

$$3) d_{end-end} = N(d_{proc} + d_{trans} + d_{prop})$$

a) $N = 3$ toll booths

$$d_{proc} = 0$$

$$d_{trans} = \frac{10 \text{ cars}}{(1 \text{ car}/12 \text{ sec})} = 120 \text{ sec} = 2 \text{ min}$$

$$d_{prop} = \frac{L}{R} = \frac{150 \text{ km}}{100 \frac{\text{km}}{\text{hr}}} = 1.5 \text{ hr}$$

$$3(0 + 2 \text{ min} + 90 \text{ min}) = 276 \text{ min} = \boxed{4.6 \text{ hr}}$$

b) $N = 3$ toll booths

$$d_{proc} = 0?$$

$$d_{trans} = \frac{8 \text{ cars}}{(1 \text{ car}/12 \text{ sec})} = 96 \text{ sec} = 1.6 \text{ min}$$

$$d_{prop} = \frac{150 \text{ km}}{100 \frac{\text{km}}{\text{hr}}} = 1.5 \text{ hr}$$

$$3(0 + 1.6 \text{ min} + 90 \text{ min}) = 274.8 \text{ min} = \boxed{4.58 \text{ hr}}$$

4) givens

64 kbps (stream)

$$\frac{56(8) \text{ bits}}{64 \times 10^6 \frac{\text{bits}}{\text{sec}}} = .007 \text{ sec}$$

56 bytes (packets)

2 Mbps

10 msec

$$\frac{56(8) \text{ bits}}{2 \times 10^6 \frac{\text{bits}}{\text{sec}}} = .000224 \text{ sec}$$

$$0.007 + 10 \times 10^{-3} + 0.000224 = \cancel{0.007224} \boxed{0.017224 \text{ sec}}$$

$$5) \text{ } d_{\text{end-to-end}} = n(d_{\text{proc}} + d_{\text{trans}} + d_{\text{prop}})$$

$$d_{\text{trans}} = 3 \left(\frac{12,000 \text{ bits}}{2,000,000 \frac{\text{bits}}{\text{sec}}} \right) = 0.018 \text{ sec}$$

$$d_{\text{proc}} = 3 (0.003 \text{ sec}) = 0.009$$

$$d_{\text{prop}} = \frac{6,000,000}{260,000,000} + \frac{4000000}{260,000,000} + \frac{1000,000}{260,000,000} = 0.04$$

$$d_{\text{end-to-end}} = 0.04 + 0.009 + 0.018 = 0.067 \text{ sec}$$

6) Packets containing ACK = 200 bits = 25 bytes = 0.025 kb

Packets containing DATA = 100,000 bits = 12,800 bytes = 12.8 kb

$$\begin{aligned} \text{non-persistent} &= 3 \left(\frac{200 \text{ bits}}{150 \frac{\text{bits}}{\text{sec}}} \right) + \left(\frac{100,000 \text{ bits}}{150 \frac{\text{bits/sec}}{\text{sec}}} \right) \\ &+ 3 \left(\frac{200 \text{ bits}}{\frac{150}{100}} \right) + \left(\frac{100,000}{\frac{150}{10}} \right) = 7,377 \text{ sec} \end{aligned}$$

$$\begin{aligned} \text{persistent} &= 3 \left(\frac{200 \text{ bits}}{15 \frac{\text{bits}}{\text{sec}}} \right) + \left(\frac{100,000 \text{ bits}}{15 \frac{\text{bits/sec}}{\text{sec}}} \right) + 10 \left(\frac{100,000 \text{ bits}}{150 \frac{\text{bits}}{\text{sec}}} \right) \\ &= 7337 \text{ sec} \end{aligned}$$

Yes there is a significant improvement of 40 sec from non-persistent to persistent

$$\text{Cost} = 2415 (8) / 32 = 615 \times 5$$