Enabling FTTx Broadband Services using Smart Grid Infrastructure
Final Project Report
MINT.

University of Alberta

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SECTION-1

Case Study

1 ABSTRACT

Deployment of network between Edmonton and Leduc through Nisku so that this IT structure can be incorporated with Smart Grid to provide smart solutions to the end user comprising of utilities and their IT services ranging from high speed internet to plain old telephone system, smart utility solutions like real time power utilization, peak usage calculations for anticipating any outages and smart metering and data storage solutions.

1.1 PREFACE

The concept and help was taken from various sources as mentioned in the list of references on Page-70 of this report. Especially help was taken from Alberta Smart Grid Enquiry Report by Alberta Utilities commission and ComSoc Guide to PON networks by Stephen B, Yuanqin Lo, Ting Wang.

Reference: Wikipedia

1.2 STATISTICS AND GEOGRAPHY

EDMONTON
Population: 1160000
Area: 684.37 km sq.

NISKU
Population: 1000
Area: 65.5 km sq.
Distance from Edmonton: 27 km.

LEDUC
Population: 28000
Area: 42 km sq.
Distance from Edmonton: 36 km

SECTION-2

Network Type Selection

2 PON – OUR TECHNOLOGY OF CHOICE

In order to select the right technology for our task we need to compare different available technologies and the advantages of PON. In the following section some of the core components of the PON are looked into details and the advantages it offers over other copper based solutions. The suggested solution should have the ability to deal with all the bottlenecks to avoid traffic congestions and latencies associated with a network and yet deployment of such architecture should be economical and feasible in the long term operations with lower cost of maintenance.

A variety of network technologies have emerged over the period of time offering some advantages over the other with some limitations, however, pretty much with every access network architecture that comprises of the last segment of communication infrastructure (connecting individual subscriber to a service provider's central office CO) has limited the network's servicing ability and has proven to be the bottleneck due to ever growing number of services available and ever increasing demand of the bandwidth.

2.1 ACCESS NETWORK, FEEDER NETWORK AND DISTRIBUTION NETWORK

2.1.1 ***Access network*** consists of terminating equipment in the Head-End, a remote node and a network interface unit installed on the subscriber's side.

2.1.2 ***The feeder network*** on the other hand refers to the connection between central office and the remote node.

2.1.3 ***Distribution network*** connects NIU to remote node (RN). Downstream communication to the subscriber can be broadcast, multicast or individually directed to the user.

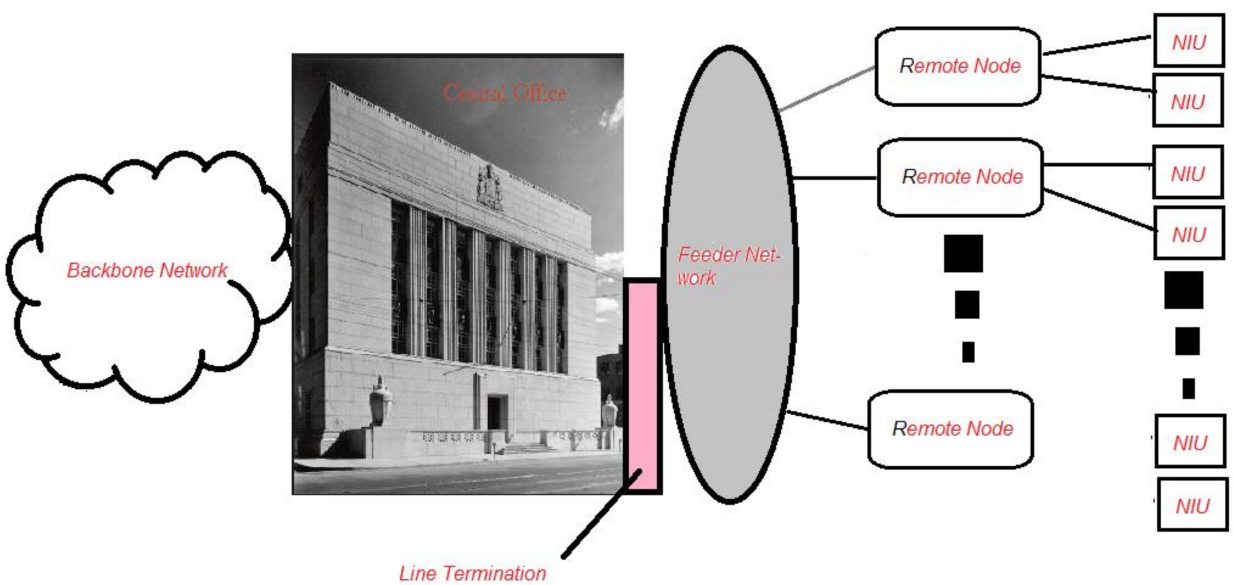


FIGURE - 1

Higher bandwidths are already available with optical networks and local area networks however this bandwidth is limited in residential access technologies such as digital subscriber line or cable data. A large disparity exists between legacy access systems with low megabits per second user rates and the network operator's optical network using multiple career wavelengths in WDM systems where each wavelength can carry data in gigabits per second (*Reference :Comsoc Guide to PON by Stephen B*). Upgrading the current access network with low cost and high bandwidth has become need of the day and so is required to successfully implement our solution to provide subscribers with all the services and the utility company the ability to smartly and remotely measure the utilization of their services.

To realize true high speed broadband access major technology companies are investing significantly in fiber – to – the - home (FTTH) and broadband wireless access (BWA). Among wired approaches PON is very attractive technology for its capability to carry network traffic at gigabit rates in an economical way. In comparison to the main contestants in this category very high speed digital subscriber line and cable data infrastructure require active components in the distribution network, PON deploys passive components in remote node between optical line terminal and optical network unit, thus lowering the cost of deployment and maintenance.

2.2 PASSIVE OPTICAL NETWORK LAYOUT (Source www. wikipedia.org)

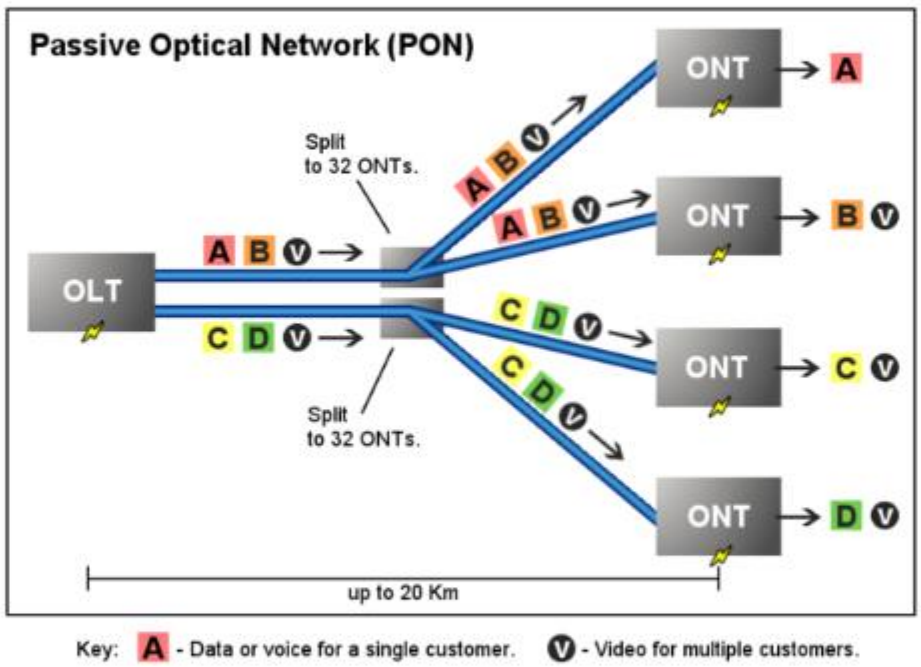


FIGURE - 2

It has been found that with appropriate selection of access sites, PON is less expensive than active optical fiber access networks by a factor of two, compared to P2P gigabit Ethernet which is not only more expensive but consumes more energy. There are variety of PON standards available including broadband passive optical network – BPON, Ethernet passive optical network – EPON, Gigabit capable passive optical network – GPON.

Data is sent to different users in assigned slots through a single optical carrier using time division multiplexing (TDM) for downstream and time division multiple access (TDMA) for upstream. PON offers a higher performance to cost ratio than any other copper based technologies. Its earlier data rates of 50 – 100 Mbps for down and upstream data were already faster than the commonly deployed version of the fastest copper based system.

Other advantages of PON include:

- Elimination of active optoelectronic devices specially when deployed in outside harsh environment.
- No more power conversion equipment or backup batteries are required in remote locations in general.
- No need to filter or isolate equipment for electromagnetic interferences on the fiber.
- For business customers PON offers higher data rates at the operating cost cheaper than those of DS-1 and DS-3 services.

http://arunkumaranand.bizhat.com/down/sem02.ppt.

https://books.google.ca/books?id=kU25BQAAQBAJ&pg=PA139&lpg=PA139&dq=operational+cost+comparison+of+GPON+with+DSL&source=bl&ots=IQshMued9k&sig=nOFzzmvVJSCF7pmt27VnJi0K9r0&hl=en&sa=X&ved=0CDcQ6AEwBGoVChMIlLH35N7UxwIVgaKICh0JPwdI#v=onepage&q=operational%20cost%20comparison%20of%20GPON%20with%20DSL&f=false

2.3 STANDARDS OF PON NETWORKS

Reference: ComSoc Guide to PON by Stephen B

There are various standards of PON available today. Some use fixed packet switching for data transmission while other can exploit variable packet size.

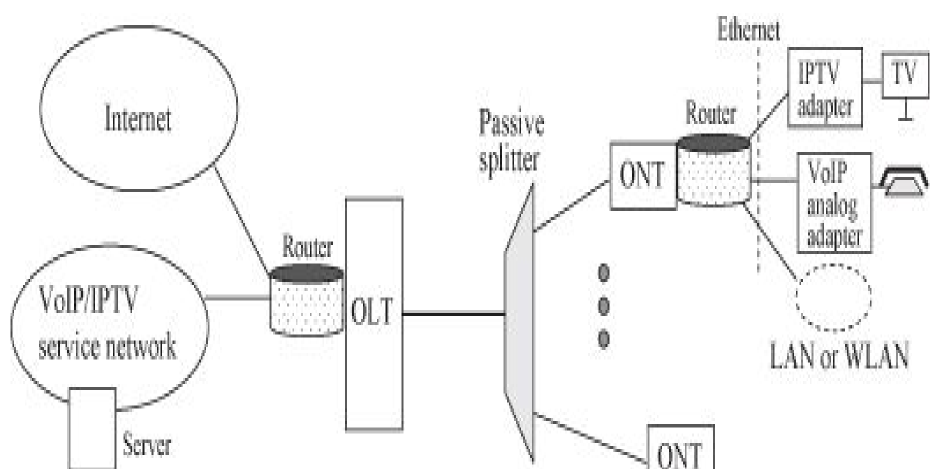
Internet protocol traffic dominates the network today. Majority of the networks support IP traffic to some extent. BPON utilizes circuit switching for its traffic through either asynchronous transfer mode (ATMs) or through time division multiplexing (TDMA). The both methods use fixed packets for transferring data however newer technologies such as GPON and EPON can transport packets of variable size of IP traffic, which are received in a router at Central office CO. Ethernet based PON especially sends packets using flexible multipoint control protocol (MPCP) to coordinate upstream data transmission for different users.

Through dynamic bandwidth allocation DBA algorithm (AYDA) supports internet's differentiated services for heterogeneous traffic that includes VoIP and internet protocol television also abbreviated as IPTV. Because of the low cost bandwidth PON are likely to become technology of choice for triple play over an IP oriented PON.

2.3.1 TRIPLE PLAY

Triple play refers to a combined package of video, voice and high speed internet on a single connection. If wireless is included it is called quadruple play. The low cost and profitability have inspired carriers to deploy Fiber based access systems like FTTX in broadband access networks. TDM based PON technologies like BPON, GPON and EPON are getting popularity for enabling carriers delivery of triple play to end users.

ILLUSTRATION OF TRIPPLE PLAY OVER AN IP ORIENTED PON



Reference: ComSoc Guide to PON by Stephen B

FIGURE - 3

Following table illustrates the triple and quadruple play services available for PONs.

Category	Services	Category	Services
Data	High-speed Internet Private lines Frame relay ATM	Wireless	Wi-Fi WiMAX Cellular pico/femtocells Ultra-wideband (UWB) Medium-speed Internet Multimedia "apps"
Voice	Plain old telephone service (POTS) VoIP		
Video	Digital broadcast video Analog broadcast video High-definition television (HDTV) Video on demand (VoD) Interactive TV TV pay per view Video blog		

Reference: ComSoc Guide to PON by Stephen B

With PON optimum utilization of bandwidth is possible. Many subscribers can share single feeder fiber that minimizes cost of deployment and maintenance and they also share transmission equipment at the central office CO. AT the CO an IP router and a class 5 switch is used to integrate telephone network (PSTN) and internet with PON. Video transmitters convert video signals into an optical format. OLT combines various services and transmits over PON. At the user end existing twisted pair cables are used to deliver telephone services and 10/100/1000G base Ethernet cables are used for the delivery of data services. Some deployments also use Wi-Fi. IPTV set top units will provide connectivity to IPTV Headend for the delivery of video content. Future deployment may include power line communication using power systems. We can easily integrate those deployments in our existing PON networks thus simplifying our task for smart metering.

Reference:

https://books.google.ca/books?id=5H65y7UiZCQC&pg=PA12&dq=use+of+fiber+in+power+line+communication&hl=en&sa=X&ved=0CB0Q6AEwAGoVChMIovjP4OTUxwIVkyuICh0zygOa#v=onepage&q=use%20of%20fiber%20in%20power%20line%20communication&f=fals

For transmission of video services low latency and low losses are essential. Voice consumes very little bandwidth as compared to Data or video but requires very low BER, jitter and latency. As a result TDM based PON feeder provides:

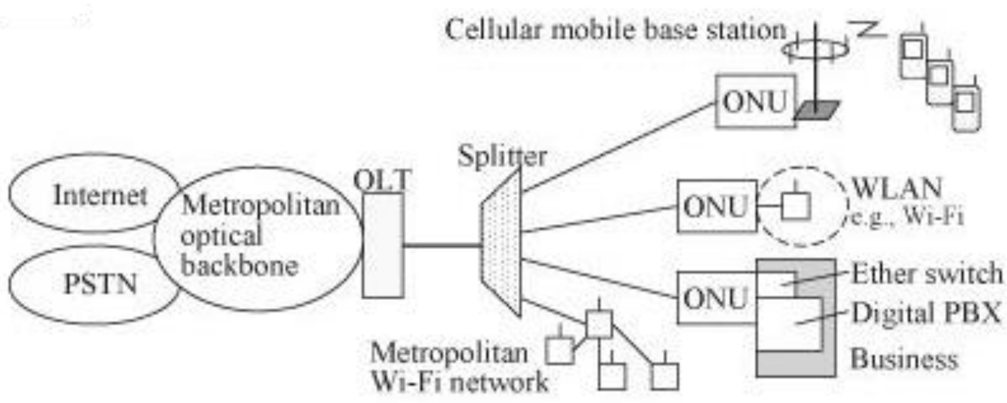
- Package services (different services sold as a bundle).
- A service level agreement (SLA) for access requirements and the limits for each service.
- QoS (quality of service - agreement and mechanism).

PON also has sufficient capacity to accommodate multimedia applications such as video/audio conferencing with inclusion of high definition applications.

2.4 BACKHAUL SERVICES

Backhaul is the connection of remote traffic collection points to the metropolitan backbone networks. These aggregation points include wired LANs for businesses and residential, Wi-Fi access points and cellular mobile base stations. With legacy systems most mobile operators bridge their mobile network to core infrastructure by leasing T1/E1 copper based lines. Ever increasing bandwidth allocation requirements are creating need for a greatly extended backhaul systems. With PON integration of such mobile users with backbone networks is easier than any other available alternate.

2.4.1 PON BACKHAUL APPLICATION



Reference: ComSoc Guide to PON by Stephen B

FIGURE – 4

The clear advantages of PON backhaul are:

- Greater capacity than leased T1/E1 lines with excellent time synchronization.
- On-demand bandwidth allocation.
- Network scalability as the requirement grows.

2.5 PON STANDARDS OVERVIEW AND THEIR COMPARISON

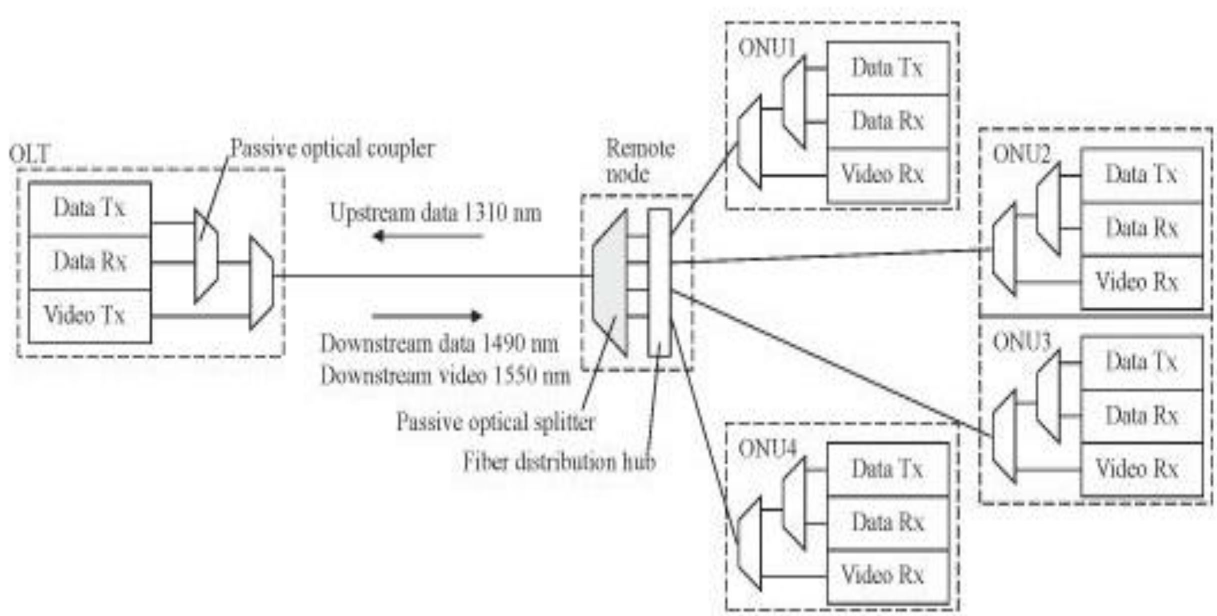
2.5.1 BPON OVERVIEW (Reference: ComSoc guideto PON by Stephen B)

BPON is a higher performance version or extension of asynchronous transfer mode passive optical network (APON). In APON data is also encapsulated in ATM cells for the transmission between OLT and ONUs. It supports wave division multiplexing (WDM), supports allocation of dynamic and high upstream bandwidth. Following table illustrates the rates supported by BPON for line signal transmission that employs bipolar scrambled non-return-to-zero (NRZ modulation).

Downstream (Mbps)	Upstream (Mbps)
155.52	155.52
622.08	155.52
622.08	622.08
1244.18	155.52
1244.18	622.08

622.08 Mbps data rate for downstream and 155.2 Mbps for upstream signaling rates are commonly accepted by the industry. The line signal consists of NRZ binary pulses with ON state when the light being transmitted and the OFF state when no light is being transmitted.

A typical deployment of BPON concept



Reference: Comsoc Guide to PON_by Stephen B

FIGURE-5

2.6 GPON OVERVIEW

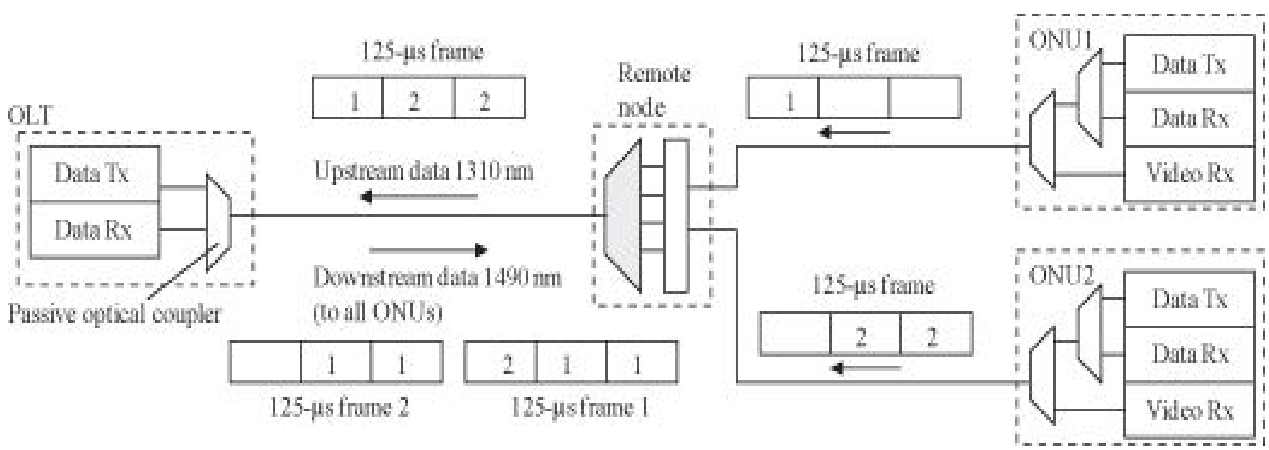
GPON defined in the G.984 family of standards is an extension of BPON, having most of the characteristics described in the previous section. It offer higher data rates , better security and a choice among ATM, GPON encapsulation method (GEM) and the Ethernet transmission protocols in contrast to BPON that only supports ATM protocol. Significantly large bandwidth and higher efficiencies are achieved by supporting large, variable length packets depicting much of the traffic on IP networks.

The collective upstream and downstream rates range up to 2.488 Mbps. GEM efficiently reduces latency and thus improve QoS for delay sensitive voice and video traffic.

G.984 standards specify the PMD layer, the transmission convergence (TC) layer and the ONU/ONT control interface. The supported transmission rates over GPON are listed in the table below:

Downstream – Gbps	Upstream
1.24416	155.52, 622.08, 12244.16 Mbps
2.48832	155.52, 622.08, 1244.16, 248832 Mbps
9.95328	2.48832 Gbps

An example of GPON showing TDMA multiplexing of upstream frames is shown below:



Reference: ComSoc Guide to PON by Stephen B

FIGURE - 6

2.7 GPON encapsulation method - GEM

GEM effectively minimizes the encapsulation overhead (5 bytes per frame) and is thus able to accommodate variable length packets. A variant of the generic framing procedure (GEP) is used to carry TDM and Ethernet traffic over the GPON network. A 5 byte header is used in in a GEM frame that delineates the start of a GEM frame allowing OLTs to identify the upstream frames. Physical control block downstream (PCBd) provides the frame's bit synchronization without monitoring the alignment information between consecutive frames. The header of the frame is consists of following fields:

- Pay load length indicator (PLI) – Its value L is the number of bytes in the payload part of the GEM frame.
- Port ID – Identifies the GFP port a GEM frame belong to.
- Payload Type indicator (PTI) – indicates whether the GEM frame carries user data or a GEM OAM message. If it carries user data, the PTI field also indicates if the GEM frame is the end of a data frame.
- Header Error Check (HEC) – Error detection and correction for the GEM frame header.

GEM maps an Ethernet frame directly into the payload field. The field in an Ethernet frames are:

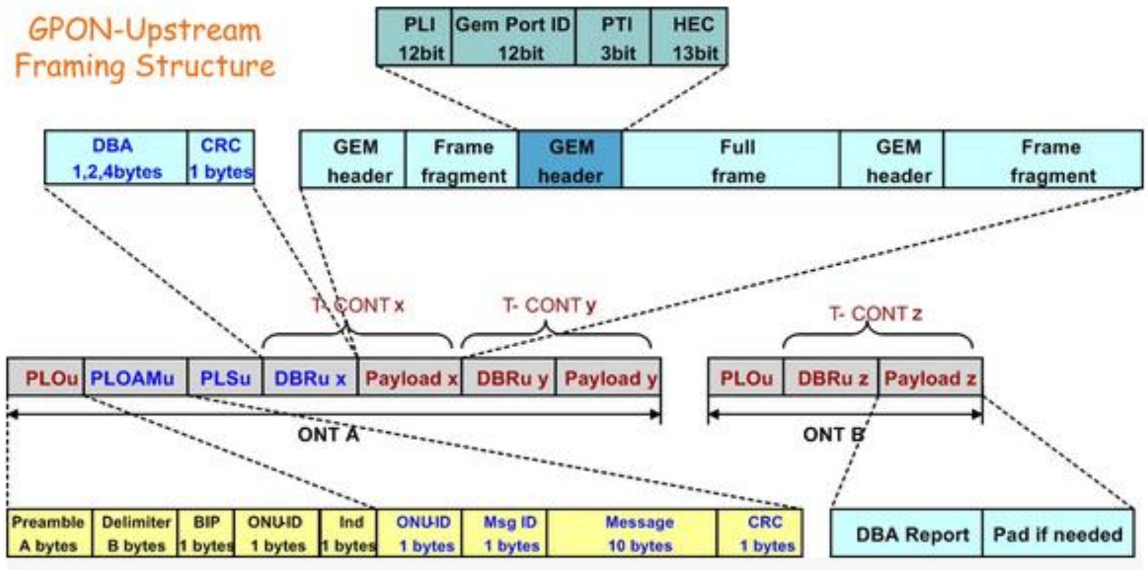
- Destination address
- Source address
- Length type
- Operation code
- Time stamp
- Ethernet pay load and frame check sequence (FCS)

The above fields are mapped octet by octet into GEM payload. For TDM data, a group of consecutive TDM data values are accumulated and are mapped octet by octet into GEM payload. In GEM an appropriate encapsulation layer over GPON is provided so no other encapsulation layer is required. This dramatically increases the provisioning of bandwidth.

2.7.1 Mapping of TDM Octets and Ethernet frames into GEM

Mapping of upstream and downstream data are illustrated below:

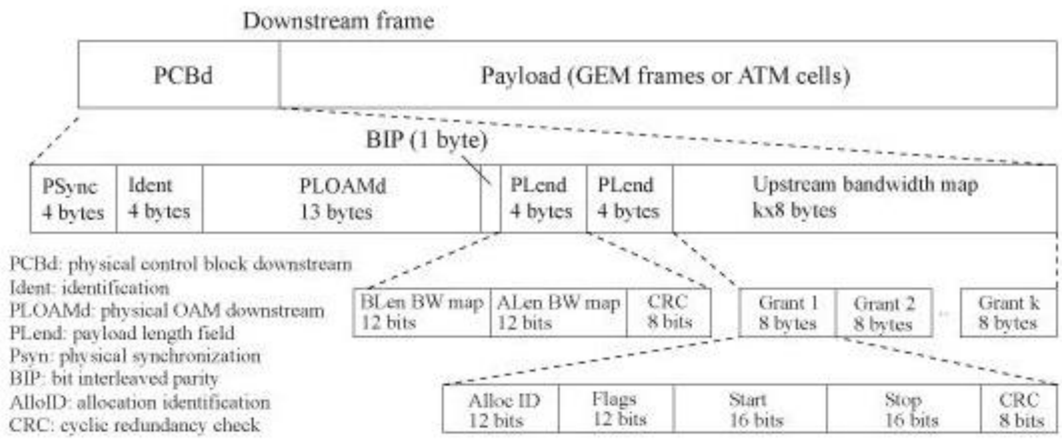
2.7.2 Frames for Upstream Data



Reference:http://www.fiberoptictel.com/gpon-framing-structureuplink-frame/

FIGURE - 7

GPON Downstream Data Format



Reference:https://sites.google.com/site/amitsciscozone/home/gpon/gpon-fundamentals

FIGURE - 8

The fields in PCBd that can be monitored in a central office or other control hubs are:

- Physical synchronization (PSYNC) indicating the beginning of downstream frame.
- Identification (IDENT) indicating whether forward error correction is used and the superframe count.
- Physical layer operation, administration and maintenance downstream (PLOAMd).
- BIP providing error detection for downstream frame.

- PLend (payload length field), consisting of a BLen field for the number of grants carried by the downstream frame, the ALen field for the number of ATM cells and the PCBd and a CR.
- C for error correction.

2.8 EPON OVERVIEW

Ethernet has been universally deployed in networks. It dominates LANs and high speed switched carrier Ethernet is ubiquitous in metropolitan area networks (MANs) and wide area networks (WANs). The following main features of Ethernet has made it the most popular choice:

- Low – cost Ethernet UNI
- Medium access control address for low cost layer 2 switching.
- Designed to carry traffic with variable packet sizes.

EPON uses a downstream wavelength between 1480 and 1580 nm and an upstream wavelength between 1260 and 1360 nm.

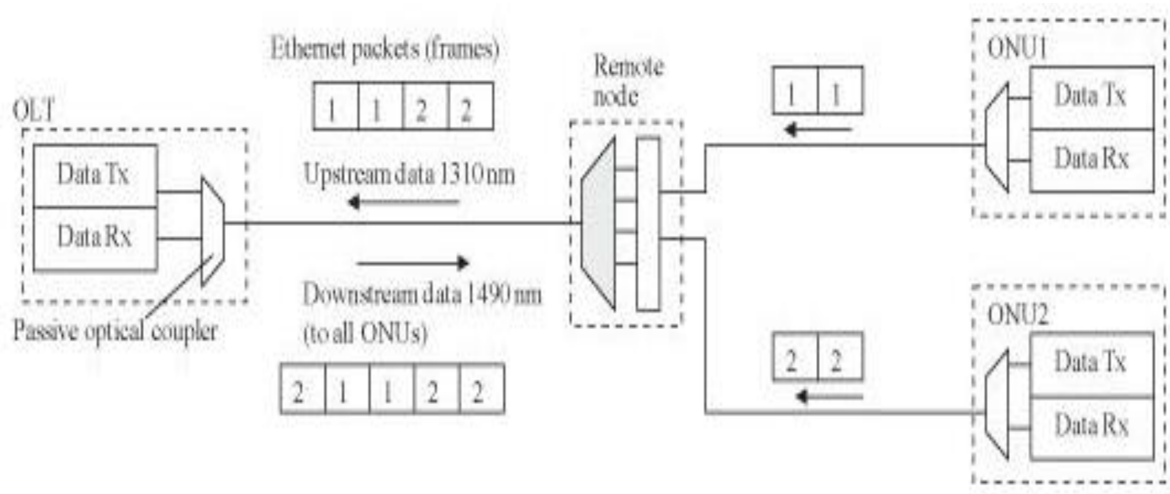
The enhanced version of EPON supports user data rates of 10 Gbps downstream and in the upstream direction. 10 G EPON was developed keeping in view the market drive for delivery of digital video to subscribers. 10 Gbps data rate allows delivery of multiple high definition video streams to every ONU/ONT with a split ratio of 1:32. It was developed to support band-width intensive applications that require fast, reliable and scalable connections e.g. broadcast TV, IPTV, Video on demand, 3D gaming, ultra-high speed internet, video casting and medical imaging.

EPON relies on switched Ethernet. Ethernet frames from different ONUs are transmitted without interference. This is accomplished using buffers in the ONUs and OLTs. Frames are queued and switched into the backbone network using these buffers thus avoiding any occasional collision and retransmission as in the original Ethernet that uses Carrier sense multiple access with collision detection (CSMA-CD). The multiple queues for different priority services can be maintained at switching points with Ethernet frames carrying a priority field.

Every Ethernet device has a unique 48 bit MAC address assigned by the manufacturer. Pay load for Ethernet ranges from 40 to 1494 bytes, making it suitable to carry traffic with variable packet size.

Tag control field, a 3 bit priority value selects one of eight queues of ordered priority. This is especially helpful in the industrial environments and utility distribution systems where certain alarms and faults require immediate attention.

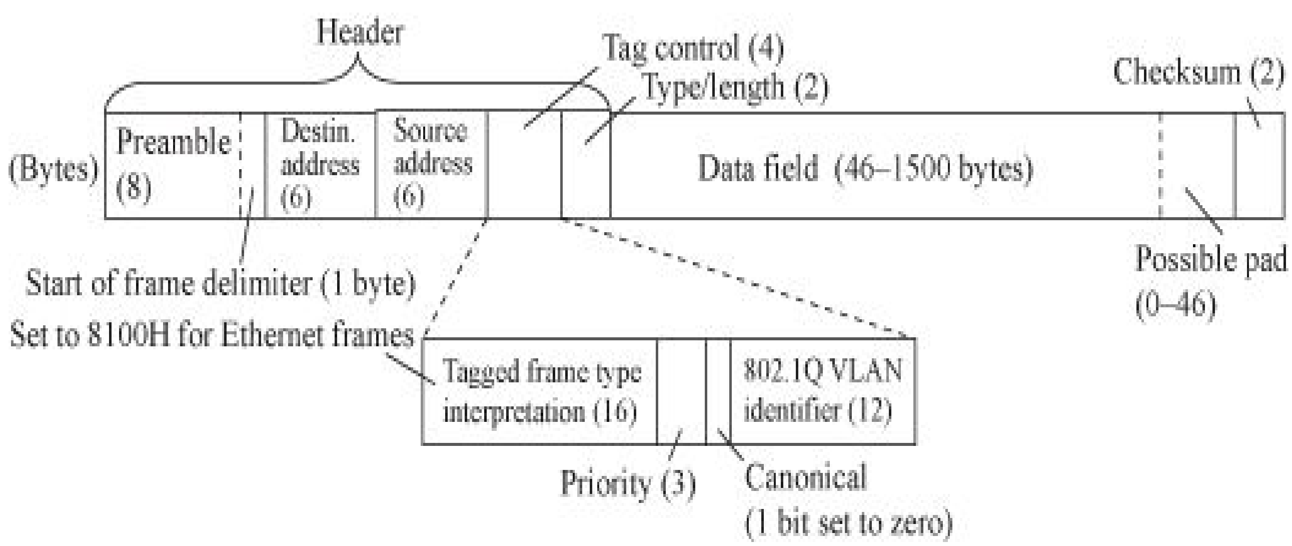
Implementation of EPON Concept



Reference: ComSOc Guide to PON by Stephen B

FIGURE - 9

Ethernet Frame Including Priority Field



Reference: ComSOc Guide to PON by Stephen B

FIGURE - 10

2.9 COMPARISON OF 1G EPON AND GPON

EPON is an enhancement of Ethernet technology from LANs to the access network domain. Its features simple implementation and compatibility with existing low-cost available Ethernet equipment. It can support densely populated areas and has gain its markets quite successfully especially in Asia. In North America GPON is more popular with 74% of FTTx subscribers while EPON for only 5% whereas rest are legacy networks.

2.9.1 ADVANTAGES OF GPON OVER EPON

As an evolved version of BPON, GPON broadband access features are based on BPON. It has protection switching better encryption and strong error detection as compared to EPON that lacks in protection switching and has weak error correction capability. Because GPON uses GEM mechanism that provide more flexible services with better efficiency. Its improved transmission rate and compatibility with ATM technology make GPON the PON technology of choice in North America.

A brief comparison of the two technologies is given on the next page.

Features	EPON	G-PON
Standard	IEEE 802.3 ah-2004	ITU-TG.984.x
Line Rate	1.2 Gbps symmetric	Max 2.448 Gbps symmetric
Revenue BW	900 Mbps	2300 Mbps
Downstream Efficiency	72%	92%
Upstream wavelength	1310 nm	1310 nm
Downstream wavelength	1490 nm	1490 and 1550 nm
Data Unit	Ethernet frame	GEM frame, ATM cell
Split ratio	1:16, 1:32 with FEC	1:64 or 1:132 possible
Max Distance	20 km	20 km
TDM Support	Ethernet frame encapsulation	Directly
QoS support	802.1Q priority levels	Fixed, assured, non-assured, best effort
Address Space	48 bits	8 bits
Class of Service	8 queues	5T- Cont Types
Security	Not specified	AES encryption
Protection	Not specified	Four Specified architecture

From Cost perspective GPON also enjoys significant advantage over EPON.

From the above comparison GPON is a clear technology of choice for our task. Therefore in next sections hardware requirements and number of subscribers that can be supported and the placement of OLTs are discussed based on the geographical region of Edmonton and surroundings.

SECTION-3

Hardware Requirements

3 HARDWARE REQUIRED FOR OUR CASE STUDY

3.1 CORE ELEMENTS OF GPON

3.1.1 Optical Line Terminal (OLT): Interface at the central office

Provides interface between a GPON and service providers core network this typically include IP traffic over fast Ethernet, Gigabit Ethernet or 10 Gigabit Ethernet.

In point to multipoint physical system OLTs are passively connected to ONT/ONUs through an optical splitter. Downstream optic signals are combined through TDMA into a single fiber for upstream transmission.

Service provider's end point in a GPON is an OLT. Digital data and audio transmission uses 1490 nm laser, analog video transmission uses 1550 nm laser and digital data and voice signals are received at receiver using 1310 nm detector.

3.1.2 Optical Network Unit (ONU): Near end users – at the user premises

End point in a GPON is ONU/ONT usually located at subscriber's premises however it can also be in the field e.g. a Wi-Fi access point. ONU usually represent field unit serving more than one network termination while ONT is usually referred to only one termination.

3.2 HARDWARE LIMITATIONS

Maximum distance from OLT to ONT is 20 km. This range can be extended by using remote OLTs placed in the field.. This can extend the range of GPON serving radius from 20 km to 40 km. Example of such equipment is E7 GPON optical interface module (OIM). These can be plugged into any of the available ports of OLT. No complicated equipment is required.

Pluggable Extended Reach GPON optical interface module (OIM)

FIGURE - 11

The other limitation is the splitters. They are passive splitters and usually come in 1x32, 1xs16 and 1x8 and 1x4 configuration.

EDMONTON:

Total Area: 684.37 km sq.

In order to find out the linear distance from one end of the city to the other end we need to take square root of 684.37 would give us approximately 26 km on each side of the square. Distance from the center of the city to one end would therefore be around 13 km.

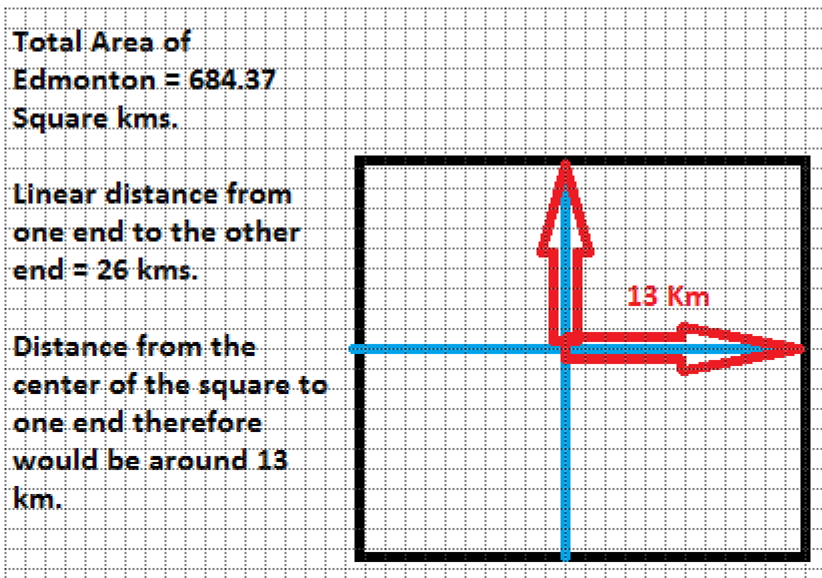


FIGURE - 12

Population of Edmonton is supposedly 1,160,000. In order to simplify our study we have to make some assumptions here:

- Suppose one house hold is consists of 4 persons.

- Take rate is 100%, in reality due to competing Service provider take rate is around 50%.
- We are not considering multiunit dwellings to simplify calculations of our power budget and hardware.
- Density of 1160000 people living is uniform in all four quadrants.
- Split ration of 1:64 is considered.

3.3 Calculation for Hardware required for Edmonton (One quadrant only):

Assuming people are uniformly distributed in all four quadrants of the city means number of people living in one quadrant is:

1160000/4 = 290000 is the population density of one quadrant.

As per our assumption, one house hold is comprised of 4 person's means total number of households in one quadrant will be: 72500

Number of households in one quadrant: 72500

Total number of splitters required per quadrant: 72500/32 = 2265.65 i.e. 2266.

2266 splitters will be sufficient to serve radius of 13 km sq for the total houses of 72500 in one quadrant of Edmonton.

Using E7 calix terabit chassis it has 20 slots. We can use 18 slots with 8 GPON ports hence total GPON ports will be

8x18= 144 ports.

Each port will have split ratio of 64,

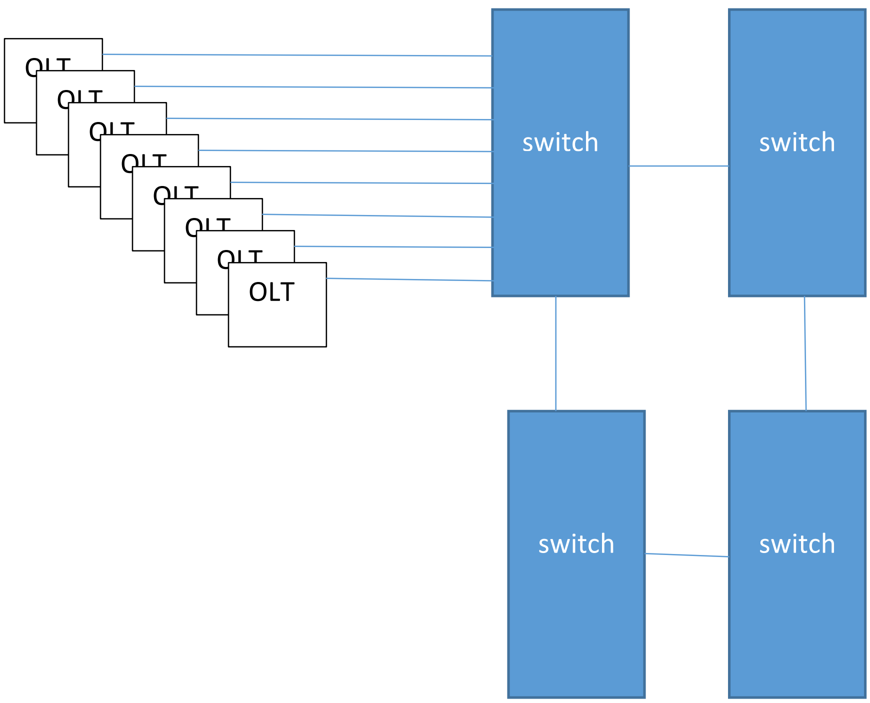
144x64=9216 density to service 9216 residents.

2 remaining slot of E7 are reserved for uplink connectivity.

One chassis of OLT can accommodate 9216 ONTs. Total number of house hold per quadrant is 72500. Therefore, Total OLTs required would be:

72500/9216 = 8 OLTs per quadrant.

Multiple OLTs are required to serve one full quadrant. That means we need to connect multiple OLTs together through backbone switches. Thus multiple OLTs will share the same switch per quadrant.



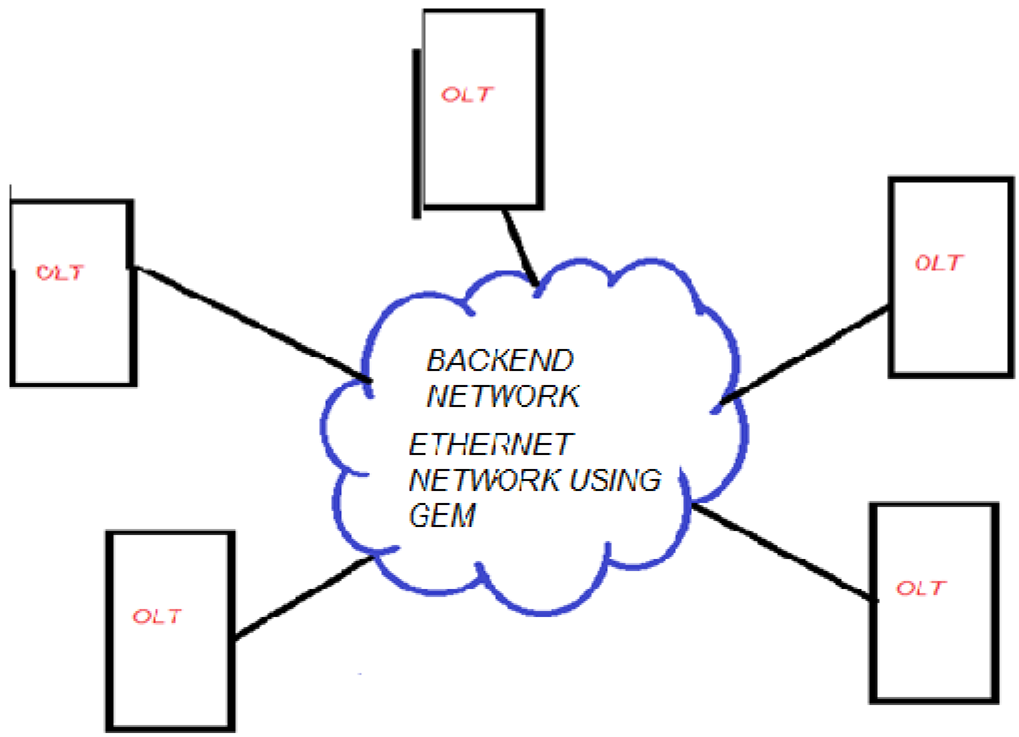


FIGURE - 13

3.3.1 HARDWARE REQUIRED FOR THE ENTIRE AREA OF EDMONTON:

Total number of OLTs required = 8x4=32

Total number of Splitters required= 2266x4= 9064

Total number of ONTs required = 72500 x 4 = 290000

SECTION-4

Deployment and Placement of OLTs

4 PLACEMENT OF OLTs (Source: www.wikipedia.org)

Since one side is only 13 kms of length and we can cover 20 kms with 1 OLT therefore placement of these OLTs is relatively easy and of least significant. Edmonton is divided into 7 geographic sectors and 375 neighborhoods. Edmonton's mature area sector, or inner city corresponds with those neighborhoods deemed mature in the city's municipal development plan. Placing our OLTs alongside these neighborhoods would provide us the most coverage geographically and population wise.

4.1 OLT#1 – DOWNTOWN AREA

Edmonton's central core comprises Downton and its 11 surrounding neighborhoods. This OLT can geographically cover the following neighborhoods:

1. Capital City Boulevard area
2. Legislature Grounds
3. Arts District
4. Commercial Core
5. River's Edge area
6. Station Lands Area
7. Jasper Avenue

4.2 OLT#2 – WAREHOUSE AREA

1. Mackay Avenue Neighborhood
2. Central warehouse area
3. Heritage Area
4. Mac. Evan area
5. Railtown Area

4.3 OLT#3 - BEVERLY AREA

1. Abbotsfield
2. Beacon Heights
3. Bergman
4. Beverly Heights
5. Rundle Heights

4.4 OLT#4 – JASPER PLACE

1. Britannia Youngstown
2. Canora
3. Elmwood
4. Glenwood
5. High Park
6. Jasper Park
7. Lynnwood
8. Mayfield
9. Meadowlark Park
10. Rio Terace

11. Sherwood
12. West Jasper Place
13. West Meadowlark Park

4.5 OLT#5 – NORTH EDMONTON AREA

1. Strathcona
2. West Edmonton

4.6 OLT#6 – CASSELMAN – STEELE HEIGHTS

4.7 OLT#7 – DICKINS FIELD

4.8 OLT#8 - LONDONDERRY

4.9 OLT#9 – CASTLDOWN AREA

1. Baranow
2. Baturyn
3. Beaumaris
4. Carenarvon
5. Canossa
6. Carlisle
7. Chamberry
8. Dunluce
9. Elsimore
10. Lorelei
11. Rapperwill

4.10 OLT#10 – LAKE DISTRICT AREA

1. Belle Rive
2. Crystallina Nera
3. Eaux Claires
4. Joviz
5. Klarvatten
6. Lagolind
7. Mayliewan
8. Ozerna
9. Schonsee

4.11 OLT#11 – THE PALISADES AREA

1. Albany
2. Carlton
3. Cumberland
4. Hudson
5. Oxford
6. Pembina

4.12 OLT#12 – CASSELMAN-STEELE HEIGTHS

1. Casselman
2. Ebbers
3. Mcleod
4. Miller

4.13 OLT#13 – CLAREVIEW AREA

1. Bannerman
2. Belmont
3. Clareview Town Centre
4. Fraser
5. Hairsine
6. Kernohan
7. Kirkness
8. Sifton Park

4.14 OLT#14 – HERMITAGE AREA

1. Cannon Ridge
2. Homesteader
3. Overlanders

4.15 OLT#15 – HORSE HILL AREA

4.16 OLT#16 – PILOT SOUND AREA

1. Brintnell
2. Cy Becker
3. Gorman
4. Hollick Kenyon
5. Matt Berry
6. Mc Conachie

4.17 OLT# 17 – BIG LAKE AREA

1. Hawks Ridge
2. Kinglets Garden
3. Pintail Landing
4. Starling
5. Turmpeter

4.18 OLT#18 – DECOTEAU AREA

1. Ellerslie
2. The Meadows
3. Millwoods
4. Burne Woods, Knottwoods, Lakewood
5. Millwoods Towncentre, Millbourne, Millhurst

4.19 OLT # 19 – RIDGEWOOD AREA

1. Southwood
2. Woodvale
3. Charlesworth
4. Mattson
5. Walker

4.20 OLT#20 – HERITAGE VALLEY AREA

1. Allard
2. Blackmud creek
3. Callaghan
4. Cashman

5. Cavanagh
6. Chappelle
7. Desrochers
8. Graydon
9. Haysridge
10. Heritage valley town center
11. McEwan
12. Paisley
13. Richford
14. Rutherford

4.21 OLT#21 – KASKITAYO

1. Bears Paw
2. Blue Quill
3. Emineskin
4. Kehaewin
5. Skyrattler
6. Sweet Grass
7. Steinhauer
8. Twin Brooks

4.22 OLT#22 - RIVER BAND

1. Brander Gardens
2. Brookside
3. Bulyea Heights
4. Carter Crest
5. Falconer Heights
6. Henderson Estates
7. Oglivie Ridge
8. Ramsay Heights
9. Rhatigon Ridge

4.23 OLT#23 – TERWILLEGAR HEIGHTS AREA

1. Ambleside
2. Glennridding Heights
3. Glenridding Ravine
4. Keswick
5. Winderemere
6. Blackburne

4.24 OLT#24 – THE GRANGE AREA

1. Glastonebury
2. Granville
3. The Hamptons

4.25 OLT#25 – LEWIS FARMS

1. Breckenridge Greens
2. Potter Greens
3. Rosenthal
4. Secord
5. Stewart Greens
6. Suder Greens
7. Webber Greens

4.26 OLT#26- RIVERVIEW AREA

4.27 OLT#27 – WEST JASPER PLACE

1. Aldergrove
2. Belmead
3. Callingwood North
4. Calling wood South
5. Dechnen
6. Donsdale
7. Gariepy
8. Jasmieson Place
9. La Perle
10. Lymburn
11. Oleskiw
12. Ormsby
13. Summerslea

14. Terra Losa
15. Thorncliff
16. Wedgeood Heights
17. Westridge

4.28 OLT#28 – NORTH EAST INDUSTRIAL

4.29 OLT#29 – NORTH WEST INDUSTRIAL

4.30 OLT#30 – RIVER VALLEY AND RAVINE SYSTEM

Two OLTs are left to accommodate any shuffling required in the placement of OLTS from population point of view. Edmonton's most populated areas are South East and north, hence we may need to place one more OLT in order to completely cover the population.

4.31 HARDWARE CALCULATION FOR NISKU

Population: 1000

Area: 65.5 km sq.

Distance from Edmonton: 27 km

Again as per our assumption of 4 persons per house hold we can calculate total number of houses i.e 1000/4

Total number of houses: 250

Total number of splitters required: 250/32 = 7.8 ~ 8

Because of the distance of 27 km we can use one extended GPON module in one of the OLTs that are in the southern quadrant of Edmonton. This will extend the range from 20 km to 40 km. Keeping in view the potential future growth of the city we can install one OLT in Nisku area and that should not only cover the entire Nisku but will also help covering the nearby areas including Leduc.

4.32 HARDWARE REQUIREMENT FOR LEDUC

Population: 28000

Area: 42 km sq.

Distance from Edmonton: 36 km

Total number of household:

Based on assumption 4 persons comprises of 1 house: 28000/4 = 7000

Total number of splitters required: 7000/32 = 218.75 ~ 219

Distance between Leduc and Nisku is only 10.7 km therefore the OLT placed in Nisku can easily cover the entire Nisku and Leduc region.

4.33 PLACEMENT OF OLTS IN LEDUC AND NISKU REGIONs

Due to very small geographic region and low population density placement of OLTs is insignificant but the future growth should be kept in mind.

4.34 LASER AND BANDWIDTH REQUIRMENT FOR IMPLEMENTATION

GPON uses optical wavelength division multiplexing (WDM) so a single fiber can be used for both downstream and upstream data.

A laser on a wavelength of 1490 nm transmits downstream data. Upstream data is transmitted on a wavelength of 1310nm. If TV is being distributed, a wavelength of 1550 nm is used.

4.35 DATA FORMAT

While each ONU gets the full downstream rate of 2.48 Gbps GPON uses a time division multiple access (TDMA) format to allocate a specific time slot to each user. This divides the bandwidth so each user gets a fraction such as 100 Mbps that depends upon how the service provider wants to allocate it.

The upstream rate is less than the maximum because it is shared with other ONUs in a TDMA scheme. The OLT determines the distance and time delay of each subscriber. Then software provides a way to allot time slots to upstream data for each user.

SECTION-5

Media Access

5 GPON ENCAPSULATION METHOD (GEM)

Reference: Comsoc Guide to PON by Stephen B

GPON as discussed earlier is an extension of BPON inheriting most of its characteristics. One main difference is GPONs ability of variable size packet transmission especially Ethernet transmission protocol support rather than single ATM protocol of BPON. Supporting large variable length packets on IP networks increases bandwidth and bandwidth efficiency.

GEM efficiently aggregates IP traffic and through frame segmentation reduces latency to improve quality of service (QoS) for voice and video traffic.

- In order to carry variable packet sizes GEM encapsulates them with minimum overhead that is only 5 bytes per frame.
- GEM utilizes a variant of Generic Frame Procedure (GFP) to carry TDM and Ethernet traffic over GPON.
- GEM frame has a 5 byte header which is used as a START identifier of a GEM frame allowing OLT to identify the upstream frames.
- No alignment monitoring information is transmitted between the consecutive frames.

- Physical Control Block Downstream (PCBd) is responsible for monitoring alignment information between consecutive frames and provides bit synchronization.

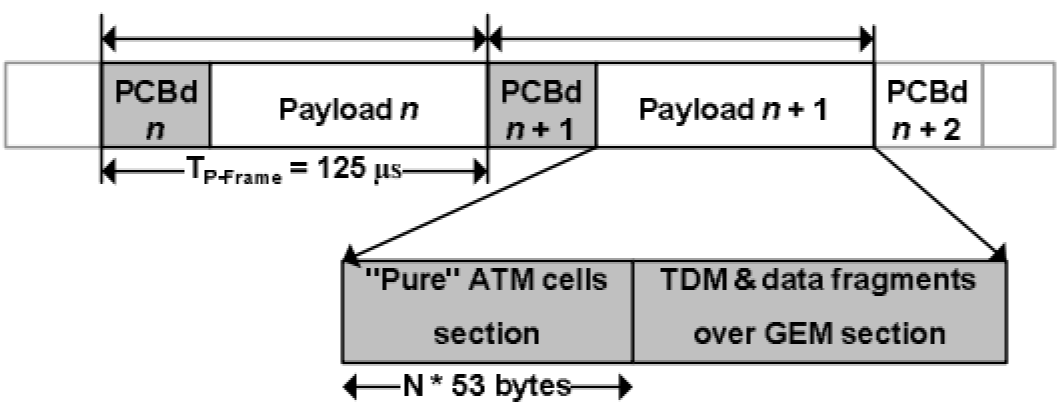
5.1.1 DOWNSTREAM TRAFFIC GPON FRAME FORMAT

Reference:Gigabit Passive Optical Network – GPON by Ivica Cale, Aida Salihovic and Matija Ivekovic

TDM is used to broadcast all downstream traffic from OLTs to all ONUs. ONU only considers the packet that is intended for it.

The downstream frame consists of the physical control block downstream (PCBd), the ATM partition and the GEM partition. The downstream frame provides the common time reference for the PON and provides the common control signaling for the upstream.

A diagram of the downstream frame structure is shown in Figure 15.



The frame is 125 µm for both downstream data rates. The PCBd length range is the same for both speeds and depends on the number of allocation structures per frame. If there is no data for sending, downstream frame is still transmitted and used for time synchronization.

Through GEM, GPON can encapsulate Ethernet, IP, TCP, UDP, T1/E1, Video, VoIP, or other protocols as called for by the data transmission.

SECTION-6

Factors affecting Network Performance

6 KEY PHYSICAL PARAMETERS AFFECTING NETWORK PERFORMANCE

Reference: EXFO_Reference-Guide_FTTH-PON

Controlling the power losses in the network in the network against the link's loss budget specification from ITU-T standard is the primary factor in ensuring proper transmission. This is done by establishing a total end-to-end loss budget with enough o f a buffer while reducing back reflections to a minimum. High power analog RF video signals (especially at 1550 nm) from narrow band lasers have strong back reflections that de-grade the quality of video transmission.

6.1 THE LOSS BUDGET

Calculating the loss budget is the first step towards designing a fiber optic network. Following parameters need to be considered during the evaluation of losses:

- Transmitter: Launch Power , temperature and aging
- Fiber Connections: splitter, connectors and splices
- Cable: Fiber loss and temperature effects

Performance of network can be greatly affected if any of these are compromised.

As shown in the following table loss budget also depends upon the type of PON being deployed. For a Class B GPON system, allowable maximum loss budget for the upstream path at 1.25 Gbps can be 32 dB (delta between minimum sensitivity and maximum launch power).

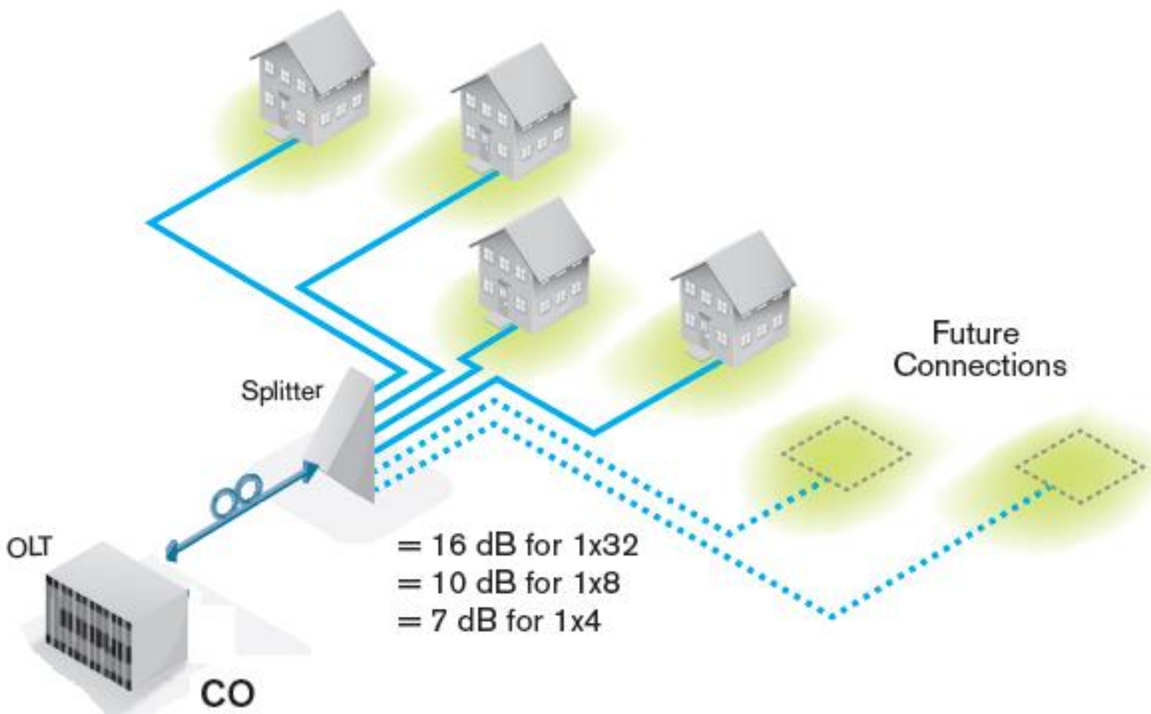
Type		GPON									
Standard		ITU-T G.984.1									
Optical distribution network class (ODN)		A	B	A	B	A	B	A	B	A	B
		Downstream				Upstream					
Nominal bit rate		1244,16		2488,32		155,52		622,08		1244,16	
$<P_{launch}>$Min	dBm	−4	+1	0	+5	−6	−4	−6	−1	−3	−2
$<P_{launch}>$Max	dBm	+1	+6	+4	+9	0	+2	−1	+4	+2	+3
Sensitivity Min	dBm	−25	−25	−21	−21	−27	−30	−27	−27	−24	−28

Reference : EXFO_Reference-Guide_FTTH-PON

FIGURE - 16

6.2 Power Loss Calculation for Proposed Architecture

For our case study we are using the following layout:



Reference: EXFO_Reference-Guide_FTTH-PON

FIGURE - 17

We need to calculate power losses from every connection of OLT to the ONTs served by one splitter.

We are using 1x32 splitter with power loss of 16 dB.

Connector and splices losses are typically 2.0 to 3.0 dB for the complete link from OLT to ONT whereas Fiber loss is equal to attenuation multiplied by the distance. It is usually in the range of 0.33 dB/km with

1310 nm wavelength. Since each segment is 20 km in length from OLT to ONT therefore total loss per link will be:

0.33x20= 6.6 dB.

6.2.1 Total Power Loss

Splitter loss = 16 dB

Connector loss per link = 3.0 dB

Fiber optic loss per link = 6.6 dB

Total Loss = 25.5 dB per link

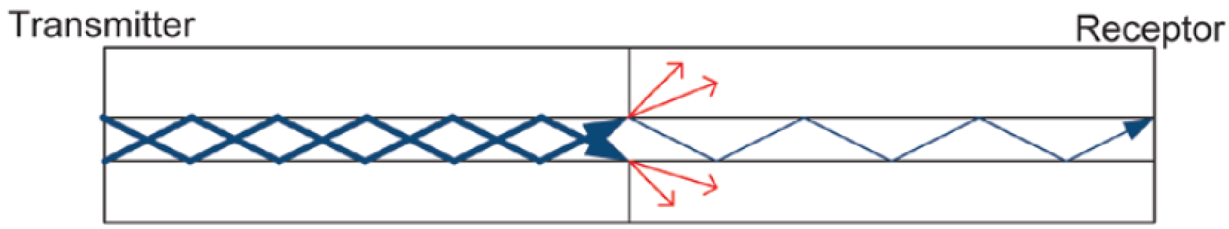
Total loss measured during the network deployment should not exceed the total loss budget of 25.5 dB allowed by the system design.

6.2.2 LOSS BUDGET AFFECTING FACTORS

In theory considering the loss of every hardware component and finally adding them on per link basis should be sufficient to calculate total loss budget. However when the network is deployed insertion loss and optical return loss, bad connections etc. can disturb the accuracy of our calculations.

6.2.3 INSERTION LOSS (IL)

IL is the increase in attenuation caused by inserting a connector pair or passive component into a fiber link. A certain amount of signal will be lost at each point.

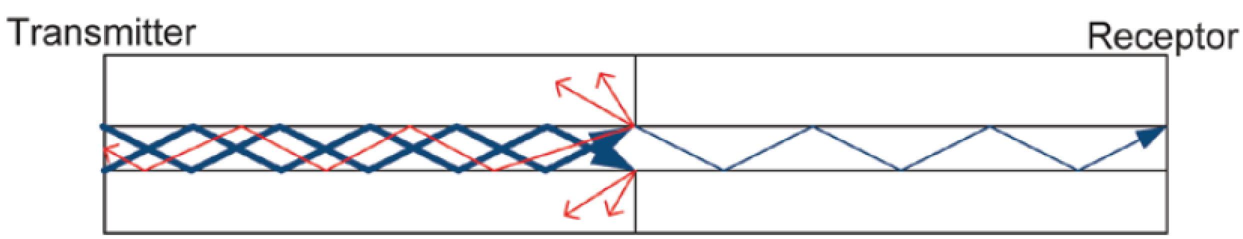


Reference:EXFO_Reference-Guide_FTTH-PON

FIGURE - 18

6.2.4 OPTICAL RETURN LOSS (ORL)

Optical return loss is the ratio of the forward optical power to the reflected optical power.



Reference: EXFO_Reference-Guide_FTTH-PON

FIGURE - 19

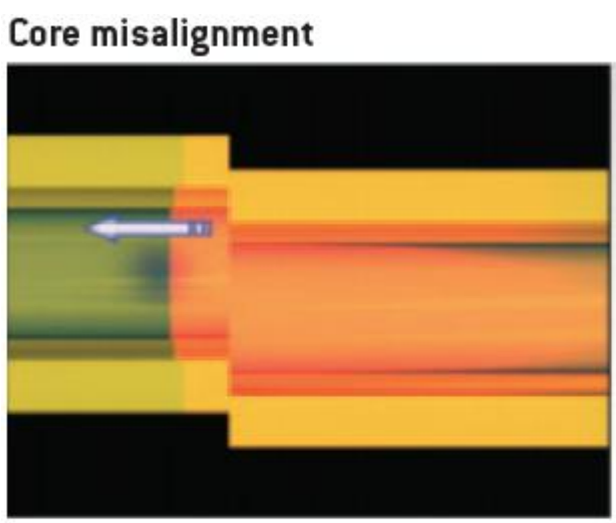
6.2.5 BAD CONNECTIONS

Network elements are interconnected through connectors and splices. It is important to maintain them in good working condition. Single mode fiber has a very small core typically 9 to 10 micrometer in diameter so a single dust particle or smoke particle can block significant transmission area. Bad connectors can lead to the following:

- Erroneous test results
- Poor transmission due to high IL or ORL
- Permanent damage to the core

6.2.6 INCORRECT SPLICING

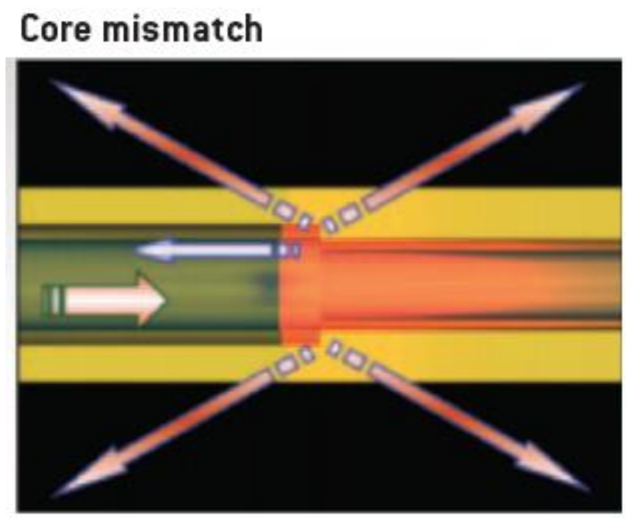
Coupling loss is caused by the poor core alignment when two fibers are connected using a splice.



Reference: EXFO_Reference-Guide_FTTH-PON

FIGURE - 20

Also if the spliced fibers have different core or cladding diameters then coupling loss can increase.



Reference: EXFO_Reference-Guide_FTTH-PON

FIGURE - 21

A bad connection will generally increase the insertion loss of a device/element (e.g., splitter) in the ODN, which will contribute to the overall loss budget. If there are too many bad connections in the ODN, or if there is one with exaggerated loss, the overall loss budget may not be respected, potentially resulting in a non-functional network that does not deliver the services it should.

Another effect that can result from a bad connection (e.g., UPC connector connected to an APC connector) is the increase in the overall ORL. This parameter was not taken into consideration for testing in the past. Now, with the analog-video over-PON networks, ORL measurement from the CO to the ONT is strongly recommended in order to obtain ghost-free transmissions when analog video is present. In general, high ORL may have the following effects on the network:

- Strong fluctuations in laser output power
- Potential permanent damage to the OLT
- Higher bit-per-error rate (BER) in digital systems
- Distortions in analog video signals

6.2.7 MACROBENDS

Macro bend is kind of a curvature in fiber. Its radius is of a few centimeters. Mostly they are found in fiber organizers and at or near patch panels. They are the result of cable mishandling, mechanical stress caused by poor installation or environment. Macro bends can increase link loss beyond system’s loss budget.

SECTION-7

SMART GRID

7 DEPLOYMENT OF GPON NETWORK INTO SMART GRID

Reference: Alberta Smart Grid enquiry by Alberta Utilities commission

The following sections are the extract from Alberta Smart Grid Enquiry paper submitted by Alberta Utilities Commission for implementation of Smart Grid in Alberta for informational purposes.

7.1 INTRODUCTION TO SMART GRID

“Smart grid is a broad concept that describes the integration of hardware, software, computer monitoring and control technologies, and modern communications networks into an electricity grid. The attractiveness of the smart grid is its promise of helping electric utilities become more efficient and effective in operating generation, transmission and distribution networks, helping with the integration of more renewable and variable energy sources into the grid and empowering consumers with greater information and the capability to control their electricity consumption and costs.

7.2 ADVANTAGES OF A SMART GRID

- The smart grid applies to the entire electricity system including generation, transmission, distribution, and customers.
- The smart grid provides enhanced ability to warn of and identify potential failures and take remedial action before users are affected, that is, the smart grid self-heals.
- The smart grid withstands cyber-attacks.
- Electricity market participants must have access to all necessary information to make informed choices.

While smart grid is a broad term, it does not describe a single complete and inextricably linked set of technologies. Instead, smart grid technologies are best assessed in each of the segments of the utility system: smart generation, smart transmission, smart distribution and smart meters as well as smart technologies that can be employed in the retail segment and in the customers ‘premises. Each of these segments is made up of a number of elements. For example, there are multiple technologies that are smart transmission technologies, and different companies with different circumstances will choose to include different smart transmission technologies in their transmission systems. Furthermore, smart grid technologies can be deployed in each of these five segments independently of deployment in the other segments. It is not necessary, for example, to install smart meters in order to enjoy the benefits of smart transmission technologies. In some cases, however, the potential benefit of deploying a technology in one segment may be increased if other technologies are employed in other segments.

7.3 SMART GRID IN ALBERTA

Altalink has installed many devices that are considered to be smart transmission technologies such as phaser measurement units (PMUs), dynamic thermal line ratings (DTLRs) technology and Flexible AC transmission (FACTS) on transmission projects. Altalink has also upgraded the telecommunication system in their substations to enhance its protection, control, automation and monitoring system.

7.4 ELECTRIC DISTRIBUTION NETWORK CAN BE USED TO BUILT OUR GPON NETWORK

The biggest issue in incorporating such a big GPON network would be the right of way and to laydown fiber cables throughout the city and between cities. This problem can be easily solved if the existing electric distribution network can be used to run our cables and substations could be ideal locations for our Cos.

An electric distribution system takes electricity from the transmission system and delivers it to customers. The typical distribution system begins as the primary feeder circuit leaves the substation and ends at the customer‘s meter. The distribution system has traditionally operated with a one-way flow of electricity from centrally-located generation plants to end-use customers with relatively little or no monitoring and control automation”.

8 CONCLUSION

Alberta is fast implementing smart grid technologies for its utilities. Deploying GPON using the existing distribution and transmission networks of electric companies can not only reduce cost of implementation but utilities companies could enormously benefit since this would give them ability to add their smart devices across the network and transfer data using GPON network over fiber optic cable.

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