EECS 122: Introduction to Communication Networks
Homework 5 Solutions

Solution 1. There are only a finite number of ID values, so eventually they must be reused. To prevent any risk of fragments from different datagrams being spliced together, we must make sure that two datagrams with the same ID number do not circulate in the network at the same time. Therefore, after using an ID number the sender must wait 60 seconds to make sure it is removed from the network before before using the same ID number again (with the same source and destination addresses). The ID field is 16 bits wide, so there are 2^{16} different ID numbers, each of which can be used once every 60 seconds, for a total rate of

$$\frac{2^{16}\text{ datagrams}}{60\text{ seconds}} \cdot \frac{576\text{ bytes}}{\text{datagram}} \cdot \frac{8\text{ bits}}{\text{byte}} \cdot \frac{\text{Mbps}}{10^6\text{ bit/second}} \doteq 5.03\text{ Mbps}$$

Solution 2. Acknowledgements include a window field containing the number of available bytes (w) in the receiver's buffer. In order to prevent the receiver's buffer from overflowing, the sender is restricted to sending only the w bytes following the last acknowledged byte. In the absence of packet loss, the acknowlegements arriving at the sender acknowledge the data it sent one round-trip time ago (RTT), so if the sender sends at a rate r, the amount of data that has been sent but not yet acknowledged at any moment is on average $r \cdot RTT$, but this is limited by the protocol to w bytes, so $r \leq w/RTT$. Since the window field is 16 bits wide, w can be at most $2^{16} - 1 = 65,535$. With $RTT = 100$ ms, the maximum rate is

$$\frac{65,535\text{ bytes}}{100\text{ ms}} \cdot \frac{8\text{ bits}}{\text{byte}} \cdot \frac{1000\text{ ms}}{\text{second}} \cdot \frac{\text{Mbps}}{10^6\text{ bit/second}} \doteq 5.24\text{ Mbps}$$

Solution 3. Call the transmitting node station A. After the signal has reached the other stations, they will not begin transmitting (this is the "carrier sense" in CSMA/CD). So the latest time another station (call it B) could start transmitting a frame that will cause a collision is just as station A's signal is about to arrive. Station B's signal will first reach the hub, which will then detect the collision and send a collision signal to all stations, including A. So in addition to the time for the hub to detect the collision (0.1 μs), there is the time for a signal to get from station A to station B (at most 200 m) and back (at most another 200 m). Therefore the maximum time between when station A starts transmitting and when it learns that a collision has occurred is

$$0.1\ \mu\text{s} + 400\text{ m} \cdot \frac{\text{second}}{1.75 \times 10^8\text{ m}} \cdot \frac{10^6\ \mu\text{s}}{\text{second}} \doteq 2.39\ \mu\text{s}$$