DESIGN AND IMPLEMENTATION OF FTTH NETWORK BASED ON GPON TECHNOLOGY

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Abstract—Fiber to the Home provides best transmission possibilities to conventional wired or wireless techniques. It offers advantages such as high bandwidth, immunity against interference, low cost & flexible designs, makes the telecom operators to choose FTTX networks. FTTH based on GPON technology is the most efficient method for FTTH implementation since it provides triple play, high splitting ratio, low CAPEX (Capital expenditure) and OPEX (Operational expenditure) , high speed transmission and so on. This design proves the allocation of maximum number of users for a multi dwelling buildings with tolerable power budget and cost. This design is also capable to incorporate future services like IPTV and provides dynamic allocation of bandwidth (DAB) according to the user requirements. INAS EMS software is used to show the active ports, diagnose the issues by fire alarm settings, physical / logical topological configuration support etc. after the network implementation.

Keywords—Fiber to the Home (FTTH), Passive optical network (PON) , Optical network terminal (ONT), Optical line terminal (OLT), Gigabit Passive optical network (GPON).

1. INTRODUCTION

The requirement such as high bandwidth and capacity, high speed internet, HDTV, VoIP causes the thought for FTTX access networks. FTTH based on GPON technology is one of the techniques which can provide triple play services at a reasonable cost. It uses only passive equipment's except at central office (CO) and at the customer premises. Now most of the telecom operators uses FTTH network based on GPON due to its flexibilities in handling extended technologies and services in future. For a GPON technology maximum of 128 uses can be included in a network with maximum reachability of 60 km and maximum distance between concecutive ONTs of 20 km as per G.984.6 ITU-T specification [8]. It uses tree topology to maximize the coverage with minimum network splits thus reducing optical power [7]. GPON uses 2.44 Gbps downstream with AES encryption and 1.24 Gbps upstream data transmission. Broadcasting or continuous transmission for downstream and TDM technique for upstream are used as transmission method.

In this paper, the validation of proposed design is done on the basis of power budget and cost. The results shows that the received power levels falls within tolerable power budget and the consumed cost is low compared to other networks. INAS EMS software is used to check the connectivity's, active ports location diagonisation of ONTs etc. The different profile configurations like ONU profile, VoIP profile ,DBA (Dynamic Bandwidth Allocation) profile are also done to have different services. This paper includes different sections like Components of GPON network, design, Implementation, testing results, and finally the conclusion.

2. COMPONENTS OF GPON FTTH NETWORK

A Passive Optical Network (PON) is capable of having P2M (point to multipoint) network with passive components like optical splitter or coupler along the transmission section. It uses active components only at CO and at customer premises. It uses WDM to mix up video signals with the data and voice from OLT. The Figure.1 shows the basic FTTH Network.

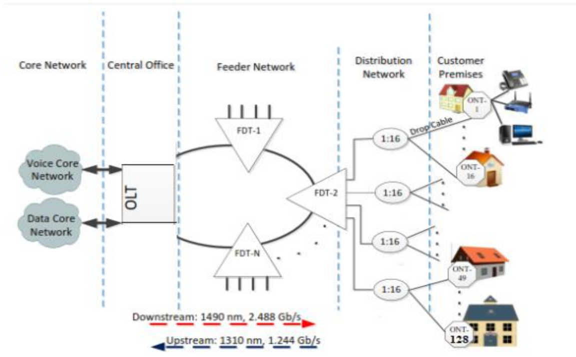


Figure 1: FTTH Network [7]

2.1 Optical Line Terminal (OLT)

It is the most important part of the network, where the electrical signal from the service provider's equipment are converted into optical signals and given to the feeder network. The mode of transmission from ONT is broadcasting [8] from where it sends GEM frames through the GEM port with GEM port IDs It is capable of having Multi-service chassis for FTTx deployments, Supports a variety of service types, Non-blocking architecture with & Routing within distributed architecture, scalability and line rate performance, Full electrical and optical redundancy Outstanding scalability and line rate performance, Real-time network traffic monitoring and analysis.V8240 GPON OLT is used. Specifications are given in the table 1.

Table 1: V8240 GPON OLT Specifications.

Flash Memory	72 MB
SDRAM	1 GB
Dimensions (W x H x D)	17.1 x 12.2 x 11.2 in (434 x 310 x 285 mm)
Switching Capacity	296Gbps
Power Voltage AC type	100-240VAC, 50/60Hz
DC type	-48/60VDC
Operating Temp	32 to 122°F (0 to 50°C)
SIU (Subscriber Interface Unit)	10 slots
NIU (Network Interface Unit)	2 slots
SFU (Switching Fabric Unit)	2 slots

2.2 Optical Network Terminal (ONT)

It is an active component used at customer premises which converts optical to electrical signals. ONU/ONT represents the single customer where they will get the triple play application. H640 series GPON ONT are used. It is capable of having carrier class VoIP telephony supporting both MGCP and SIP protocols, Flexible VLAN tagging support, QoS for traffic prioritization and bandwidth management, IGMP support for IPTV applications. Its specifications are given in table 2.

Table 2: H640 Series GPON ONT

Service Interface	4 10/100Base-TX ports (RJ45) 2 POTS ports (RJ11) 1 RF video port (F-connector)
Uplink Interface	1 GPON port (SC/APC type)
Operating Temp	32 to 104°F (0 to 40°C)
Storage Temp	-4 to 140°F (-20 to 60°C)
Input	100-240VAC
Dimensions (W x H xD)	• Excluding bracket:10.24 x 2.05 x 7.87 in (260 x 52 x 200 mm) • Including bracket, wall mounting:10.51 x 2.60 x 7.87 in (267 x 66 x 200 mm) • Excluding bracket, desktop mounting: 10.24 x 2.80 x 7.87 in (260 x 71 x 200 mm)

2.3 Splitter

Splitters are used to physically split the fiber to number of fibers; to couple same or different information's to N users. MxN planar splitters are used which is based on planar light wave circuit (PLC) technology and high precision alignment. MxN splitters can split or combine light from one or two fibers into N outgoing fibers uniformly over a wide spectral range with ultra-low insertion loss and low polarization dependent loss. With upto 64 output ports, these splitters are ideal for high density split applications like Fiber To The Home (FTTH) networks, FTTx Deployments Optical CATV Networks, CWDM and DWDM Systems, Passive

Optical Networks, Fiber Communication Systems Telecom, LANs. It has the features like Low Insertion Loss, Ultra broadband performance (1260 – 1630nm),Low PDL and PMD, Stable towards thermal variations, Superior port to port uniformity. A splitter type is shown in Figure.2

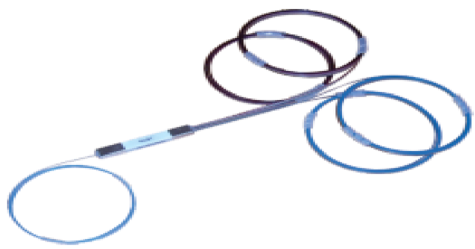


Figure 2: PLC splitter with Ribbon fiber

2. 4 EDFA

Erbium Doped Fiber Amplifier (EDFA) is used to amplify the video signal from the cable TV service provider and feed into WDM. EDFA CATV (cable TV) is used which signify different models of endless power output booster EDFA used in CATV network application as C band signal promoter in optical domain. It has continuous circuit parameter monitoring for safe operation, auto shutdown for safe guard of internal units, future proof upgradeable modules, free monitoring software, and continuous display of optical power. EDFA View 5.0 is the software provided with the system. By installing this software & interfacing EDFA with the PC, the system performance parameters like the input power, output power, gain can be monitored. The entire pump laser related parameters are displayed for easy trouble shooting of the system. The input power is 1.566 dBm ,output power and gain obtained are 18.043dBm, 16.526dB respectively .The software output is shown in Figure.3.

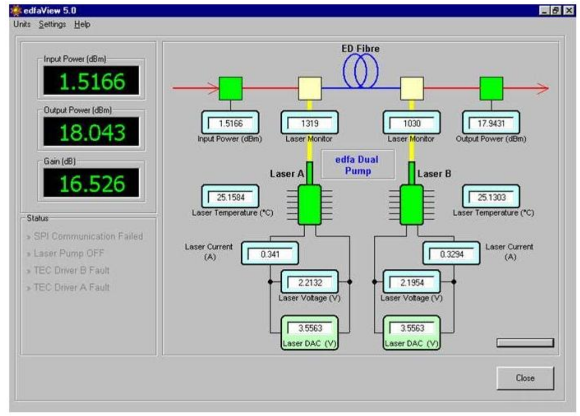


Figure 3: EDFA View 5.0 front view

3. DESIGN

The design includes the steps involved in the initial stage of FTTH network design, splitter allocation design to each floor, overall FTTH network from OLT to an ONT, Power budget calculation, link loss calculation, cost calculation, power meter testing results at initial checking stage. The design flow chart showing the each stage of developing an optimum design is given in Figure. 4. The cost and power budget are the main two parameters considered while designing. The customer requirements includes :High bandwidth data service, National, international voice calling facilities on all rooms, VoIP service and video phone facilities in all rooms, WiFi coverage in all common areas,CATV services in all rooms, IPTV service provisions in all rooms in near future, Dedicated bandwidth allocation as per requirement, multiple service provider facility, for doctor's room : data and voice, for each floor there should be WiFi ONT , data point and voice in nurses room, for patients room there should be ONT terminal that supports IPTV in future along with other connections.

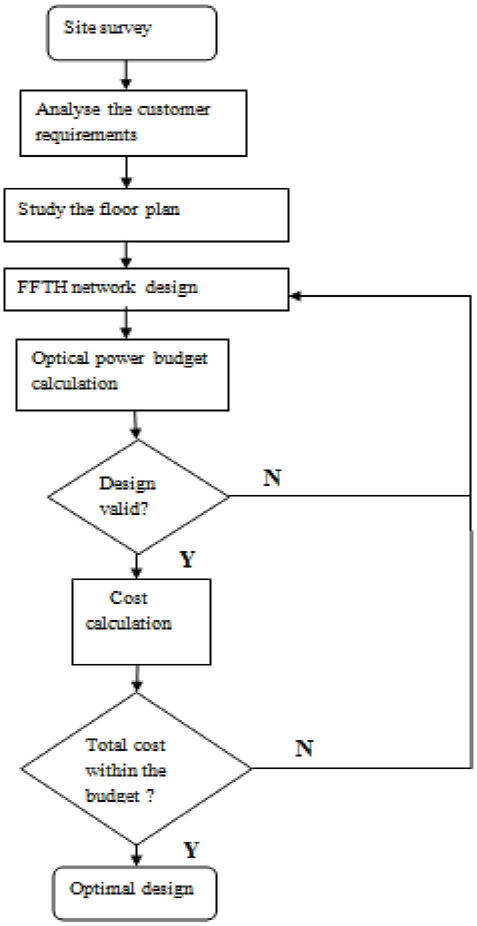


Figure 4: Design Flow Chart

The FTTH network design showing the transmission from OLT to one ONT is shown in Figure.5. The video signals are given to EDFA where there is an isolator to have the transmission only in one direction and transmitted at 1550nm and the voice , data are given to OLT to convert to optical signal and transmitted at 1310nm.WDM mixes these two signals from EDFA and OLT.

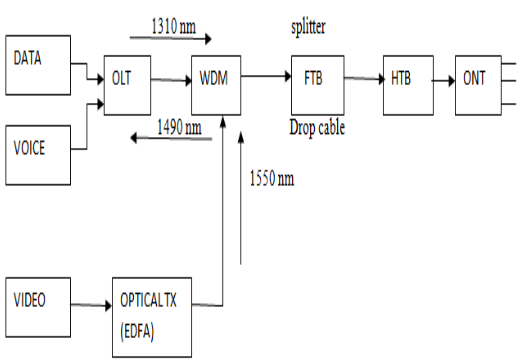


Figure 5: FTTH network design

The splitter allocation in each floor is designed considering the insertion losses, power transmitted and received at OLT and ONT. The power and the losses are calculated using the power meter testing. The splitter allocation design is shown in Figure.6 which is drawn using coral drawing and power ,insertion losses (IL) calculated are given in table 3. This design is flexible to accommodate future extensions to each floor. Even though the design is made upto 9th floor , the implementation is performed only upto 5th floor as per the customer requirement.

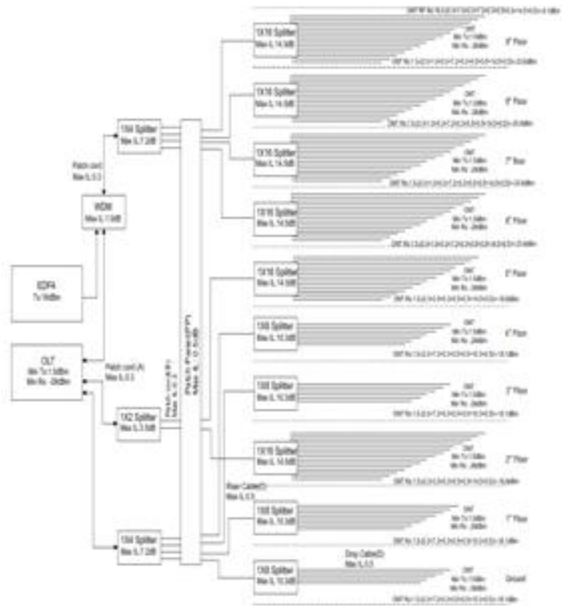


Figure 6: Splitter allocation design

Table 3: Power and Losses in the Components

components	Tx power (dBm)	Rx power (dBm)	IL (dB)
EDFA	16		
OLT	1.5	-28	
ONT	1.5	-28	
WDM			1.0
1x4 splitter			7.2
1x2 splitter			3.5
Patch cord			0.3
Patch panel			0.5
1x16 splitter			14.5
1x8 splitter			10.3
Drop cable			0.5
Riser cable			0.5

Power budget, link loss and cost are calculated using the following equations:

Rx power at ONT = min tx of OLT – (patch cord A max IL + patch cord B IL + splitter max IL + riser cable (C) IL + drop cable (D) IL).

Rx power at ONT = tx power at OLT – (all losses along the path from OLT to ONT).
Patch cord A : OLT to WDM and splitter
Patch cord B : splitter to patch panel.
Link loss = total length of fiber x attenuation (dB/km) + no. of splices x splicing loss + no. of connector x connector loss.
Total loss = Link loss + safety margin (3 dB).

Total cost = active component cost + passive component cost+ labor cost including implementation and maintenance cost.

Using these equations, the results are shown in table 4. The number of splices and connectors in each link are 4 and 9 respectively. Standard values of splice loss and connector loss are taken which is equal to 0.3dB/km and 0.75 dB respectively. Using this link loss = 7.168 dB & total loss = 10.168 dB. Only at OLT we use the connector type as SC-PC and all the other sections SC-APC is used. Transmit power for ONT and OLT are 1.5 dBm and the maximum tolerable power receive is -28 dBm.

Table. 4 Received power levels in ONT

Floor	Rx Power at ONT (dBm)
Ground	-18.1
1	-18.1
2	-18.6
3	-18.1
4	-18.1
5	-18.6
6	-23.6
7	-23.6
8	-23.6
9	-23.6

4. IMPLEMENTATION

The optimal design leads to implementation of the FTTH network. The design is done for 9 floors including the future works. This is a green field project for the implementation of FTTH network based on GPON in a new building which consists of :Ground Floor : MRI scan, consult, reception, First floor: endoscopy , nurse's room, ICU, consult, pre/post-operative room, Second floor: Doctor's room, nurse's room, consult room, nuero lab, Urodynamic, Third floor : not assigned, Fourth floor : consult room, Fifth Floor : Pathologists, lab in charge room, staff room, reception, lab tech/data entry, serology lab, TTD lab , cytopathologist's room. The implementation procedure is shown in the Figure. 7 . For testing, the methods used are OTDR and LSPM. Optical Time Domain Reflectrometry (OTDR) will launch the light into the network and it will used to measure the total length of the fiber, loss of fiber, connector, splice, bent positions and break point detection by using any one of the following output trace, table and summary. It can't be used for power measurement. Figure. 8 shows the OTDR testing. Light source and power meter (LSPM) testing is a type of testing which uses a light source as laser and power meter to test the loss and power in the equipments. Figure.9 shows the LSPM testing.

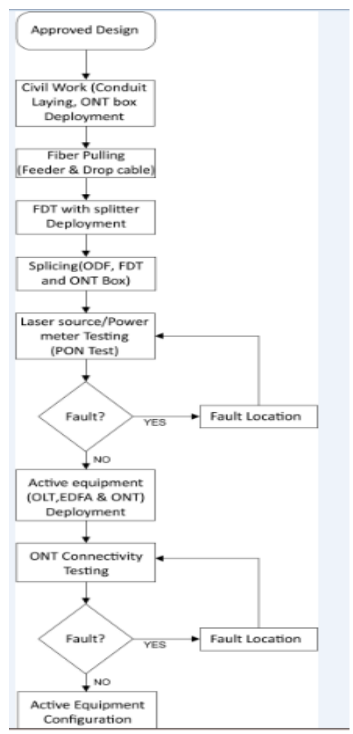


Figure 7: Implementation flow chart

Noise M210 OTDR , a product of AFL (American Fugikura Ltd) , Fugikura 80S splicer and F2H product, FHP1 series of power meter were used for OTDR testing, splicing and LSPM testing. Figure.10 shows the spicing.

Figure 8: OTDR testing.

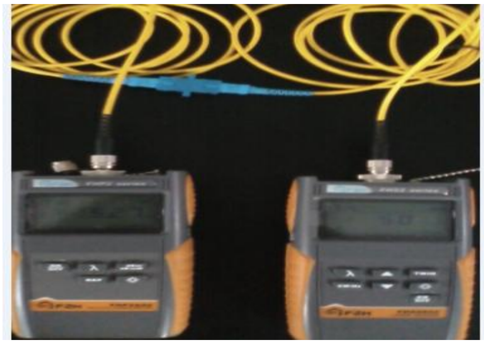
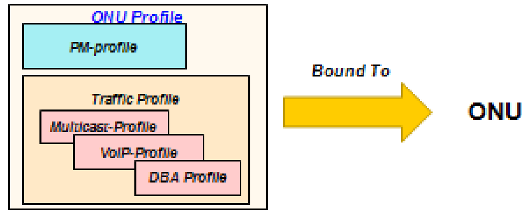


Figure 9: LSPM testing

Figure 10: Splicing

After implementation Profile configurations for each ONU is done. The categories of profile configurations are given in Figure. 11. Each profile configurations commands are run in hyperterminal of Ubundu and using Ethernet port it is connected to NIU (Network Interface Unit) of OLT. Multicast profile is for having IPTV which is considered for the future work. Performance Management (PM) is not performed here, it is mainly meant for performance monitoring and bandwidth usage analyzing used by the service providers.



Figureure 11: ONU profile

ONU profile will create a profile for each ONU which includes Traffic profile to handle the trafiic from each ONT , VoIP (voice over IP) profile which provides voice over IP including the POTS (Plain Old Telephone Service), DBA profile will allocate bandwidth dynamically at every milli sec as per the customer requirement.

5. RESULTS

The results include profile Configuration results, Received power results, INAS EMS results and total cost acquired result. From the profile Configuration result it is clear that all the services are successfully configurated and the received power results shows that the received power at each ONT is within the tolerable value. The INAS EMS shows the active GPON OLT ports with green light indication, Topological information, fault locations and its indication and so on. All these results in INAS EMS can be viewed instead of going for Hyperterminal profile configurations. Figure. 12 shows the received power level in putty software and Figure 13: show the details of power levels, distance and ID number of each ONT. INAS EMS Viewer result is shown in Figure. 14. The calculated cost result of proposed design is shown in Figure 15, it is about 1,36,2694 rupees and the cost of other design with 2x32 splitter at CO is shown in Figure 16.It is clear that for any other design the cost is high (14 lakh) due to the increase in patch cord, indoor cables and labor work such as splicing, laying etc. Even the copper network has high cost of implementation since it needs huge amount of copper for video, voice and data separately as well as the maintenance cost needed per year is comparatively high.

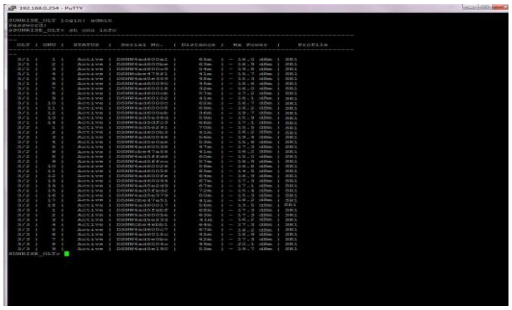


Figure 12: Received Power Levels in Putty Software

serial no.	Floor	ONU	STATUS	ONT Serial No.	ONT Model	Configuration	Distance	RX power in dBm
1	1st	1	Active	DSNW4ad600a1	H640GV	4Data+2voice	43m	-16.3
2	1st	2	Active	DSNW4ad600be	H640GV	4Data+2voice	40m	-17.1
3	1st	3	Active	DSNW4ad600c9	H640GV	4Data+2voice	38m	-17.8
4	1st	4	Active	DSNWcbe478f1	H640GW	4Data+2voice+WiFi	45m	-15.7
5	1st	5	Active	DSNW4ad5e359	H640GV	4Data+2voice	48m	-15.2
6	1st	6	Active	DSNW4ad60090	H640GV	4Data+2voice	46m	-17.5
7	1st	7	Active	DSNW4ad60016	H640GV	4Data+2voice	32m	-16.2
8	1st	8	Active	DSNW4ad600cb	H640GV	4Data+2voice	36m	-18.0
9	5th	1	Active	DSNW4ad5e291	H640GV	4Data+2voice	72m	-15.7
10	5th	2	Active	DSNW4ad600b3	H640GV	4Data+2voice	64m	-15.9
11	5th	3	Active	DSNW4ad60048	H640GV	4Data+2voice	57m	-19.6
12	5th	4	Active	DSNW4ad5e0ae	H640GV	4Data+2voice	55m	-15.4
13	5th	5	Active	DSNW4ad60038	H640GV	4Data+2voice	68m	-17.4
14	5th	6	Active	DSNWcbe47a58	H640GW	4Data+2voice+WiFi	81m	-17.4
15	5th	7	Active	DSNW4ad6000f	H640GV	4Data+2voice	59m	-17.4
16	5th	8	Active	DSNW4ad5ffd6	H640GV	4Data+2voice	61m	-15.1
17	5th	9	Active	DSNW4ad5ffcc	H640GV	4Data+2voice	57m	-17.3
18	5th	10	Active	DSNW4ad60026	H640GV	4Data+2voice	60m	-16.9
19	5th	11	Active	DSNW4ad60058	H640GV	4Data+2voice	63m	-16.6
20	5th	12	Active	DSNW4ad600fe	H640GV	4Data+2voice	63m	-17.0
21	5th	13	Active	DSNW4ad60094	H640GV	4Data+2voice	66m	-17.5
22	5th	14	Active	DSNW4ad5e2d9	H640GV	4Data+2voice	67m	-16.7
23	5th	15	Active	DSNW4ad5fed2	H640GV	4Data+2voice	73m	-15.6
24	5th	16	Active	DSNW4ad5e379	H640GV	4Data+2voice	81m	-15.9
25	2nd	1	Active	DSNWcbe47a51	H640GV	4Data+2voice	42m	-16.7
26	2nd	2	Active	DSNW4ad5febf	H640GV	4Data+2voice	48m	-16.7
27	2nd	3	Active	DSNW4ad6005e	H640GV	4Data+2voice	55m	-16.7
28	2nd	4	Active	DSNW4ad5e233	H640GV	4Data+2voice	49m	-16.7
29	2nd	5	Active	DSNW4ad600c7	H640GV	4Data+2voice	62m	-16.7
30	2nd	6	Active	DSNW4ad6018c	H640GV	4Data+2voice	44m	-18.5
31	2nd	7	Active	DSNW4ad5e0bc	H640GW	4Data+2voice+WiFi	42m	-18.2
32	2nd	8	Active	DSNW4ad6004c	H640GV	4Data+2voice	50m	-17.8
33	2nd	9	Active	DSNW4ad5e190	H640GV	4Data+2voice	56m	-18.1

Figure 13: Received Power Levels of Each ONT

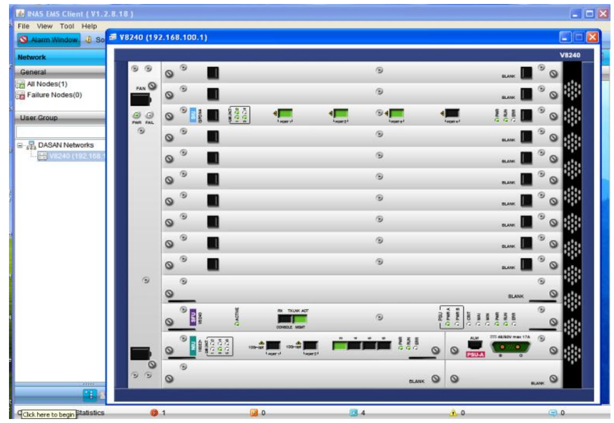


Figure 14: INAS EMS Viewer

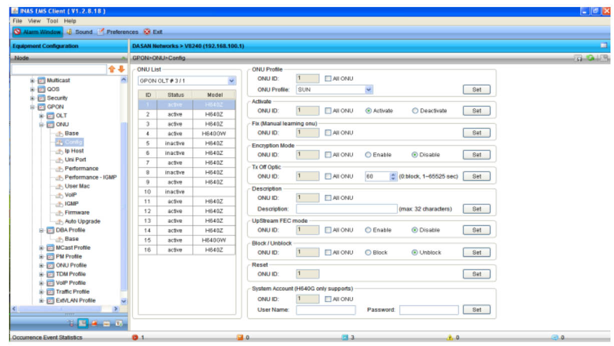


Figure 15: ONU Configuration

	Sl No	Description	Unit	Qty	Unit Price	Total Price
Active & Passive Parts CO	1	ODF Rack 36U	EA	1	32959	32959
	2	Chassis for NeST-40 - 10-slot: Subscriber Interface Unit - 2-slot: Network Interface Unit - 2-slot: Switching Fabric Unit _ N4040	EA	1	90321	90321
	3	Switching Fabric Unit - Switching capacity: 220Gbps - MGMT - Console _ SFU	EA	1	129992	129992
	4	Network Interface Unit with 2-port 10G XFP and 4-port 1G SFP (Excluding Optics)_ NIU_10GE2+	EA	1	78807	78807
	5	Subscriber Interface Unit 4-port GPON SFP (Excluding Optics)_ SIU_GPON4	EA	1	71305	71305
	6	Fan Unit _ FAN	EA	1	15124	15124
	7	Dust Filter _ Dust Filter	EA	1	10843	10843
	8	Cable Duct _ Cable Duct	EA	1	6596	6596
	9	DC Power Supply Unit with external alarm interface - Combination D-Sub 7W2 Connector _ PSU_DC_A	EA	2	15937	31874
	10	SFP GPON OLT_ SFP-GPON-OLT20	EA	3	10213	30639
	11	SFP UPLINK 1G_SFP-UPLK	EA	1	3362	3362
	12	48V DC Power Supply	EA	1	20925	20925
	13	EDFA	EA	1	85000	85000
	14	3U Splitetr module chassis	EA	1	5500	5500
	15	2x2 splitter Pluggable module	EA	2	4166	8332
	16	2x4 splitter Pluggable module	EA	1	5100	5100
	17	24 Port Patch panel	EA	1	7111	7111
	18	1u Cable management tray	EA	2	900	1800
	19	3M SC/UPC to SC/APC 2mm patch cord	EA	2	170	340
	20	3M SC/Apc to SC/APC 2mm patch cord	EA	20	160	3200
Active & PAsssive part - Shaft	1	Duplex fiber armored cable	mtr	3300	42	138600
	2	Wallmount termination box	EA	5	3500	17500
	3	1x8 Splitter with SC/APC connector	EA	3	4591	13773
	4	1x16 Splitter with SC/APC connector	EA	2	8708	17416
Active & PAsssive part -Room	1	4xGE + 2 POTS	EA	40	8643	345720
	2	4xGE + 2 POTS +Wifi	EA	5	10871	54355
	3	4xGE + 2POTS + RF	EA	0	14100	0
	4	ONT Box	EA	45	1200	54000
	5	1m SC/APC pigtail	EA	90	80	7200
Installation & Commissioning	1	Installation & Commissioning Cost,Includes Supply & Laying of 1" & 1/2" PVC Pipe ,Laying/Pulling of Fiber Cables,Fixing of ONT Box & Splicing at all the ends,Rack Dressing,Fixing of Wallmount Splitters/Rack mount splitters,Fixing & Configuration of OLT & ONT,Laying of CAT6 Cables for Voice & data & RG6 Cables,fixing & termination of CAT6 I/o s & RG6 Jacks.	EA	1	75000	75000
		GRAND TOTAL				1362694

Figure 16: Cost Calculated of Proposed Design

	Sl No	Description	Unit	Qty	Unit Price	Total Price
Active & Passive Parts CO	1	ODF Rack 42U	EA	1	42739	42739
	2	Chassis for NeST-40 - 10-slot: Subscriber Interface Unit - 2-slot: Network Interface Unit - 2-slot: Switching Fabric Unit _ N4040	EA	1	90321	90321
	3	Switching Fabric Unit - Switching capacity: 220Gbps - MGMT - Console _ SFU	EA	1	129992	129992
	4	Network Interface Unit with 2-port 10G XFP and 4-port 1G SFP (Excluding Optics)_ NIU_10GE2+	EA	1	78807	78807
	5	Subscriber Interface Unit 4-port GPON SFP (Excluding Optics)_ SIU_GPON4	EA	1	71305	71305
	6	Fan Unit _ FAN	EA	1	15124	15124
	7	Dust Filter _ Dust Filter	EA	1	10843	10843
	8	Cable Duct _ Cable Duct	EA	1	6596	6596
	9	DC Power Supply Unit with external alarm interface - Combination D-Sub 7W2 Connector _ PSU_DC_A	EA	2	15937	31874
	10	SFP GPON OLT_ SFP-GPON-OLT20	EA	2	10213	20426
	11	SFP UPLINK 1G_SFP-UPLK	EA	1	3362	3362
	12	48V DC Power Supply	EA	1	20925	20925
	13	EDFA	EA	1	85000	85000
	14	1U Splitetr module chassis	EA	1	4500	4500
	15	2x32 splitter Rackmountable module SCAPC	EA	2	21322	42644
	16	48 Port Patch panel	EA	2	10079	20158
	17	1u Cable management tray	EA	5	900	4500
	18	3M SC/UPC to SC/APC 2mm patch cord	EA	2	170	340
	19	3M SC/Apc to SC/APC 2mm patch cord	EA	60	160	9600
Active & PAssive part - Shaft	1	Duplex fiber armored cable	mtr	3300	42	138600
	2	12 Fiber indoor cable	mtr	600	75	45000
	3	Wallmount termination box	EA	5	3500	17500
Active & PAssive part -Room	1	4xGE + 2 POTS	EA	40	8643	345720
	2	4xGE + 2 POTS +Wifi	EA	5	10871	54355
	3	4xGE + 2POTS + RF	EA	0	14100	0
	4	ONT Box	EA	45	1200	54000
	5	1m SC/APC pigtail	EA	90	80	7200
Installation & Commissioning	1	Installation & Commissioning Cost,Includes Supply & Laying of 1" & 1/2" PVC Pipe ,Laying/Pulling of Fiber Cables,Fixing of ONT Box & Splicing at all the ends,Rack Dressing,Fixing of Wallmount Splitters/Rack mount splitters,Fixing & Configuration of OLT & ONT,Laying of CAT6 Cables for Voice & data & RG6 Cables,fixing & termination of CAT6 I/o s & RG6 Jacks.	EA	1	115000	115000
		GRAND TOTAL				1466431

Figure 17: Cost Calculated for 2x32 Splitter Design

6. CONCLUSION

The results shows the above mentioned design of FFTH network based on GPON technology is an optimum design which has tolerable power budget and the cost of implementation of this particular design is comparatively low than the other network designs. It is proven that the above design can include extended versions of technology and services like IPTV in future.

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Figure 18: Central Office

Figure 19: FTB with Splitter

Figure 20: WiFi ONT

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