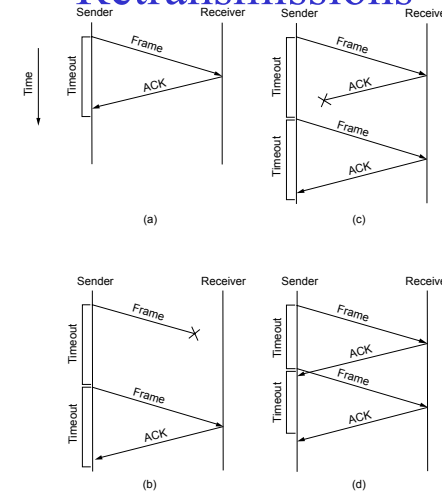


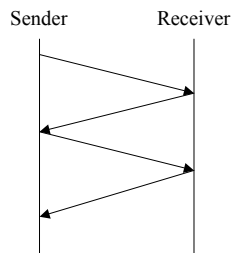
Housekeeping

Acknowledgements, Timeouts &

Retransmissions



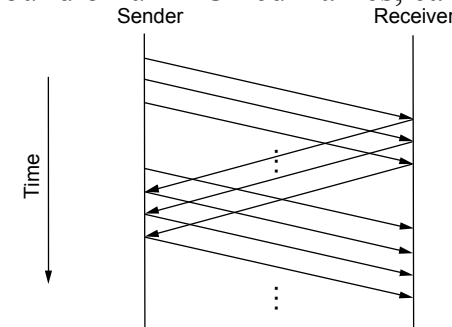
Stop-and-Wait



- Problem: keeping the pipe full
- Example
 - 1.5Mbps link x 45ms RTT = 67.5Kb (8KB)
 - 1KB frames implies 1/8th link utilization

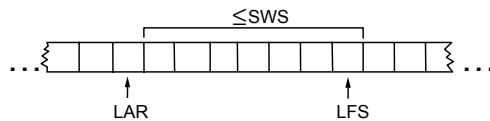
Sliding Window

- Allow multiple outstanding (un-ACKed) frames
- Assume no reordering of frames
- Upper bound on un-ACKed frames, called *window*



SW: Sender

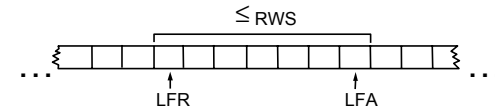
- Assign sequence number to each frame (**SeqNum**)
- Maintain three state variables:
 - send window size (**SWS**)
 - last acknowledgment received (**LAR**)
 - last frame sent (**LFS**)
- Maintain invariant: $LFS - LAR \leq SWS$



- Advance **LAR** when ACK arrives
- Buffer up to **SWS** frames

SW: Receiver

- Maintain three state variables
 - receive window size (**RWS**)
 - largest acceptable frame (**LAF**)
 - last frame received (**LFR**)
- Maintain invariant: $LAF - LFR \leq RWS$



- Frame **SeqNum** arrives:
 - if $LFR < SeqNum \leq LAF \rightarrow$ accepted
 - if $SeqNum \leq LFR$ or $SeqNum > LAF \rightarrow$ discarded
- Send cumulative ACKs

Sequence Number Space

- **SeqNum** field is finite; sequence numbers wrap around
- Sequence number space must be larger than number of outstanding frames
- $SWS \leq MaxSeqNum - 1$ is not sufficient
 - suppose 3-bit **SeqNum** field (0..7)
 - $SWS=RWS=7$
 - sender transmit frames 0..6
 - arrive successfully, but ACKs lost
 - sender retransmits 0..6
 - receiver expecting 7, 0..5, but receives second incarnation of 0..5
- $SWS < (MaxSeqNum + 1) / 2$ is correct rule
- Intuitively, **SeqNum** “slides” between two halves of sequence number space

Questions

- How big should the SWS be?
- How many bits are needed for the seqno field?
- What happens when $SWS \neq RWS$?
- How long should the timeouts be?
- When should reliability be provided at the link layer? At the transport layer?

Concurrent Logical Channels

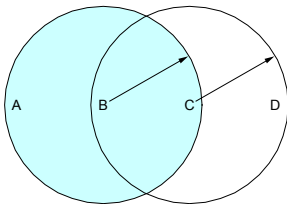
- Multiplex 8 logical channels over a single link
- Run stop-and-wait on each logical channel
- Maintain three state bits per channel
 - channel busy
 - current sequence number out
 - next sequence number in
- Header: 3-bit channel num, 1-bit sequence num
 - 4-bits total
 - same as sliding window protocol
- Separates *reliability* from *order*

Wireless LANs

- IEEE 802.11 family
- Bandwidth: 1, 2 or 11 Mbps, w/ higher proposals
- Physical Media
 - spread spectrum radio (2.4GHz)
 - diffused infrared (10m)

Collisions Avoidance

- Similar to Ethernet
- Problem: *hidden* and *exposed* nodes
- A & C Hidden from each other when sending to B



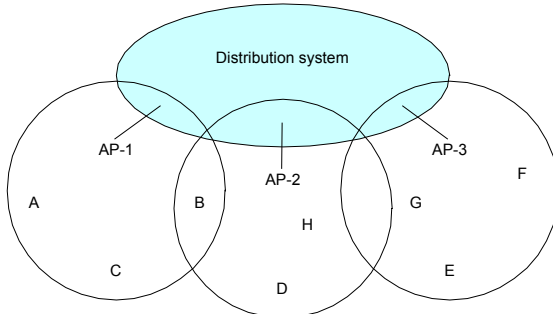
- B exposed to C when C sends to D

MACAW

- Multiple Access with Collision Avoidance for Wireless
- Sender transmits **RequestToS**end (RTS) frame
- Receiver replies with **clearToS**end (CTS) frame
- Neighbors...
 - see CTS: keep quiet
 - see RTS but not CTS: ok to transmit
- Receiver sends **ACK** when has frame
 - neighbors silent until see ACK
- Collisions
 - no collision detection
 - known when don't receive CTS
 - exponential backoff

Supporting Mobility

- Case 1: *ad hoc* networking
- Case 2: *access points* (AP)
 - tethered
 - each mobile node associates with an AP



Fall 2001 9/9

CptS/EE 555

13

Mobility (cont)

- Scanning (selecting an AP)
 - node sends **Probe** frame
 - all AP's w/in reach reply with **ProbeResponse** frame
 - node selects one AP; sends it **AssociateRequest** frame
 - AP replies with **AssociationResponse** frame
 - new AP informs old AP via tethered network
- When
 - active: when join or move
 - passive: AP periodically sends **Beacon** frame

Fall 2001 9/9

CptS/EE 555

14

Spread Spectrum

- Idea
 - spread signal over wider frequency band than required
 - originally designed to thwart jamming
- Frequency Hopping
 - transmit over random sequence of frequencies
 - sender and receiver share...
 - pseudorandom number generator
 - seed
 - 802.11 uses 79 x 1MHz-wide frequency bands

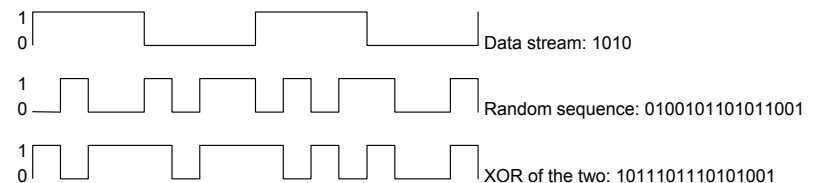
Fall 2001 9/9

CptS/EE 555

15

Spread Spectrum (cont)

- Direct Sequence
 - for each bit, send XOR of that bit and n random bits
 - random sequence known to both sender and receiver
 - called n -bit *chipping code*
 - 802.11 defines an 11-bit chipping code



Fall 2001 9/9

CptS/EE 555

16