**Assignment 1**

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**1.**For each application message, the length is M bytes. After encapsulating headers of each layers, each message contains M+20+30+80+30+20+110 = (M+290) bytes to be transmitted, so the fraction of the network bandwidth which is filled with headers is 290/(M+290).

**2.1)**The number of bits of the image 1920\*1080\*2\*103\*8 = 33,177,600,000 bits

Transmission Delay = number of bits / bandwidth =33,177,600,000/(56\*103) = 592,457.14s

Propagation Delay = distance / speed of signal = 10,000/200,000 = 0.05s

Total Latency = Transmission Delay + Propagation Delay = 592,457.19s

**2)**The number of bits for the image 1920\*1080\*2\*103\*8 = 33,177,600,000 bits

Transmission Delay = number of bits / bandwidth =33,177,600,000/(1\*10^6) = 33177.6s

Propagation Delay = distance / speed of signal = 10,000/200,000 = 0.05s

Total Latency = Transmission Delay + Propagation Delay = 33177.65s

**3.**Based on Shannon’s theorem: Max.data rate = B\*log2(1+S/N) bits/sec. S/N = 2(Max.data rate/B)-1 = 2(56\*10^3/(4\*10^3))-1 = 16383. Converting S/N to SNR from the formula SNR = 10\*lg(S/N) = 10\*lg(16383)dB = 43dB. Thus, to support the data rate, the minimum SNR should be at least 43dB.

**4.1)**The rule of bit stuffing shows that we insert 0 after 5 consecutive 1s, so the stream of bits should be “01111011111001111101011111000” after bit stuffing.

**2)** According to the relation of n data bits and k check bits using Hamming code: 2k >= n + k +1, if n = 16, the minimal number of k is 5. Hence, we need at least 5 check bits for receiver correcting single error.

**5.1)**Both layer k-1 and k+1 will not be affected by layer k in this case, because changing the algorithm is just modifying how the service is implemented, but not changing the service itself. Hence, layer k-1 and k+1 are not affected.

**2)**If the service at layer k has a change, it means service provided by layer k will have an impact on layer k+1. Since the definition of service tells us service provides set of primitives only to the upper layer, there is no impact on the operations at layer k-1.