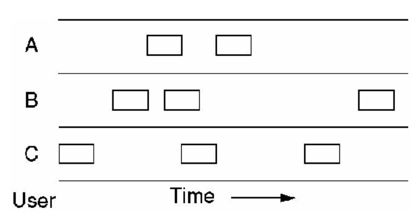
Multiple Access Protocols

- Aloha
- CSMA Protocols
- Collision Free Protocols
- Limited Contention Protocols
- Wavelength Division Multiple Access Protocols
- Wireless LAN Protocols

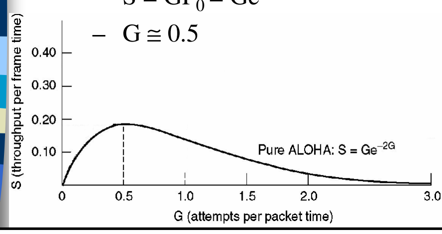
Pure ALOHA

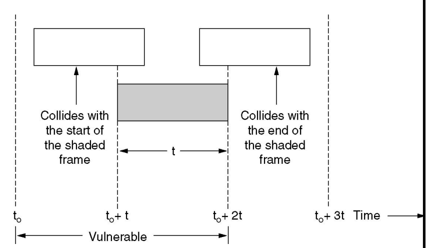
- Dynamic Allocation
  – Stations transmit at completely arbitrary times on a shared channel.
- Therefore there is contention for the channel
  – And this results in collisions,
  – Stations listen to detect collision and then retransmit after a random wait time.



Pure ALOHA (2)

- We must consider the efficiency of this
  - N: average number of frames arriving PER FRAME TIME where ($0 < N < 1$)
  - G: the combined frame rate with retransmitted frames where G >= N
  - $Pr(k) = (G^k e^{-G}) / k!$ This is the probability that k frames are generated during a given frame time. Probability of 0 frames arriving is e^{-G}
  - The vulnerable period for a frame is 2 frames long
  - So the probability of no other traffic is $P_0 = e^{-2G}$
- Throughput
  - $S = GP_0 = Ge^{-2G}$
  - $G \cong 0.5$





MAC Sublayer, Topic 8.[2,3], Multiple Access Protocols

Slotted ALOHA

ALOHA
CSMA
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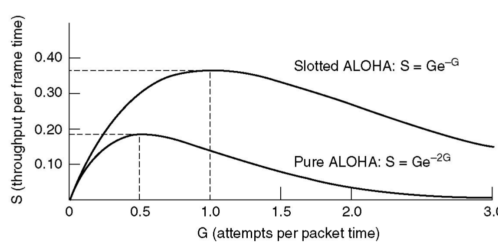
WDMA
Wireless

- Intended to improve the capacity of ALOHA,
- Transmission restricted to discrete timeslots,
- Frames have the same probability of arriving
  - $Pr(k) = (G^k e^{-G}) / k!$
- However the vulnerable period is halved
  - $P_0 = e^{-G}$
- Throughput
  - $S = GP_0 = Ge^{-G}$
  - $G \cong 1.0$



MAC Sublayer, Topic 8.[2,3], Multiple Access Protocols

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CSMA: Carrier Sense Multiple Access

- Stations can detect what is happening,
- 1-persistent CSMA
  - Stations sense the medium and begin transmitting as soon as it idle. Probability to transmit is 1, hence 1-p.
  - If a collision occurs, we must wait a random time and retransmit.
- Nonpersistent CSMA
  - If the line is busy waits a random time, rather than wait for an idle state,
- p-persistent CSMA
  - Applies to slotted channels
  - If the line is idle transmits a frame with probability *p*
- Performance At values of G > 1, the system can never transmit all packets.

MAC Sublayer, Topic 8.[2,3], Multiple Access Protocols

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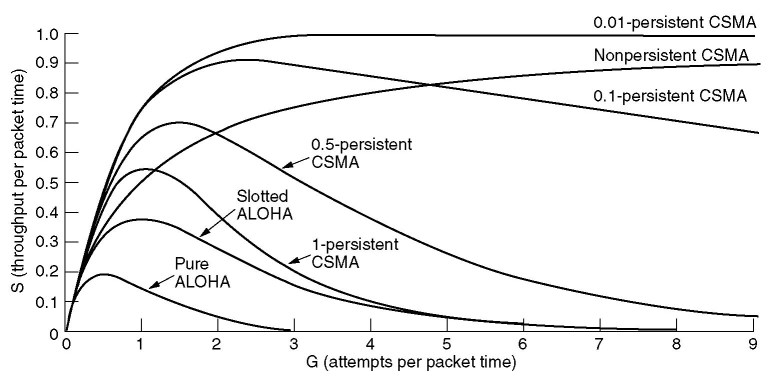
CSMA

- Performance
  - Only considering throughput,
  - What about average delay? Non-persistent CSMA is worse that 1-persistent in terms of average latency,



CSMA / CD: CSMA with Collision Detection

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- Should be able to detect a collision almost immediately so there is no reason to continue transmitting a frame,
- The line can be in one of 3 states:
  - Idle: no stations transmitting,
  - Transmission: one station is transmitting successfully,
  - Contention: multiple stations transmitting
- How long does it take to detect a collision?
  - The minimum time to detect a transmission is the propagation time from one station to the other,
  - The contention period though is twice as long as it is possible for a station to transmit just as the signal arrives.
  - To place an upper bound on the contention period we must place an upper bound on the maximum distance between stations,
  - This also means imposing a minimum length on a frame.

Collision-Free

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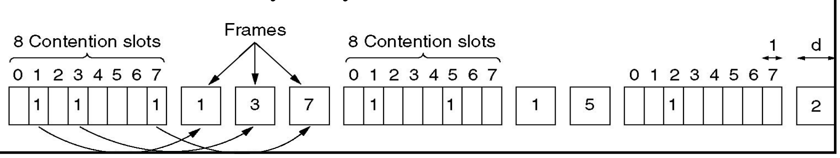
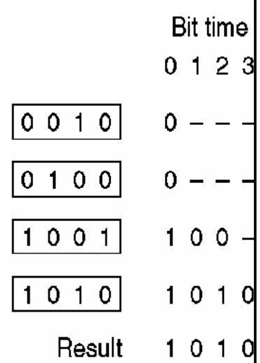
- There are also protocols which prevent collisions
- Assume N stations each with an address (0..N-1)
- Basic bit map method:
  - N contention slots (one for each station)
  - If a station wants to transmit, it transmits a 1 in its slot corresponding to its address,
  - The stations then, transmit their frames in order of their addresses,
  - Performance
    - Low load: stations have to wait on average the length of the contention period (all the contention slots)
    - High load: stations may have to wait until a frame is transmitted by every other station



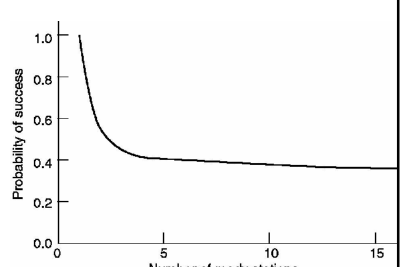
Collision-Free (2)

- Length of contention periods: Each contention slot must be the maximum propagation time
- **Binary countdown method**:
  - Assume N stations with addresses in the range $0..2^N$
  - Use N contention slots,
  - If a station wants to transmit, it transmits its address bits in order ,
  - If a stations sees a higher number, it stops transmitting its station address and waits for the next slot.
- Performance:
  - Low load: we wait for much less time, as there are less contention slots,
  - High load: we have starvation for lower number of stations



Limited-Contention

- Symmetric protocols
  - Each station has the same probability of transmitting
  - p: probability of a station transmitting during a slot,
  - k: number of stations,
  - $kp(1-p)^{k-1}$: probability of some station successfully acquiring the slot
  - The best result for p is $1/k$
  - Probability of success is with an optimal value of p, is $((k-1)/k)^{k-1}$
- Performance
  - To improve probability of success we need to reduce contention.



Limited-Contention (2)

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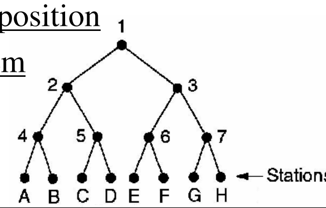
- Adaptive Tree Walk Protocol
  - Start with a single contention slot which any station can claim,
  - If there is a collision then another contention slot is used which any station under 2 can claim,
  - If successful then next contention slot is under 3,
  - This is done until a single station is identified
  - Next time done the tree the order is reversed (3 before 2)
  - Under a heavy load the starting position needs to be dependent on the system load.



WDMA: Wavelength Division Multiple Access

ALOHA
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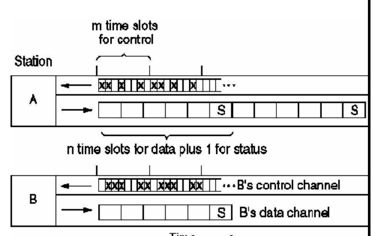
- **Available bandwidth is divided into 2N channels (where N is the no. of stations). Each station is allocated**
  - A Control channel so that other stations can signal it
  - A Data channel so it can transmit data
    - n slots & 1 status slot



- Each station needs
  - Fixed transmitter: to transmit its data and status,
  - Fixed receiver: to receive control requests,
  - Tunable receiver: to sense other data and status
  - Tunable transmitter: to transmit on other control channels

WDMA

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- To set up a connection oriented connection
  - Sense the status slot for the station they want to send data to,
  - Make a connection request using a free control slot
  - Sense the status slot to know control slot was allocated and announce an available data slot in the allocated control slot,
  - Two way communications requires two channels,
  - Fixed data rate can be achieved by dedicating a particular data slot to a particular station,
- Datagram communication (once off message)
  - Indicate "Data in Slot" using the control slot of the receiver,
  - Problem if two stations use the same slot number simultaneously

Wireless LAN

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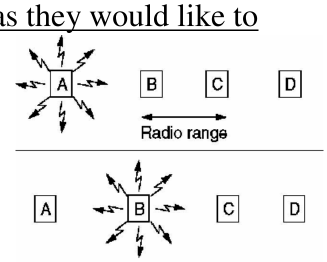
- Problems for wireless networks:
  - Hidden Station Problem: C cannot see that A is transmitting to B. So C might transmit.
    - Result: Collision
  - Exposed Station Problem: C can see that B is transmitting to A, but doesn't know that it could safely transmit to D
    - Result: Wasted Time
- The root of the problem is that the Sender can only detect activity around themselves, whereas they would like to know the activity around the receiver.



Wireless LAN (2)

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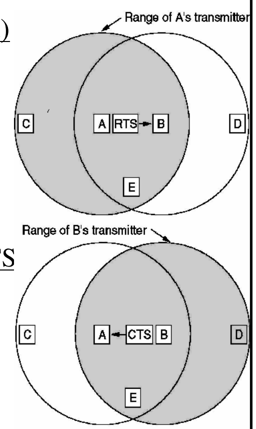
- MACA: Multiple Access with Collision Avoidance
  - Station broadcasts an RTS (Request to Send)
    - Include the length of message to be sent
  - Recipient responds with CTS (Clear to Send)
  - Other stations
    - If they hear an RTS then wait to hear a CTS
    - If they hear a CTS then stay silent
    - If no CTS then stations can send
  - Collisions ?
    - Obviously two RTS messages can collide



Wireless LAN (3)

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- MACA vs. MACA for Wireless
  - In MACA, there were problems without data link layer acknowledgements. MACAW added acknowledgements after each successful frame,
  - MACAW also added carrier sense,
  - The back-off algorithm was run separately for each data stream (source-destination pair), rather than for each station,
  - Congestion control was also added in MACAW.