

SOLUTIONS TO CS 536 MIDTERM, FALL 2025 (PARK)

P1(a) 20 pts

$((8 * s) / r) + d$
7 pts

It takes $8s/r$ seconds for all the bits to be transmitted/put on the link at the sender's link (transmission time). After that, the last bit requires d seconds to reach the destination (latency).
6 pts

It makes little sense. Since transmission time is $8000/10^9 = 8$ microseconds, it is negligible compared to latency 30 msec. Reducing 8 microseconds to 4 microseconds yields marginal benefit.
7 pts

P1(b) 20 pts

To detect collision across a specified maximum diameter allowed (2.5 km in the original Ethernet), a worst-case round-trip latency of 51.2 microseconds is needed. A sender must remain active for this duration which is achieved by requiring a minimum payload of 46 bytes.
// Total Ethernet frame size $6 + 6 + 2 + 46 + 4$ bytes (512 bits) which at
// 10 Mbps link speed corresponds to 51.2 microseconds.
5 pts

No.
// Since the diameter of electrical copper wiring in a building is, in general,
// given and unknown.
4 pts

802.11 CSMA/CA (i.e., DCF) implements stop-and-wait where the ACK is transmitted by the receiver SIFS time after receiving data. DIFS prevents other stations from attempting to transmit during the SIFS period during which a wireless channel is sensed as being idle (thus prioritizes ACK to complete its transmission).
5 pts

When an 802.11 frame is transmitted by a wireless station, there may be multiple APs in its vicinity that can sense the transmission (i.e., multi-access link). Only the AP the station is associated with should receive and forward the frame. To do so, the AP's address is specified in the 802.11 frame. Since the AP is not the final destination, the final destination's MAC address needs to be specified. The mobile station's address is specified so that the final destination knows who the source of the frame is.
6 pts

P2(a) 20 pts

Bandwidth is $6 \text{ GHz} - 5 \text{ GHz} = 1 \text{ GHz}$. Base frequency is $1 \text{ GHz} / 1000 = 1 \text{ MHz}$. The $n = 1000$ carrier frequencies are the harmonics of the base carrier 1 MHz shifted to 5 GHz: 5.001 GHz, 5.002 GHz, ..., 5.999 GHz, 6 GHz.
// It's OK to state 1 MHz, 2 MHz, ..., 999 MHz, 1 GHz under the implicit
// assumption that all frequencies are multiplied by 5 GHz to shift to the
// 5-6 GHz band.
4 pts

Symbol period $n / \text{bandwidth } W = 1000 / 1 \text{ GHz} = 1 \text{ microsecond}$.
4 pts

Each user (i.e., carrier) sends 3 bits per 1 microsecond, hence 3 Mbps.
4 pts

Bandwidth of the system as a whole: $1000 * 3 \text{ Mbps} = 3 \text{ Gbps}$.

4 pts

No. Increasing n to 10000 increases parallelism 10-fold but also increases symbol period 10-fold. Thus increase of parallelism by having 10000 carriers simultaneously transmitting is cancelled/offset by each carrier transmitting 10 times slower.

4 pts

P2(b) 20 pts

An ARP packet which is carried as payload of an Ethernet frame uses Ethernet's broadcast address to transmit an ARP request to all Ethernet devices. The ARP packet requests that a station with a specified MAC address respond with an ARP packet containing its IPv4 address.

6 pts

DIX destination address contains all 1's (i.e., broadcast address), the type field contains 0x0806 to specify that payload is an ARP packet.
// Source address field contains the sender's MAC address.

4 pts

Through source discovery a switch knows through which links a destination MAC is reachable. An embedded spanning tree specifies on which link to forward the Ethernet frame.

6 pts

If the switch does not know how to reach the destination, it broadcasts the frame in the sense of sending out the frame on all links (i.e., uses flooding) but for the link on which it arrived.

4 pts

P3 20 pts

frame size / RTT.

4 pts

Suppose a frame has been successfully received but its ACK is lost. The sender retransmits the frame which is successfully received. The receiver needs to know that the latest received packet is a retransmission, not a packet containing new data. This is achieved by a binary sequence number that toggles between 0 and 1, staying the same if a packet is a retransmit.

// Or ACK arrives but sender's timer is too aggressive so that it retransmits before the ACK arrives.

// For the binary case, a single bit can be used to directly specify if a packet is a retransmission (say value 1) or not (value 0).

4 pts

Since increasing frame size is limited, sending multiple frames at once (i.e., before their ACKs are received) helps achieve a similar effect of increasing stop-and-wait throughput.

4 pts

Twice as large.

4 pts

Negative ACK

Pro: Works well in low loss environments since few ACKs are needed to repair holes in data.

Con: Does not work well in high loss environments.

Vise versa for positive ACK.

4 pts

Bonus 10 pts

Bandwidth of signal.

// Assuming bandlimited signal, range of frequencies where its spectrum is
// non-zero.

2 pts

Bandwidth of communication link/medium.

// Over a specified distance and environmental conditions for which the link can
// transmit a signal of the said bandwidth with acceptable distortion.

2 pts

Bandwidth bps.

2 pts

Bandwidth in the generic sense Hz.

// For example, for Problem 2(a) where OFDMA is assumed operate in the frequency
// range 5–6 GHz which has bandwidth 1 GHz.

2 pts

Long sequence of 0's (or alternating 0's and 1's) affects a signal's bandwidth.

2 pts