

King Fahd University of Petroleum & Minerals Computer Engineering Dept

COE 540 – Computer Networks
Term 111
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11/20/2011

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Lecture Contents

1. The channel allocation problem
2. Multiple access protocols
3. Ethernet
4. Wireless LANs
5. Broadband Wireless
6. Bluetooth, RFID
7. Data link layer switching

These slides are based on the Tanenbaum's
textbook and original author slide

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Medium Access Control (MAC)

- Data link layer typically divided into
 - Logical link control (LLC), and
 - Medium access control (MAC)
- MAC determined how to access the medium and transmit the information
 - Point-to-point link – MAC is simple
 - Shared media - ?
- The central theme of the chapter is how to allocate a single broadcast channel among competing users.

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The Channel Allocation Problem – Static Allocation

- Traffic:
 - Bursty – data (variable/random intensity)
 - Non-bursty – constant arrival rate (bits, frames, etc.)
- FDM – an example of static allocation scheme
 - System bandwidth B Hz is divided equally between N users – each user has B/N Hz
 - Excellent for non-bursty traffic but VERY poor for highly bursty traffic.
 - Hard capacity limit – if more than N users want to access the channel → blocked
- Same arguments apply for time division multiplexing (TDM) as well

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The Channel Allocation Problem – Static Allocation (2)

- Assume total capacity = C b/s, frames arrive with λ frames/sec and have average length of $1/\mu$ bits, then the mean time delay T is given by

$$T = \frac{1}{\mu C - \lambda}$$

- The above formula is valid for an M/M/1 queue setting
- Now, divide the total capacity in to N sub-channels (FDM or TDM) and let the frame arrivals per sub-channel to be λ/N . The mean time delay now, T_N , is given by

$$T_N = \frac{1}{\mu(C/N) - \lambda/N} = \frac{N}{\mu C - \lambda} = N T$$

- It is clear than T_N is N times the original T – This is referred to by the scaling effect for M/M/1 queues; refer to queueing slides.
- Conclusion – Static allocation is very bad for bursty traffic
 - No need to reserve the channel for the entire duration of the bursty traffic session

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Dynamic Channel Allocation - Assumptions

- Independent traffic – N independent sources (e.g. computers, telephones, users)
 - Average number of arrivals during Δt is equal to $\lambda \Delta t$.
 - Once a frame is generated, the source is blocked till the frame has been successfully transmitted
 - Poisson model – mathematically tractable.
- Single channel – only a single channel is available for all communications
- Observable collisions
- Continuous or slotted time
- Carrier sense versus no carrier sense

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Multiple Access Protocols – Pure ALOHA

- Two versions
 - Pure ALOHA
 - Slotted ALOHA
- Pure ALOHA – users transmit whenever they have data to be sent
- Assumptions:
 - Group of N terminals send frames to a central computer
 - Correctly received frames are acknowledged on the downlink channel
 - Frames not acknowledged (i.e. were not received or not correctly received) are scheduled for retransmission
 - Two or more frame overlapping in time are said to be collided
- ALOHA is a contention system

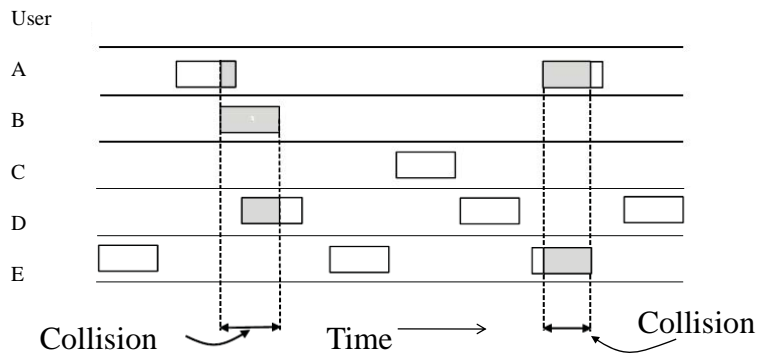
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Multiple Access Protocols – Pure ALOHA (2)

- PURE ALOHA = Start of transmission for frames can be at *any* point in time
- Example below – 5 terminals transmitting frames whenever the frames are ready to be sent
 - Observe the two collision events



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Multiple Access Protocols – Slotted ALOHA (3)

- Slotted ALOHA = Start of transmission for frames can be only at slot border
- Time axis is divided into equal slot periods equal to the frame time
 - Frames arriving in one slot can be transmitted at the beginning of the next slot

Throughput of Pure/Slotted ALOHA (4)

- Throughput – fraction of transmitted frames that are correctly received per frame time.
- Assume new frames generation follow Poisson distribution – average of N frames per frame time
 - Note the channel can handle at most 1 frame per frame time
 - For reasonable throughput we expect $0 < N < 1$.
- Further assume that old and new frames generated follow Poisson distribution – average of G frames per frame time
 - Clearly $G \geq N$
- Throughput, S , is the fraction of G that do NOT collide

$$S = G \text{ Prob [no transmissions from the rest of the population in the vulnerable period]}$$
$$= G P_0$$

where G – frames per frame time represent the average load injected into the system

Throughput of Pure/Slotted ALOHA (5)

- Vulnerable period for pure ALOHA is of length equal to TWO frame time
- Vulnerable period for Slotted ALOHA is of length equal to ONE frame time
- Prob of k frames generated during a given frame time in which G frames are expected is given by the Poisson distribution:

$$P_k = \frac{G^k e^{-G}}{k!}$$

- Therefore, P0 is equal to

$$\begin{aligned} P_0 &= (2G)^0 e^{-(2G)} / 0! = e^{-2G} \leftarrow \text{Pure ALOHA} \\ &= (1G)^0 e^{-(1G)} / 0! = e^{-G} \leftarrow \text{Slotted ALOHA} \end{aligned}$$

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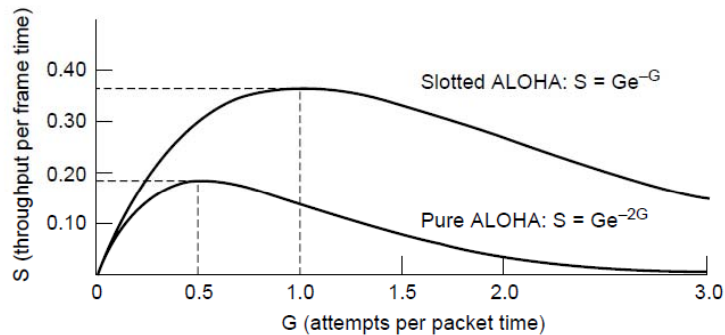
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Throughput of Pure/Slotted ALOHA (6)

- Throughput versus offered traffic



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Throughput of Pure/Slotted ALOHA (7)

- Throughput peak at G^*
 - $G^* = 0.5$ attempt per packet time for pure ALOHA
 - $G^* = 1.0$ attempt per packet time for slotted ALOHA
- For $G > G^* \rightarrow$ collisions increase exponentially \rightarrow throughput approaches zero
- Proof (Slotted ALOHA case)
 - Probability of success = $P_0 = e^{-G}$
 - Prob of failure = $1 - P_0 = 1 - e^{-G}$
 - Consider the random variable (RV) k defined as then number of transmission for packet until it is success $\rightarrow k$ is a geometric RV – refer to discrete RVs material

$$P_k = e^{-G}(1 - e^{-G})^{k-1} \quad \text{for } k = 1, 2, \dots$$

The expected number of transmission can be computed as

$$E = \sum_{k=1}^{\infty} kP_k = \sum_{k=1}^{\infty} ke^{-G}(1 - e^{-G})^{k-1} = e^G$$

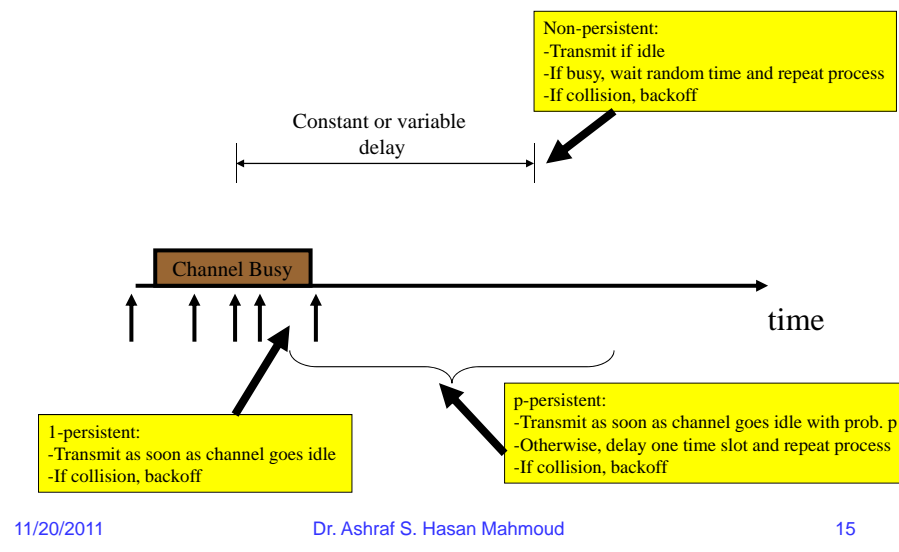
Exponential increase with load

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Carrier Sense Multiple Access Protocols

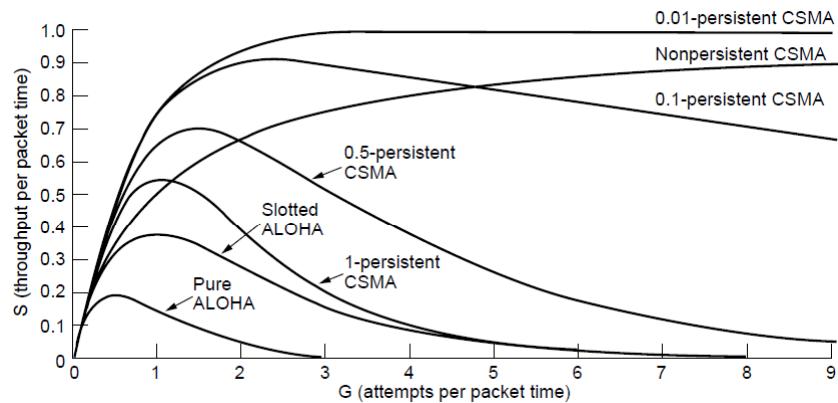


Throughput of CSMA Protocols

- Unslotted Nonpersistent CSMA $S = \frac{Ge^{-aG}}{G(1+2a) + e^{-aG}}$
 - Slotted Nonpersistent CSMA $S = \frac{aGe^{-aG}}{1 - e^{-aG} + a}$
 - Unslotted 1-Persistent CSMA $S = \frac{G[1 + G + aG(1 + G + aG/2)]e^{-G(1+2a)}}{G(1+2a) - (1 - e^{-aG}) + (1 + aG)e^{-G(1+a)}}$
 - Slotted 1-Persistent CSMA $S = \frac{G[1 + a - e^{-aG}]e^{-G(1+a)}}{(1+a)(1 - e^{-aG}) + ae^{-G(1+a)}}$
- $a = T_{prop}T_p$
 T_{prop} = propagation delay
 T_p = packet/frame transmission time
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Throughput of CSMA Protocols – cont'd

- Comparison of the channel utilization versus load for various random access protocols



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CSMA with Collision Detection

- Persistent and nonpersistent CSMA protocols are an improvement over ALOHA protocols. Why?
- An added improvement is CSMA with collision detection – CSMA/CD; the basis for the classical Ethernet LAN
- CSMA/CD model:
 - At t_0 a station has finished transmission
 - Stations may attempt to transmit during the contention period
 - If collision
 - Abort transmission
 - Wait for a random time
 - Retry

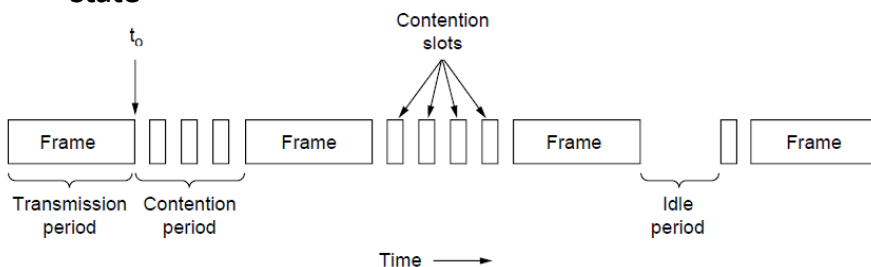
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CSMA with Collision Detection (2)

- CSMA/CD can be in contention, transmission, or idle state



- If two stations begin transmitting at t_0 – How long does it take them to detect the collision?
- A station cannot be sure that it has seized the channel until it has transmitted for 2τ without detecting a collision
 - τ is the signal propagation time for the full cable length

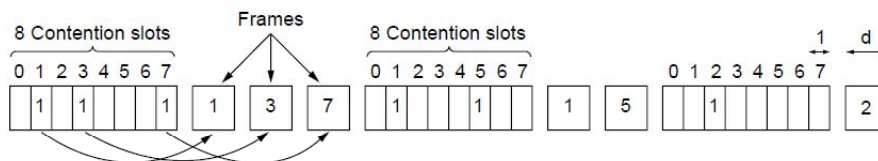
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Collision-Free Protocols – Bit-Map Protocol

- For N stations we have N contention slots
 - There is not real contention here – i th slot is dedicated for i th station.
 - If station i has data to send, then it transmits a bit 1 in its contention slot
- When the N contention slots are complete, all stations (assuming all are listening) have a map of traffic to be sent from all stations
- Refer to the figure.



- Example for $N = 8$; stations 1, 3, and 7 have traffic to send for the first round
- A form of reservation protocol
- Length of contention slot = 1 unit, length of data frame = d units

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Bit-Map Protocol (2)

- Mean access delay:
 - Low numbered stations (such as 0 or 1) – $N/2 + N = 1.5 N$
 - High numbered stations (such as $N-1$ and N) – $N/2$
 - Average = $1.5 N + 0.5 N = N$ for all terminals
- Channel efficiency
 - Low load – $d/(d + N)$
 - High load – $Nd/(Nd + N) = d/(d + 1)$

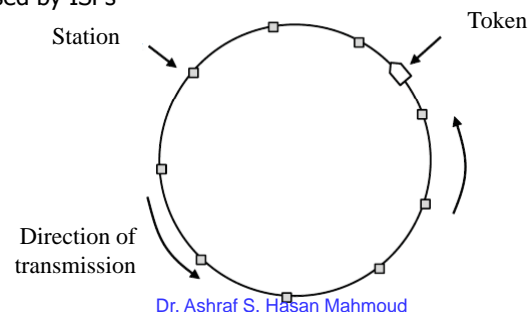
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Token Passing

- Token = permission to send
- Topology determines the order of transmission/permissions
- Frames transmitted in the direction of the token
- Source of destination of frame must remove frame transmission from ring
- Performance –
- IEEE802.5
- Fiber Distributed Data Interface (FDDI)
- Resilient Packet Ring (RPR) – IEEE802.17 ~ 2000's metropolitan area rings used by ISPs



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