Ethernet

Surasak Sanguanpong
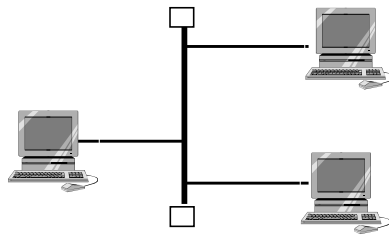*nguan@ku.ac.th*
http://www.cpe.ku.ac.th/~nguan
Last updated: 11 July 2000

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

Ethernet and IEEE 802.3

- **Developed during the mid- 1970s at Xerox Palo Alto Research Center (Bob Metcalfe)**
- **Later refinement by DEC, Intel and Xerox (DIX standard)**
- **Became IEEE 802.3 in 1985**
- **Different frame format between Ethernet and IEEE 802.3**
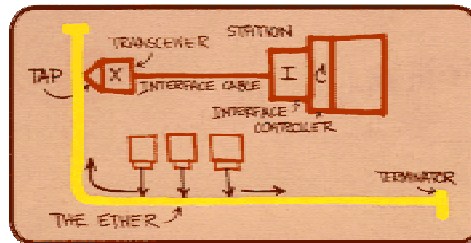
Applied Network Research Group   Department of Computer Engineering, Kasetsart University

Xerox performed initial development of Ethernet and was joined by the Digital Equipment Corporation (Digital) and Intel to define the Ethernet 1 specification in 1980. The same group subsequently released the Ethernet 2 specification in 1984. The Ethernet specification describes a CSMA/CD LAN.

The IEEE 802.3 subcommittee adopted Ethernet as its model for its CSMA/CD LAN specification. As a result, Ethernet 2 and IEEE 802.3 are identical in the way they use the physical medium. However, the two specifications differ in their descriptions of the data link layer. These differences do not prohibit manufacturers from developing network interface cards that support the common physical layer, and software that recognizes the differences between the two data links.

A Drawing of the First Ethernet System

http://www.ots.utexas.edu/ethernet/ethernet.html

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

``*The diagram ... was drawn by Dr. Robert M. Metcalfe in 1976 to present Ethernet ... to the National Computer Conference in June of that year. On the drawing are the original terms for describing Ethernet. Since then other terms have come into usage among Ethernet enthusiasts."*

The Ethernet Sourcebook, ed. Robyn E. Shotwell (New York: North-Holland, 1985), title page.

For a report on the experimental Ethernet system by two of the inventors see:

Robert M. Metcalfe and David R. Boggs. ``Ethernet: Distributed Packet Switching for Local Computer Networks," Association for Computing Machinery, Vol19/No 5, July 1976.

Ethernet architecture
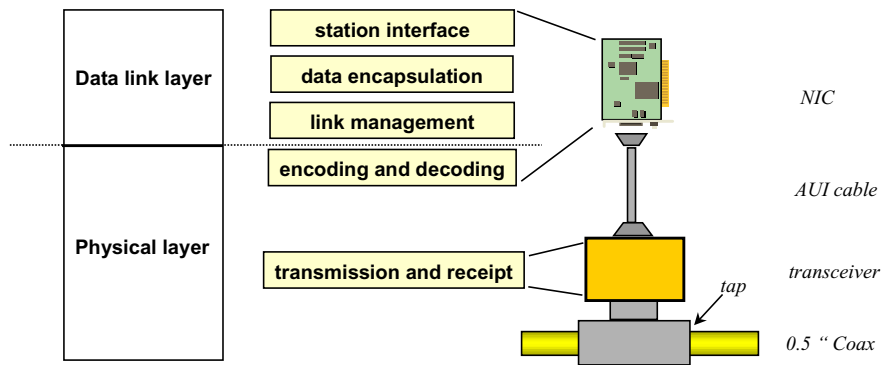
The IEEE 802.3 10Base5 supports 10 Mbps baseband transmission. The standard specifies the 0.5 inch diameter coaxial cable (normally yellow cable) , known as *yellow cable* or *thick Ethernet*. Up to a maximum of 5 cable segments can be connected using repeaters with maximum length of 2500 m.

Multi segments network
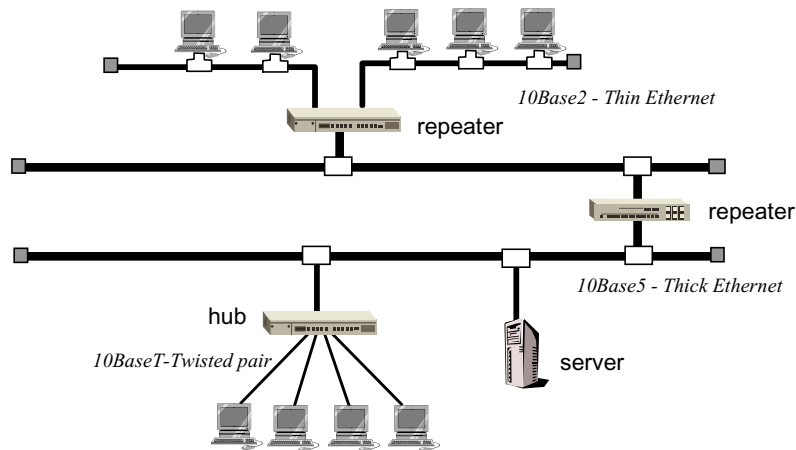
10Base2 - Thin Ethernet

repeater

repeater

10Base5 - Thick Ethernet

hub

10BaseT-Twisted pair

server

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

The Ethernet and IEEE 802.3 standards define a bus-topology LAN that operates at a baseband signaling rate of 10 Mbps. The graphic illustrates the three defined wiring standards:

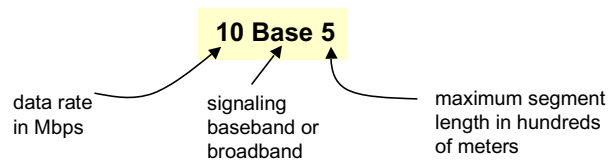 10Base2 - known as *thin Ethernet* - allows network segments up to 185 meters on coaxial cable.

• 10Base5 - known as *thick Ethernet* - allows network segments up to 500 meters on coaxial cable.

• 10BaseT - carries Ethernet frames on twisted pair wiring

The 10Base5 and 10Base2 standards provide access for several stations on the same segment. Stations are attached to the segment by a cable that runs from an attachment unit interface (AUI) in the station to a transceiver that is directly attached to the Ethernet coaxial cable. In some interfaces, the AUI and the transceiver are built in to the network interface card and no cable is required.

Because the 10BaseT standard provides access for a single station only, stations attached to an Ethernet by 10BaseT are connected to a hub. The hub is analogous to an Ethernet segment, and the twisted-pair cable is analogous to the cable running between the AUI and the transceiver.

IEEE 802.3 specification

- **Various standard defined for IEEE802.3 with a concise notation**
  - 10Base5 -- thickwire coaxial
  - 10Base2 -- thinwire coaxial or cheapernet
  - 10BaseT -- twisted pair
  - 10BaseF -- fiber optics
  - 10Broad36 -- broadband
- **Fast Ethernet**
  - 100BaseTX, 100BaseT4, 100BaseF

10 Base 5

data rate
in Mbps

signaling
baseband or
broadband

maximum segment
length in hundreds
of meters

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

10Base5

- **tap :** cable does not to be cut
- **transceiver :** send/receive, collision detection, electronics isolation
- **AUI :** Attachment Unit Interface
- Use for backbone networks
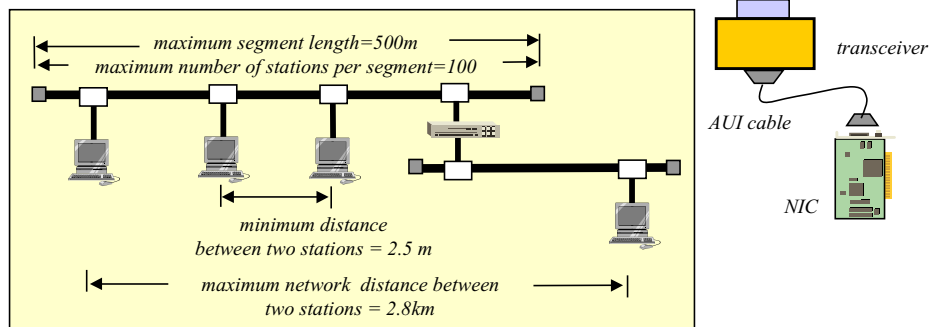
∅0.5" Coax *vampire tap*

transceiver

AUI cable

NIC

maximum segment length=500m
maximum number of stations per segment=100

minimum distance between two stations = 2.5 m

maximum network distance between two stations = 2.8km

Applied Network Research Group　　　Department of Computer Engineering, Kasetsart University

The IEEE 802.3 10Base5 supports 10 Mbps baseband transmission. The standard specifies the 0.5 inch diameter coaxial cable (normally yellow cable) , known as *yellow cable* or *thick Ethernet*. Up to a maximum of 5 cable segments can be connected using repeaters with maximum length of 2500 m.

The length of 500 meters per segment is limited. This restriction is due to the maximum permissible attenuation along the cable. If the segment is too long, collision detection can not be guaranteed, since the signals may be too weak.

At most 1024 stations per Ethernet are allowed. This figure is not derived from the above limitation. This restriction is intended to reduce the congestion probabilities.

10Base2

- **BNC connector**
- **No drop cable**
- **use for office LAN**

0.25 " Coax (RG58)

BNC T-connector

NIC

maximum segment length=185m
maximum number of stations per segment=30

minimum distance
between two stations = 0.5 m

maximum network distance between
two stations = 925 m

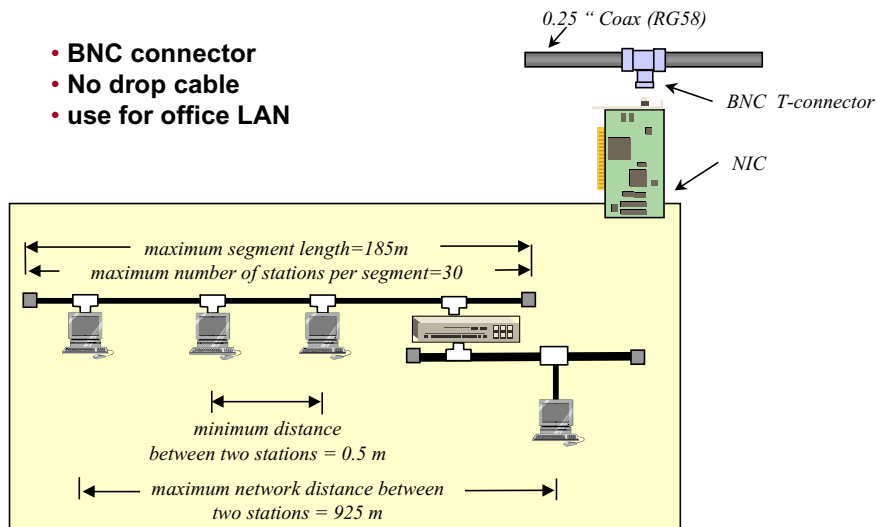Applied Network Research Group   Department of Computer Engineering, Kasetsart University

The IEEE 802.3 10Base2 supports 10 Mbps baseband transmission. The standard specifies the 0.25 inch diameter coaxial cable known as *cheapernet* or *thin Ethernet.* Up to a maximum of 5 cable segments can be connected using repeaters for a maximum span of 925 m. The length of each segments is limited to 185 m.

10BaseT

- **A hub functions as a repeater**
- **use for office LAN**

hub

*maximum segment
length = 100m*

NIC
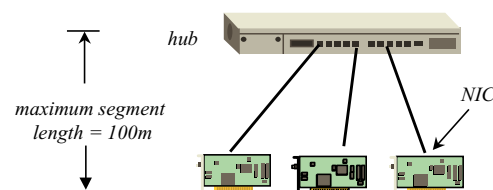
The IEEE 802.3 10BaseT supports 10 Mbps baseband transmission. The standard specifies the 24AWG Unshielded Twisted Pair (UTP). Stations connect with RJ45 connector.

10BaseF

- **10BaseF specification enable long distance connections with**
- **the use of optical fiber. Three standards are:**

    - **10BaseFP -** 10-Mbps fiber-passive baseband Ethernet specification using fiber-optic cabling.It organizes a number of computers into a star topology without the use of repeaters. 10BaseFP segments can be up to 500 meters long
    - **10BaseFL** - An asynchronous point-to-point link
        (a new FOIRL) , up to 2 km link

    - **10BaseFB -** A synchronous point-to-point link , up to 2 km link
        with 15 cascade repeaters

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

10base FP defines a passive star topology that supports up to 33 stations attached to a central passive hub.

10BaseFL is a new *Fiber Optic Inter-repeater Link* (FOIRL) with enhanced performance. 10BaseFL connect transceivers opposite each other or to construct a star topology around the hub.

10BaseFB defines point-to-point links with synchronous signaling. Optical signal will be retimed, hence reduced distortions. As a result, 10BaseFB can be used to cascade up to 15 repeaters.

Carrier Sense Multiple Access

● **Station listens to the medium before transmitting *(listen before talking ;LBT)***

● Non persistent CSMA
 ■ if medium is idle, transmit
 ■ if medium busy, waits a random periods an then resense medium

● 1-persistent CSMA
 ■ if medium is idle, transmit
 ■ if medium busy, continue to listen until the channel is sensed idle; then transmit immediately

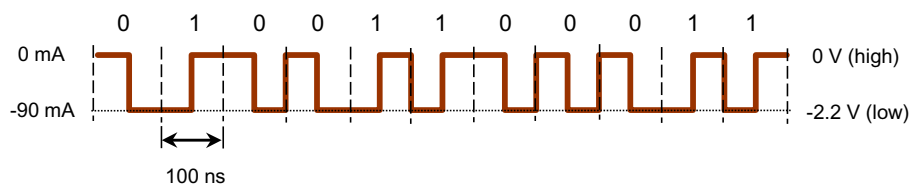Applied Network Research Group   Department of Computer Engineering, Kasetsart University

Nonpersistent: if the medium is busy, a station waits a random period of time and then resenses the medium is it has become free.

1-persistent: when the medium is free, any waiting station may transmit immediately. Waiting stations therefore have probability of transmitting of 1 whenever it finds the channel idle.

Media Access Control technique

- **Carrier Sense Multiple Access with Collision Detection (CSMA/CD)**
- listen before talking
- Station senses to the medium before transmitting : CS
- Topology supports multiple access (listening) : MA
- Manchester encoding ensures a transition every bit
  - 0 : high-to-low
  - 1 : low-to-high

```
         0    1    0    0    1    1    0    0    0    1    1
0 mA    ┌─┐  ┌──┐ ┌─┐  ┌─┐ ┌──┐┌──┐┌─┐  ┌─┐  ┌─┐ ┌──┐┌──┐  0 V (high)
        │ │  │  │ │ │  │ │ │  ││  ││ │  │ │  │ │ │  ││  │
-90 mA  └─┘  └──┘ └─┘  └─┘ └──┘└──┘└─┘  └─┘  └─┘ └──┘└──┘  -2.2 V (low)

          |←→|
          100 ns
```

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

CSMA/CD can be described as a listen-before-talking access method. Before transmitting, a station has to find out whether any station is sending data and, if so, the station defers transmission. During this listening process, each station sense the carrier signal of another function, hence the prefix *carrier sense*.

In a broadband network, carrier signal can be direct detected because RF modems are used to generate a carrier signal. A baseband network has no carrier signal in the conventional sense of a carrier as periodic waveform. However, the carrier can be detected as quasi-carriers from Manchester coding characteristic. There are frequent voltage changes representing bit transitions, so a station can detect that the medium is occupied (The ethernet frame preamble 010101… produces a nice 10 MHz square wave using Manchester encoding).

Collision
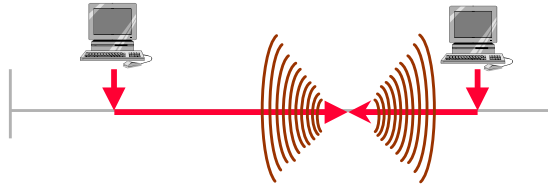
- **More than two station send frame at the same time**
- **Station transmits its data while checking the channel for collision**
- **If average DC voltage level exceeds the CD threshold, collision is detected**

When a station wishes to transmit, it checks the network to determine whether another station is currently transmitting. If the network is not being used, the station proceeds with the transmission. While sending, the station monitors the network to ensure that no other station is transmitting. Two stations might start transmitting at approximately the same time if they determine that the network is available. If two stations send at the same time, a collision occurs.

Collision detection

- **How to detect**
  - **The station sends frame and senses the medium**
  - **Collision detected if**
    - **station senses power exeeding transmitted signal strength (coax)**
    - **there is signal on more than one port (UTP)**
- **How stations react**
  - **Transmitting nodes send a jamming signal after a collision is detected.**
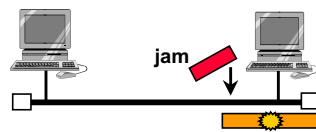
when a collision occurs, the detected station sends a 32-48 bits jam signal consists of 10101010- 10101010- 10101010- 10101010 (10101010-10101010) bit combination [Switching technology in the local area network, M. Hein, ITP,1997].

The jam signal serves as a mechanism to cause nontransmitting stations to wait until the jam signal ends prior to attempting to transmit.

Ethernet frame format

7	1	6	6	2	46-1500	4	
PA	SFD	DA	SA	LEN	LLC PDU	Pad	FCS	IEEE 802.3

calculation of the FCS

64-1518 bytes

8	6	6	2	46-1500	4	
PA	DA	SA	Type	Data	Pad	FCS	Ethernet
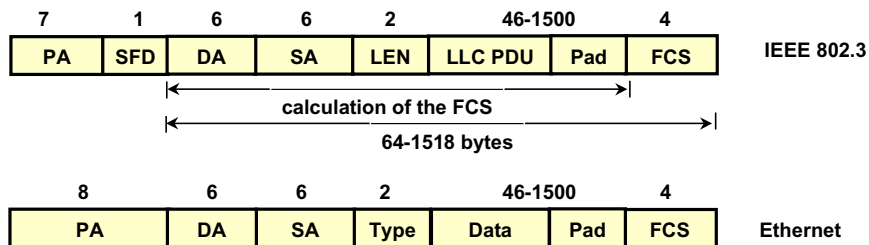
PA : Preamble - 10101010s for synchronization
SFD : Start of Frame delimiter -- 10101011 to start frame
DA: Destination Address -- MAC address
SA: Source Address -- MAC address
LEN: Length -- Number of data bytes
Type: identify the higher -level protocol
LLC PDU+pad -- minimum 46 bytes, maximum 1500
FCS : Frame Check Sequence -- CRC-32

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

From the perspective of these lower MAC sublayers, the service access point (SAP) process provides a convenient interface to the upper layers. These SAP entries simplify access to the shared channel up to the specified upper-layer service identified by LLC SAP entities. LLC carries two 8-bit addresses (the destination SAP and the source SAP) and one byte of control.

LLC sublayer options include support for connections between applications running on the LAN, flow control to the upper layer by means of ready/not ready codes, and sequence control bits.

Ethernet MAC address

Two address format:
- **48 bits**
- **16 bits**

```
  1    1          46
┌───┬───┬──────────────────┐
│I/G│U/L│   46-bit address │
└───┴───┴──────────────────┘

  1        15
┌───┬──────────────────┐
│I/G│  15-bit address  │
└───┴──────────────────┘
```
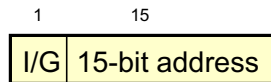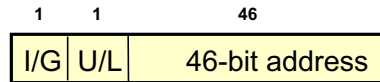
I/G =0 Individual address
I/G =1 Group address
U/L=0 Global administered address
U/L=1 Local administered address

Unicast : define a single destination
Broadcast : FFFFFFFF each station on the network receive and accept frames
multicast : a group address defines multiple recipient

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

The first bit of the address is Individual/Group bit.

Interframe gap

PA	DA	SA	Type	Data	Pad	FCS		PA

Interframe gap > 9.6 μs
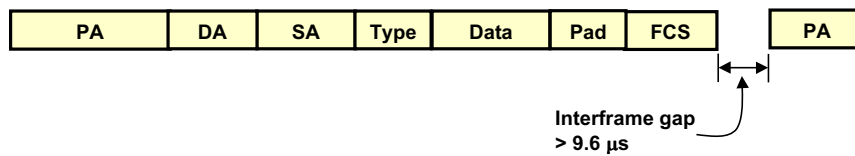
- **Obligatory 9.6μs interval between the emitted frame and the new one**
- **To enable other stations wishing to transmit to take over at this time**

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

The 96 bit-time delay is provided between frame transmissions.

Frame transmission

```
          ┌──────────────────────┐
          ▼
   ┌──────────────┐
   │ Assemble frame │
   └──────────────┘
          │
          ▼
   ◇ carrier sense signal ON ?  ──Y──┐ (loop back)
          │ N
          ▼
   ┌──────────────────────┐
   │ Wait interframe gap time │
   │ Start transmission       │
   └──────────────────────┘
          │
          ▼
   ◇ collision detected? ──Y──→ ┌──────────────────────┐
          │ N                    │ send jam sequence      │
          ▼                      │ Increment attempt.     │
   ◇ transmission done? ─N       └──────────────────────┘
          │ Y                            │
          ▼                              ▼
   ┌──────────────┐            ◇ attempt limited? ──Y──→ ┌──────────────────┐
   │ transmit OK  │                     │ N                │ Compute backoff   │
   └──────────────┘                     ▼                  │ and wait          │
                              ┌──────────────┐             │ backoff time      │
                              │ Discard frame │            └──────────────────┘
                              └──────────────┘
```
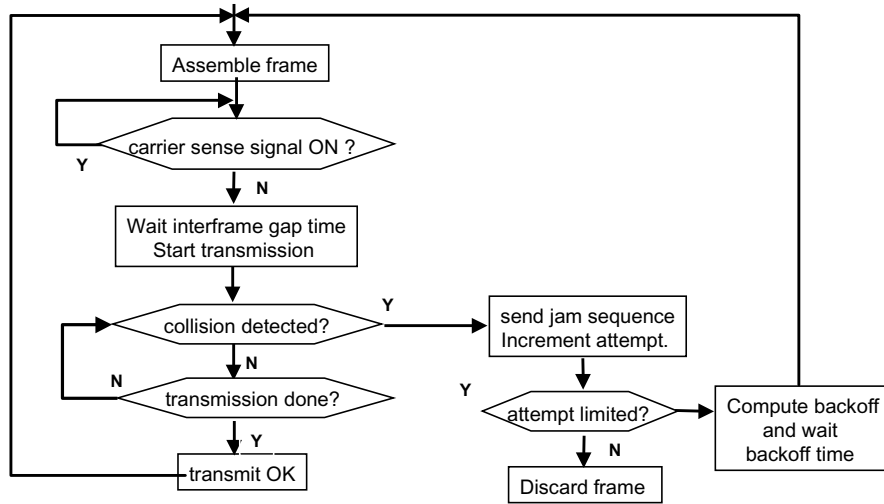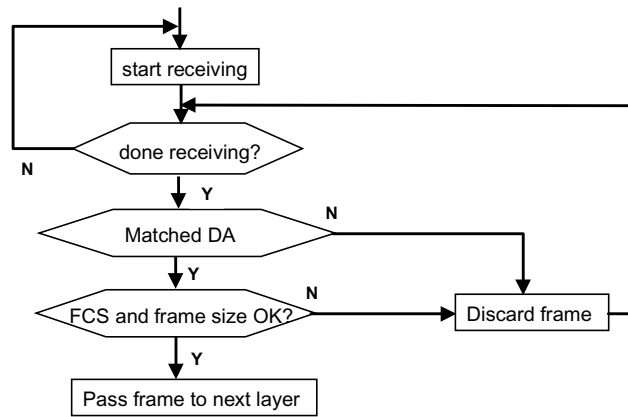
Assemble frame

carrier sense signal ON ? Y / N

Wait interframe gap time
Start transmission

collision detected? Y

send jam sequence
Increment attempt.

transmission done? N / Y

attempt limited? Y / N

Compute backoff
and wait
backoff time

transmit OK

Discard frame

Applied Network Research Group   Department of Computer Engineering, Kasetsart University

Frame reception

Binary Backoff
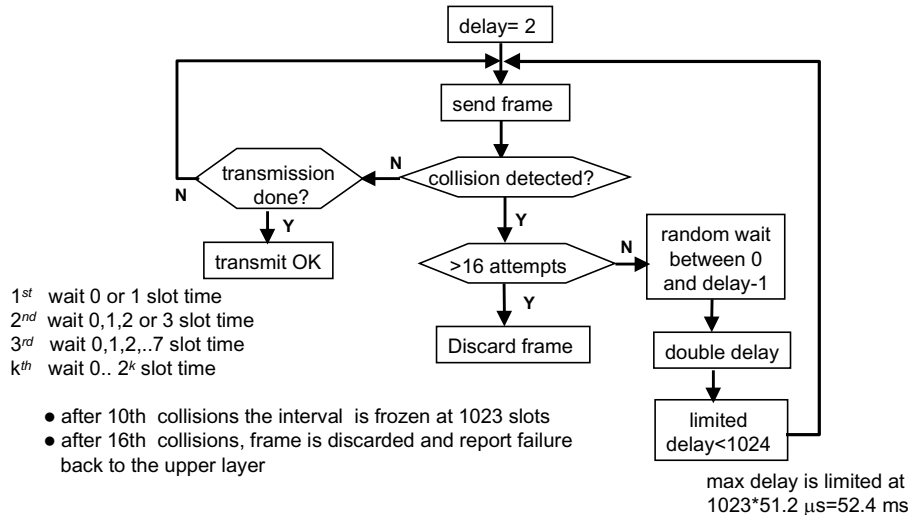
delay= 2

send frame

transmission done?

collision detected?

N

N

Y

transmit OK

>16 attempts

N

random wait between 0 and delay-1

Y

Discard frame

double delay

limited delay<1024

1st   wait 0 or 1 slot time
2nd wait 0,1,2 or 3 slot time
3rd   wait 0,1,2,..7 slot time
kth   wait 0.. 2^k slot time

● after 10th collisions the interval is frozen at 1023 slots
● after 16th collisions, frame is discarded and report failure
   back to the upper layer

max delay is limited at
1023*51.2 μs=52.4 ms
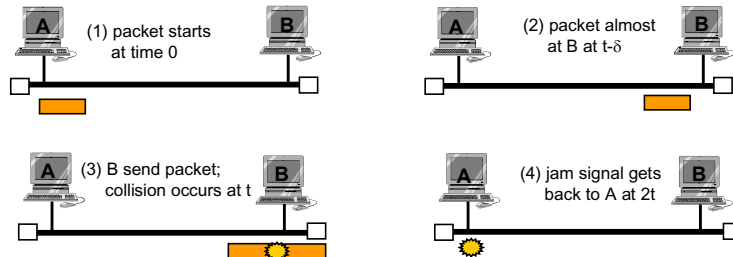
Applied Network Research Group   Department of Computer Engineering, Kasetsart University

Ethernet uses the *truncated binary exponential backoff algorithm* to handle collision. When a collision occurs, the station sends a jam, then ceases all transmission.After the first collision, each station waits either 0 or 1 slot time before trying again. If two stations collide again because they pick the same random number, then each station randomly selects either 0,1,2 or 3 and wait that number of slot times (known as *delay windows*). After the *k* collisions, a delay window between 0 and 2^k is chosen. Finally, after the tenth attempt (*backoff limit*), this window is limited by 1023 slot times. The attempt can continue up to the sixteenth times (*attempt limit*) with the same delay number. If a collision occurs again, that MAC layer discards the frame and reports a failure to upper layers.

The exponential growth of randomization interval ensures a low delay when only a few station collides, but also ensures that the collision is resolved in a reasonable time when many stations collide.

Minimum frame size

A and B located at the far ends of the cable

(1) packet starts at time 0

(2) packet almost at B at t-δ

(3) B send packet; collision occurs at t

(4) jam signal gets back to A at 2t

- A frame must take more than 2t to send to prevent the situation that the sender incorrectly concludes that the frame was successfully sent.
- This slot times equal 51.2 μs corresponds to 512 bit (64 bytes)
- The minimum frame length is 64 bytes (excluding preamble)
- This answers why data field must have 46 bytes minimum

Applied Network Research Group

Department of Computer Engineering, Kasetsart University
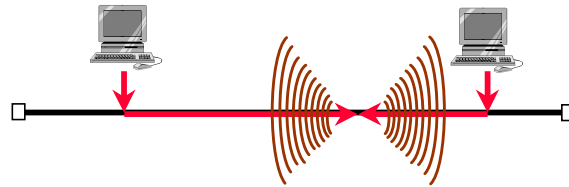
Late Collision

- **Late collisions are collisions which occur after the first 64 bytes have been transmitted on to the network**
- **Primary causes: excessive cable lengths and repeaters**

A late collision is the detection of a collision after a station places a complete frame on the network. A late collision is normally caused by an excessive network cable length, resulting the sender incorrectly concluding that the frame was successfully sent. The detection of a late collision is exactly the same manner of a detection of normal collision; just only later than normal.

Excessive cable lengths, an excessive number of repeaters, faulty connector or defective network interface card can also result in late collisions.