# IST 220 Exam 2 Notes

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## Chapter 7 – Packets, Frames, and Error Detection

Assume Alice wants to send a contract of 80,000 characters to Bob. We can send the contract in two possible ways:

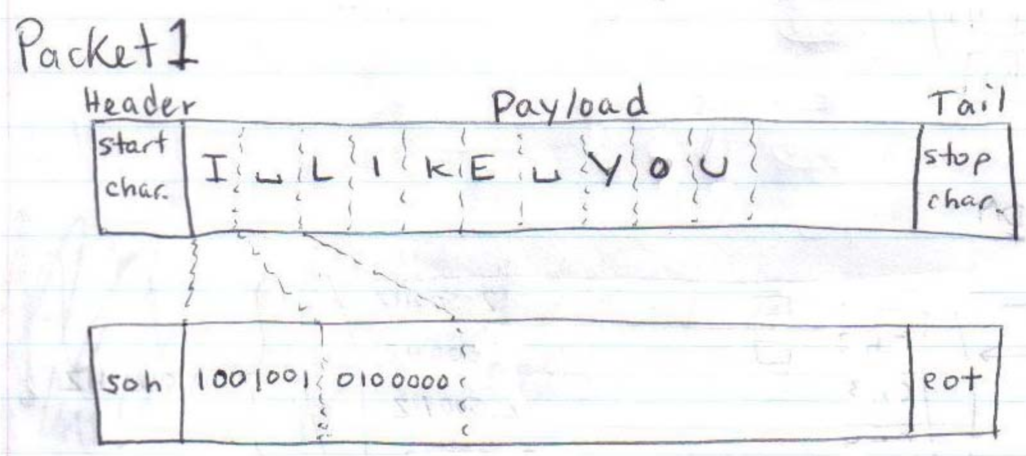
(1) **Bit by Bit**: If we use RS-232 plus modulation, we need to send 9 bits per character. So 80,000 * 9 = 720,000 bits @ 7,200 bps = 10 seconds
(2) **Packets**: Split the contract into a bunch of packets, and then send the data packet by packet. If each packet contains 80 characters, we need to send 1,000 packets.

**Observations**:
O1. These two ways are almost the same speed when there are no errors.
O2. When there are errors, packets are better.
O3. The single most important factor in networking is error.

In bit-by-bit communication, whenever a bit is corrupted by an error, it is very difficult to tell which bit is wrong; so in many cases, the whole contract needs to be retransmitted.

In packet-by-packet communication, when a packet is corrupted, it can be detected, so only this packet needs to be retransmitted.

### How to compose a packet?




**Note 1:** Here, we send NO idles in any packet
**Note 2:** To enable computer 2 to distinguish packet 2 from packet 1, the start character and stop character must be unique and different from the payload.

**In real world:**
soh = start chatacter
- soh stands for "Start of header"
- Not printable
- 7 bits

eot = stop character
- eot stands for "end of transmission"
- Not printable
- 7 bits

**Note:** Without soh and eot, computer 2 could not receive the message correctly.

When transmitting graphics, the picture is broken up into a grid and each cell is assigned a value of 1 or 0 depending on the cell (empty cell = 0, cell with content = 1)

**Problem:** We can have soh and eot in payload!
*Answer:* Data stuffing

The idea of data stuffing is to replace soh and eot in the payload with two normal characters.

For example:

| Original | After Replacement |
|---|---|
| soh → | esc x |
| eot → | esc y |
| esc → | esc z |

When computer 2 receives this packet, computer 2 will do reverse data stuffing to restore the original image.

**Q1**. Here, esc will not cause trouble. Why do we also replace esc?
*Answer:* If the original image has esc x in the payload, we will have trouble if we do not replace esc.

## Error Detection:

We do packet-by-packet communication because of errors.
In real world, a transmission system has two types of errors
**Type 1**: end system errors. Ex. Computer 1 crashes
**Type 2**: transmission errors during transmission

- 2a. some bits are changed
- 2b. some bits are lost
- 2c. some bits not transmitted appear

We will focus on 2a, the most common case.
We handle two problems:
**P1.** During transmission, a character is changed. How do we detect this error?
*Answer:* Parity Checking
**P2.** During transmission, a packet is changed. How do we detect this error?
*Answer:* CRC checking, checksum

**How Parity Checking works:**

(a) if a character is to be sent, for example, 'E' – 010 0101
  - we add one extra bit, called a parity bit
  - the value of the parity bit is determined by the requirement that the total number of '1' bits within the 8 bits must be an even number
  - hence, we send 010 0101**1** (8 bits)

(b) When computer 2 received the 8 bits
- if the total number of '1' bits is an even number, report "no error"
- the total number of '1' bits is an odd number, report "there are trans. errors"

The above technique is called even parity checking.

To detect if a character is changed, we can do parity checking.

Parity checking is NOT perfect!
(a) when one bit of the character is changed, parity checking can detect the error.
(b) However, when 2 bits of the character are changed, parity checking cannot detect the error and makes a mistake

**Q1**. When _____ bits of the character are changed, parity checking will make a mistake?
(a.) 3 (b.) 4 (c.) 5 (d.) 6 (e.) 7
*Answer:* (b) 4 or (d) 6 are the correct answers

**Note:** The parity bit may also be changed. This will cause more problems.

**Example 1**: When the parity bit is changed, when at the same time, one bit of the character is changed ex. 100101**1** → 100001**0**

**TRUE/FLASE:** The parity checking mechanism will detect the error?
*Answer:* False, parity checking will report no error

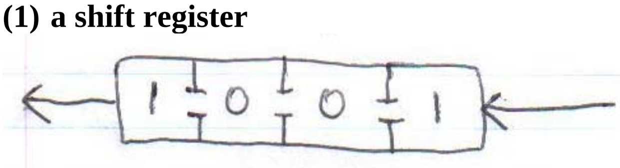
**Summary**: In real world, since the probability that only one bit is changed is much larger than other cases, parity checking is good thing and can detect most errors.

## CRC Checking – for packets

- totally done by hardware – part of the NIC
- very very quick

The hardware has 2 components:

**(1) a shift register**

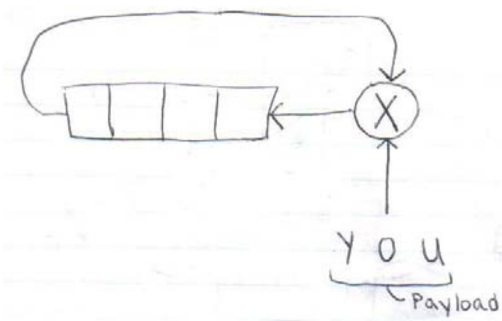



- one directional
- only one door to get in and one door to get out
- The register has one operation called a shift; During a shift, the leftmost bit will move out and all the other bits will move left one cell

**(2) XOR operator**

| A | B | A (XOR) B |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

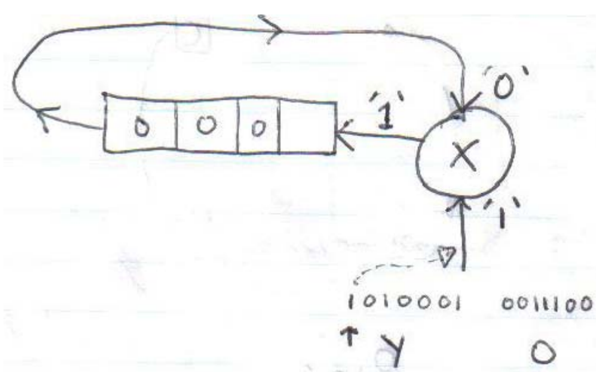
**A CRC Checker:**



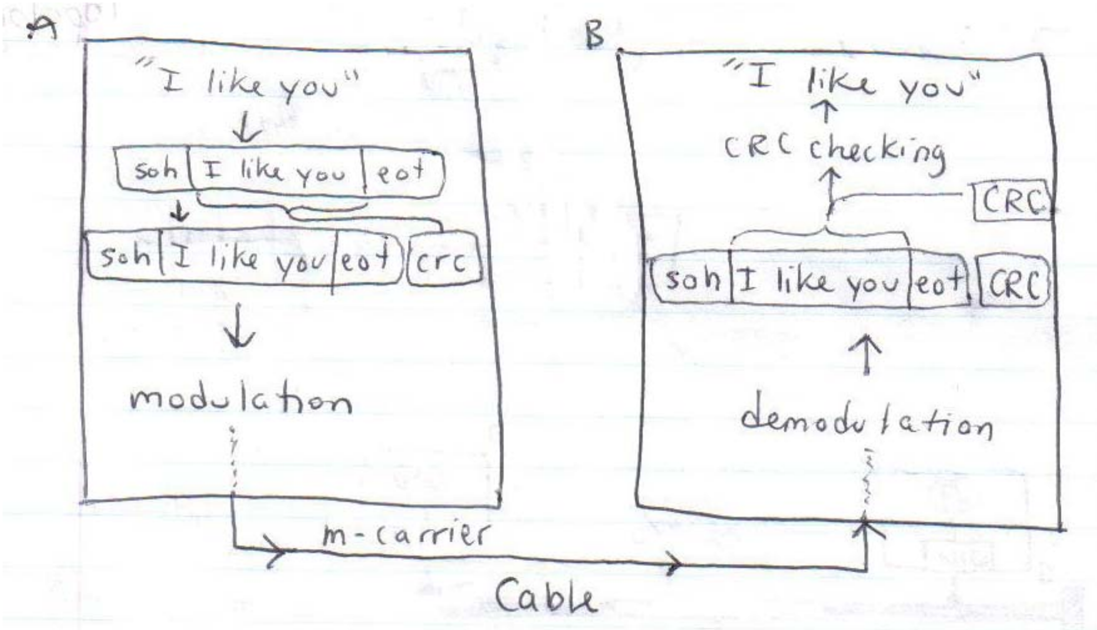

The goal of this hardware is to generate the CRC for each packet which is attached to each packet, much like a parity bit

**To compute CRC**

(1) Initialize the register with "0000"
(2) Process the payload from left to right, bit by bit
    a. For each bit we do 4 steps:
        i. Shift
        ii. Feed back
        iii. XOR
        iv. Move in
(3) After all the bits in the payload are processed, the bits that remain in the register are the CRC




(1) Before comp. A sends out the packet, comp. A will compute the CRC
(2) When comp. B receives the packet, comp. B will re-compute the CRC and compare it with the received CRC
    a. If they are the same report "no error"
    b. Otherwise, report error

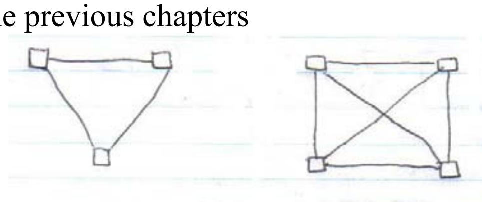



**Character**
- Use parity checking
  - in some rare cases, a parity bit can be changed

**Packets**
- use CRC checking
- no need to use parity bits

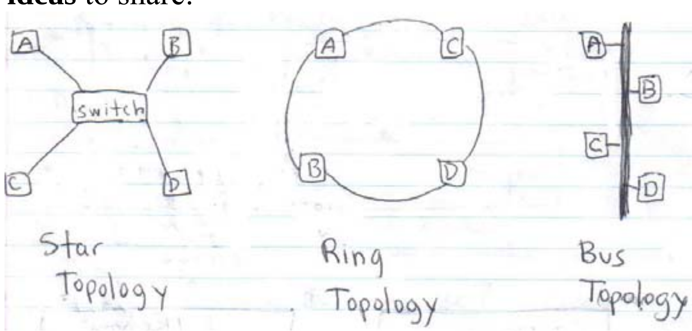
## Chapter 8 & 9

**Naive idea:** one to one communication: connect every two computers so we can use the technologies learned in the previous chapters

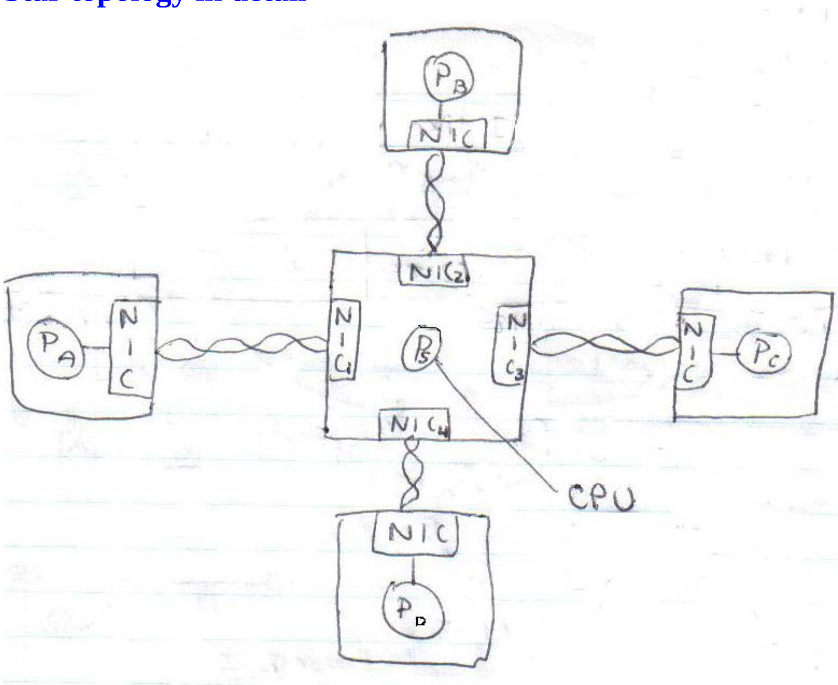


**Problem** – too many cables. We need new technologies. The key idea is to <u>share</u> transition media.

There are **3 main ideas** to share:

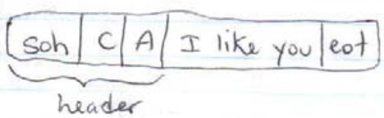


## Star topology in detail



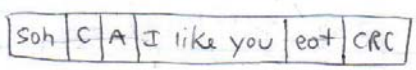

When computer A sends a message to computer C,

(1) P-A will compose the packet




(2) P-A forwards the packet to NIC-A

(3) NIC-A will calculate the CRC




(4) NIC-A modulates the packet → sends out

(5) After a while, NIC-1 will receive the m-carrier

(6) NIC-1 demodulates the m-carrier

(7) NIC-1 puts the packet into the queue

(8) After a while, P-S will check this packet because the destination is "C" computer. P-S will only forward the packet to NIC-3

(9) NIC-3 will modulate the packet → send out

(10) After a while, NIC-C will receive the m-carrier

(11) NIC-C demodulates the packet

(12) NIC-C will do CRC checking; if this fails, the packet will be discarded

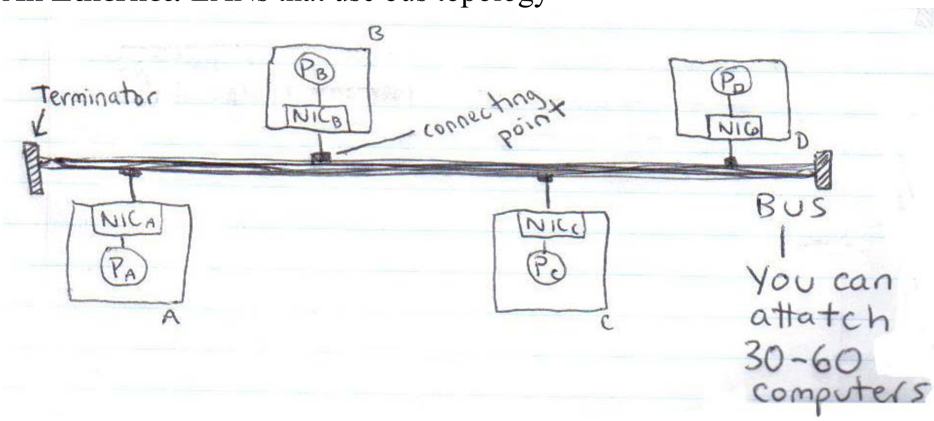
(13) If the packet passes CRC checking, NIC-C will strip off soh, eot, crc, and send "|C|A|I Like You|" to P-C

* "C" in header signifies the destination – destination field is needed for switching
  "A" in header signifies the sender – sender field is needed for receiver

## LAN Technologies

1980s: Ring → IBM Token Ring
1990s: Bus → Ethernet
2000s - Now: Star → switched LAN (robust, simple)

**An Ethernet:** LANs that use bus topology




**Easy Case**: At one point of time, only one computer is sending.
Suppose Computer A wants to send a message to computer B

**Step 1**: PA composes the packet
**Step 2:** NIC-A will calculate the CRC
**Step 3:** NIC-A modulates the packet; sends out the m-carrier

**Q1**. This m-carrier will go which direction on the bus?
*Answer:* Both

**Q2.** After the m-carrier that goes left reaches the left end, what will happen?
*Answer:* If we do not put on the terminator, the m-carrier will be bounced back.

**Step 4:** After a while, NIC-C will sense this m-carrier, demodulate this m-carrier, and put the packet in its cache.

**Q3.** In your opinion, at this moment, has NIC-B sensed the m-carrier or not?
*Answer:* Yes, NIC-B will also demodulate → cache
*Idea:* When a signal is on the bus, everybody can sense it.

**Step 5:** NIC-C will check if the packet is for Computer C or not; if not, discard.
**Step 6:** If yes, NIC-C will do two checkings (if either fails, discard):
(1) length checking: the payload should be 46 ≤ size ≤ 1500 characters
(2) CRC Checking
**Step 7:** If all checks are passed, NIC-C will strip off soh, eot, and CRC; then forward "|C|A|I Like You|" to P-C.

**Hard Case:** Multiple computers are sending packets (or messages) simultaneously.
Suppose Computer A sends M1 to Computer C and Computer D sends M2 to Computer B simultaneously

## The Collision Problem

Could we avoid collision?

**Basic Solution:** CSMA (Carrier Sense Multiple Access)

a.) Before any packet is sent out, the sender will first senses its connecting point to see if the bus is idle.
b.) If nothing is sensed, it will send out a packet, otherwise it will wait until nothing is sensed.

**Q1**. Do you believe that CSMA can avoid all collisions?

*Answer:* NO, can help to avoid many, but not all

**Advanced Solution:** CSMA/CD (CD = Collisions Detection)

Idea: To make an Ethernet simple, cheap, profitable, collisions are not avoidable. So, we want to:

- Firstly, be able to detect all collisions
- Then, we can retransmit

Details: during the whole transmission period of any packet (after it is send out) the sender keeps on sensing the bus. If any other m-carrier is sensed, stop transmitting instantly; wait for a random amount of time; then retransmit.

**Q2**. Why do we wait a random amount of time?

*Answer*: So that we are sure that there isn't as great a chance that the packets collide again

**Q3.** After the collision, who will NOT detect the collision?

*Answer:* Every computer will sense the collision

**Q4.** When a NIC senses a collided m-carrier, will the NIC card demodulate it?

*Answer*: Yes, there is no discrimination. You have to demodulate the packet in order to know if it is corrupted.

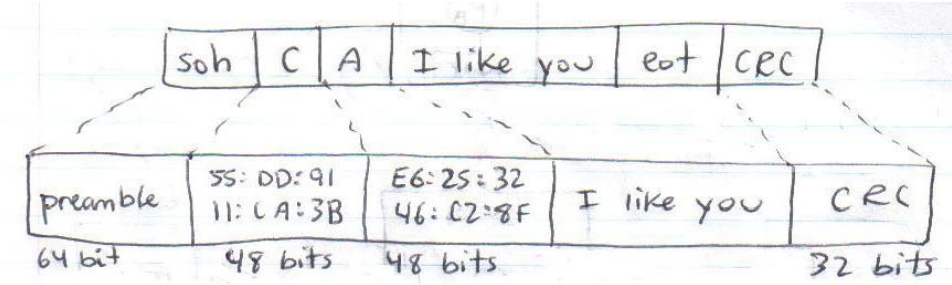
**Q5.** When a NIC senses a collided m-carrier, will the NIC forward the packet to the processor?

*Answer*: NO. The packet will be discarded by the NIC.

In real Ethernet, end packet is in a specific format.

a.) There is no EOT
b.) SOH is replaced by 64 bit preamble
c.) Destination is no longer a computer name like 'C.' Instead, it is replaced by a MAC address, also called a physical address. Ex. E6:25:32:46:C2:8F

Therefore, the packet looks totally different:




**Note:** Each NIC has a unique MAC address.

## Chapter 10 – LAN wiring

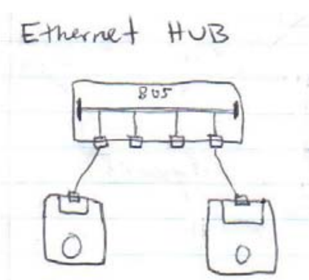
There are multiple ways to wire a LAN.

LAN wiring schemes (industry standards):

(1) 100BaseT – Project 2
(2) 10Base2 – 1990s
(3) 10Base5 – 1970s & 1980s
(4) 10BaseT – 1990s
(5) Fiber optic

100BaseT: 100 = 100 MB
Base = No multiplexing
T = Twisted Pair

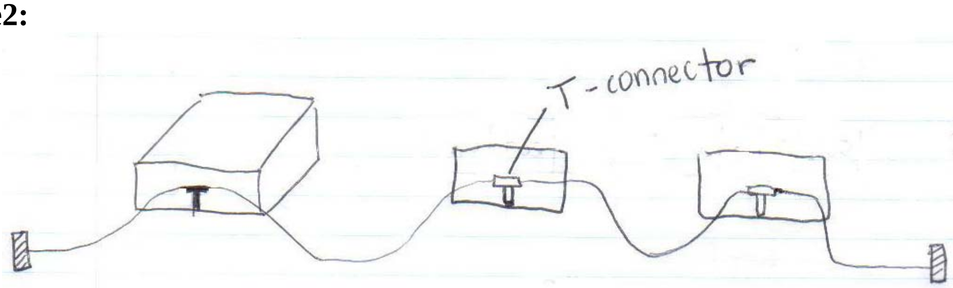
To wire a switched LAN, RJ-45 connectors are used




The length limit for each twisted pair is 100 meters.

100BaseT was developed from 10BaseT.

**10Base2:**



Uses a T Connector = BNC = British Navy Connector

a. fragile
b. difficult to maintain

Bus → Coaxial cable → Thinnet

**Q1**. What does the "2" mean in 10Base2

Answer: Max distance is 200 meters (max distance in real world = 185 meters)

**Q2.** If you unplug a T-connector, what will happen?

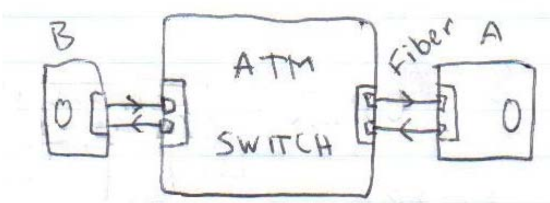
Answer: Crashes the whole LAN

**Q3**. If you unplug a terminator, what will happen?

Answer: the whole network goes down

10BaseT uses a HUB; therefore, if one RJ-45 connector is disconnected, the others still function.

**Fiber Optic:**




- Transfer rate up to 2 Gbps!
- too expensive
- difficult to maintain
- fragile

| **Wiring Schemes** | **Speed** | **Distance** | **Install** | **Interference** | **Cost** | **Star or Bus** |
|---|---|---|---|---|---|---|
| **10Base2** | 10 MBps | 185 M | Medium | Somewhat resistant | Inexpensive | Bus |
| **10Base5** | 10 MBps | 500 M | More diff. | More Resistant | More | Bus |
| **10BaseT** | 10 MBps | 100 M | Easy | Highly susceptible | Least | Star/Bus |
| **100Base T** | 100 MBps | 100 M | Easy | | Least | Star/Bus |
| **Fiber** | 10 Mbps → 26 Gbps | 2000 M | More diff. | Not susceptible | Most expensive | Star |

# Chapter 11

## A. Intro.

We learned how to wire a LAN using such wiring schemes such as 100BaseT and 10Base2, but every wiring scheme has distance limitations.

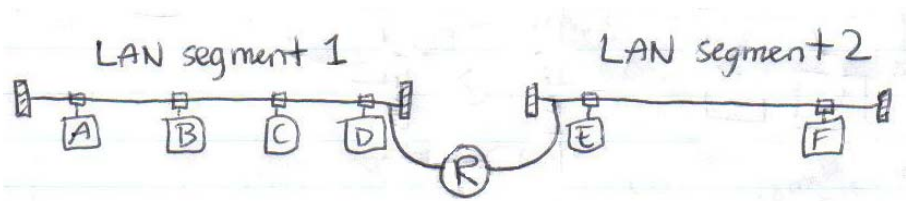
The max distance between two computers using 100BaseT and a switch is 200 M (100 M for each)

But, we still cannot achieve a campus wide LAN! – We need to extend LANs
Four techniques

- Fiber Modems – expensive and fragile, seldom used
- Repeaters, early 90s
- Bridges, better
- Switches

## B. Using Repeaters:

Let's use 10Base2 as an example:




R, the repeater, is an analog electronic device that amplifies and replies m-carriers from one segment to another.

**Note:** The repeater is totally different from the repeaters used in phone switches. (no demodulation or modulation, just amplification)

**Q1**. When there is a collision on segment 1, will NIC-F sense the collision?
*Answer*: YES
**Q2**. (T/F) R1 can detect collisions happening on segment 1.
*Answer*: False
**Q3**. Repeaters can extend your LAN, but do you believe we can use 99 repeaters to connect 100 LAN segments and still make the LAN work?
*Answer:* Won't Work!

Why won't this work?

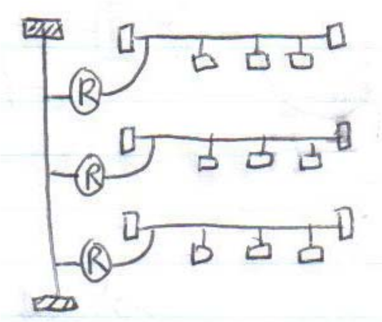
Reason 1: repeaters will also amplify distortions, so accumulated distortions will cause a lot of errors.

Reason 2: Now the 100 buses are connected into a super long hallway which is (a.) too busy and (b.) too many collisions, and repeaters will propagate collisions.

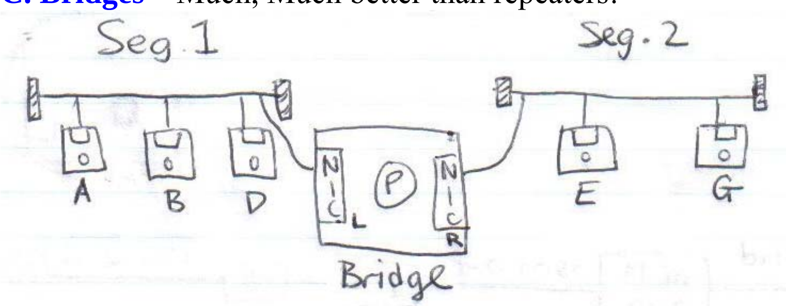
Because of the two reasons, industry uses a 5-4-3 rule:

(a.) at most 5 segments, 4 repeaters, 3 populated segments (a segment with a computer attached)

How people use the 5-4-3 rule optimally:

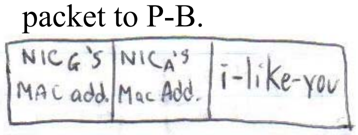



**C. Bridges** – Much, Much better than repeaters!




Step 1: P-A composes the packet
Step 2: NIC-A will calculate CRC and attach CRC.
Step 3: NIC-A uses CSMA/CD to send out the packet
Step 4: After a while, NIC-L, will sense the m-carrier,

(a.) demodulate
(b.) put into cache
(c.) length checking
(d.) CRC checking
(e.) NIC-L will strip off the CRC & preamble, and forward the following to packet to P-B.




Step 5: P-B will check the destination address of this packet, if this address is for a computer on segment 1, the packet will be discarded; otherwise, the bridge should forward the packet because the destination is on segment 2.
Step 6: Once NIC-R receives the packet:

(a.) calculate CRC
(b.) add preamble
(c.) use CSMA/CD to send out

Step7: After a while, NIC-G will sense the m-carrier ….

Q1. If the packet was sent from computer A to computer B, will P-B see the packet?
*Answer*: Yes, because NIC-L will not do address filtering.

Q2. If there is a collision on segment 1, will P-B know of this collision?

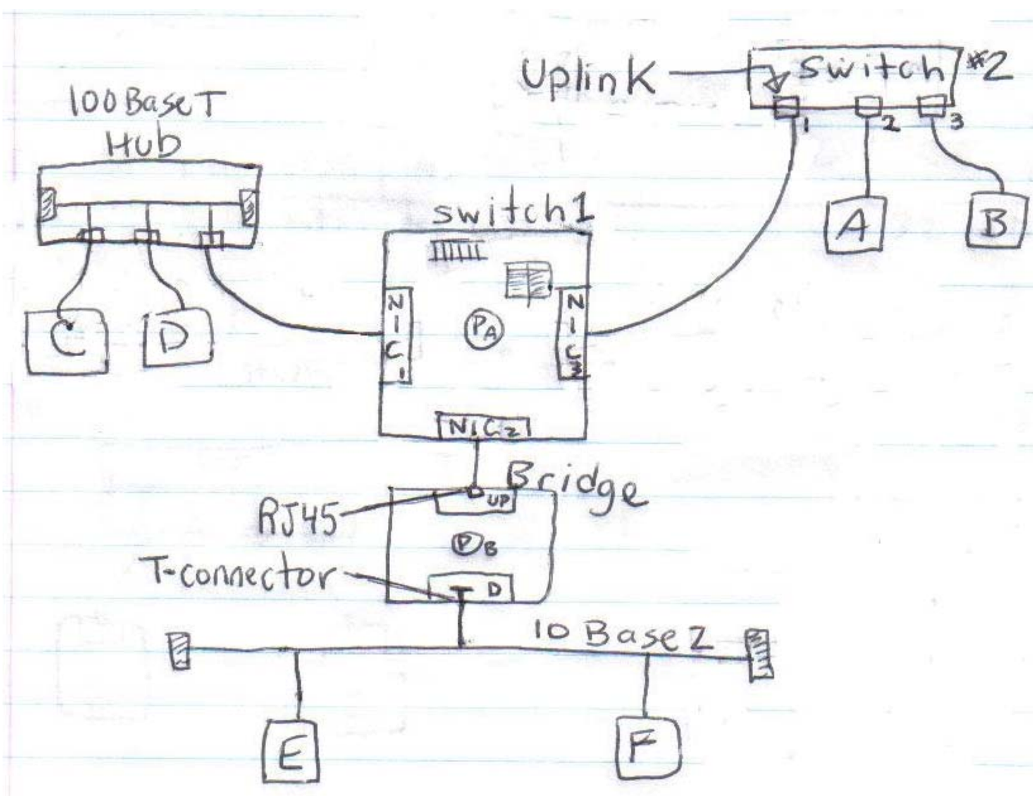
*Answer*: No, because NIC-L will do CRC checking and discard the packet. So, bridges <u>block</u> collisions.

Q3. When we use bridges, do we need to follow the 5-4-3 rule?

*Answer:* No. Signal distortion will be propagated when we use repeaters, but never with bridges.

## D. Switches:

A hybrid LAN




Assume computer A wants to send a message to computer E

Step 1: P-A composes frame with MAC addresses and message

Step 2: NIC-A will add preamble and CRC to the frame (no CSMA/CD), modulate, and send out the packet.

Step 3: NIC-2-2 will (a.) demodulate (b.) put into cache (c.) forwarded to P-S2

Step 4: P-S2 will check the destination address and find that the packet should be forwarded to switch 1 (S1).

Step 5: NIC-2-1 will modulate and send out (no CSMA/CD)

Step 6: After a while, NIC-1-3 will get the packet, demodulate, put into cache, and forward to P-S1.

Step 7: Now, P-S1 has some trouble because he needs to know where to forward. To solve this problem, he needs a <u>forwarding table</u>.

| Destination Address | Where to go? |
|---|---|
| NIC-C's MAC | NIC-1-1 |
| NIC-E's MAC | NIC-1-2 |
| NIC-B's MAC | NIC-1-3 |
| …....for every computer | ....... for every computer |

Step 8: Based on the forwarding table, the packet will be forwarded to NIC-1-2. NIC-1-2 will modulate and send out the packet.
Step 9: NIC-UP will do exactly the same thing as NIC-L did before
Step 10: P-B will send to NIC-D
Step 11: NIC-E will sense the m-carrier, demodulate, cache, add filtering, length checking, CRC checking, strip off preamble and CRC → P-E
Step 12: Computer E displays the message.