COMPARISON STUDY OF NEXT GENERATION FTTH PON ARCHITECTURES

MOHAMED ELMAGZOUB ABDALLA ZEINELABDIN

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical- Electronics & Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2012

To my beloved mother and father

To my brothers and sisters

To the Islamic nation

ACKNOWLEDGEMENT

In The Name Of Allah, Most Gracious, Most Merciful

First and foremost, I must be thankful to Allah SWT on His blessing for finishing the research.

I would like to express my sincere thanks and appreciation to my supervisor Assoc. Prof Dr. Sevia M. Idrus, for his precious guidance, encouragement, constructive criticisms, advice and motivation. Without his continual support and interest, this project report would not have been that same as presented here.

Besides that, my highly appreciation extended to my parents for their supporting, patience, love, prayer and sacrifice are unbounded during my study. My special thanks must be extended to Prof. Abu Bakar bin Mohammad who taught me Optical Communication and showed to me how this area is interesting. Also, I would like to express my thanks to Mr. Redhwan Qasem Shaddad for introducing me to Optisystem software.

ABSTRACT

Recent research activities in the area of optical networks technology are focusing on possible extensions of current GPON and EPON since these systems may suffer bandwidth limitations in the future, and they do not make use of the full optical bandwidth. In this project two network architectures were proposed to satisfy the requirements of NG-PON1 while being compatible with the standardized GPON to protect the investment that have been spent. The two proposed architectures have been simulated by using Optisystem simulation tool, and then analyze the performances of the networks according to simulation results. The performance evaluation parameters were the Q Factor (BER) and optical power budget. The first architecture is a TDM-PON based. The main reason behind using TDMA in the first architecture (10G TDM-PON) is to allow co-existence with the current generation PONs. The second architecture is Hybrid TDM-WDM PON. After knowing the optimum performance for each architectures by considering numbers of users (32, 64 and 128) and different length fiber (from 20 to 100 km), a comparison between the architectures is done. The Hybrid TDM-WDM PON architecture has more power budget capability than the 10G TDM-PON architecture. Therefore Hybrid TDM-WDM PON architecture was found capable to serve longer distance than 10G TDM-PON architecture. The two proposed architectures meet the requirements of NG PON1, such as providing higher splitting ratio, higher bandwidth and longer reach then current GPON system.

ABSTRAK

Aktiviti penyelidikan terkini dalam bidang teknologi rangkaian optik banyak memberi tumpuan kepada bentuk sambungan yang mungkin bagi konfigurasi GPON dan EPON kerana sistem ini juga akan mengalami had jalurlebar pada masa akan datang, ini kerana ia tidak menggunakan jalur lebar optik sepenuhnya. Dalam projek ini, dua seni bina rangkaian telah dicadangkan untuk memenuhi keperluan NG-PON1 dan pada masa yang sama diserasikan dengan GPON diseragamkan untuk melindungi pelaburan yang telah dibelanjakan. Kedua-dua seni bina yang dicadangkan telah diuji dan disimulasikan dengan menggunakan program simulasi komesial Optisystem 7.0, dan kemudiannya prestasi rangkaian dianalisi berdasarkan hasil keputusan simulasi. Parameter penilaian prestasi Q-Factor (BER) dan anggaran kuasa optik juga dianalisa. Seni bina pertama adalah berasaskan TDM-PON, yang menggunakan teknik TDMA adalah dengan membenarkan kewujudan kaedah yang mendokong generasi semasa PONs. Seni bina kedua pula ialah Hibrid TDM-WDM PON. Setiap senibina rangkaian terpilih diuji untuk mengetahui prestasi optima bagi setiap bilangan pengguna (32, 64 dan 128) dengan mengambilkira berbagai panjang gentian (20-100 km), untuk membuat perbandingan keupayaan di antara seni bina rangkaian. Dalam simulasi ini didapati, senibina hibrid TDM-WDM PON mempunyai keupayaan bajet kuasa yang lebih mampan daripada seni bina rangkaian 10G TDM-PON. Oleh itu senibina Hibrid TDM-WDM PON mempunyai keupayaan jarak penhantaran yang lebih jauh daripada seni bina 10G TDM-PON. Kedua-dua seni bina yang dicadangkan memenuhi kehendak NG PON1, seperti kemampuan menyediakan nisbah belahan spektra lebih tinggi, lebar jalur yang lebih luas dan jarak capaian ketibaan yang lebih jauh berbanding sistem GPON semasa.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

10G-EPON	-	10 Gigabit Ethernet Passive Optical Network
AES	-	Advanced Encryption Standard
APON	-	ATM Passive Optical Network
ATM	-	Asynchronous Transfer Mode
BER	-	Bit Error Rate
BPON	-	Broadband Passive Optical Network
CAPEX	-	Capital Expenditures
CO	-	Central Office
CWDM	-	Coarse Wavelength Division Multiplexing
DS	-	Downstream
DWDM	-	Dense Wavelength Division Multiplexing
EFM	-	Ethernet in the First Mile
EPON	-	Ethernet Passive Optical Network
FEC	-	Forward Error Correction
FSAN	-	Full-Services Access Networks
FTTB	-	Fiber-To-The-Building
FTTC	-	Fiber-To-The-Curb
FTTH	-	Fiber-To-The-Home
FTTN	-	Fiber-To-The-Node
FTTP	-	Fiber-To-The-Premises
GEM	-	GPON Encapsulation Method
GEPON	-	Gigabit Ethernet Passive Optical Network
GPON	-	Gigabit Passive Optical Network
IEEE	-	Institute of Electrical and Electronics Engineers

ITU	-	International Telecommunication Union
IPTV	-	Internet Protocol Television
MAC	-	Media Access Control
NG-PON	-	Next-Generation Passive Optical Network
OCDMA	-	Optical Code Division Multiple Access
ODN	-	Optical Distribution Network
OFDMA	-	Orthogonal Frequency Division Multiple Access
OLT	-	Optical Line Terminal
ONUs	-	Optical Network Unit
P2MP	-	Point to Multi-Point
P2P	-	Point to Point
PON	-	Passive Optical Network
Q Factor	-	Quality Factor
QoS	-	Quality of Service
R&D	-	Research and Development
RN	-	Remote Node
TDMA	-	Time Division Multiple Access
US	-	Upstream
WDM	-	Wavelength Division Multiplexing
XG-PON	-	10 Gigabit Passive Optical Network

CHAPTER 1

INTRODUCTION

1.1 Introduction

Demands on bandwidth are growing rapidly, and end users have killer applications such as IPTV and peer-to-peer downloading, which they need huge bandwidth. It becomes ever harder to support the fast growing capacity demands of the users, as these copper-based technologies are facing their fundamental bandwidth limitations. That has become the driving force for the recent enthusiasm in PONs and FTTx developments. In a fiber-to-the-home (FTTH) system, fiber is connected all the way from the service provider to household users.

Gigabit-capable Passive Optical Network systems, such as GPON (standardized in ITU-T Rec. G.984 series) and EPON (IEEE 802.3ah) have been standardized and are now being mass-deployed in various markets around the world. With the continuous increase in bandwidth demand generated by consumer and business applications, the need for a new, higher capacity access architecture is more than obvious. Therefore, one

of the principal requirements for next-generation PON (NG-PON) is to provide a substantial increase of the bandwidth available to end-subscribers, when compared with GPON and EPON. Additionally, the investment made for deploying gigabit-capable PON systems, NG-PON must be able to protect the investment of the legacy networks by ensuring a subscriber seamless migration from GPON/EPON to NG-PON.

In this project, the discussion will be focused on the performance analysis of NG-PON to investigate and compare the performances of the two candidate NG-PON architectures.

This chapter presents the problem statement, project objectives, scopes of project, methodology and finally the thesis outline.

1.2 Problem Statement

GPON (ITU-984) and EPON (IEEE 802.3ah) have been standardized and are now widely deployed. With the ever increasing bandwidth demand from consumer and business applications, these standards are running out of bandwidth. Therefore, there is a high need for next generation PON.

The most general requirement for a NG- PON is to provide higher bandwidth than Gigabit PON. In addition, given the major investments by operators in deploying Gigabit PON, NG-PON must be able to protect the investment of the legacy Gigabit PONs by ensuring a subscriber seamless migration from Gigabit PON to NG-PON.

1.3 Project Objectives

The objectives of this project are:

1. To study and investigate the performance of candidate architectures for next generation FTTH PONs.
2. To do performance comparison for the architectures in terms of bandwidth and distance.
3. To facilitate higher bandwidth provision, higher number of users and extended network reach than current PON architectures (GPON & EPON).

In this project, will try as much as possible to consider the current GPON architecture and flow its standard, as long as we meet the next generation objectives (increasing the bandwidth, the number of users and the reached distance).

1.4 Scopes of Project

The scopes of this project are:

1. Literature review on the previous PONs and current. Then, Review on the current progress towards the NG PON that to be compatible with GPON.
2. Design and simulation different NG PON architectures. The simulation tool that will be used to achieve the objectives is Optisystem software.
3. Systems performance analysis, optimization and comparison.
4. Performance analysis: Analysis for the system performance will be done. The performance evaluation will be in terms of the Q Factor (BER) and optical power budget.

1.5 Methodology

The methodology of this research is shown in the flow chart in Figure 1.1 below:

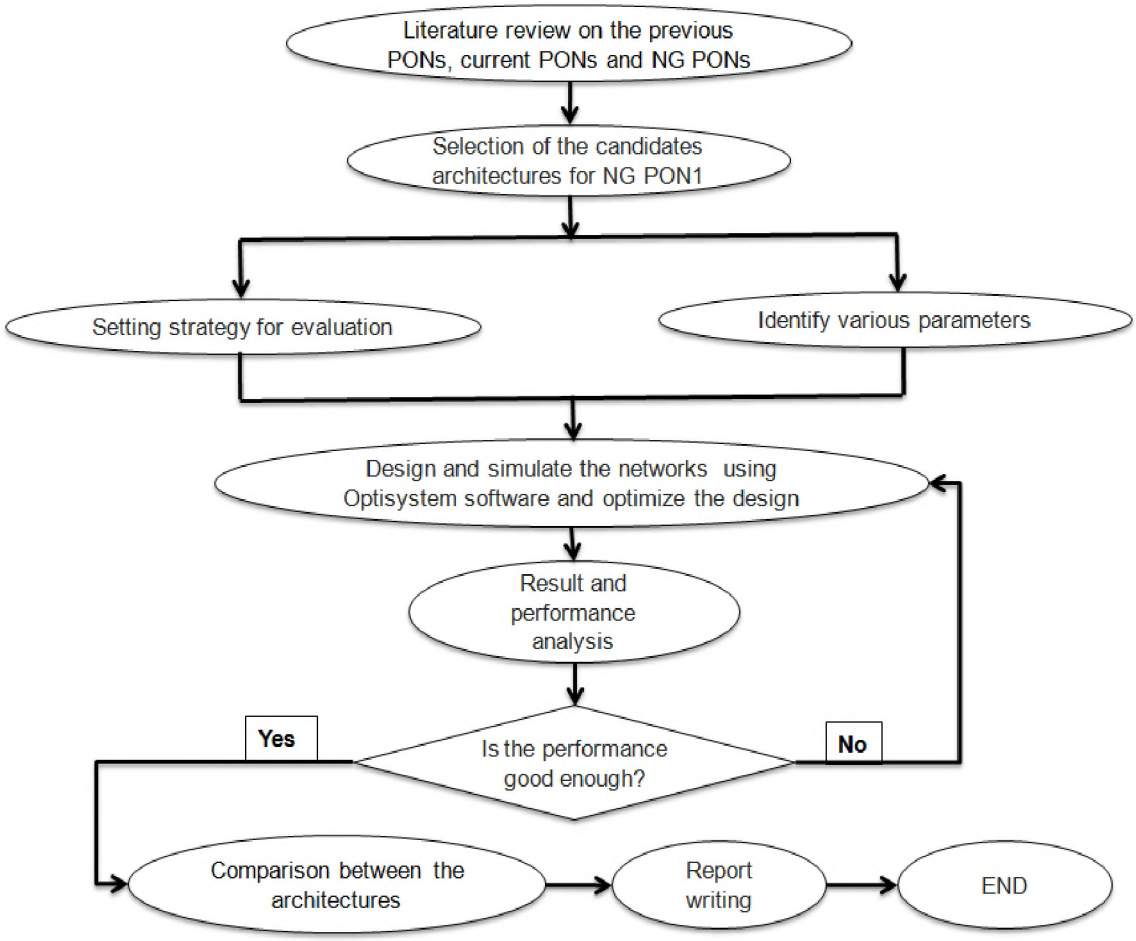

Figure 1.1: The methodology flow chart

First of all, to design and simulate NG-PONs, full understanding and literature review on the previous PONs and current have to be done. Then, review on the current progress towards the NG PON that to be compatible with GPON.

After completing the comprehensive literature review, two candidate architectures for NG PON can be selected to be design, simulated and Compared.

The next two steps can be done in parallel. Identifying various parameters and set the strategy for evaluation.

After knowing the various parameters of the design, simulate the networks by using Optisystem software.

The performance evaluation as the evaluation strategy is set, will be in terms of the Q Factor (BER) and optical power budget.

If the performance satisfies the specified criteria, comparison between the architectures will be done. Otherwise, optimizing in the design has to be done. Finally, writing the report.

1.6 Thesis Outline

Chapter 1 consists of introduction of the project. It includes the problem statement, project objectives, scopes of project and the methodology.

Chapter 2 explains about the basic theory of Passive Optical Network and Fiber to the Home. Then, brief explaining on Gigabit-capable Passive Optical Network systems.

Chapter 3 focuses on the Next Generation Passive Optical Network and literature review on the latest developments on NG-PONs.

Chapter 4 presents the simulation network models of the candidate architectures for the NG-PON.

Chapter 5 discusses the simulation results and performance analysis based on the plotted graphs which were obtained after simulate the network model.

Chapter 6 describes the summary of all have been done, conclusion and suggests for future work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

10G-EPON	-	10 Gigabit Ethernet Passive Optical Network
AES	-	Advanced Encryption Standard
APON	-	ATM Passive Optical Network
ATM	-	Asynchronous Transfer Mode
BER	-	Bit Error Rate
BPON	-	Broadband Passive Optical Network
CAPEX	-	Capital Expenditures
CO	-	Central Office
CWDM	-	Coarse Wavelength Division Multiplexing
DS	-	Downstream
DWDM	-	Dense Wavelength Division Multiplexing
EFM	-	Ethernet in the First Mile
EPON	-	Ethernet Passive Optical Network
FEC	-	Forward Error Correction
FSAN	-	Full-Services Access Networks
FTTB	-	Fiber-To-The-Building
FTTC	-	Fiber-To-The-Curb
FTTH	-	Fiber-To-The-Home
FTTN	-	Fiber-To-The-Node
FTTP	-	Fiber-To-The-Premises
GEM	-	GPON Encapsulation Method
GEPON	-	Gigabit Ethernet Passive Optical Network
GPON	-	Gigabit Passive Optical Network
IEEE	-	Institute of Electrical and Electronics Engineers

ITU	-	International Telecommunication Union
IPTV	-	Internet Protocol Television
MAC	-	Media Access Control
NG-PON	-	Next-Generation Passive Optical Network
OCDMA	-	Optical Code Division Multiple Access
ODN	-	Optical Distribution Network
OFDMA	-	Orthogonal Frequency Division Multiple Access
OLT	-	Optical Line Terminal
ONUs	-	Optical Network Unit
P2MP	-	Point to Multi-Point
P2P	-	Point to Point
PON	-	Passive Optical Network
Q Factor	-	Quality Factor
QoS	-	Quality of Service
R&D	-	Research and Development
RN	-	Remote Node
TDMA	-	Time Division Multiple Access
US	-	Upstream
WDM	-	Wavelength Division Multiplexing
XG-PON	-	10 Gigabit Passive Optical Network