FUNDAMENTALS OF TELECOM
PROJECT – TELECOM 2100
GROUP 1

By

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AIM:

To analyse optimal Passive Optical Network (PON) that is to serve a community of 64 homes (20 Kms from the company's facilities) with an error rate of 10^{-6} using either single mode fiber or multi-mode fiber. [LED or Laser]

DATA PROVIDED:

FIBER TYPE	**ATTENUATION**	**TRANSMIT POWER**	**RECEIVER SENSITIVITY**	**MARGIN**	**NOISE**	**RECEIVER NOISE**
Single mode	0.4 dB/km	3dBm	-30dBm	30dB	-40 dB/km	-40dBm
Multi-mode	1 dB/km	0dBm	-15dBm	3dB	-40 dB/km	-40dBm

COST			
SINGLE MODE FIBER		**MULTI MODE FIBER**	
LASER TRANSMITTER	$10,000	LED TRANSMITTER	$100
LASER REPEATER	$50,000	LED REPEATER	$500
PER METER COST	$0.50	PER METER COST	$1
MAINTENANCE COST PER KM PER YEAR	$100	MAINTENANCE COST PER KM PER YEAR	$70
PON COST FOR BOTH SINGLE MODE & MULTI MODE = $200			

OBSERVATION:

From the graph provided, it is noticed that for a desired BER of 10^{-6}, the value of SNR is approximately found to be 16 dB and a repeater is needed only when the SNR value falls below 16 dB

CALCULATION: Before starting the calculation we make some assumptions like the attenuation occurs only in the link between company and the splitter. Moreover, the distance between splitter and the home is negligible. The distance we consider here is 20Km between company and splitter.

1) a) We are calculating maximum fan out of each PON(i.e. 1x2,1x4,…1x64) without repeaters in single mode and multi mode system.

SINGLE MODE:

PON		1x2	1x4	1x8	1x16	1x32	1x64
Before splitting	Transmit power (in dBm)	3	3	3	3	3	3
	Attenuation per Km (in dB)	0.4	0.4	0.4	0.4	0.4	0.4
	Attenuation for 20 Km	8	8	8	8	8	8
	Power received at splitter(in dBm)	3 – 8 = 5	3 – 8 = 5	3 – 8 = 5	3 – 8 = 5	3 – 8 = 5	3 – 8 = 5
	Power received at splitter(in watts)	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
After splitting	Power transmitted from splitter(in watts)	0.0003/2 = 0.00015	0.0003/4 = 0.000075	0.0003/8 = 0.0000375	0.0003/16 = 0.00001875	0.0003/32 = 93.75×10^{-7}	0.0003/64 = 468.75×10^{-8}
	Power transmitted from splitter(in dBm)	-8.239	-11.249	-14.259	-17.269	-20.280	-23.290

MULTI MODE:

PON		1x2	1x4	1x8	1x16	1x32	1x64
Before splitting	Transmit power (in dBm)	0	0	0	0	0	0
	Attenuation per Km (in dB)	1	1	1	1	1	1
	Attenuation for 20 Km	20	20	20	20	20	20
	Power received at splitter(in dBm)	0-20= -20	0-20= -20	0-20= -20	0-20= -20	0-20= -20	0-20= -20
	Power received at splitter(in watts)	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
After splitting	Power transmitted from splitter(in watts)	0.00001/2 = 0.000005	0.00001/4 = $25x10^{-7}$	0.00001/8 = $125x10^{-8}$	0.00001/16 = $625x10^{-9}$	0.00001/32 = $3125x10^{-10}$	0.00001/64 = $15625x10^{-11}$
	Power transmitted from splitter(in dBm)	-23.010	-26.020	-29.030	-32.041	-35.051	-38.061

Note:

1) It is possible to subtract or add dB from dBm and get the result in dBm itself.

2) Power (in watts) = $10^{((P_{(dBm)} - 30) / 10)}$

3) Power (in dBm) = $10 * \log_{10}(P_{(W)} / 1W) + 30$

It is noticed that power transmitted from laser transmitters via splitters in single mode fiber is greater than power transmitted from led transmitters via splitters in muti mode fibers.

b)

We need to calculate SNR(Signal to Noise Ratio) and before calculating the cost.

SINGLE MODE:

Distance (in Km) (L)	**(Tx power – Attenuation)**	**(Receiver Power – 10log(L/n +1)**	**SNR = (Tx power – Attenuation) – (Receiver Power – 10log(L/n +1)**
0	3 – 0 = 3	-40 – 0 = -40	3 – (-40) =43
5	3 – 5(0.4) = 1	-40 – 3 = -37	1 – (-37) =38
10	3 – 10(0.4) = -1	-40 – 5 = -35	-1 – (-35) =34
15	3 – 15(0.4) = -3	-40 – 6 = -34	-3 – (-34) =31
20	3 – 20(0.4)= -5	-40 – 7 = -33	-5 – (-33) =28

Since, the SNR of the link doesn't fall below the desired SNR (16dB), there is no repeater needed. Hence the cost will be**,**

COST	**IN USD($)**
Laser Transmitter	10,000
Repeater needed (0)	0
Passive Optical Network (PON)	200
Single Mode Fiber ($0.5 / m * 20,000m)	10,000

Total Cost for provisioning the system in Single Mode fiber = $20,200

This cost is for a single mode fibre up till the splitter while the receiver will receive power which is equal to received power at the splitter/64.This power which is received at each home will not be able to provide the desired minimum SNR of 16dB [calculated by code attached in appendix A]. This problem then can be resolved by the use of repeaters or by increasing the number of lines from the transmitting station this would then increase cost.

Single mode with repeaters :

If a single mode fibre needs to be used along with a repeater there are three possible options to determine the distance of the repeater from the transmitting station they are

1. At 5km 2. At 10km and 3. At 15km from the transmitting station.

A single repeater at 10 km will be enough to provide satisfactory power at the splitter such that the SNR requirements at each home are met.

Note : This is considering that no further expansion is planned. In case of a planned expansion both the number of repeaters as well as their distance from the transmitting station will change**.**

In this case the revised cost will be

COST	IN USD($)
Laser Transmitter	10,000
Repeater needed (1)	50,000
Passive Optical Network (PON)	200
Single Mode Fiber ($0.5 / m * 20,000m)	10,000

Cost for provisioning the system in Single Mode fiber = $70,200

Single mode fibre without any repeaters :

From the code attached in appendix A, we determined that it would be possible to service the 64 homes provided that they would be further divided into smaller groups which could be serviced by a single PON and each PON will be connected to the transmitting station by the means of a fibre.

By our calculations we would require a minimum of 4 separate fibres , each of which would be connected to a 1x16 PON. We therefore require 4 transmitters and our fibre cost will be 4 times of that we required for a single fibre single mode based implementation.

COST	IN USD($)
Laser Transmitter(4)	40,000
Repeater needed (0)	0
Passive Optical Network (PON)	800
Single Mode Fiber ($0.5 / m * 20,000m)	40,000

Cost for provisioning the system in Single Mode fiber = $80,800

MULTI MODE:

Distance (in Km) (L)	(Tx power – Attenuation)	(Receiver Power – 10log(L/n +1)	SNR = (Tx power – Attenuation) – (Receiver Power – 10log(L/n +1)
0	0 – 0 = 0	-40 – 0 = -40	0 – (-40) = 40
5	0 – 5(1) = -5	-40 – 3 = -37	-5 – (-37) = 32
10	0 – 10(1) = -10	-40 – 5 = -35	-10 – (-35) = 25
15	0 – 15(1) = -15	-40 – 6 = -34	-15 – (-34) = 19

20	0 – 20(1) = -20	-40 – 7 = -33	-20 – (-33) = 13

Since, the SNR of the link falls below the desired SNR(16dB) after 15Km, there is a need for a repeater . It is to be noted that the repeater will make the attenuation zero i.e. it again sends the signal with originally transmitted power. It is 0dBm in this case. So SNR between 15Km and 20Km will become as 32dB again (i.e. (0 – 5)-(-37)) after passing through the repeater.

Hence the cost will be,

COST	IN USD($)
LED Transmitter	100
Repeater needed (1)	500
Passive Optical Network (PON)	200
Single Mode Fiber ($1 / m * 20,000m)	20,000

Adding all the above costs, the total is displayed below

Cost for provisioning the system in Multi Mode fiber = $20,800

Based on the cost calculated in previous steps, transmitting through Multi Mode fiber costs $600 more than the Single Mode fiber with all the requirements included in both cases.

The above power calculations provide the power available at the splitter. Once the signal is divided by a 1x64 PON the signal power received at each home will be much less due to which it won't be possible to maintain our required SNR of 16dB. Therefore it becomes necessary to increase the power input to the splitter this can be done by increasing the number of repeaters between the transmitting station and the splitter

From appendix (A) we found that repeaters must be there at intervals of 3 km so that the power input is quite high at the splitter input. We therefore require at least 6 repeaters between the splitter and the transmitting station.

COST	IN USD($)
LED Transmitter	100
Repeater needed (6)	3000
Passive Optical Network (PON)	200
Single Mode Fiber ($1 / m * 20,000m)	20,000

Adding all the above costs, the total is displayed below

Cost for provisioning the system in Multi Mode fiber = $23,300

c)

The above calculated cost was for a year. Here we are calculating the cost over life time of the system which is 15 years. So, the total cost for 15 years will be,

SINGLE MODE FIBER with repeater:

COST	IN USD($)
Laser Transmitter	10,000
Repeater needed (1)	50,000
Passive Optical Network (PON)	200
Single Mode Fiber ($0.5 / m * 20,000m)	10,000
Maintenance for 15yrs ($100 / Km / yr *15yr * 20Km)	30,000

Total cost for the LASER based Single Mode fiber system = $100,200

SINGLE MODE FIBER without repeater :

COST	IN USD($)
Laser Transmitter (4)	40,000
Repeater needed (0)	0
Passive Optical Network (PON) (4)	800
Single Mode Fiber ($0.5 / m * 20,000m) (4)	40,000
Maintenance for 15yrs ($100 / Km / yr *15yr * 20Km)(4 Fibers)	120,000

Total cost for the LASER based Single Mode fiber system = $200,800

MULTI MODE FIBER with repeater :

COST	IN USD($)
LED Transmitter	100
Repeater needed (6)	3000
Passive Optical Network (PON)	200
Multi Mode Fiber ($1 / m * 20,000m)	20,000
Maintenance for 15yrs ($70 / Km / yr *15yr * 20Km)	21,000

Total cost for the LED based Multi Mode fiber system = $44,300

d)

The suggestion to my boss will be inclined towards LED based Multi Mode fiber system for serving the community of 64 homes because the cost of LASER based system is magnitudes higher than a LED based system. Since, the system is going to function for 15 years implementing it in Single Mode fiber proves costly and futile. Moreover, considering the other costs like capital cost, sunken cost, it is seen that those costs are less for Multi mode fiber than Single Mode fiber. In case, if there is any problem or technology development, replacing Multi mode fibers is easy as its cost-effective.

2) Home run system was suggested by Sirbu and Banerjee. We are calculating the cost for it in both Single Mode and Multi Mode fiber. Since, a home run system is considered, there is a need for individual component for every link.

SINGLE MODE FIBER (LASER) :

COST	COST PER ONE QUANTITY	IN USD($)
64 Laser Transmitter	10,000	640,000
Repeater needed (0)	0	0
64 Single Mode Fiber ($0.5 / m * 20,000m)	10,000	640,000

Total cost for the Single Mode fiber system = $1,280,000

MULTI MODE FIBER (LED) :

COST	COST PER ONE QUANTITY	IN USD($)
64 LED Transmitter	100	6,400
64 Repeaters needed	500	32,000
64 Single Mode Fiber ($1 / m * 20,000m)	20,000	1280,000

Total cost for the Multi Mode fiber system = $1,318,400

After looking at the two tables (above ones) we can deduce that for a home run fiber system, single mode fiber (LASER) system is an economical option. But , if we compare the above calculation with the PON system cost, the cost of provisioning the home run single mode and multi mode fiber is very expensive. The increase in the expenditure of the home run system is due to fact that additional transmitters and links are being attached to the individual fiber in the system.

APPENDIX A

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

int main ()
{


   //SINGLE MODE
   float TPwr_dbm = 3 ;                                        //Transmitted Power
   float No_of_links;
   float signal_attn = 0.4;                                    //db/Km
   float Length = 20 ;                                         //kms
   float Rvr_Noise = -40;                                          //40 db per 5 km
   float TPwr_in_mW = pow(10.0,(TPwr_dbm/10));         //Transmitted Power in
milliWatts


   int N = 5;

   // Calculating number of lines to be installed for single mode fiber

   for(int i = 1; i <=4; i+=1)
   {
        int No_of_lines = i;

        switch(No_of_lines)
        {
                case 1:
                {
                        No_of_links = 64;
                        float TPwr_per_home_in_mW = TPwr_in_mW / No_of_links;
                        float TPwr_in_dbm_perhome = 10 *
log10(TPwr_per_home_in_mW);    //mW to dbm
                        printf("DBM %f\n",TPwr_in_dbm_perhome);
                        float SNR = (TPwr_in_dbm_perhome - signal_attn * Length) -
(Rvr_Noise + 10 * log10((Length/N) + 1));
```

```
			printf("SNR for links 64 (%d Lines)= %f\n",i,SNR);
		//SNR
		}	break;

		case 2:
		{
			No_of_links = 32;
			float TPwr_per_home_in_mW = TPwr_in_mW / No_of_links;
			float TPwr_in_dbm_perhome = 10 *
log10(TPwr_per_home_in_mW);	//mW to dbm
			printf("DBM %f\n",TPwr_in_dbm_perhome);
			float SNR = (TPwr_in_dbm_perhome - signal_attn * Length) -
(Rvr_Noise + 10 * log10((Length/N) + 1));
			printf("SNR for links 32 (%d Lines)= %f\n",i,SNR);
		//SNR
		}	break;

		case 3:
		{
			No_of_links = 16;
			float TPwr_per_home_in_mW = TPwr_in_mW / No_of_links;
			float TPwr_in_dbm_perhome = 10 *
log10(TPwr_per_home_in_mW);	//mW to dbm
			printf("DBM %f\n",TPwr_in_dbm_perhome);
			float SNR = (TPwr_in_dbm_perhome - signal_attn * Length) -
(Rvr_Noise + 10 * log10((Length/N) + 1));
			printf("SNR for links 16 (%d Lines)= %f\n",i,SNR);
		//SNR
		}	break;

		case 4:
		{
			No_of_links = 8;
			float TPwr_per_home_in_mW = TPwr_in_mW / No_of_links;
			float TPwr_in_dbm_perhome = 10 *
log10(TPwr_per_home_in_mW);	//mW to dbm
			printf("DBM %f\n",TPwr_in_dbm_perhome);
			float SNR = (TPwr_in_dbm_perhome - signal_attn * Length) -
(Rvr_Noise + 10 * log10((Length/N) + 1));
```

```
                    printf("SNR for links 8 (%d Lines)= %f\n",i,SNR);
                    //SNR
              }   break;
        }
    }

                    No_of_links = 64;
                    Length = 10;
                          //repeater needs to be placed at 10km
                    float TPwr_per_home_in_mW = TPwr_in_mW / No_of_links;
                    float TPwr_in_dbm_perhome = 10 *
log10(TPwr_per_home_in_mW);   //mW to dbm
                    printf("DBM %f\n",TPwr_in_dbm_perhome);
                    float SNR = (TPwr_in_dbm_perhome - signal_attn * Length) -
(Rvr_Noise + 10 * log10((Length/N) + 1));
                    printf("SNR for links = %f\n",SNR);
        //SNR


        //MULTI_MODE
        TPwr_dbm = 0 ;
//Transmitted Power
        No_of_links = 64;
        signal_attn = 1;                                      //Units : db/Km
        Rvr_Noise = -40;                                              //40 db per
5 km
        TPwr_in_mW = pow(10.0,(TPwr_dbm/10));        //Transmitted Power in
milliWatts

                    for (int i = 5 ; i >=0 ; i--)
                    {
                          Length = i;
                          TPwr_per_home_in_mW = TPwr_in_mW /
No_of_links;
                          TPwr_in_dbm_perhome = 10 *
log10(TPwr_per_home_in_mW);   //mW to dbm
                          printf("DBM (Multimode)
%f\n",TPwr_in_dbm_perhome);
```

```
                SNR = (TPwr_in_dbm_perhome - signal_attn * Length)
- (Rvr_Noise + 10 * log10((Length/N) + 1));
                printf("SNR for links multimode %d km= %f\n",i,SNR);

            }
    return 0;

}
```