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King Fahd University of Petroleum & Minerals
Computer Engineering Dept

COE 541 – Design and Analysis of Local Area Networks

Term 051

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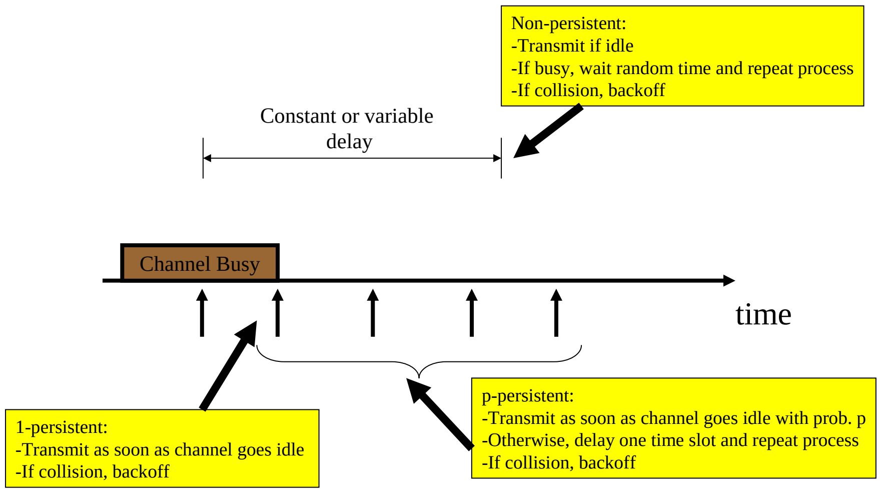
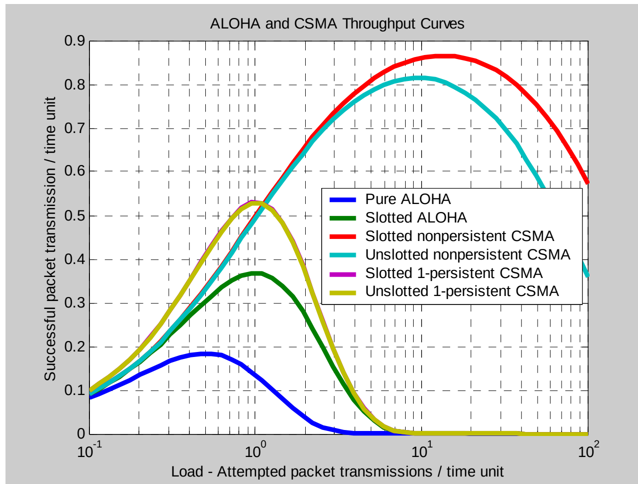
CSMA Protocols - Summary



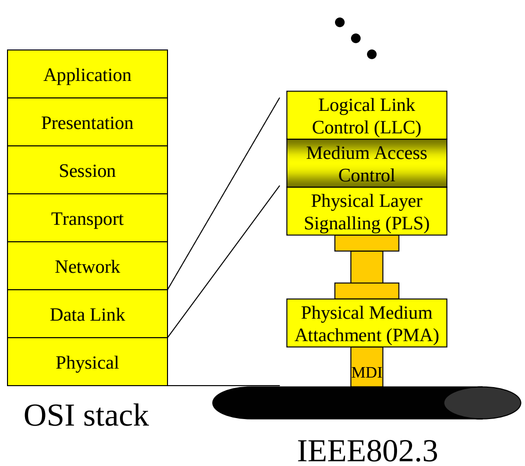
Throughput Figures for CSMA Protocols – cont'd

- For a = 0.01
- How does the performance look like for a ~ 1? What about a >> 1?

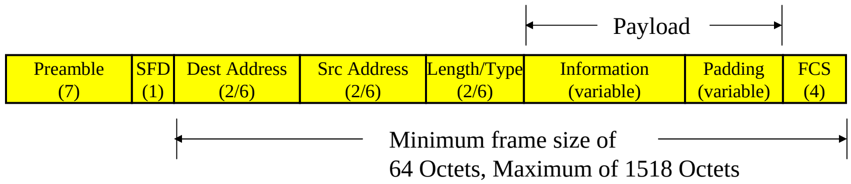


Medium Access Control

- MAC: is a medium independent facility built up the medium-dependent physical layer
- Two main functions:
  - Data encapsulation (framing, addressing, error detection), and
  - Media access (media allocation and contention resolution)



Medium Access Control Frame Structure



- Frame transmitted from left-to-right, with each field (except FCS) transmitted LSB first
- Preamble: pattern of 101010… - for synchronization
- SFD (Start of Frame Delimiter): 10101011

Medium Access Control Frame Structure – cont'd

- Destination Address – most implementations use 6 bytes
  - I/G – bit (unicast, multicast, broadcast)
  - U/L bit (locally administered addresses versus universally administered addresses – the 2nd type is the dominant
  - Of the form: XX-YY-ZZ-ab-cd-ef
    - Organization Unique Identifier (OUI): XX-YY-ZZ
    - A unique identifier (assigned at the time of manufacturing): ab-cd-ef
    - Use the command "ipconfig /all" to know the MAC address of your network card!
- Source Address – to identify the source station

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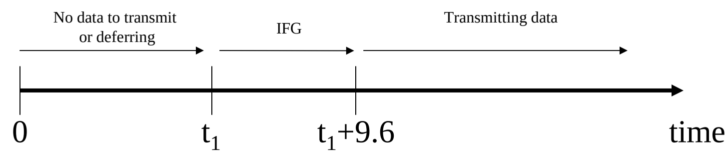
Medium Access Control Frame Structure – cont'd

- Length/Type
  - IEEE802.3 – length of information field – range: 0000_{16} (zero bytes) to $05DC_{16}$ (1500 bytes)
  - Ethernet – EtherType code to indicate the type or protocol of the information (0600 Xerox NS IDP, 0800 Internet Protocol, 0806 ARP, etc.)
  - EtherType codes CAN NOT be confused for frame lengths – Why?
- Information and Padding
  - Padding (mostly 0s) is added to make the length of the information field 46 octets
- FCS: the following generator polynomial is used: $X^{32}+X^{26}+X^{23}+X^{22}+X^{16}+X^{12}+X^{11}+X^{10}+X^{8}+X^{7}+X^{5}+X^{4}+X^{2}+X+1$

CSMA/CD Operation – No Collision

- When station has data to transmit
  - MAC layer monitors channel (Carrier Sense signal from PLS)
  - When channel idle – defer for Inter-Frame Gap (IFG)
    - IFG – a fixed gap of 9.6 μsec (for 10Base-T)
  - When IFG expires – station can transmit using PLS signalling function



CSMA with Collision Detection (CSMA/CD)

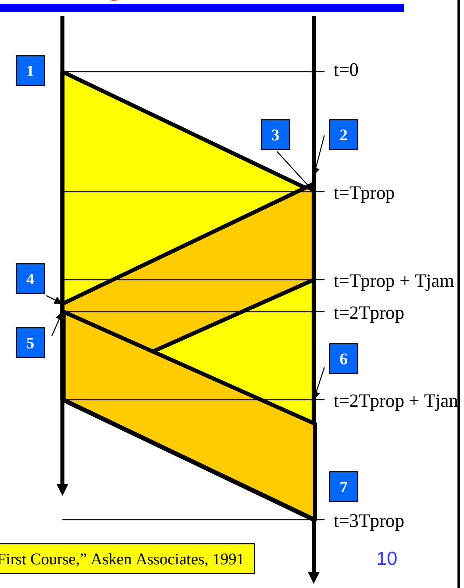
- Used for wired LANs
- Adopted in the IEEE802.3 (Ethernet) standard
- Can support up to Giga bits per second
- The MAC protocol
  1) Wait until the channel is idle
  2) Transmit and listen while transmitting
  3) If collision, stop packet, transmit a jam signal, and then wait for a random delay
  4) Goto (1)
- Protocol gives up transmission after 16 attempts

Note: no feedback mechanism for CSMA/CD is required

CSMA with Collision Detection (CSMA/CD) – Timing Diagram

Collision Scenario

1. A starts transmitting
2. B starts transmitting
3. A's transmission reaches B
   - B detects collision and transmits a jamming signal
4. B's transmission reaches A
5. A detects collision and transmits a jamming signal
6. The jamming signal transmission is complete – A stops
   - All stations on bus are aware of collision
7. A's jamming signal reaches B – Channel is clear after 3Tprop +Tjam



Based on Figure 5.9 of Jean Walrand, "Communication Networks: A First Course," Asken Associates, 1991

CSMA/CD – Timing Diagram – cont'd

- CSMA/CD is a "polite version" of ALOHA
  - (Listen before talk rule)
  - ALOHA is designed for long propagation links – carrier sensing is inefficient – collisions will be detected long after packets are transmitted
- A Node detect collision while transmitting when its transceiver measures excessive current on the cable
- The maximum collision detection time equals twice the propagation time
- The minimum packet length allowed has to exceed the collision detection window + the longest jamming pattern (32 to 48 bits)

With 1-persistent

Binary Exponential Back-off

- For a terminal that have collided n (n=1, …,15) successive times (station aborts if the 16th collision occur):
  - Choose a random number K from set {0, 1, 2, …, 2^m-1}, where m = min(10,n) – uniform distribution
  - Wait for K time slots – slot time = 512 bits or 51.2 μsec
  - E.g. after first collision – terminal waits either 0 or 1 time slot – after 2nd collision – terminal waits either 0, 1, 2, or 3 time slots, and so on
- The probability of repeated collisions is reduced significantly
  - **E.g.** What is the probability that two terminals will collide the third time if they have collided 2 consecutive times?
  - **Soln:** = Prob[both choose the same random number for the 4th time] = 8 X 1/8 X 1/8 = 1/8

CDMA/CD – Performance

- Time slot = 2 X Tprop
- The time which guarantees that all terminals know (receives the jamming signal) of the collision
- By 3 X Tprop – the channel is clear
- Efficiency of CSMA/CD ≈ 1/(1+3a)
  where a = Tprop/Tframe

CDMA/CD – Performance – cont'd

Proof:

Prob[1 terminal transmits] = β = $Np(1-p)^{N-1}$

This probability is maximized if p = 1/N

For large N ➔ Prob[1 terminal transmits] = $\beta \approx 0.4$

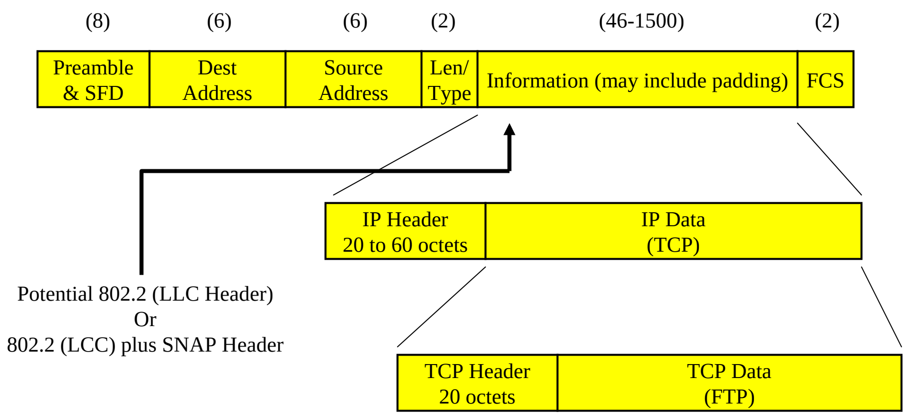
Let A be number of time slots waisted till a successful tx goes through, therefore A = βX0 + (1- β)X(1+A)

➔ A = 1.5

Therefore Efficiency = Tframe/(Tframe + 1.5X2*Tprop), or
= 1/(1+3a)

Actual performance is closer to = 1/(1+5a)

Data Encapsulation



Fast Ethernet

- Introduced by IEEE802.3u – know as 100Base-X:
  - 100Base-T4: 100 Mb/s over 4 pairs of CAT-3, 4, 5
  - 100Base-TX: 100 Mb/s over 2 pairs of CAT-5, STP
  - 100Base-FX: 100 Mbps CSMA/CD over 2 fibers
  - 100Base-T4)
- Uses same scalable MAC as in IEEE802.3/Ethernet
- Segment length ≈ 205 meters (as opposed to 2.5 km for IEEE802.3/Ethernet)

Fast Ethernet Repeaters

- Repeaters (class I/II) used to extend range with limitations
  - Class I: connect dissimilar devices – large internal delays – a maximum of 1 repeater per maximum length segment
  - Class II: multiport – connect similar devices – relatively smaller internal delays – a maximum of two repeaters per maximum length segment
- Functionality: Reception and transmission of data, plus collision and error handling
  - Faithfully reproducing any signal including code violations
  - I.e. Collision domain is NOT split
- Jamming signal propagated to all connected ports

Gigabit Ethernet

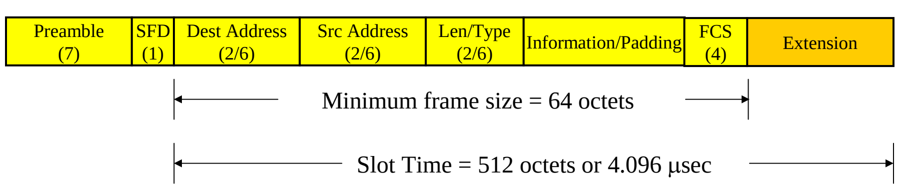
- IEEE802.3z defines an extended MAC and a set of physical layers for the gigabit Ethernet
- 1000Base-LX (long wavelength optical), 1000Base-SX (short wavelength optical), 1000Base-CX (sheilded twisted pair), and 1000Base-T (category 5 UTP – defined in IEEE802.3ab)
- The original MAC protocol is extended to allow the network to operate at 1 Giga bit per second
- Range ≈100 meters 1000Base-T with Cat 5 UPT

Gigabit Ethernet – MAC Extension

- Recall for fast Ethernet (using both class I/II repeaters) and employing copper segments – the network diameter ≈ 200 meters ➔ therefore at 1 Gb/s, the network should shrink to 20 meters – not practical
- MAC extensions:
  - Carrier Extension
  - Frame Bursting
- In reality – these and CSMA/CD are rarely used in the field since most deployments employ full-duplex switched star-like solutions!!

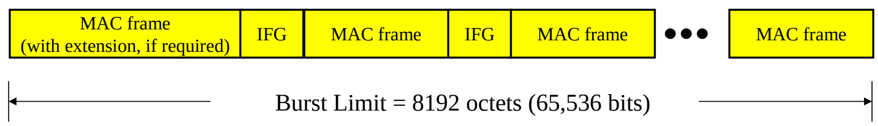
MAC Extension – Carrier Extension

- Minimum slot time is increased from 64 octets to 512 octets by padding
- Frames that are 512 octets or longer do not require extension
- The maximum frame size of 1518 octets remains the same
- Note – for short frames, the network efficiency is less than 64/512 = 12.5% !!



MAC Extension – Frame Bursting

- Devices are allowed to optionally transmit multiple frames without relinquishing the transmission medium
- First frame transmitted with extension if needed – subsequent frames are transmitted with IFG filled with extension bits
- Transmission limit: 8192 octets
- Increases efficiency by 3 folds for half-duplex mode



Note – IFG time = 0.096 μsec

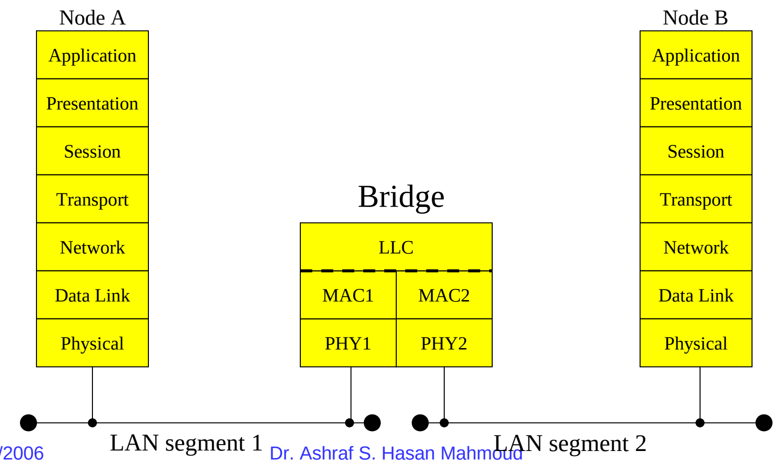
10 Gigabit Ethernet

- 10 Gigabit Ethernet MAC and media independent interface as specified in IEEE 802.3ae
- Same MAC protocol as before – half-duplex operation is not supported
- Lower rates are also supported using pacing mechanisms
- BER of 10^{-12} !!
- Range:
  - To 100m on Class F (Cat 7)
  - To at least 55m on Class E (Cat 6)

Main source: www.ieee802.org/3/10GBT/public/ nov03/10GBASE-T_tutorial.pdf - November 10, 2003

Switched Ethernet

- Bridge is a layer 2 device
  - Transparent – end stations need not know of their existence



Bridges versus Switches

- Switches are also a layer 2 device
  - Switches can perform bridges functions + a little more
- Switches operate at (or near) wire speed – Latency is less
- Switches tend to be connected to end systems as opposed to LAN segments – a switch usually has higher port density compared to a bridge
- Classes of switch:
  - store-and-forward: function similar to bridge - slower
  - cut-through: frame is forwarded as it is being received - faster
- Both bridges and switches split/isolate collision domains

Bridge/Switch Applications

- Isolating areas of high utilization
- Linking geographically distant LANs
- Virtual LANs
- Creating Secure Environments
  - Bridge filter table
- Constructing failure tolerant networks

- Issues: broadcast storms

References

1. Philip Miller and Michael Cummins, "LAN Technologies Explained," Digital Press, 2000
2. Jean Walrand, "Communication Networks: A First Course," Asken Associates, 1991
3. www.ieee802.org/3/10GBT/public/nov03/10GBASE-T_tutorial.pdf
4. http://www.10gea.org/
5. http://www.cis.ohio-state.edu/~jain/refs/gbe_refs.htm (contains many references)