

Solutions to Written Exam in  
**Internetworking**  
**TSIN02**

18th January 2025

- 1      a) See the course literature.  
       b) See the course literature.  
       c) See the course literature.  
       d) See the course literature.
  
- 2      a) See the course literature.  
       b) See the course literature.  
       c) See the course literature.
  
- 3      a) See the course literature.  
       b) See the course literature.  
       c) See the course literature.  
       d) See the course literature.
  
- 4      a) See the course literature.  
       b) See the course literature.
  
- 5      a) See the course literature.  
       b) See the course literature.

- 6 a) See the course literature.  
b) See the course literature.  
c) See the course literature.
- 7 We consider a simple design (source, optical fiber and photodetector). In the first instance, we consider a link without amplifiers to reduce monetary cost.

$$P_s \leq P_{in} - \alpha \cdot l \Rightarrow \alpha \cdot l \leq P_{in} - P_s$$

Calculating  $\alpha \cdot l = 23\text{dB}$ , and we see that with different types of lasers and photodetectors we get:

| $P_{in} - P_s$  | Laser A | Laser B | Laser C |
|-----------------|---------|---------|---------|
| Photodetector A | 12      | 19      | 22      |
| Photodetector B | 17      | 24      | 27      |
| Photodetector C | 25      | 32      | 35      |

We see that the green marked values in the table fulfills the condition. The cheapest of the green options is laser B and photodetector B. We are not far away from the limit though. In order to get a little more margin, we could make an argument for choosing laser C and photodetector B instead. It is not the cheapest, but it gives a bit more compensation for future extra losses in the fiber without using a more sensitive photodetector.

- 8 a) Starting by converting the input power to dBm.  $0.5\text{mW} = -3\text{ dBm}$ . Then looking at the optical fiber to the city center. After the first fiber coupler the input power to  $l_1$  is  $-3\text{ dBm} - 3\text{dB} = -6\text{ dBm}$ . Using the formula to calculate the sensitivity:

$$\begin{aligned} P_{s,l_1} &\leq P_{in,l_1} - l_1 \cdot \alpha - L = -6\text{dBm} - 110\text{km} \cdot 0.2 \frac{\text{dB}}{\text{km}} - 10\text{dB} \\ &= -38\text{dBm} \Rightarrow P_{s,l_1} \leq -38\text{dBm} \end{aligned}$$

Now we look at the sensitivity to the industrial and suburban areas. Starting by looking at what input power it should be to the second fiber coupler. This gives us the formula:

$$\begin{aligned} P_{in,FC_2} &= P_{out,FC_1} - l_2 \cdot \alpha + G \\ &= -6\text{dBm} - 70\text{km} \cdot 0.2 \frac{\text{dB}}{\text{km}} + 4\text{dB} = -16\text{dBm} \end{aligned}$$

This means that the input power to fiber  $l_3$  and  $l_4$  (aka after fiber coupler 2) is:

$$-16\text{dBm} - 3\text{dB} = -19\text{dBm}$$

This gives us that the sensitivity for the photodetectors at the industrial and suburban areas should be:

$$P_{s,l_3} \leq -19\text{dBm} - l_3 \cdot \alpha = -29\text{dBm}$$

$$P_{s,l_4} \leq -19\text{dBm} - l_4 \cdot \alpha = -24\text{dBm}$$

- b) To compensate these losses we could use a photodetector with higher sensitivity or an amplifier to amplify the signal. Or in this case, it would probably be better to switch the whole fiber because of the really high losses. The losses are calculated as  $L_1 = \alpha \cdot l_1 = 0.6 \cdot 110 = 66\text{dB}$ .

- 9 a) For the first group:

$$256 \leq 2^N \Rightarrow N = 8$$

$$32 - 8 = 24$$

$$(256 - 1)_{dec.} = 0.0.0.255_{dot.dec.}$$

$$(150 \cdot 256 - 1)_{dec.} = 0.0.149.255_{dot.dec.}$$

First customer, Subnet: 150.30.0.0/24

First address: 150.30.0.0 Last address: 150.30.0.255

Second customer, Subnet: 150.30.1.0/24

First address: 150.30.1.0 Last address: 150.30.1.255

...

150th customer, Subnet: 150.30.149.0/24

First address: 150.30.149.0 Last address: 150.30.149.255

For the second group of businesses:

$$64 \leq 2^N \Rightarrow N = 6$$

$$32 - 6 = 26$$

$$(64 - 1)_{dec.} = 0.0.0.63_{dot.dec.}$$

$$(250 \cdot 64 - 1)_{dec.} = 0.0.62.127_{dot.dec.}$$

First customer, Subnet: 150.30.150.0/26  
 First address: 150.30.150.0 Last address: 150.30.150.63

Second customer, Subnet: 150.30.150.64/26  
 First Address: 150.30.150.64 Last Address: 150.30.150.127

...

250th customer, Subnet: 150.30.212.64/26  
 First address: 150.30.212.64 Last address: 150.30.212.127

For the third group of households:

$$10 \leq 2^N \Rightarrow 3.3219... \leq N \Rightarrow N = 4$$

$$32 - 4 = 28$$

$$(2^4 - 1)_{dec.} = 0.0.0.15_{dot.dec.}$$

$$(400 \cdot 16 - 1)_{dec.} = 0.0.24.255_{dot.dec.}$$

First customer, Subnet: 150.30.212.128/28  
 First address: 150.30.212.128 Last address: 150.30.212.143

Second customer, Subnet: 150.30.212.144/28  
 First Address: 150.30.212.144 Last Address: 150.30.212.159

...

400th customer, Subnet: 150.30.237.112/28  
 First address: 150.30.237.112 Last address: 150.30.237.127  
 The third group will get 16 addresses each instead of 10.

b) Addresses left after allocations:

$$2^{16} - 64 \cdot 250 - 150 \cdot 256 - 16 \cdot 400 = 4736$$

c) Yes! It is possible. For example, for the first business:

$$\frac{256}{4} = 64$$

Each subblock will get 64 addresses.

$$64 \leq 2^N \Rightarrow N = 6$$

$$32 - 6 = 26$$

$$(64 - 1)_{dec.} = 0.0.0.63_{dot.dec}$$

First Subblock, Subnet: 150.30.0.0/26  
 First address: 150.30.0.0 Last address: 150.30.0.63  
 Second Subblock, Subnet: 150.30.0.64/26  
 First address: 150.30.0.64 Last address: 150.30.0.127  
 Third Subblock, Subnet: 150.30.0.128/26  
 First address: 150.30.0.128 Last address: 150.30.0.191  
 Fourth Subblock, Subnet: 150.30.0.192/26  
 First address: 150.30.0.192 Last address: 150.30.0.255

- 10 a) The stationary channel loss probability is calculated as:

$$P_l = \frac{p_{l|r}}{p_{l|r} + p_{r|l}} = \frac{0.07}{0.07 + 0.45} = 0.1346153846153 \approx 0.1346$$

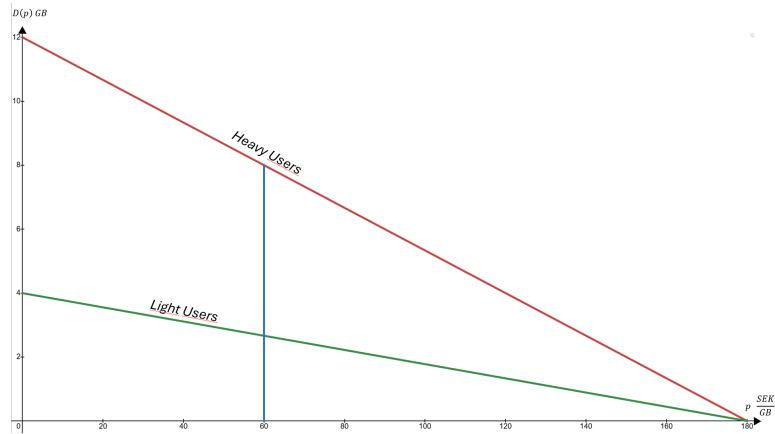
- b) The distortion when packet arrives is calculated as:

$$D_r = \frac{\Delta^2}{12} = \frac{1}{12} \cdot \left( \frac{A}{M} \right)^2 = \frac{1}{12} \cdot \left( \frac{10}{30} \right)^2 \approx 0.009259$$

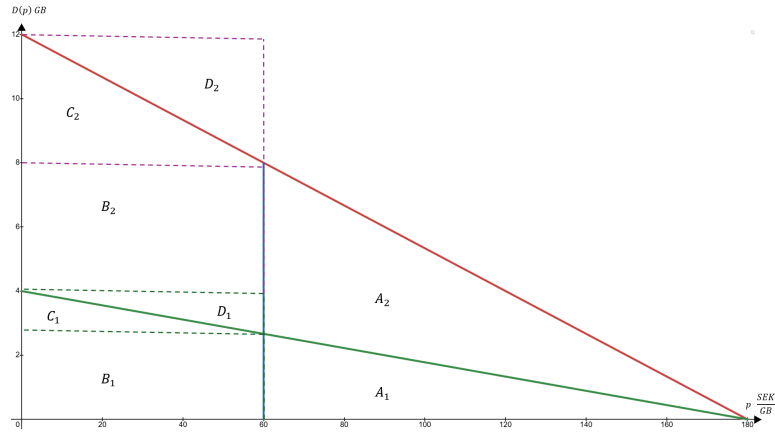
- c) The overall stationary mean MSE distortion is calculated as:

$$D = P_l D_l + P_r D_r \approx 0.1346 \cdot 1 + \frac{0.45}{0.07 + 0.45} \cdot 0.009259 \approx 0.1426$$

- 11 a) Drawing the demand functions for the users we get:



From this calculating  $D_1(60) = 8$ ,  $D_2(60) = 8/3 \approx 2.6667$ .  
 With this we get the graph with the different areas drawn in.



The net utility for usage based pricing for heavy users:

$$\begin{aligned}
 \text{Net utility} = \text{Utility} - \text{Cost} &= A_2 + B_2 - B_2 = A_2 \\
 &= \frac{(180 - 60) \cdot 8}{2} = 480 \text{ SEK}
 \end{aligned}$$

And for light users:

$$\begin{aligned}
 \text{Net utility} = \text{Utility} - \text{Cost} &= A_1 + B_1 - B_1 = A_1 \\
 &= \frac{(180 - 60) \cdot 8/3}{2} = 160 \text{ SEK}
 \end{aligned}$$

- b) We assume that the price is set such that the heavy users will still pay 60 SEK/GB when using their maximum demand (12 GB), ie that the cost is  $60 \cdot 12 = 720$  SEK.

For the net utility or surplus using flat rate, heavy users:

$$\begin{aligned}
 \text{Net utility} &= A_2 + B_2 + C_2 - (B_2 + C_2 + D_2) \\
 &= \frac{180 \cdot 12}{2} - 60 \cdot 12 = 1080 - 720 = 360 \text{ SEK}
 \end{aligned}$$

And for the light users:

$$\begin{aligned}
 \text{Net utility} &= A_1 + B_1 + C_1 - (B_2 + C_2 + D_2) \\
 &= \frac{180 \cdot 4}{2} - 60 \cdot 12 = 360 - 720 = -360 \text{ SEK}
 \end{aligned}$$

- c) The ISP should use usage based pricing, because the surplus is positive for both kind of users if that is used.