1) A pair of nodes A and B close to each other is sending packets to node C using IEEE 802.11 DCF. Both nodes A and B have many packets pending for node C. Show on a timing diagram the sequence of events that occurs until each of nodes A and B has received ACK for their 1st packet sent to C, assuming that they pick their successive backoff intervals as follows:
Node A: 3, 4, 6, 8, 1
Node B: 4, 6, 2, 9, 11
Assume that the propagation delay is negligible, and that the two nodes choose their initial backoff exactly at time t0, and that at time t0 channel changes status from busy to idle, because node D completes a transmission. In your timing diagram, show one timeline each for hosts A, B and C. In the timeline, show the various packets sent by the hosts, and backoff slots counted by the hosts. Also, if a packet transmission results in a collision, indicate that as well. Assume that RTS/CTS are sent prior to Data and ACK, and that in the absence of a collision, all transmissions are received reliably. (30 points)

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A
  DIFS B=3 RTS SIFS Data DIFS B=4

B
  DIFS B=4
  DIFS B=1 RTS SIFS Data

C
  SIFS CTS SIFS ACK SIFS CTS SIFS ACK
```

2) Suppose an 802.11a station is configured to always reserve the channel with the RTS/CTS sequence. Suppose this station wants to transmit 1,000 bytes of data, and all other stations are idle at this time. As a function of SIFS and DIFS, and ignoring propagation delay and assuming no bit errors, calculate the time required to transmit the frame and receive the acknowledgment. FYI, 802.11 physical layer transmission rate = 54Mbps, MAC layer data payload = 1452 bytes, MAC header = 28 bytes, ACK Frame Size = 14 bytes, RTS length = 20 bytes, CTS length = 14 bytes, Propagation Delay = 1μs, Slot Time = 9 μs, SIFS Time = 16μs, DIFS Time = 34μs, Physical layer overhead = 20μs (every frame has the same PHY overhead). (20 points)

Assume the backoff interval is 10 slots.
The whole transmission involves the following slots:
DIFS + Backoff + RTS + SIFS + CTS + SIFS + Data + SIFS + ACK
(1) Backoff: 10 * 9 μs = 90 μs
(2) RTS: RTS frame size at MAC layer is 20+28=48 bytes. The time to transmit 48 bytes is (48*8)/54 μs = 7.1 μs
Considering physical overhead, the total time to transmit RTS pkt is: 7 + 20 μs = 27 μs
(3) Data: Data frame size at MAC layer is 1000+28=1028 bytes. The time to transmit 1028 bytes is (1028*8)/54 μs = 152 μs
Considering physical overhead, the total time to transmit data pkt is: 152 + 20 μs = 172 μs
(4) CTS: CTS frame size at MAC layer is 14+28=42 bytes. The time to transmit 42 bytes is (42*8)/54 μs = 6 μs
Considering physical overhead, the total time to transmit CTS pkt is: 6 + 20 μs = 26 μs
(5) ACK: ACK frame size at MAC layer is 14+28=42 bytes. The total time to transmit ACK pkt is 26 μs, which is the same as CTS pkt

Thus, the time required to transmit the frame and receive the ack is: DIFS+3SIFS+90μs +27 μs+172 μs+26 μs+26 μs = DIFS+3SIFS+341μs (or 423μs)
Note that it is okay if backoff is not considered.

3) What are the roles of beacon signal and probe message in 802.11 based WLANs? (10 points)

Beacon: announce the presence of a WLAN, synchronization.
Probe: request the presence of a WLAN.

4) IEEE 802.11 has RTSThreshold, which specifies the packet size over which RTS/CTS should be used (e.g., if RTSThreshold = 100 bytes, then all packets smaller than 100 bytes do not use RTS/CTS; all the packets 100 bytes or larger use RTS/CTS). What are the advantage and disadvantage of using small RTSThreshold?

Advantage: reduce the chance of collisions
Disadvantage: Lots of frames including small frames require RTS/CTS, which incurs too much overhead and RTS/CTS overhead might be too high to offset the penalty incurred due to collisions.

Can RTSThreshold be smaller than RTS frame size? Why or why not?

RTSThreshold cannot be smaller than the RTS frame size, since that would require an RTS an RTS frame itself, resulting in an infinite loop.

5) In IEEE 802.11, a node retransmits a packet if the previous transmission of the packet is unsuccessful. A limit is imposed on the number of retransmissions. If the number of retransmissions equals this limit, and yet no acknowledgement is received, the packet is dropped. What is a potential disadvantage of using a very large upper bound on the number of retransmissions of a given packet?

(1) Large delay and blocking other transmissions
(2) Waste time if the link is broken

What is a potential disadvantage of using a very small upper bound on the number of retransmissions of a given packet?

(1) May not succeed in recovery in time, which propagates the packet loss to upper layer.
(2) The loss recovery at upper layer is more expensive, often requires end-to-end retransmission than local recovery.
(3) If upper layer uses TCP, TCP performance degrades significantly on packet losses.