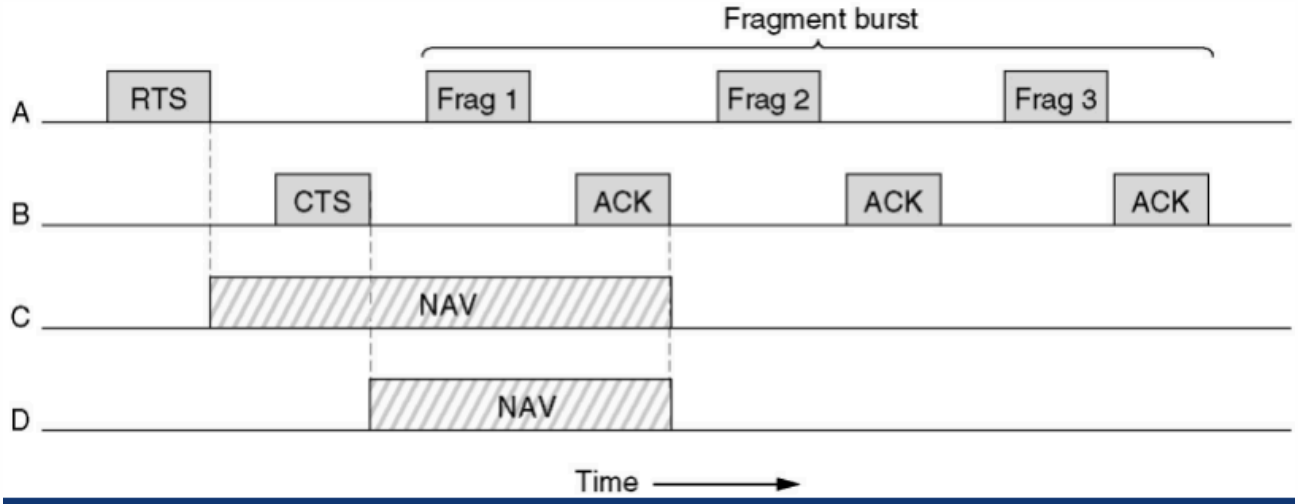


Figure 4-28. A fragment burst.

- 把data数据包拆开来发送
- 但是NAV为什么等待一段就停了呢：因为后面的flag间隔小于抢信道PCF的时间，所以CD实际上根本没机会抢到信道
- PIFS(PCF InterFrame Spacing): After PIFS, base station is given a chance to grab the channel.
- DIFS(DCF InterFrame Spacing): After DIFS, usual contension rules apply, binary exponential backoff if needed.

4.4 The 802.11 Frame Structure

4.5 Services

5 Data Link Layer Switching

5.1 Bridges from 802.x to 802.y

- Operation principle: [see Fig. 4-40]
  - a bridge connecting k different LANs will have k different MAC sublayers and k different physical layers, one for each type

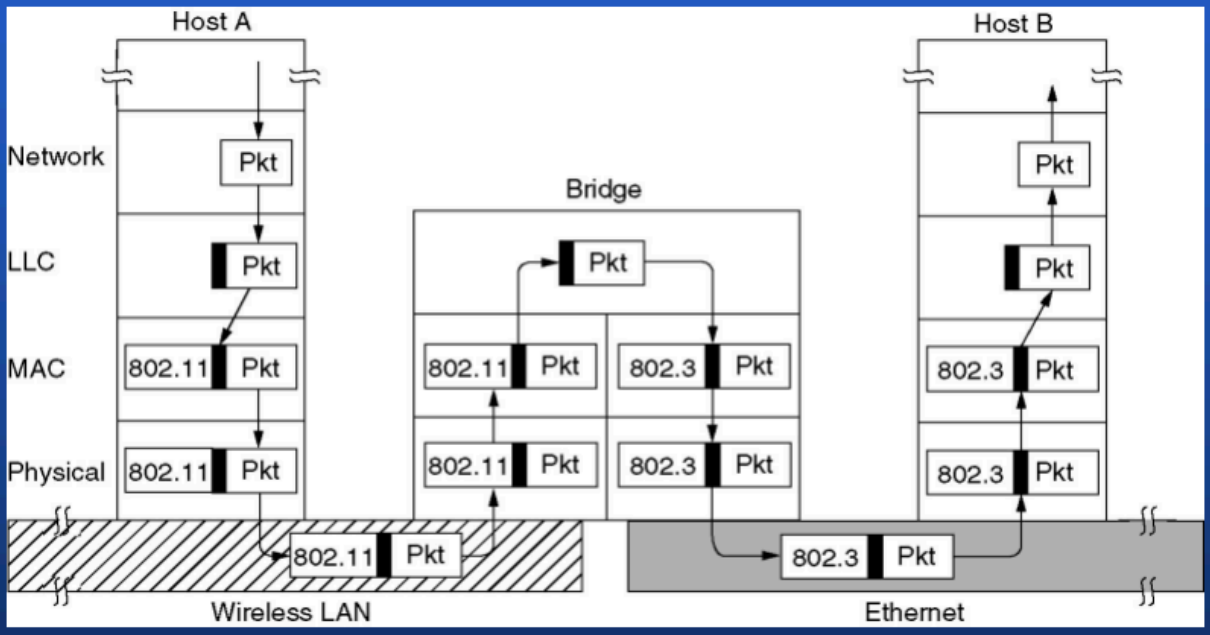


Figure 4-40. Operation of a LAN bridge from 802.11 to 802.3.

5.2 Local Internetworking

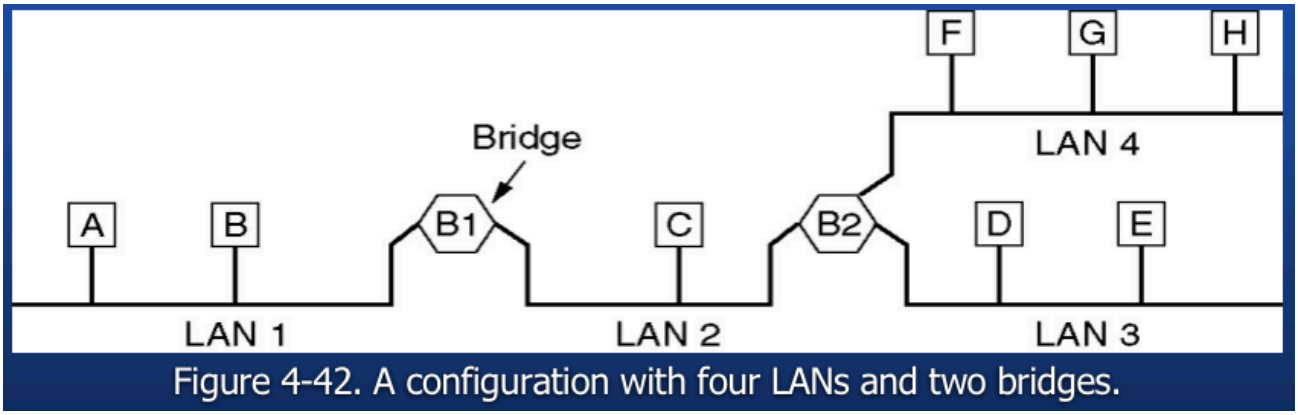
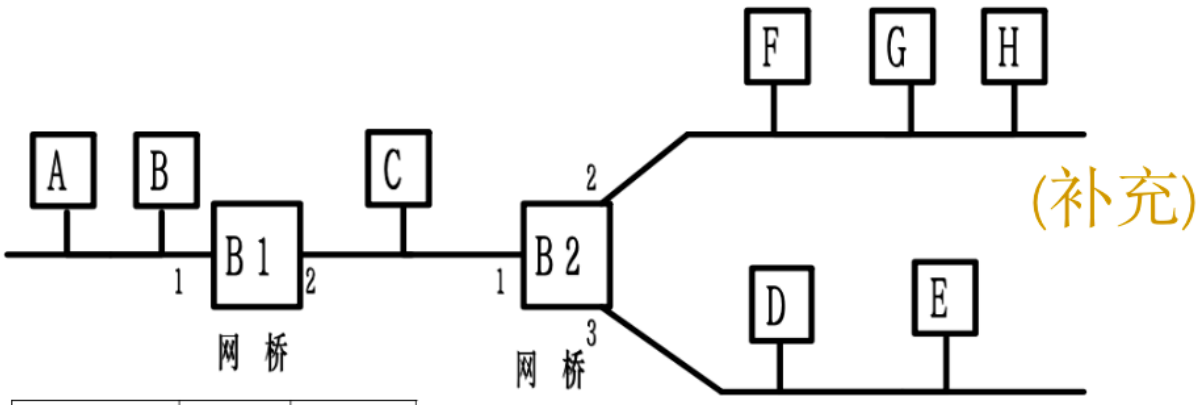


Figure 4-42. A configuration with four LANs and two bridges.

- Transparent bridge [see Fig. 4-42]
- hash table, flooding algorithm（洪泛算法）, backward learning（后象学习）, promiscuous mode
- routing procedure for an incoming frame:
  - If destination and source LANs are the same, discard the frame
  - If destination and source LANs are different, forward the frame

    - If the destination LANs is unknown, use flooding
- supporting dynamic topologies: arrival time is contained in table entry.



站地址	端口	时间
A	1	2s
C	1	3s
F	2	3s
G	2	6s
D	3	13s
B	1	27s

网桥B2的转发表

老化时间默认为300秒。从一个MAC地址加入转发表以后开始计时，如果在老化时间内网桥未收到源地址为该MAC地址的帧，那么，该MAC地址所在的一行会被删除。手工输入的静态MAC地址表项不受老化时间影响。

switch(config)#mac-address-table aging-time 100

设置老化时间为100ms，在PacketTracer7内不能用

- 网桥会在发送给站的记录下抓到包的端口、站地址、收到的帧进入网桥的时间
- 网桥转发规则
    - 目的地址和源地址不同，就转发操作
    - 目的地址和源地址相同，不转发，扔掉
    - 目的地址的端口不知道，那就洪泛算法，向所有的端口转发（广播）
    - 目的地址是一个广播地址，就进行广播
- 还有老化时间：如果长时间没有发帧，就会把站点信息删掉，避免信息更新了，导致帧发错了

5.3 Spanning Tree Bridges

- 为了避免出现回路，继而广播风暴

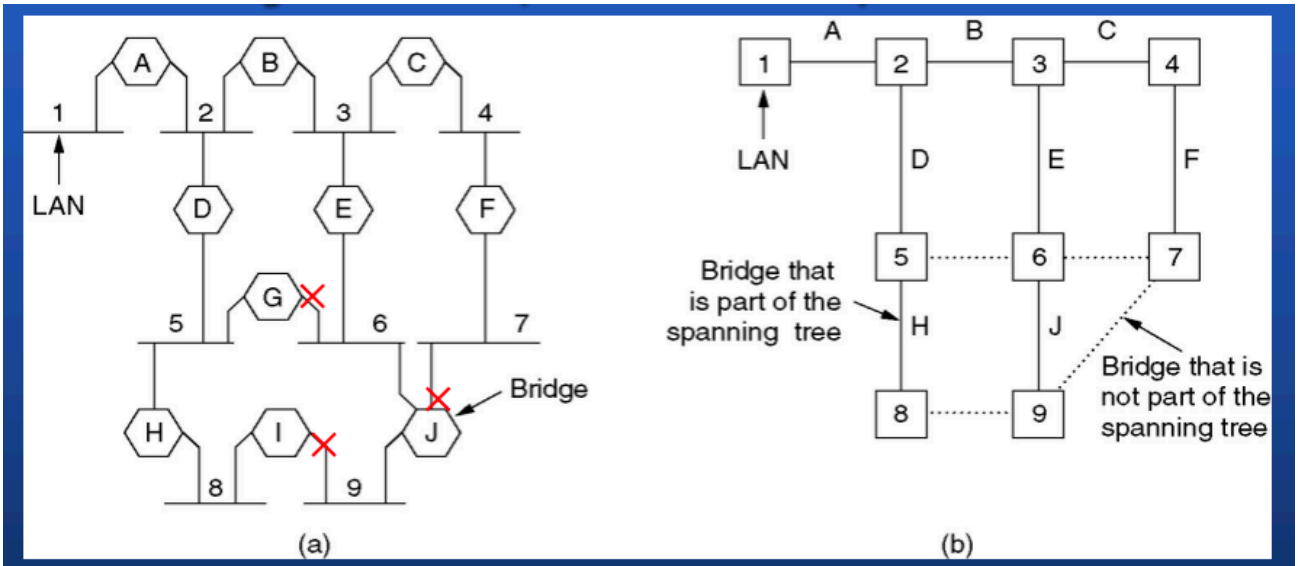


Figure 4-44. (a) Interconnected LANs. (b) A spanning tree covering the LANs. The dotted lines are not part of the spanning tree.

- each bridge broadcasts its serial number, one bridge with the minimum serial number is chosen to be the root of the tree. 最小的端口，被标记为根网桥。
- a tree of shortest paths from the root to every bridge and LAN is constructed 根据根网桥，找最短通路树。其他的某些网桥就不会用起来，也就是断开了
- if a bridge or LAN fails, a new one is computed

5.4 Repeaters, Hubs, Bridges, Switches, Routers and Gateways

- hubs: not amplify incoming signals, not examine 802 addresses. The entire hub forms a single collision domain [see Fig.4-47(a)]
- bridges: connect LANs, route on frame address, each line is its own collision domain [see Fig.4-47(b)]
- switches: connect individual computers, route on frame address, never lose frames because of collisions [see Fig.4-47(c)]
  - cut-through switches

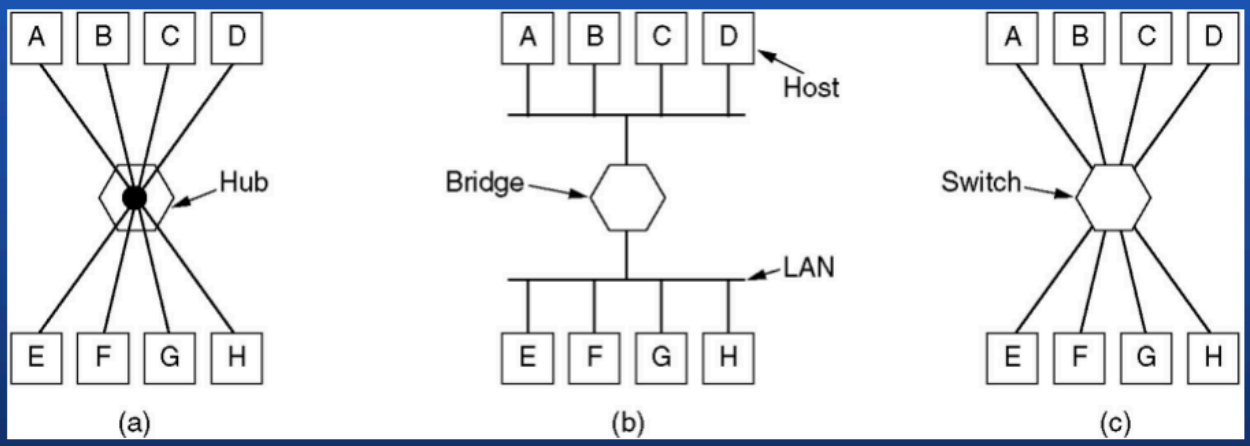


Figure 4-47. (a) A hub. (b) A bridge. (c) a switch.

- 冲突域：一个单波帧能到达的计算机
  - 集线器：1个冲突域，每个冲突域是8
  - 交换机：8个冲突域，每个冲突域是1
- 广播域：一个广播帧能到达的计算机（受限于VLAN）
  - 集线器：1个广播域
  - 交换机：1个广播域
- 1个24口交换机（每口通过HUB连10个电脑）没划分VLAN，只有1个广播域，但有24个冲突域（每端口是1个），如果该交换机收到一个广播帧，会被该交换机转发到240台电脑。
- 如果该交换机划成4个VLAN（每VLAN含6个端口），就有4个广播域，但有24个冲突域，如果该交换机收到一个广播帧，会被该交换机转发同一VLAN的其他5个端口的电脑

5.5 Virtual LANs

- A building with centralized wiring using hubs and a switch:

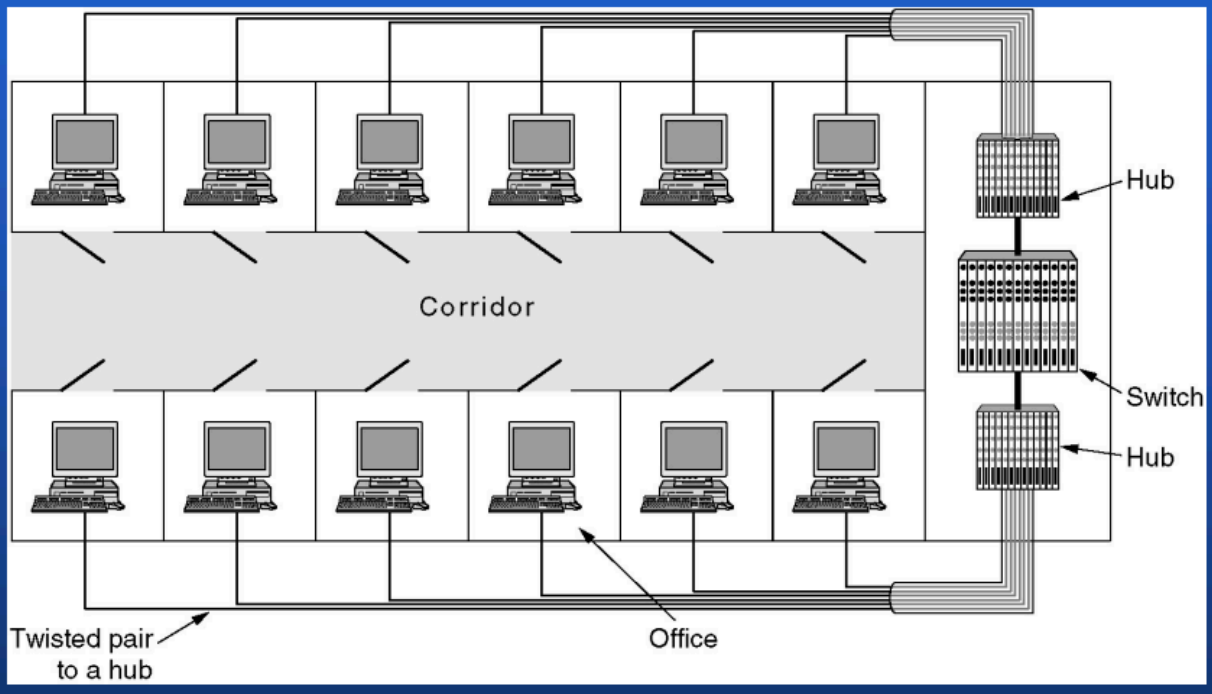


Figure 4-48. A building with centralized wiring using hubs and a switch.

– Configuration tables tell which VLANs are accessible via which ports(lines). When a frame comes in from, say, the gray VLAN, it must be forwarded on all the ports marked G(指“在所有标为灰色的端口间转发”，不是“转发到所有标为灰色的端口”)

– if all machines on LAN 2 and 4 become G, then B2's ports to LAN4 and LAN2 become G, and B1's port to B2 also becomes gray.

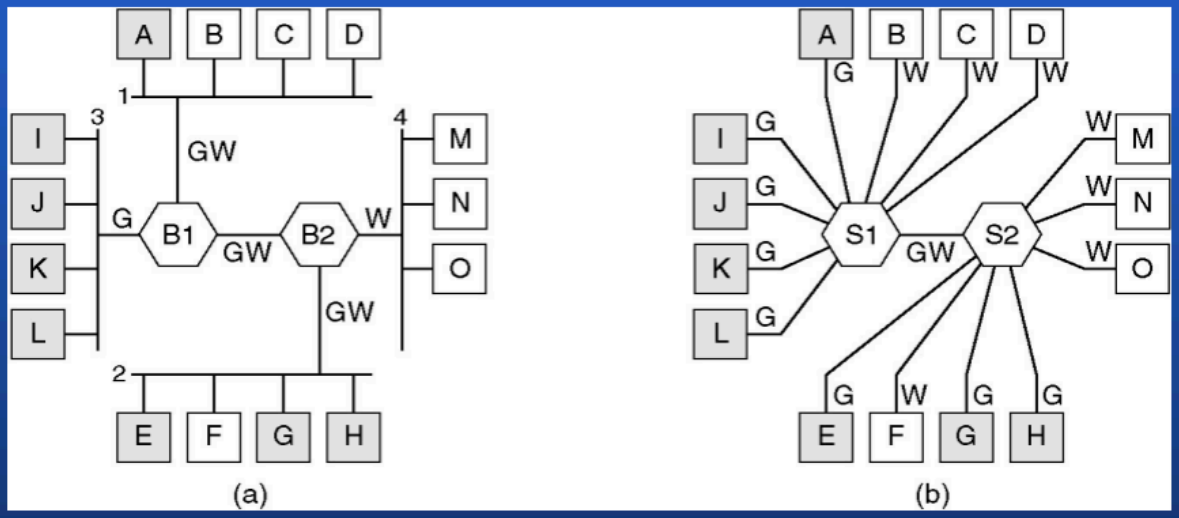


Figure 4-49. (a) Four physical LANs organized into two VLANs, gray and white, by two bridges. (b) The same 15 machines organized into two VLANs by switches.

- 这里有问题，只有集线器的不同端口能划分VLAN，集线器、同位电缆是不允许划分VLAN的

5.5.1 The IEEE 802.1Q Standard

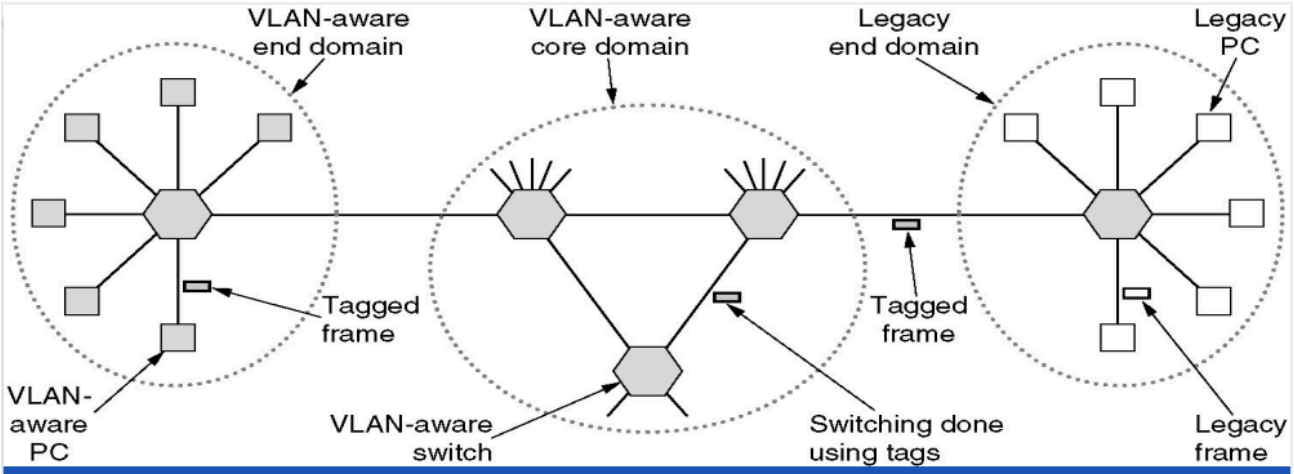


Figure 4-50. Transition from legacy Ethernet to VLAN-aware Ethernet. The shaded symbols are VLAN aware. The empty ones are not.

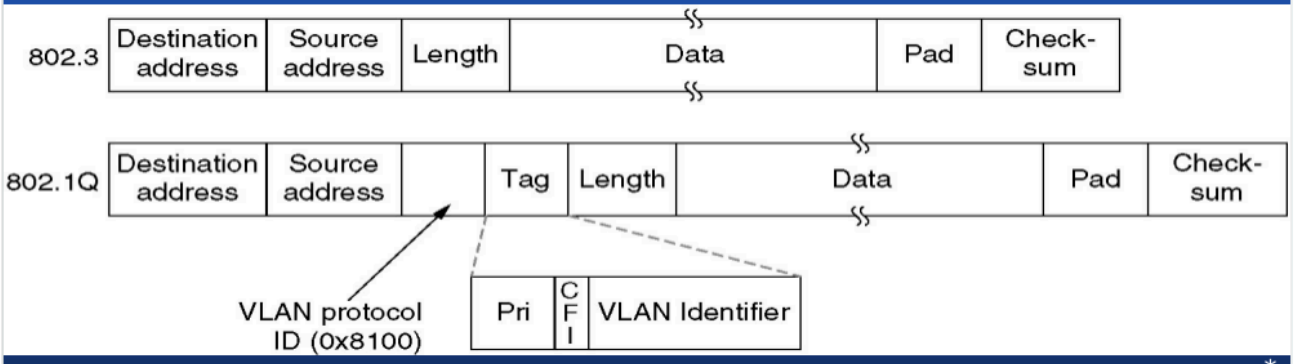


Figure 4-51. The 802.3 (legacy) and 802.1Q Ethernet frame formats. *

- A few questions:
  - Need we throw out several hundred million existing Ethernet cards?
    - 不需要。交换机会更改变化的帧结构，使老式的网卡也能用。
  - If not, who generates the new fields?
    - 交换机。
  - What happens to frames that are already the maximum size?

- priority (3 bits): has nothing to do with VLAN, to identify time-sensitive traffic so as to provide better QOS over Ethernet, voice over Ethernet.
- VLAN identifier (12 bits)
- CFI (Canonical Format Indicator): to indicate little-endian or big-endian MAC address originally.