UNIVERSITI PUTRA MALAYSIA

PERFORMANCE EVALUATION OF OPTICAL CDMA RING NETWORK DUE TO SELF INTERFERENCE INDUCED BY POWER CIRCULATION

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By

ZOOL HILMI BIN MOHAMED ASHARI

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

June 2008

To My Beloved Parents, Wife and Kids

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

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June 2008

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

Faculty: **Engineering**

Presently, there is great interest in the telecommunication research community and industries on the optical code multiple access (OCDMA) techniques. This is due to the huge bandwidth offered by the optical link, highly efficient optical signal processing and decreasing cost of optical components. The performance of OCDMA systems depend on the code properties and detection scheme. In this thesis, an OCDMA system for a ring topology based on K-S code was proposed to be implemented in the metro environment. K-S code is a new code for Optical CDMA with variable weight greater than 2. In this thesis the weight of 4 is chosen. The code possesses ideal cross correlation properties which can reduce multiple access interference (MAI) and noise. However, there are two main types of interferences exist in the OCDMA ring topology. Besides MAI, there are another interference due to the circulation of power in the ring namely self–interference. It will deteriorate the next concurrent data stream for the same user to be transmitted into the ring and could make the system performance decreased.

A direct detection scheme was used to eliminate MAI and hence only the effect of self-interference was investigated. Before performing the simulation, limited theoretical results on receive power were developed to show the trend of receive power at each receiver. The formula is depended on the transmitted power, fiber length, coupling ratio, number of nodes and the number of circulating power in the ring. The performance of the ring network was then simulated using commercial simulation software, OptiSystem Version 5.0. The network performance is evaluated against several design parameters by comparing the signal turns in the first and second transmission by referring to the bit error rate, BER, received power, P_{sr} and the eye patterns. In this thesis, it was found that the effect of the self-interference is determined by the transmitted power, fiber length, coupling ratio and the bit rate. It proves that the self-interference is increased with the increment of transmitted power. It also experience losses with the increment of fiber span but the system will suffer the serious effect when the fiber length is shorter than 30 km at 1Gbps. Results also proves that the self-interference effect is worst at 30% coupling ratio although the system performance is better with the increment of coupling ratio until certain point. Finally, the best transmission rate for this system is 1Gbps while there were another optimum values for each parameter supported by the system in order to minimize the self-interference.

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

KAJIAN PRESTASI RANGKAIAN CINCIN BAGI PEMULTIPLEKSAN PEMBAHAGIAN KOD OPTIKAL YANG DISEBABKAN OLEH GANGGUAN SENDIRI YANG TERHASIL DARIPADA KITARAN KUASA

Oleh

ZOOL HILMI BIN MOHAMED ASHARI

Jun 2008

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

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Ketika ini terdapat minat yang begitu mendalam dikalangan komuniti pengkaji bidang telekomunikasi dan industri terhadap teknik capaian pelbagai kod bagi gentian optik (OCDMA). Ini disebabkan oleh gentian optik menawarkan kelebihan seperti lebarjalur yang besar, pemprosesan isyarat yang efisyen serta dapat mengurangkan kos perolehan komponen-komponen optik. Prestasi sebarang sistem CDMA sangat bergantung kepada ciri-ciri kod dan juga teknik pengesanan sistem tersebut. Dalam tesis ini, satu sistem OCDMA bagi topologi cincin menggunakan kod K-S telah diperkenalkan untuk di aplikasikan dalam kawasan metro. Kod K-S adalah satu kod yang baru diperkenalkan dimana ia mempunyai pemberat yang boleh diubah dan lebih besar daripada 2. Dalam tesis ini pemberat yang dipilih adalah 4. Kod ini mempunyai sifat-sifat sekatan bersilang yang unggul yang dapat menghapuskan gangguan capaian pelbagai (MAI) dan mengurangkan hingar. Walau bagimanapun, terdapat dua jenis gangguan yang wujud di dalam topologi cincin. Disamping MAI, terdapat satu lagi gangguan yang disebabkan

oleh peredaran kuasa di dalam rangkaian tersebut dikenali sebagai gangguan sendiri. Ia akan mengganggu penghantaran peket-peket data seterusnya bagi pengguna yang sama ke dalam sistem rangkaian dan menyebabkan prestasi sistem merosot.

Satu sistem yang dikenali sebagai sistem pengesanan langsung telah digunakan untuk menghapuskan MAI dan oleh itu hanya kesan daripada gangguan sendiri yang akan dikaji. Sebelum membuat simulasi, satu formula terhad telah diterbitkan bagi menunjukkan corak kuasa yang diterima pada setiap penerima. Ia bergantung kepada kuasa penghantaran, panjang gentian optik, nisbah pengganding, bilangan nod dan juga bilangan pengulangan kuasa di dalam rangkaian cincin. Seterusnya, prestasi sistem rangkaian cincin telah disimulasikan menggunakan perisian simulasi komersil, Optisistem versi 5.0. Ia dinilai berdasarkan beberapa parameter rekabentuk melalui cara membandingkan penghantaran peket data pertama dan peket data yang kedua dengan merujuk kepada kadar ralat bit, (BER), kuasa terima, P_{sr} dan corak mata.

Dalam tesis ini, telah didapati bahawa kesan gangguan sendiri dipengaruhi oleh kuasa penghantaran, panjang gentian optik, nisbah pengganding dan juga kadar bit. Dibuktikan bahawa kesan gangguan sendiri meningkat dengan pertambahan kuasa penghantaran. Ia mengalami kemerosotan dengan pertambahan panjang gentian optik dan memberi kesan yang serius jika panjang gentian optik adalah kurang daripada 30 km pada 1Gb sesaat. Keputusan kajian juga menunjukkan gangguan sendiri adalah kritikal pada 30% kadar nilai pengganding walaupun prestasi sistem bertambah baik dengan pertambahan kadar nilai pengganding pada titik-titik tertentu. Akhirnya, sistem ini beroperasi dengan

berkesan pada kadar bit 1Gb sesaat. Selain itu, terdapat nilai-nilai optimum bagi setiap parameter yang dapat disokong oleh sistem ini dalam mengurangkan kesan gangguan sendiri tersebut.

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I certified that an Examination Committee has met on 13 June 2008, to conduct the final examination of Zool Hilmi b. Mohamed Ashari on his Master of Science thesis entitled "Performance Evaluation Of Optical Cdma Ring Network Due To Self Interference Included By Power Circulation" 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 a relevant degree. Member of the Examination Committee are as follows:

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DECLARATION

I declare that the thesis is my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at Universiti Putra Malaysia or at any other institution.

_____

ZOOL HILMI BIN MOHAMED ASHARI

Date: 10 October 2008

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LIST OF ABBREVIATIONS

BER	-	Bit Error Rate
CD	-	Chromatic Dispersion
CD	-	Collision Detection
CDM	-	Code Division Multiplexing
CDMA	-	Code Division Multiple Access
CSMA	-	Carrier Sense Multiple Access
DW	-	Double Weight
FBG	-	Fiber Bragg Grating
FDMA	-	Frequency Division Multiple Access
FH	-	Frequency-Hopping
FTTH	-	Fiber to the Home
GF	-	Galois Field
ISI	-	Inter Symbol Interference
LAN	-	Local Area Network
LCM	-	Liquid Crystal Modulator
LED	-	Light Emitting Diode
MAI	-	Multiple Access Interference
MAN	-	Metropolitan Area Network
MDW	-	Modified Double Weight
MFH	-	Modified Frequency Hopping
NRZ	-	Non-Return to Zero

OAM	-	Operation-Administration-Maintenance
OCDM	-	Optical Code Division Multiplexing
OCDMA	-	Optical Code Division Multiple Access
OOC	-	Optical Orthogonal Codes
OOK	-	On/Off Keyed
OSCDMA	-	Optical Spectrum Code Division Multiple Access
PIIN	-	Phase Induced Intensity Noise
PLC	-	Planar Lightwave Circuit
PMD	-	Polarization Mode Dispersion
PMP	-	Point to Multipoint
PON	-	Passive Optical Network
PRBS	-	Pseudo Random Binary Sequence
RF	-	Radio Frequency
SAC	-	Spectral Amplitude Coding
SMF	-	Single Mode Fiber
SNR	-	Signal-to-Noise Ratio
TDM	-	Time Division Multiplexing
TDMA	-	Time Division Multiple Access
WAN	-	Wide Area Network
WDM	-	Wavelength Division Multiplexing
WDMA	-	Wavelength Division Multiple Access
WHTS	-	Wavelength Hopping Time Spreading

CHAPTER 1

INTRODUCTION

1.1 Background

Since the 1970's, telecommunication technology has made great advances, offering capabilities that were unthinkable a decade earlier. Today, the bandwidths possible with the new transmission technologies are vast and virtually unlimited, offering the ability to carry large numbers of voice, data and video signals [1] making the telecommunication sector as one of the fastest-growing fields in the world. It also has become one of the most important infrastructures that are very essential to the socio-economic well-being of any nation. A major advancement in telecommunications is the implementation of optical communication system as an alternative to the traditional media such as twisted wire pair and coaxial cable. Optical fiber communication systems play a main part of the digital communications in backbone networks, in Metropolitan Area Network (MAN) and Wide Area Network (WAN), in the access networks with Fiber to The – *Home, Curb, Cabinet*, *Building* (FTTX) and the high speed Local Area Network (LAN). Optical fiber communications offers several advantages over the traditional media. It offers high-speed transmission with virtually unlimited bandwidth. It also allows longer transmission distances between amplifiers or repeaters in the fiber span and sometimes in certain conditions, even amplifiers or repeaters are not needed at all. It is also non-conductive and is subsequently immune to electromagnetic interferences.

Telecommunication networks are usually divided into four hierarchies; long haul, metropolitan, access and local network. The top hierarchy is backbone or long haul network, which is a long distance network, ranging from several hundred to thousands of kilometers. It connects systems together throughout a country, to outside the country. Metropolitan networks are typically tens to a few hundred kilometers interconnecting between the backbone and access network. An access network is that part of a communications network which connects subscribers to their immediate service provider before distributed to a small region of space, typically a single building, which is known as local network. This is illustrated in Figure 1.1, which shows a high-level view of the overall network hierarchy [2].

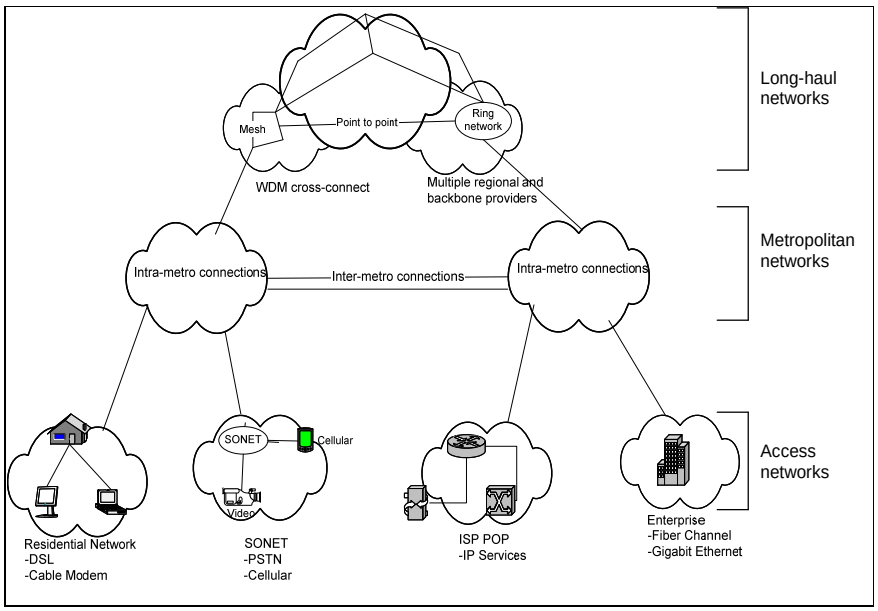

Figure 1-1: Optical Network hierarchy: long-haul, metro, and access networks

1.2 Motivation and Problem Statement

Optical Code Multiple Access communication systems have been given an intensive interest currently. This is due to the huge bandwidth offered by the optical links and the ultra-high optical signal processing speed bestowed by optical components. In OCDMA systems, all users can simultaneously share the same channel, asynchronously access the network and flexibly utilize the broad bandwidth [3-4]. As a result, the OCDMA is regarded as a promise multiple access technology. The most important consideration in OCDMA systems is the code design. Until today, many codes have been proposed for OCDMA such as Hadamard, Optical Orthogonal Codes (OOC), Prime Codes, and Modified Frequency Hopping (MFH) codes. However these codes suffer from various limitations; the codes are either too long (e.g. Optical Orthogonal Codes and Prime Codes), the constructions are complicated or the cross-correlation are not ideal. In 2004, a new code structure for OCDMA systems was developed namely K-S Code [5]. This code possesses numerous advantages including the efficient and easy code construction, simple encoder and decoder design, existence for every natural number ***n***, ideal cross-correlation ($\lambda = 1$) and also higher Signal to Noise Ratio (SNR). K-S Code will be the code of choice used in this thesis.

So far researches have been mostly focusing on the use of OCDMA in star topology. A LAN network with bus topology also has been reported recently [3]. However, due to the majority of fiber networks today are ring topology, it is chosen as the architecture for this research. Although star is the most widely used topology in today's FTTX access