CSMA (Carrier Sense Multiple Access)

**CSMA**: listen before talk (transmit (LBT))
- If channel sensed idle: transmit entire frame
- If channel sensed busy, defer transmission

Human analogy: don’t interrupt others!
CSMA

• We could achieve better throughput if we could listen to the channel before transmitting a packet
• This way, we would stop avoidable collisions.
• To do this, we need “Carrier Sense Multiple Access,” or CSMA, protocols
Assumptions with CSMA Networks

1. Constant length packets
2. No errors, except those caused by collisions
3. No capture effect
4. Each host can sense the transmissions of all other hosts
5. The propagation delay is small compared to the transmission time
CSMA (cont’d)

• There are several types of CSMA protocols:
  – 1-Persistent CSMA
  – Non-Persistent CSMA
  – P-Persistent CSMA
1-Persistent CSMA

• Sense the channel.
  – If busy, keep listening to the channel and transmit immediately when the channel becomes idle.
  – If idle, transmit a packet immediately.

• If collision occurs,
  – Wait a random amount of time and start over again.
1-Persistent CSMA \((cont\’d)\)

The protocol is called 1-persistent because the host transmits with a probability of 1 whenever it finds the channel idle.
The Effect of Propagation Delay on CSMA

A

packet

B

carrier sense = idle

Transmit a packet

Collision
1-Persistent CSMA with Satellite Systems

Satellite system: long prop. delay (270 msec)

Carrier sense makes no sense

It takes 270 msecs to sense the channel, which is a really long time

Vulnerability time = 540 msec

(1/2 a second is forever in a network!)
1-Persistent CSMA (cont’d)

• Even if prop. delay is zero, there will be collisions

• Example:
  – If stations B and C become ready in the middle of A’s transmission, B and C will wait until the end of A’s transmission and then both will begin transmitted simultaneously, resulting in a collision.

• If B and C were not so greedy, there would be fewer collisions
Non-Persistent CSMA

• Sense the channel.
  – If busy, wait a random amount of time and sense the channel again
  – If idle, transmit a packet immediately

• If collision occurs
  – wait a random amount of time and start all over again
Tradeoff between 1- and Non-Persistent CSMA

• If B and C become ready in the middle of A’s transmission,
  – 1-Persistent: B and C collide
  – Non-Persistent: B and C probably do not collide

• If only B becomes ready in the middle of A’s transmission,
  – 1-Persistent: B succeeds as soon as A ends
  – Non-Persistent: B may have to wait
3.3.3 P-Persistent CSMA

• Optimal strategy: use P-Persistent CSMA
• Assume channels are slotted
• One slot = contention period (i.e., one round trip propagation delay)
P-Persistent CSMA (cont’d)

1. Sense the channel
   - If channel is idle, transmit a packet with probability $p$
     • if a packet was transmitted, go to step 2
     • if a packet was not transmitted, wait one slot and go to step 1
   - If channel is busy, wait one slot and go to step 1.

2. Detect collisions
   - If a collision occurs, wait a random amount of time and go to step 1
CSMA (cont’d)

Nonpersistent strategy

• reduces chance of collisions
• reduces the efficiency

Persistent strategy

• increases the chance for collisions
• 1-persistent
• p-persistent
CSMA/CD collision detection

collision detect/abort time

A B C D

t₀ t₁

space

HMG/HUT MAC Protocols
(CSMA) June 2004
CSMA/CD Protocol

All hosts transmit & receive on one channel
Packets are of variable size.

When a host has a packet to transmit:
1. Carrier Sense: Check that the line is quiet before transmitting.
2. Collision Detection: Detect collision as soon as possible. If a collision is detected, stop transmitting; wait a random time, then return to step 1.

binary exponential backoff
CSMA/CD Network Size Restriction

To ensure that a packet is transmitted without a collision, a host must be able to detect a collision before it finishes transmitting a packet.

Events:
- $t=0$: Host A starts transmitting a packet.
- $t=PROP--$: Just before the first bit reaches Host B, Host B senses the line to be idle and starts to transmit a packet.
- $t=PROP-$: A collision takes place near Host B.
- $t=PROP$: Host B receives data whilst transmitting, and so detects the collision.
- $t=2PROP-$: Host A receives data whilst transmitting, and so detects the collision.
CSMA/CD Network Size Restriction

“To ensure that a packet is transmitted without a collision, a host must be able to detect a collision before it finishes transmitting a packet.”

From example on previous slide we can see that for a Host to detect a collision before it finishes transmitting a packet, we require:

$$\text{TRANSP} > 2 \times \text{PROP}$$

In other words, there is a minimum length packet for CSMA/CD networks.
CSMA with Collision Detection (CSMA/CD)

- CSMA/CD can be in one of three states: contention, transmission, or idle.

**Example** of CSMA/CD: Ethernet

- Time taken to detect collisions?
• Collision detection requires a minimum slot time 2 x max. propagation delay ($\tau$) between stations.
• Channel is acquired on 1-persistence basis.
• In case of collision detection a jam signal is put on the channel.
  – And Binary exponential back-off algorithm is used
  – Window size after i collisions (0, $2^{i-1}$) for $i \leq 10$, (0, $2^{10}-1$) for $10 < i \leq 16$
• Channel States: Contention, Idle, Data
Comparison of CSMA and ALOHA Protocols

(Number of Channel Contenders)

HMG/HUT MAC Protocols
(CSMA) June 2004
Performance of CSMA/CD

- Performance (under heavy load) [Tanenbaum]
  Number of stations = K
  P [Transmission in a slot] = p
  P [Some station acquired the channel] = A
  = K (1-p)\textsuperscript{K-1}

\[ A_{\text{max}} = \left(1 - \frac{1}{K}\right)^{K-1} \text{ at } p = \frac{1}{K} \]

\[ A_{\text{max}} \rightarrow \frac{1}{e} \text{ as } K \rightarrow \infty \]
Under heavy load $K$ is large and idle period is negligibly small, $P$ (contention interval is exactly $J$ slots)

$$= A(1-A)^{(J-1)} \text{ [Geometric Distribution]}$$

Mean contention interval

$$= \frac{2\tau}{A} \text{ slots}$$

Channel utilization

$$= \frac{P}{P + \frac{2\tau}{A}}$$

Channel utilization (Optimal p)

$$= \frac{P}{P + 2\tau e}$$
PERFORMANCE OF NON-PERSISTENT CSMA

Cycle time analysis used
Define

\[ a = \frac{\text{Propagation Delay}}{\text{Packet Transmission Time}} \]

In LANs, \( a \ll 1 \)
- All periods are normalized w.r.t packet transmission time.
- Successful Transmission: Packet Transmission followed by no transmission in the interval ‘a’.

![Diagram showing cycle time analysis with variables a and 1]
• Collision of Packets: Transmission of another packet in interval ‘a’ after a packet has started transmission.
• Station 2 senses transmission of $P_1$ at $A(1)+a$, begins packet at $Y [B(1)]$.
• $Y$ is a RV, $0 \leq Y \leq a$
• Channel can be sensed unused at $B(2)+a$
• Unsuccessful busy period: $Y+1+a$
• Idle Period: No transmission following successful or busy period
• Utilization (U): At most one successful transmission during a busy period
• $E[U] = P(\text{no transmission in interval } a] = e^{-aG}$ (Poisson Process)
• \( F_I(x) = P[I \leq x] = 1 - P(I > x) \)

• \( F_I(x) = I - P \) (no of transmission during \( x \)) = 1 - \( e^{-Gx} \)

• \( f_I(x) = Ge^{-Gx}, x \geq 0 \) (Exponential Distribution)

• \( E[I] = 1/G \)
• Busy Period = $B = Y + 1 + a$
• $E[B] = 1 + a + E[Y]$

• $F_Y(y) = P(y <= y) = P(\text{no of arrival duration } a-y)$
  
  $= e^{-G(a-y)}$ (Poisson Process)

• $F_Y(y) = Ge^{-G(a-y)}$

• $E[Y] = G - (1 - e^{-aG})/G$
• \( S = \frac{E[U]}{E[B] + E[I]} \)
  \[ = \frac{Ge^{-aG}}{G(1+2a) + e^{-aG}} \]

\[ \lim_{a \to 0} S = \frac{G}{1+G} \quad \text{for} \quad G \to \infty \]

Similar throughput analyses are available for:

- 1 - persistent CSMA
- p – persistent CSMA
- CSMA / CD