EN 02/29
18/DON/44/2015

BROADBAND CONNECTIVITY USING OPTICAL ACCESS FOR THE EASTERN PROVINCE OF SRI LANKA

Ms.B.Alakurajah

(108005J)

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

Thesis Submitted in Partial Fulfillment of the Requirement for the Degree Master of Science By research

Department of Electronics and Telecommunication Engineering

University of Moratuwa
Sri Lanka

621.38'14"
621.39(043)

108946
+
CD-ROM

August 2014

University of Moratuwa
108946

108946

Declaration

I declare that this is my own work and this theses does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books)

Signature: *UOM Verified Signature* Date: 15/08/2014

The above candidate has carried out research for the Masters under my supervision.

Signature of the supervisor: *UOM Verified Signature* Date: 15/08/2014

UNIVERSITY OF MORATUWA LIBRARY

Abstract

In Sri Lanka the widely used wired technology for broadband access is Asymmetric Digital Subscriber Line (ADSL). Fiber access is available in the Western Province with limited usage such as for business purposes. The Eastern Province is the focus for this research because it is one of the affected areas during the last two decades of war and therefore has limited facilities for the people living in that part of the country. The development work in the Eastern Province is in progress at present and it also includes facilities for broadband access.

ADSL broadband usage within Eastern Province is available but limited to city areas only. This work focuses on a system to implement Fiber to the Home (FTTH) for the Eastern Province and thus provide efficient broadband access for its people. The available Fiber Access technologies are analyzed and the most suitable one is selected for implementation. The thesis proposes a network based on Passive Optical Network (PON) technology to be employed with Gigabit PON (GPON) in order to provide FTTH to a wider area of the Eastern Province. The GPON technology includes Coarse Wavelength Division Multiplexing (CWDM) with Time Division Multiple Access (TDMA); known as Hybrid PON.

For the selected four cities Optical Line Terminal (OLT) locations are identified and Ring topology access is used with Remote Nodes which can be expandable when customer number increased.

A cost estimate using the current equipment prices and the payback of the capital are calculated and presented in the thesis. The performance of the proposed network is analyzed which includes the Link Power Budget and the Bit Error Rate (BER). The performance analysis shows that the proposed Optical Access Network using GPON is feasible for implementation in the Eastern Province.

Acknowledgements

I am deeply indebted to my supervisor Eng. A.T.L.K. Samarasinghe, who proposed the topic for my research and guided me and supervised me throughout the period of my research work. He met me regularly and spent long hours to help me and to be in the right direction until the completion of the work. Without him this thesis would not have been a reality. Prof. (Mrs.) I.J. Dayawansa also contributed to several discussions I had with my supervisor. She also gave valuable advise whenever I needed. She was almost a second supervisor to me. I offer a big 'Thank You' to her.

I wish to gratefully acknowledge the useful contributions towards this research work, by Dr.Ruwan Weerasuriya, Senior Lecturer of the Department.

Several Engineering and other members of Sri Lanka Telecom were a great support for me in collecting the necessary data for the project. I offer my sincere thanks to them all. I also wish to place on record my thanks to the officers of Survey Department and Eastern Province Kachcherry whose contribution were very valuable for the project.

Prof.Kapila Gunasekare, Vice Chancellor, UNIVOTEC encouraged me to go for higher studies and approved the necessary leave to register for this M.Sc. degree. I am very grateful to him. Without 'leave of absence' from my work place, the UNIVOTEC, I would not have been able to undertake and complete this work.

I wish to convey my heartfelt gratitude to anyone who gave me a hand in some way to make this research success.

TABLE OF CONTENTS

Declaration of the candidate and Supervisor i

Abstract ii

Acknowledgement iii

Table of Contents iv

List of figures viii

List of Tables xi

Abbreviations xiii

Chapter 1: Introduction

1.1 Background 01

1.2. Objective of the Research 02

1.3. Literature Review 02

1.3.1. Definition of Broadband 02

1.3.2. Fixed Line Technologies (Wired Broadband) 02

1.3.3. Cable Modems 04

1.3.4. Broadband Power Line (BPL) 05

1.3.5. FTTC/FTTH/FTTB/FTTx 06

1.3.6. Wireless Technologies 07

1.3.7. Wi-Fi (wireless Fidelity) 08

1.3.8. WiMAX 09

Chapter 2: Broadband Quality Measurement

2.1. Broadband Quality 11

2.1.1. Worldwide Broadband Quality Score Study 11

2.1.2. Broadband Quality Score 12

2.2. ITU Indexes for worldwide ICT sector 19

2.2.1. The Digital Access Index (DAI) 19

2.2.2. The ICT Opportunity Index (ICT-OI) 19

2.2.3. The Digital Opportunity Index (DOI) 20

2.2.4. ICT Development Index 20

Chapter 3: Optical Fiber Access Network

3.1.Technology 24

3.2. Passive Optical Networks (PONs) 26

3.3. PON Topologies 28

3.4. APON/BPON 29

3.5. GPON 30

3.6. EPON 30

3.7. WDM PON 31

3.8. Reason for GPON Selection 31

3.9. Signal Transmission in a PON 32

Chapter 4: Proposed Optical Access Network for the Eastern Province

4.1. Broadband in Sri Lanka 34

4.2. Eastern Province of Sri Lanka 35

4.3. Optical Access Network for the Eastern Province 36

4.4. CWDM Technology 37

4.5. Proposed four CWDM rings to cover the city areas 39

4.6. Selected Equipment and components 43

4.7. Cost Analysis 46

Chapter 5: Performance Analysis of the Proposed Access Network

5.1. Introduction 47

5.2. Design considerations 47

5.3. Link Power Budget 48

5.3.1. Power Budget of a PON 49
5.3.2. Typical Loss Values Selection 49
5.4.Signal to Noise Ratio(SNR) 51
5.4.1. Electrical Signal Power Equation 51
5.4.2. Noise Power 52
5.4.3. The Q-Factor 54
5.5. Considered Noise Effects 54
5.5.1. Shot Noise Effect 54
5.5.2. Thermal Noise Effect 55
5.5.3. Laser Intensity Noise 56
5.6. Bit Error Rate 58
5.6.1. BER calculation 58
5.7. Design Objective 63
5.7.1. SNR Analysis by varying PON length 64
5.7.2. SNR Analysis by varying Amplifier Gain 66
5.7.3. SNR Analysis by varying transmitted Power 67
5.7.4. SNR analysis for Different Wavelengths 68
5.8. Receiver Sensitivity 69
5.9. Dispersion in Fibers 72
5.9.1. Dispersion 72
5.9.2. Types of Dispersion 72
5.9.3. GVD calculation 73
5.9.4. Polarization Mode Dispersion 74
5.10. Analysis of Results 76
5.11. Discussion and Recommendations 79
5.11.1. Size of the Proposed CWDM Ring 79

5.11.2. Cost Analysis 79

5.11.3. Link Power Budget 79

5.11.4. SNR Analysis 80

5.11.5. Uplink BER 80

Conclusion 81

References 83

LIST OF FIGURES

		Page
Figure 1.1	Broadband fixed line access technology evolution	03
Figure 1.2	Cable Modem connection	04
Figure 1.3	Typical BPL connection	05
Figure 1.4	Typical Fiber Access Network	07
Figure 1.5	Wi-Fi Configuration	08
Figure 1.6	WiMAX Architecture	09
Figure 2.1	Broadband Quality Score in 2008	13
Figure 2.2	Broadband Quality Score in 2009	14
Figure 2.3	Broadband Quality Divides in 2009	15
Figure 2.4	Broadband Leadership (Top 20 in 2009)	16
Figure 2.5	Broadband users/100 in Asia 2006	18
Figure 2.6	IDI development stages	21
Figure 3.1	FTTx Architecture	26
Figure 3.2	PON Architecture	27

Figure 3.3	PON Topologies	28
Figure 3.4	Signal Transmission in a TDM/TDMA PON	33
Figure 4.1	SLT Optical Core Network	34
Figure 4.2	Eastern Province of Sri Lanka	36
Figure 4.3	Hybrid PON	37
Figure 4.4	Possible CDMA Wavelengths(ITU-T G.694.2)	38
Figure 4.5	Proposed Ring optical Access Network for the Kalmunai City	39
Figure 4.6	Proposed Ring optical Access Network for the Ampara City	40
Figure 4.7	Proposed Ring optical Access Network for the Batticaloa City	40
Figure 4.8	Proposed Ring optical Access Network for the Trincomalee City	41
Figure 4.9	Eastern Province of Sri Lanka Proposed Optical Access Network	43
Figure 4.10	OLT and ONU Devices and Connection	44
Figure 5.1	Link Power Losses	48
Figure 5.2	Possibility of random noise at the threshold detection	59
Figure 5.3	PDFs $(p_i(v)dv, i = 0 \; or \; 1)$ for levels of '0' and '1' v_0 and v_i in the presence of random (Gaussian) noise.	60

Figure 5.4	SNR(dB) vs PON length(km)	65
Figure 5.5	Maximum possible distance(km) vs. No.of Splits	66
Figure 5.6	SNR(dB) vs Amplifier gain(dB)	67
Figure 5.7	SNR(dB) vs Transmitted Power(dBm)	68
Figure 5.8	SNR(dB) vs wavelengths(μm)	69
Figure 5.9	Pulse Broadening due to dispersion	72
Figure 5.10	$DL\Delta\lambda$ vs.length	74
Figure 5.11	No PMD in a perfect fiber(top) & Real fiber with some asymmetries.(Bottom)	75
Figure 5.12	PMD parameter variation up to 60 km	76

UNIVERSITY OF MORATUWA LIBRARY SRI LANKA

LIST OF TABLES

		Page
Table 1.1	DSL technologies	03
Table 1.2	Some available wireless Broadband Technologies	07
Table 1.3	Wi-Fi Technologies	09
Table 1.4	WiMAX Standards	10
Table 1.5	Some Available 3G Technologies	10
Table 2.1	Top /Changes in Broadband Quality Score (2008-2009)	16
Table 2.2	IDI Development Index for the top 20 Countries	23
Table 3.1	PON Standards	29
Table 4.1	Population Report-2009	35
Table 4.2	Selected 8 wavelengths for up and down link	38
Table 4.3	ADSL Customers in the city areas of Eastern Province	39
Table 4.4	Proposed CWDM ring access length	41
Table 4.5	Eastern Province Optical Access network Covered Areas	42
Table 4.6	Eastern Province Optical Access ring Cost Estimate	45
Table 4.7	Total cost and capital get back Period for each Ring	46
Table 5.1	PON classes	49
Table 5.2	OLT to RN Power budget	50
Table 5.3	RN to ONU Power Budget	50
Table 5.4	PON length vs. Noise variance for 64 splits	64
Table 5.5	PON length vs. SNR for 64, 128, 256 and 512 splits	64
Table 5.6	Maximum Possible PON length for each Splits	65
Table 5.7	SNR values for different amplifier gain	66

Table 5.8	SNR values for different values of transmitted power	67
Table 5.9	SNR values for different wavelengths	69
Table 5.10	BER vs. Receiver Sensitivity	70
Table 5.11	BER vs. Receiver Sensitivity for different splits	71
Table 5.12	$DL\Delta\lambda$ values for different length	74
Table 5.13	Possible customer numbers with 128 splits	77
Table 5.14	Maximum receiver sensitivity for 15 km PON	78
Table 5.15	Selected design values for all splits	78

LIST OF ABBREVIATIONS

Abbreviation	Description
ADSL	Asymmetric DSL
AGC	Automatic Gain Control
AON	Active Optical Network
ATM	Asynchronous Transfer Mode
AWG	Arrayed Waveguide Gratings
BER	Bit Error Rate
CDR	Clock-and-Data Recovery
CMTS	Cable Modem Termination System
CO	Central Office
CWDM	Coarse Wavelength Division Multiplexing
DBA	Dynamic Bandwidth Allocation
DF	Distributed Fiber
DFB	Distributed Feedback
DSL	Digital Subscriber Line

DWDM	Dense Wavelength Division Multiplexing
EDFA	Erbium doped Fiber Amplifier
EPON	Ethernet Passive Optical Network
FDD	Frequency Division Duplex
FTTC	Fiber to the curb
FTTH	Fiber to the home
FWM	Four-Wave Mixing
GEM	General Encapsulation Method
GVD	Group –Velocity Dispersion
HDSL	Bit Rate DSL
HDTV	High High-Definition Television
HSBB	High Speed Broadband
IDI	ICT Development Index
IEEE	Institute of Electrical and Electronics Engineers
ITU-T	International Telecommunication Union-Telecommunication standardization sector

LMDS	Local Multipoint Distribution Service
MAC	Media Access Control
MMDS	Multichannel Multipoint Distribution Service
MPCP	Multiple-Point Control Protocol
O/E/O	Optical/Electrical/Optical
ODN	Optical Distribution Network
OFDM	Orthogonal Frequency Division Multiplexing
OLT	Optical Line Terminal
ONT	Optical Network Terminator
ONU	Optical Network Unit
P2P	Point-to-Point
PDF	Probability Distribution Function
PMD	Polarization Mode Dispersion
PON	Passive Optical Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service

QPSK	Quadrature Phase Shift Keying
RMS	Root Mean Square
RN	Remote Node
SOA	Semiconductor Optical Amplifier
SONET	Synchronous Optical Network
TDD	Time Division Duplex
TDM	Time-Division Multiplexing
VDSL	Very high Bit Rate DSL
Wi-Fi	Wireless Fidelity