UNIVERSITI PUTRA MALAYSIA

DESIGN AND ANALYSIS OF A MULTI-CHANNEL OPTICAL FIBRE LAN BASED ON MODIFIED CSMA/CD PROTOCOL

SITI BARIRAH AHMAD ANAS

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By

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

December 2002

To my beloved husband, for your devoted love and support
To my little cutie, for your joyous smiles and laughter
To my parents, for your endless care and comfort

Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science

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Chairman : Professor Borhanuddin Mohd. Ali, Ph.D.

Faculty : Engineering

Nowadays, optical communication is widely employed by telecommunication providers in the whole world due to its ability to support high bit rate applications. The urge to provide end-to-end fibre connectivity arises to overcome the bottleneck problem that occurs when packets are transmitted on the slower speed medium such as copper. In optical transmission, bandwidth utilisation can be improved further by using multiple wavelengths or channels in a single fibre.

This thesis discusses the implementation of multiple wavelengths technique for Local Area Network (LAN) environment. It proposes a new Ethernet-based protocol that uses multiple wavelengths for transmission, which runs on a single fibre. Ethernet/IEEE 802.3 is chosen because of its widespread employment in today's network and the ability of extending the transmission rate up to gigabit transmission. Even though light does not collide with each other, receiver contention might occur if more than one signal arrives at the receiver at the same time. Therefore, some arbitration mechanism is needed to synchronise the transmission and the tuning time of the respective transmitter

and receiver. The proposed design is based on the physical bus topology with n number of connected nodes and m number of operating wavelengths. All nodes are able to listen to all wavelengths. A fast control unit is used, which is responsible for packet scheduling.

The packets are scheduled based on a pre-computed time. Both transmitter and receiver will be asked to tune to the allocated wavelength. The transmitter can start transmitting and the receiver will start tuning at a specified time. Control packets are used for handshaking purposes. The main operation is placed at the control unit so that no added complexity is experienced by the receiver. Thus, this technique further reduces the cost. A suitable range of channels is obtained from the result. The network performance is evaluated against several design parameters by comparing the performance of each channel. The result shows a significant improvement whereby the throughput and efficiency are increased and average delay is minimised compared to the conventional system.

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

REKEBENTUK DAN ANALISIS RANGKAIAN KAWASAN SETEMPAT FIBER OPTIK SALURAN BERBILANG BERASASKAN PROTOKOL CSMA/CD TERUBAHSUAI

Oleh

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Pada masa kini, komunikasi optik digunakan secara meluas oleh pembekal telekomunikasi di seluruh dunia disebabkan oleh keupayaannya untuk menampung aplikasi berkadar bit tinggi. Permintaan untuk membekalkan keberkaitan gentian dari hujung ke hujung wujud untuk mengatasi masalah cerutan yang disebabkan oleh penghantaran paket menggunakan bahantara berkelajuan rendah seperti kuprum. Dalam penghantaran optik sendiri, penggunaan jalur lebar dapat ditingkatkan dengan menggunakan panjang gelombang atau saluran berbilang dalam gentian tunggal.

Tesis ini membincangkan perlaksanaan teknik panjang gelombang berbilang untuk persekitaran Rangkaian Kawasan Setempat (LAN). Ia mencadangkan satu protokol berasaskan Ethernet yang menggunakan panjang gelombang berbilang untuk penghantaran di dalam gentian tunggal. Ethernet/IEEE 802.3 dipilih kerana penggunaannya yang meluas dan keupayaan untuk menambah kadar penghantaran kepada penghantaran gigabit. Walaupun cahaya tidak berlanggar antara satu sama lain,

pertelagahan penerima boleh berlaku jika lebih daripada satu isyarat sampai di penerima pada masa yang sama. Oleh itu satu mekanisme arbitrasi diperlukan untuk menyelaraskan penghantaran dan masa penalaan bagi penghantar dan penerima yang berkenaan. Rekabentuk yang dicadangkan adalah berasaskan topologi bas fizikal dengan n nod dan m panjang gelombang pengendalian. Semua nod boleh berhubung dengan semua panjang gelombang. Unit kawalan yang pantas digunakan bagi mengendalikan penjadualan paket.

Paket-paket dijadual berasaskan masa pra-kiraan. Kedua-dua penghantar dan penerima akan diminta supaya menala kepada panjang gelombang yang diperuntukkan. Penghantar boleh memulakan penghantaran dan penerima akan menala pada masa yang ditentukan. Paket-paket kawalan digunakan untuk proses berjabat tangan. Operasi utama ditempatkan pada unit kawalan supaya penerima tidak menghadapi kompleksiti tambahan. Oleh itu, teknik ini juga dapat mengurangkan kos. Julat saluran yang sesuai diperolehi daripada keputusan tersebut. Prestasi rangkaian dinilai melawan beberapa parameter rekabentuk dengan membandingkan prestasi setiap saluran. Keputusan menunjukkan kemajuan yang bermakna bila mana truput dan kecekapan ditingkatkan dan purata kelengahan dikurangkan berbanding sistem yang sedia ada.

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I certify that an Examination Committee met on 30th December 2002 to conduct the final examination of Siti Barirah Ahmad Anas on her Master of Science thesis entitled "Design and Analysis of a Multi-channel Optical Fibre LAN Based on Modified CSMA/CD Protocol" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

SITI BARIRAH AHMAD ANAS

Date: 17/01/2003

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LIST OF ABBREVIATIONS

ABR	-	Available Bit Rate
ASK	-	Amplitude Shift Keying
ATDC	-	Asynchronous Transfer on Data Channel
ATM	-	Asynchronous Transfer Mode
CC-TTTR	-	Control Channel with Tuneable Transmitter and Tuneable Receiver
CSMA/CD	-	Carrier Sense Multiple Access with Collision Detection
FDDI	-	Fibre Distributed Data Interface
FDM	-	Frequency Division Multiplexing
FTTX	-	Fibre To The X
IEEE	-	Institute of Electrical and Electronic Engineers
IF	-	Intermediate Frequency
ISO	-	International Standards Organisation
LAN	-	Local Area Network
LFS	-	Limited Frame Size
LLC	-	Logical Link Control
MAC	-	Medium Access Control
MAN	-	Metropolitan Area Network
MMPP	-	Markovian Modulated Poisson Process
NAL	-	Node Activity List
NIU	-	Network Interface Unit
NRZ	-	Non-Return to Zero

OSI	-	Open Systems Interconnection
PLL	-	Phase Lock Loop
PMF	-	Probability Mass Function
PRBS	-	Pseudo Random Bit Stream
QoS	-	Quality of Service
RCA	-	Receiver Collision Avoidance
RSQ	-	Reception Scheduling Queue
SCM	-	Sub-Carrier Multiplexing
TDM	-	Time Division Multiplexing
TDMA	-	Time Division Multiple Access
UBR	-	Unspecified Bit Rate
VC	-	Virtual Circuit
VFS	-	Variable Frame Size
WAN	-	Wide Area Network
WDM	-	Wavelength Division Multiplexing

LIST OF NOTATIONS

N	-	Number of nodes
M	-	Number of wavelength or channel
λ	-	Wavelength or channel
C	-	Control packet
W	-	Control slot
G	-	Graph
U	-	Set of source nodes
V	-	Set of destination nodes
E	-	Set of edges
u	-	Source nodes
v	-	Destination nodes
e	-	Edges
M'	-	Number of packets used for scheduling
b	-	Bitrate per node
ch	-	Channel
c	-	Colours
Tx	-	Transmitter
Rx	-	Receiver
m	-	Number of wavelength
n	-	Number of nodes
R_i	-	Nominal rate at node i
L	-	Packet length

CU	-	Control Unit
tTx	-	Transmitter transmit time
tRx	-	Receiver tuning time
$ch\ x$	-	Assigned data channel
a	-	Probability of acceptance
r	-	Probability of reject
tTx'	-	New transmitter transmit time
tRx'	-	New receiver tuning time
S	-	Throughput
E	-	Efficiency
R	-	Channel capacity
P_{LR}	-	Packet length of the received packet
P_{TR}	-	Packet length of the transmit packet
P	-	Propagation delay
t_w	-	Waiting time
t_p	-	Propagation time
t_t	-	Transmission time
t_l	-	Tuning time

CHAPTER 1

INTRODUCTION

1.1 Background

High-speed and large bandwidth transmissions are the ultimate aim in today's communication system and optical communication emerges as the solution. Fibre is the fastest transmission medium since the information is sent in the form of light at the speed of 3×10^8 m/s (Dutton, 1998). Fibre cables have been installed as the backbone throughout the world where most of them are laid under the sea. As the applications' rates grow very rapidly, it is more efficient to provide end-to-end fibre connectivity. The fibre cabling was extended to the smaller geographical areas such as Local Area Network (LAN).

The next generation of LAN is required to provide a high level of bandwidth to the customer, as the demand of broadband services grows. Most telecommunication firms have come to the conclusion that some form of fibre optic access will be necessary to achieve this goal. In general, various bandwidth increment techniques have been implemented in fibre transmission such as Wavelength Division Multiplexing (WDM), Sub-Carrier Multiplexing (SCM), Time Division Multiplexing (TDM) and others. In LAN environment, the technologies implemented are based on IEEE standard such as Ethernet/IEEE 802.3, Token Ring/IEEE 802.5 and Fibre Distributed Data Interface (FDDI). The following sections will introduce LAN in brief and its important features.

1.2 LAN Technologies

LAN is introduced as a low-cost, time saving technology, enabling the sharing of data and network-attached devices. It is a high-speed, fault-tolerant data network that covers a relatively small geographic area. It typically connects workstations, personal computers, printers and other devices. LAN offers a lot of advantages to the computer users, and communication between users via electronic mail and other applications. A good example of LAN would be a small office with a file server, three to four computers and a shared printer.

There are several technologies implemented in LAN. The three widely used technologies are Ethernet/IEEE 802.3, Token Ring/IEEE 802.5 and Fibre Distributed Data Interface (FDDI). Figure 1.1 illustrates the basic layout of the technologies.

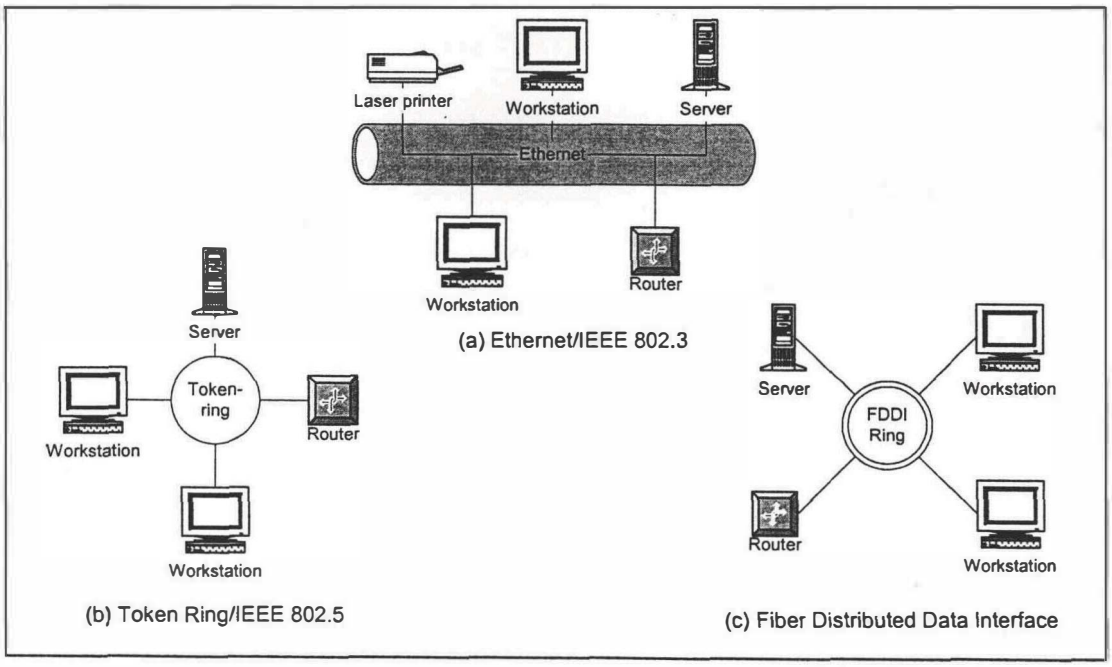

Figure1.1: Three widely used LAN technologies

IEEE 802 standard defines various protocol standards for LANs in the context of ISO reference model, which deals with the physical and data link layers (Halsall, 1996). This standard provides framework for higher layer issues. IEEE 802.3, 802.4, 802.5 and 802.11 standards define the MAC and physical layer specifications for four different LAN types namely CSMA/CD, Token Bus, Token Ring and Wireless.

Figure 1.2 defines the relationship between various IEEE standards to the ISO reference model. In the context of ISO reference model, the MAC and LLC layers of IEEE 802 series collectively perform the functions of the ISO data link layer. For this thesis, a MAC protocol is to be designed according to the physical connection. Both standards are transparent to the transmission medium. In the next subtopics, some important features of LAN such as the media access methods, transmission techniques and logical topologies are discussed.

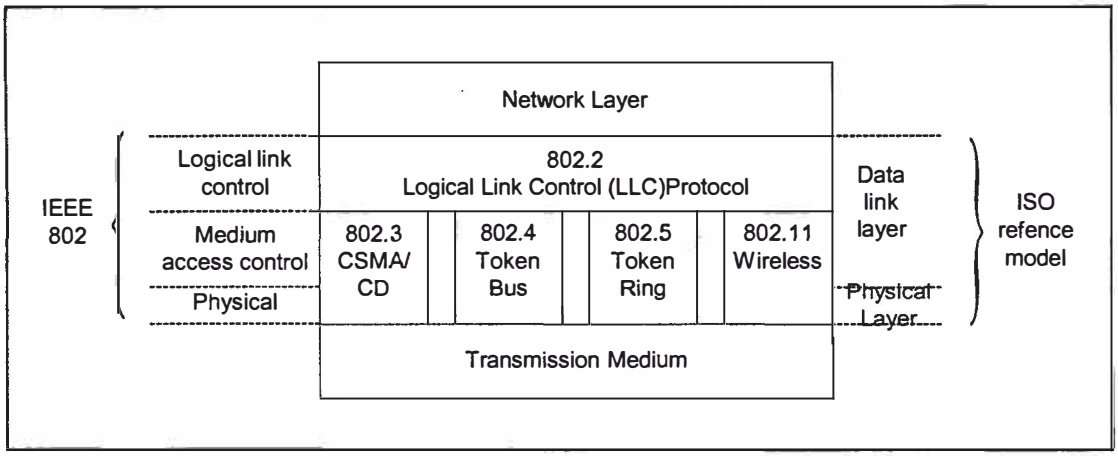

Figure 1.2: The mapping of IEEE 802 protocol set with the OSI layer of the ISO reference model

1.2.1 Media Access Method

LAN protocols have a standard to gain access to the network. The standard is adapted to govern the network access, collisions and failures that would bring the network to a grinding halt. LAN protocols typically use one of two methods to access the physical network medium, which are carrier sense multiple access with collision detection (CSMA/CD) and token passing.

In the CSMA/CD media access method, network devices contend for use of the physical network medium, therefore, it is sometimes called contention access scheme. The LAN protocols first checks for another node transmitting data. If there exist a transmission, then it waits for a specified time. If the network is free, it sends the data across the network physical medium. In other case, if collision happens, the LAN protocol senses it, initiates backoff algorithm and resends the data. Each node in the system is assigned a different backoff time to reduce the probability of packet collision. LAN protocol that uses this scheme is Ethernet/IEEE 802.3.

In the token-passing media access method, network devices access the physical medium based on the possession of a token. Token possession enables a node on the network to transmit data. Only one node at a time has the control of the token. After completing the transmission, the sending node passes the token to the next node on the network. If the node that receives the token has the data to transmit, it captures the token and begins to transmit across the network. If the receiving node has nothing to transmit, the token will be passed to the next consecutive node. Token Ring/IEEE