PERFORMANCE STUDY OF PACKET-OPTICAL TRANSPORT NETWORK PROTOCOLS

AYAD TARIQ MOHAMMED AL-MASHHADANI

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Especially dedicated to my parents, for their infinite support and care.

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ABSTRACT

This research is carried out in the field of Optical Transport Network (OTN), in particular, to investigate the performance of a new protocol called Packet Optical Network that was introduced as a successor to the legacy Synchronous Digital Hierarchy/Synchronous optical networking (SDH/SONET). The migration to IP/Ethernet application globally is forcing enterprises to address two major (Wide Area Network) WAN issues: converging Time Division Multiplexing (TDM) and packet networks to reduce expenses, and improving network and service management to support delay-sensitive, bandwidth-intensive applications. Optical Transport Network - ITU G.709 is a global standard to address these challenges by eliminating unnecessary layer, IP straight over optic without being encapsulated in ATM/SDH frames, and eventually reduce Optical-Electronic-Optical (OEO) conversion. The International Telecommunication Union Telecommunication Standardization Sector ITU-T defines an OTN as a set of Optical Network Elements (ONE) connected by optical fiber links, able to provide functionality of transport, multiplexing, switching, management, supervision, and survivability of optical channels carrying client signals. Packet Optical Network or often called Optical Channel Digital Wrapper added more functionalities to the legacy SONET/SDH such as the inclusion of stronger FEC, switching scalability, Transparency, and different frame rates. The Optical Channel Payload Envelope (OCh PE) can carry any type of data: SONET/SDH, GbE, 10GbE, ATM, IP, and so on. The objective of this research is to model an Optical Transport Network in the OMNeT++ simulation environment and OptiSystem Software, where the performance of Packet Optical Network protocols is compared with the legacy system in terms of delay and error correction capability. Simulation conducted in the metro/core optical network environment shows that the optical network performances in delay and error performance are improved when using the Packet optical network protocol, up to 30% decrease in delay can be achieved

and longer distances can be reached by employing the new more powerful Forward Error Correction of the Digital Wrapper G.709.

ABSTRAK

Kajian ini dijalankan dalam bidang optik Transport Network (OTN), khususnya, untuk menyiasat prestasi protokol baru yang dipanggil paket rangkaian optik yang diperkenalkan sebagai pengganti kepada legasi Synchronous Digital Hierarchy rangkaian optik / segerak (SDH / SONET). Penghijrahan ke application / Ethernet IP global memaksa perusahaan untuk menangani dua utama (Wide Area Network) WAN isu: menumpu Bahagian Masa Multiplexing (TDM) dan rangkaian paket untuk mengurangkan perbelanjaan dan meningkatkan rangkaian dan pengurusan perkhidmatan untuk menyokong kelewatan sensitif, jalur lebar aplikasi -intensive. Optical Transport Network - ITU G.709 adalah standard global untuk menangani cabaran-cabaran ini dengan menghapuskan lapisan yang tidak perlu, IP lurus sepanjang optik tanpa terkandung dalam bingkai ATM / SDH, dan akhirnya mengurangkan (OEO) penukaran-Electronic-optik optik. Packet Network optik atau sering dipanggil Optical Channel Digital Wrapper menambah lebih banyak fungsi kepada warisan SONET / SDH seperti kemasukan FEC kuat, beralih berskala, ketelusan dan kadar bingkai yang berbeza. The Optical Channel muatan Sampul Surat (Och PE) boleh membawa apa-apa jenis data: SONET / SDH, GbE, 10GbE, ATM, IP, dan sebagainya. Objektif kajian ini adalah untuk model yang Pengangkutan Rangkaian optik dalam ++ persekitaran OMNeT simulasi dan OptiSystem Software, jika pelaksanaan paket protokol rangkaian optik dibandingkan dengan sistem legasi dari segi kelewatan dan kesilapan keupayaan pembetulan. Simulasi dijalankan dalam persekitaran rangkaian metro / teras optik menunjukkan bahawa persembahan rangkaian optik kelewatan dan kesilapan prestasi adalah lebih baik apabila menggunakan protokol rangkaian optik paket, sehingga 30% dalam kelewatan boleh dicapai dan jarak yang jauh boleh dicapai dengan menggunakan yang baru yang lebih kuat Forward Ralat Pembetulan Digital Wrapper G.709.

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LIST OF ABBREVIATIONS

ADM	-	Add Drop Multiplexor
ATM	-	Asynchronous Transfer Mode
AU	-	Administrative Unit
BCH	-	Bose-Chaudhuri-Hochquenghem
BER	-	Bit Error Rate
DCF	-	Dispersion Compensating Fiber
DCM	-	Dispersion Compensating Module
DEMUX	-	Demultiplexer
DWDM	-	Dense Wavelength Division Multiplexing
EDFA	-	Erbium-Doped Fiber Amplifier
ETSI	-	European Telecommunications Standards Institute
FAS	-	Frame Alignment Signal
FEC	-	Forward Error Correction
GFEC	-	Generic Forward Error Correction
GUI	-	Graphical User Interface
IDE	-	Integrated Development Environment
IEEE	-	Institute of Electrical and Electronics Engineers
INI	-	Initialization
IP	-	Internet Protocol
ITU	-	International Telecommunication Union
LTE	-	Line Terminating Equipment
MSG	-	Message
MUX	-	Multiplexer

NED	-	Network Description language
OAM&P	-	Operations, Administration, Management and Provisioning
OC	-	Optical Carrier
OCH	-	Optical Channel
ODU	-	Optical Data Unit
OEO	-	Optical-Electrical-Optical
OMNeT++	-	Objective Modular Network Testbed in C++
OMS	-	Optical Multiplex Section
ONE	-	Optical Network Element
OPU	-	Optical Payload Unit
OSC	-	Optical Supervisory Channel
OTH	-	Optical Transport Hierarchy
OTN	-	Optical Transport Network
OTS	-	Optical Transmission Section
OTU	-	Optical Transport Unit
PDH	-	Plesiochronous Digital Hierarchy
PLR	-	Packet Loss Rate
QoS	-	Quality of Service
ROADM	-	Reconfigurable Optical Add/Drop Multiplexor
R-OTN	-	Reconfigurable OTN
RS	-	Reed Solomon
SDH	-	Synchronous Digital Hierarchy
SNR	-	Signal to Noise Ratio
SONET	-	Synchronous Optical Network
STE	-	Section Terminating Equipment
STM	-	Synchronous Transport Module
STS	-	Synchronous Transport Signal
TDM	-	Time Division Multiplexing
TU	-	Transmission Unit
TUG	-	Transmission Unit Group

VC	-	Virtual Container
VLSI	-	Very Large Scale Integrated Circuits
WAN	-	Wide Area Network
WDM	-	Wavelength Division Multiplexing

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CHAPTER 1

INTRODUCTION

1.1 Background

Global IP traffic is growing rapidly, statistics show that it has increased more than five times in the past five years, and will increase almost three times over the next 5 years [1]. This explosion of digital traffic is mainly caused by streaming services, cloud computing, mobile applications and social networks in addition to other applications, and it is driving the Telecommunication industry and service providers to evolve rapidly.

Previously, most network traffic was occupied by voice calls, in which traffic was carried out over connection oriented network in a predictable connection between two end points. The infrastructure was built by copper cables. But as the overall network load is increasing, optical networks replaced the previous copper-based networks, and became the dominant in transport infrastructure for data. This made it possible for the service providers to handle the rapid growing traffic, as it allows for data rates of 40 Gbps and above per wavelength. This powerful transport network was also utilized by using packet switched data deploying a variety of protocols instead of the traditional circuit-switched method of transferring data, as it was shown that it is the best option for intermittent low traffic loads from an energy-and-cost point of view [2].

The International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Recommendation G.709 is commonly called Optical Transport Network (OTN) or Digital Wrapper Technology. It was designed and employed for point-to-point links where the enhanced Forward Error Correction (FEC) capability allows longer spans or higher data rates [3]. However, it is now used as a new network layer and considered as the successor of SDH/SONET, because it was designed with future bandwidth and protocol requirements while preserving the advantages of SDH/SONET. It is employed as a transport protocol for a transparent, scalable and cost-effective network where current standards like Ethernet and SDH/SONET can be the client signals.

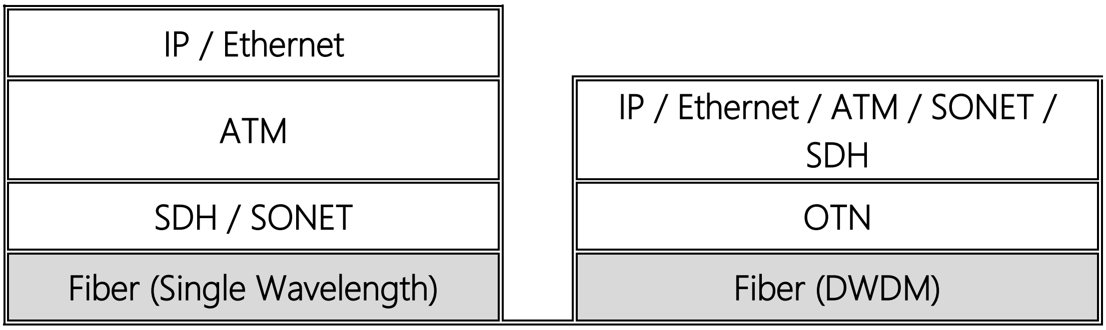

Figure 1.1 Transport Network layering; OTN supports a wide range of client signals over DWDM [4].

From the figure above, it can be observed that OTN helps to remove one unnecessary layer in the optical hierarchy, consequently, reducing cost and complexity of the overall system. Also, OTN supports a wide range of client signals (IP, Ethernet, ATM, SONET, SDH) all over a single wavelength, and make it easier for management and wavelength services.

1.2 Problem Statement

The migration to IP/Ethernet application globally is forcing enterprises to address two major WAN issues: converging TDM and packet networks to reduce expenses, and improving network and service management to support delay-sensitive, bandwidth-intensive applications.

Several problems aroused after two decades of using SONET and SDH as the infrastructure for optical networks. Inefficient data transport was one of the main reasons to search for a new optical transport protocol, as they were originally designed for circuit switched voice traffic, not for packet-dominated high transmission services of 40 Gbps or above [5]. Also, point-to-point was the only topology supported by SONET and SDH, whereas new services require other topologies [6]. In addition to those, there are some provisioning limitations leading to significant inefficiencies when providing transport for short-lived on-demand services.

Moreover, there was need for new services that cannot be added to the current transport protocols, such as a new channels to perform operations, administration, management and provisioning (OAM&P) functions in a multiwavelength multi-signal WDM/DWDM network; a need for a better and more powerful FEC for longer distances and a need for a faster switching as SONET/SDH switches at 1.5Mbps/2Mbps (T1/E1 level) and 51Mps/155Mbps (STS-1/STM-1 level.

1.3 Objectives of Research

The objectives of this research are:

a. To model an optical transport network using a discrete event simulator software and an optical software design suite.
b. To implement SONET and Packet Optical Network (G.709) protocols inside the modelled transport network.
c. To analyze the performance of both systems in terms of delay and bit error rate (BER).

1.4 1.4 Scope of Research

The goal of this research is to analyze and compare the performance of SONET and Digital Wrapper G.709 in terms of packet loss, packet delay, Bit Error Rate (BER) and bandwidth utilization. There are only few papers to study the performance of those protocols and in only one aspect of the network. This research aims to take an eagle-eye look at the performance of the overall network. The scope includes:

a. Design a three-node network scenario using OMNeT++ software.
b. Module an optical system in OptiSystem software.
c. Apply SONET and Digital Wrapper G.709 protocols in the modeled network.
d. Observe, analyze, and compare the performance of both protocols in terms of the mentioned parameters for different bit rates.

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