UNIVERSITI PUTRA MALAYSIA

INTEGRATION OF SERVICES ONTO SYNCHRONOUS DIGITAL HIERARCHY LINE UTILIZING WAVELENGTH DIVISION MULTIPLEXING

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INTEGRATION OF SERVICES ONTO SYNCHRONOUS DIGITAL HIERARCHY LINES UTILIZING WAVELENGTH DIVISION MULTIPLEXING

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of Requirements for the Degree of Master of Science

December 2005

To Islam, my beloved wife Na, Abah, Mak, teachers and friends .....

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: **Associate Professor Mohamad Khazani bin Abdullah, PhD**

Faculty: **Engineering**

The access network growth has been a hot topic in recent telecommunication industries. Either in its applications, bandwidth offered, speed of data transferred or even the techniques used to achieve network growth. Many researchers have investigated this problem and come out with many solutions which are used in today's network in variety of applications and services.

As the number of user and bandwidth grows, current network is incapable of managing the bandwidth demands. Another problem that limits this service is the availability of services in places far from the exchange office.

This thesis proposes a new system with a new architecture to be implemented in the access network in order to solve this problem and

provide flexibility in expansion the current network or system without intervening it. The proposal involves cascaded multiplexing technique which is based on Coarse Wavelength Division Multiplexing (CWDM). The cascaded multiplexing structure allows easy extension of the coverage span and CWDM provides asynchronous multiplexing at a considerably less cost than the DWDM version.

Simulation and experimental work have been done in order to develop and test the system proposed to maximize the utilization of fiber, improve the performance, and increase the distance of transmission and the bandwidth support. This system is also studied in different formatting schemes and integration with amplifier. The proposed system can support the data bandwidth up to 2.5 Gbps with the maximum network coverage about 17 km in radii and optimal wavelength spacing of about 2 nm (after consideration of wavelength shifting and laser spacing).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

INTEGRASI SERVIS DI DALAM TALIAN HIERARKI DIGITAL SEGERAK MENGUNAKAN MULTIPLEKS PEMBAHAGIAN JARAK GELOMBANG

Oleh

NORSHAMSURI ALI @ HASIM

Disember 2005

Pengerusi: **Profesor Madya Mohamad Khazani Abdullah, PhD**

Falkulti: **Kejuruteraan**

Pertumbuhan rangkaian akses telah menjadi satu isu utama di dalam industri telekomunikasi sejak kebelakangan ini. Sama ada dari segi aplikasinya, jalur lebar yang ditawarkan, kelajuan hantaran data ataupun teknik yang digunakan untuk pembangunan rangkaian. Ramai penyelidik telah menyelidiki masalah ini dan pelbagai penyelesaian telah diadaptasi ke dalam rangkaian terkini sama ada aplikasinya atau di dalam perkhidmatan yang digunakan sekarang.

Dengan bertambahnya bilangan pengguna dan jalur lebar, rangkaian yang sedia ada tidak dapat menampung keperluan ini. Satu lagi masalah yang

mengekang perkhidmatan ini adalah tiadanya ketersediaan perkhidmatan untuk pengguna-pengguna yang berada jauh dari ibu sawat.

Tesis ini mencadangkan satu sistem yang akan memperkenalkan seni bina rangkaian baru untuk digunakan di dalam rangkaian akses bagi menyelesaikan masalah ini. Disamping itu, ia juga memberi kemudahan mengembangkan rangkaian tanpa menganggu sistem atau rangkaian yang sedia ada. Cadangan ini melibatkan teknik multipleksan terkaskad yang mana CWDM digunakan sebagai teknik utama untuk permultipleksan. Struktur multipleksan terkaskad memberi kemudahan untuk penambahan jarak hubungan dan CWDM memudahkan multipleksan tak segerak dengan melibatkan kos yang rendah berbanding versi DWDM.

Simulasi dan eksperimen telah dilakukan untuk membina dan menguji sistem yang dicadangkan bagi memaksima penggunaan gentian optik, menaiktarafkan prestasi, serta menambah jarak hubungan dan jalur lebar yang ditampung. Sistem ini juga dianalisa dalam bentuk skim performatan berbeza dan integrasi bersama penguat. Sistem yang dicadangkan boleh menampung data jalur lebar sehingga 2.5 Gbps dengan jarak hubungan maksima sehingga 17 km dalam jarak lingkungan dan ruang jarak gelombang maksima ialah lebih kurang 2 nm (selepas diambil kira anjakan jarak gelombang dan jarak laser).

ACKNOWLEDGMENTS

All praise and gratitude be to ALLAH, the most Beneficent, and the most Merciful and peace and blessing upon our beloved prophet Muhammad S.A.W.

First and foremost, I would like to acknowledge my deep gratitude and appreciation to my dear supervisor Associate Professor Dr Mohamad Khazani Abdullah for his continual support and endless encouragement and patience. Without all that nothing would have been accomplished.

My special thanks go to my committee members, Associate Professor Dr. Mohd Adzir Mahdi and Puan Wan Azizun Wan Adnan for their wise council, guidance and encouragements. Thanks for providing precious suggestion and comments throughout my study.

Special thanks extended to all staffs and friends of Photonics Laboratory; Rosdishan, Shukri, Shahnan, Zahiril, Sara, Zaini, Suhairi, Sham, Fizul, Zura, Shahril, Hafiz, Ashrif, Barirah, Hanif, Syed Alwee, Fairuz, Aidie and other who has contributed to the successful completion of this study. Last but not least, deepest appreciation to all my dear friends in Wireless Laboratory.

Lastly, to my parents; Ali and Hindon, my family and in-laws, especially my beloved wife Marlina Yahayudin - for the love, helping hand, support, understanding and a fair share of nagging that made me strong to complete this thesis.

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LIST OF ABBREVIATIONS

ADM	-	Add Drop Multiplexer
AIS	-	Alarm Indication Signal
APD	-	Avalanche Photodiode
ASE	-	Amplified Stimulated Emission
ATM	-	Asynchronous Transfer Mode
B1, B2, B3	-	Bits Error
BERT	-	Bit Error Rate Tester
CW	-	Continuous Wave
TBF	-	Tunable Bandpass Filter
CWDM	-	Course Wavelength Division Multiplexing
DACS	-	Digital Access and Cross Connect System
dB	-	Decibel
dBm	-	Decibel milli
DC	-	Direct current
DCA	-	Digital Communication Analyzer
DFB	-	Distributed Feedback
DWDM	-	Dense Wavelength Division Multiplexing
DXC	-	Digital Cross Connect
EDF	-	Erbium Doped Fiber
FBG	-	Fiber Brag Grating
FEBE	-	Far End Block Error
FERF	-	Far End Received Failure

FTTx	-	Fiber to the x
FWM	-	Four Wave Mixing
Gbps	-	Gigabits per second
GHz	-	Giga Hertz
HP-RDI	-	High-order Path Remote Defect Indication
HP-REI	-	High-order Path Remote Error Indication
IC	-	Integrated Circuit
IL	-	Insertion Loss
ISDN	-	Integrated Service Digital Network
ITU	-	International Telecommunication Union
km	-	Kilometer
LAN	-	Local Area Network
LD	-	Laser Diode
LED	-	Light Emitting Diode
LOF	-	Los of Frame
LOS	-	Los of Signal
LP-RDI	-	Lower-order Path Remote Defect Indication
LP-REI	-	Lower-order Path Remote Error Indication
LP-RFI	-	Lower-order Path Remote Failure Indication
mA	-	Milliamps
Mbps	-	Megabits per second
MHz	-	Megahertz
MS-RDI	-	Multiplex Section Remote Defect Indication

STM 4	-	622 Mbps (SDH Transmission rate)
TBF	-	Tunable Bandpass Filter
TCP/IP	-	Transfer Control Protocol / Internet Protocol
TDM	-	Time Division Multiplexing
Telcos	-	Telecommunication Companies
TLS	-	Tunable laser source
BER	-	Bit Error Rate
uW	-	Microwatt
V	-	Voltage
VC	-	Virtual Cotenna
WDM	-	Wavelength Division Multiplexing

MS-REI	-	Multiplex Section Remote Error Indication
mV	-	Millivolts
mW	-	Milliwatt
NF	-	Noise Figure
nm	-	Nanometer
NRZ	-	Non Return Zero
OC	-	Optical Carrier
OSA	-	Optical Spectrum Analyzer
OSI	-	Open System Interconnection
OSNR	-	Optical Signal to Noise Ratio
PBX	-	Public Branch Exchange
PD	-	Photodiode
PPG	-	Pulse Pattern Generator
PSTN	-	Public Switch Telephone Network
RDI	-	Remote Defect Indication
REI	-	Remote Error Indication
RFI	-	Remote Failure Indication
RZ	-	Return Zero
SDH	-	Synchronize Digital Hierarchy
SNR	-	Signal to Noise Ratio
SONET	-	Synchronize Optical Network
STM 1	-	155 Mbps (SDH Transmission rate)
STM 16	-	2.5 Gbps (SDH Transmission rate)

CHAPTER 1

INTRODUCTION

1.1 Background

The access network is well known as a copper based network. These networks are connected from the switching terminal or exchange to the end user. Usually the switching terminal or exchange is within 4 km radius from the transmission site or customer, where the copper provides good performance.

However some houses and offices are located more than 4 km away from exchange, then no access services can be provided to them. In order to support the connection, another exchange or sub exchange would be built closer to them. Most telecommunication companies (telcos) nowadays have opted to use optical networking as solution in connecting the end user via FTTx technology. FTTx technology connected user all the way from telco via fiber. This solution is costly and limited only to urban area where high speed data network is in demand as compared to rural area.

Existing access networks are still predominantly voice networks, which uses E1 data frame format [Robert, 1994]. Telcos are solving this problem by introducing the devices called; fiber modem and fiber multiplexer. This device is capable to convert all E1 connections into optical signal, and transmitting the signal over the fiber to the end users who are located