EEE116 – Multimedia Systems 2007/08
Tutorial solution sheet 2 (Week 3)

Q3) Estimate the maximum uncorrupted data rate, in bits/s, for the following communication link:

Bandwidth = 12 MHz
Signal power = 100 mW
Noise power = 20 μW

From the Shannon-Hartley law, we know how to compute the maximum channel capacity for a communication link. The data rate R is $R <= W \log_2(1+S/N)$ Where, W=12 MHz signal bandwidth S=100mW signal power N= 20 μW noise power Therefore, the upper limit $R_{max}= 12x10^6 \log_2(1+ 100x10^{-3}/20x10^{-6})$ $= 1.4745 \times 10^8$ bits/sec (now devide by 10^{20} to convert into M bits/sec) = 140.6 M bits/sec

What is the signal-to-noise power ratio in dBs?

Signal-to-noise ratio (SNR) $= 10 \log_{10}(S/N)$ $= 10 \log_{10}(100x10^{-3}/20x10^{-6})$ = 37 dB.

As an engineer, you are asked to improve this link – which is best (i) to double the bandwidth, or (ii) to double the signal power?

From the Shannon-Hartley law, we can compute the data rate R as $R <= W \log_2(1+S/N)$ Let, $R_{max}= C= W \log_2(1+S/N)$ ----------------(1) (i) If we double the bandwidth $W_{new} = 2W$ Using (1) we can say the new data rate $C_{(i)}= 2W \log_2(1+S/N)$ (ii) If we double the signal power $S_{new} = 2S$ Using (1) we can write $C_{(ii)} = W \log_2(1+ (2S/N))$

Now check $C_{(i)} - C_{(ii)}$

$$= 2W\log_2\left(1+\frac{S}{N}\right) - W\log_2\left(1+\frac{2S}{N}\right)$$

$$= W\log_2\left(1+\frac{S}{N}\right)^2 - W\log_2\left(1+\frac{2S}{N}\right)$$

$$= W\log_2\left[\frac{\left(1+\frac{S}{N}\right)^2}{\left(1+\frac{2S}{N}\right)}\right]$$

$$= W\log_2\left[\frac{1+\frac{2S}{N}+\left(\frac{S}{N}\right)^2}{\left(1+\frac{2S}{N}\right)}\right]$$

$$= W\log_2\left[1+\frac{\left(\frac{S}{N}\right)^2}{\left(1+\frac{2S}{N}\right)}\right]$$

$$= W\log_2(1+x)$$

In the above expression, $x>0$. (Because SNR>0)
Therefore, $(1+x)>0$.
Therefore we can say ($C_{(i)} - C_{(ii)}$) > 0.

Therefore the method (i) is the better way to improve the data rate.

Q4) You have a 160 G Byte hard disc – full of important data – that needs to be transferred to a computer in London. Assume that the distance between London and Sheffield is 250km and the effective speed of light for cases a., b. and c. is $3\text{x}10^8$ ms^{-1}. For b. and c. assume that you can send one bit of information per period. Estimate the time it will take to transfer all this data, if you use:

We know the total time to transfer is
= Transmit time + propagation time + network queuing delays

Transmit time = Data size / capacity of the link
The data size in all cases is $D=8\text{x}160\text{x}2^{30}$ bits
Transmit time has to be computed for the three scenarios separately.

Propagation time = distance / propagation speed
$= 250 \times 10^3 / (3 \times 10^8)$
$= 83.3 \times 10^{-3}$ s.
No information on queuing time was given. So we assume no delays due to network processes.

a. A conventional phone line with a normal modem attached (assume that the modem can send 20 Kbits/s),

Transmit time = Data size / capacity of the link
$= (8 \times 160 \times 2^{30}$ bits$) / (20 \times 2^{10}$ bits/s$)$
= 776 days
In this case, the total time is totally dependent on the transmit time.

b. A high speed computer network link with a bandwidth of 10 MHz,

1 bit of information per period.
Therefore, the link capacity for 10MHz is 10×10^6 bits/s
Transmit time = Data size / capacity of the link
$= (8 \times 160 \times 2^{30}$ bits$) / (10 \times 10^6$ bits/s$)$
= 1.59 days
In this case also, the total time is totally dependent on the transmit time.

c. A direct optical link using light at a wavelength of 0.7 μm.

We have to compute the Carrier signal frequency considering the speed of light.
Frequency F = (speed of light)/(wave length) = $(3 \times 10^8)/(0.7 \times 10^{-6})$
1 bit of information per period. Therefore, the link capacity for F Hz is F bits/s
Transmit time = Data size / capacity of the link
$= (8 \times 160 \times 2^{30}$ bits$) / ((3 \times 10^8)/(0.7 \times 10^{-6})$ bits/s$)$
$= 3.2 \times 10^{-3}$ s

In this case, the total time is Transmit time+ Propagation time
$= (3.2 + 83.3) \times 10^{-3}$ s
$= 85.5 \times 10^{-3}$ s

d. The train?

Around 2 hours and 45 minutes (if you are lucky) ☺