



**OCDMA over WDM System Using Advanced
Modulation Technique for Gigabit Passive Optical
Network**

by

**S.M. Monirul Islam
(1430811523)**

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S.M. MONIRUL ISLAM
UNIVERSITY MALAYSIA PERLIS
munnaunimap@gmail.com

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LIST OF ABBREVIATIONS

AWG	Array Wavelength Grating
BER	Bit Error Rate
CDMA	Code Division Multiple Access
DWDM	Dense Wave Division Multiplexing
EDFA	Erbium Doped Fiber Amplifier
FBG	Fiber Bragg Grating
FTTH	Fiber To The Home
Gbps	Gigabit per second
ISDN	Integrated Services Digital Network
LED	Light Emitting Diode
MAI	Multiple Access Interference
Mbps	Mega bit per second
MFH	Modified Frequency Hoping
MQC	Modified Quadratic Congruence
NRZ	Non Return to Zero
NDSF	Non Dispersion Shift Fiber
OCDMA	Optical Code Division Multiple Access
ODLCs	Optical Delay Line Correlate's
OCC	Optical Orthogonal Code
OSNR	Optical Signal to Noise Ratio
DW	Double Weight

MDW	Modified Double Weight
EDW	Enhance Double Weight
ZCC	Zero Cross Correlation
OSCDMA	Optical Spectrum Code Division Multiple Access System
OOK	On-Off Keying
PD	Photo Diode
PIIN	Phase Induced Intensity Noise
PIN	Positive Intrinsic Negative
PRBS	Pseudo Random Binary Sequence
PSD	Power Spectral Density
RF	Radio Frequency
SAC	Spectral Amplitude Coding
SMF	Single Mode Fiber
SPM	Self Phase Modulation
TDM	Time Division Multiplexing
WDMA	Wavelength Division Multiple Access
FDM	Frequency Division Multiplexing
VoD	Video-on Demand
CD	Chromatic Dispersion

OCDMA ke atas Sistem WDM Menggunakan Teknik Modulasi Canggih untuk Rangkaian optik pasif Gigabit

ABSTRAK

Pembahagian kod optik pelbagai sistem akses (OCDMA) telah memberi peluang yang besar untuk kesemua rangkaian akses optik berkaitan fleksibiliti, akses tak segerak, keupayaan penghantaran jumlah tinggi, kawalan rangkaian mudah dan meningkatkan keselamatan. Dalam tesis ini, menggunakan teknologi OCDMA untuk mereka bentuk hibrid yang baru (OCDMA ke atas WDM) dan membandingkan prestasi dalam teknik pengesanan yang berbeza dengan kadar data yang berbeza. Untuk mereka bentuk OCDMA baru ke atas sistem WDM, pemilihan kod adalah bahagian yang perlu diambatkan perhatian untuk mendapatkan prestasi sistem yang lebih baik dengan keselamatan yang tinggi. Dalam tesis ini, teknik pengesanan yang digunakan adalah Mengubahsuai Sekali Ganda Kod Berat (MDW) sebagai kod signatur. Dalam sistem OCDMA, secara amnya fungsi korelasi silang yang dicipta yang telah menyebabkan bermulanya akses pelbagai bunyi inferens. Untuk mengatasi Gangguan Akses Pelbagai (MAI), teknik pengesanan telah digunakan di keseluruhan tesis. Teknik modulasi canggih digunakan untuk meningkatkan prestasi sistem dengan kadar-ralat-bit yang tinggi ($\leq 10^{-10}$). Keputusan disiasat diperolehi dengan menggunakan pengesanan langsung, dan pengesanan penolakan lengkap untuk nombor yang sama pengguna aktif. Ciri-ciri pengesanan bunyi pendek, bunyi bising yang pendek, bunyi bising haba dan fasa yang disebabkan intensiti bunyi bising adalah dianggap secara serentak untuk analisis prestasi. prestasi simulasi sistem dijalankan beberapa parameter reka bentuk seperti kadar-ralat-bit, jarak, kuasa input, menerima kuasa, jarak saluran. Untuk membandingkan keputusan simulasi kita perlu mengintegrasikan simulator optik komersial "Optisystem" versi 12. Keputusan melaporkan bahawa sistem hibrid yang menggunakan teknik modulasi maju DPSK (fasa pengkamilan anjakan menaip) menggunakan teknik pengesanan penolakan pelengkap menunjukkan peningkatan yang ketara berbanding dengan teknik pengesanan langsung dan AND teknik pengesanan penolakan daripada sistem hibrid konvensional. Prestasi sistem cadangan ini adalah baik untuk menghantar data bagi panjang gentian jarak jauh di mana kelajuan bit yang tinggi digunakan 2.5Gbps yang memberi pencapaian penting penghantaran data 15km. Tambahan pula, sistem hibrid juga memberi tumpuan kepada permohonan untuk Gigabit Rangkaian optik pasif (GPON) untuk meningkatkan prestasi untuk rangkaian kawasan tempatan. Selain itu, analisis simulasi yang mendedahkan bahawa sistem yang dicadangkan mempunyai keupayaan untuk menghantar isyarat sehingga ke jarak gentian 7 km. Dalam tesis ini, dicadangkan OCDMA atas sistem WDM dianggap kos efektif, meningkatkan keupayaan rangkaian untuk menyokong sejumlah besar pelanggan, kadar bit yang tinggi, keupayaan gentian jarak jauh dan pelbagai jenis perkhidmatan dalam rangkaian akses optik.

OCDMA over WDM System Using Advanced Modulation Technique for Gigabit Passive Optical Network

ABSTRACT

Optical code division multiple access (OCDMA) system has provides immense opportunity for all optical access networks regarding the flexibility, asynchronous access, high-volume transmission capacity, simple network control and increasing the security. This thesis deploys OCDMA technology to design a new hybrid (OCDMA over WDM) system and comparing the performance in different detection techniques with different data rates. To design a new OCDMA over WDM system, code selection is a concerning part for getting better system performance with high security. In this thesis, detection techniques used Modified Double Weight Code (MDW) as signature code. In OCDMA systems, generally the cross-correlation functions created that causes multiple access inference noise. Multiple Access Interference (MAI) is type of interference caused by multiple cellular users who are using the same frequency allocation at the same time. To mitigate this MAI issue, detection technique is used throughout the thesis. Advanced modulation technique is applied to increase the system performance with high bit-error-rates ($\leq 10^{-10}$). The investigated results obtained by using direct detection, AND subtraction detection and complementary subtraction detection techniques for similar number of active users. Detection properties of short noise, thermal noise and phase-induced intensity noise are considered simultaneously for performance analysis. System simulation performance are carried out some design parameters such as bit-error-rate, distance, input power, received power, channel spacing. To compare the simulation results we have to integrate commercial optical simulator “*Optisystem*” version 12. Results reported that the hybrid system using advanced modulation technique DPSK (differential phase shift keying) using complementary subtraction detection technique shows significant improvement compared to direct detection technique and AND subtraction detection techniques from conventional hybrid system. The proposed system performance is better to transmit data for long distance fibre length where high bit rate used 2.5Gbps which provide the significant achievement up to 15km data transmission. Furthermore, hybrid system also focuses on application for Gigabit Passive Optical Network (GPON) to enhance the performance for local area network. Moreover, the simulation analysis revealed that the proposed system have the ability to transmit signal up to 7km fibre distance. In this thesis, proposed OCDMA over WDM system is considered cost effective, increase the network capability to support large number of subscribers, high bit rate, long distance fibre capability and various types of services in optical access networks.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Over the last two decades the requirements for communication system have become increasingly demanding. A current Cisco forecast projects that global internet traffic will increase by a factor of four from 2014 to 2016, and that video-rich services will be the most prevalent cause of this increase in traffic. Advanced internet videos such as three -dimensional (3D) video, super- high- definition (SHD) video, ultra-high-definitions (UHD) video, are projected to increase 23-folds, whereas video communications traffic, e.g., video calling and video conferencing is expected to increase by 7-folds. In 2016, 89% of mobile data is expected to consist of video traffic (Cisco, 2013). Due to the present need for communication with a wide bandwidth requirement, the optical code division multiple access (OCDMA) and wavelength division multiplexing (WDM) technologies have emerged as flawless solutions. OCDMA is recognized as one of the most important technologies for supporting many users in shared media simultaneously and is considered an exciting developments in short-haul optical networking because it can support both wide and narrow bandwidth applications on the same network.

In WDM, the spectrum of optical transmission is split into a few non-overlapping wavelengths, and a single communication channel is supported by each bandwidth. In other words, WDM consists of the combination of optical signals of different wavelengths and their subsequent combined transmission. However, for

improperly designed codes, the maximum number of simultaneous users and the performance of the system can be seriously degraded by multiple access interference (MAI) or crosstalk from other users. To address this MAI and cross-talk concern, researchers have developed hybrid (OCDMA over WDM) system techniques that present increased capability for higher connectivity and for the use of flexible bandwidths and that thereby provide a new perspective for the design of effective and less-expensive communication network.

1.2 Background

Optical code division multiple access (OCDMA) communication network technology will constitute an important part of future optical networks. Optical networks use the multiple access technique to address the demands of large capacity and high-speed communication. This technology can also be applied in the implementation of optical signal multiplexing and label switching on backbone networks. The remarkable improvement in internet traffic has augmented the bandwidth demand for the telecommunication industry. Due to the steady increase in the demand for data bandwidth, optical networks are focusing on new technologies (Ahmed, N., et al., 2012).

The combination of optical signal processing with an enormous bandwidth capacity with the code division multiple access (CDMA) technique results in the OCDMA system, is a method for encoding and decoding using an optical signature code for the selection of a desired signal that allows different users to share the same bandwidth (Sabbagh, et al., 2014). This system is secure because only the intended user with the correct code can recover the user-specific optical encoded signal. As a results

of multiplexing transmission and multiple access that support multiple simultaneous transmissions in the same time slot and frequency band, OCDMA proves to be a better multiple-access system than system using other conventional multiple-access techniques, such as time-division multiple access (TDMA), wavelength division multiple access (WDMA). Users of the WDMA technique are allocated a specific wavelength slot by dividing the available optical bandwidth into fixed wavelength channels that are shared concurrently by different users (Hesham et al., 2004). Although WDMA can be used as a degree of design freedom with respect to routing and wavelength selection, WDMA adds a further dimension to the functionality of a network. The fundamental issue regarding WDMA is the limited number of useable wavelengths. Another issue associated with WDMA performance is wavelength granularity which limits the traffic on the optical channel of the wavelength path. This constraint can be overcome by OCDMA through the use of a band of code words. OCDMA can accommodate more users by offering a greater number of channels than WDMA (Baziana, 2015). Meanwhile, the performance of TDMA is restricted by the time-serial nature of the technology, and TDMA prevents the utilization of statistical multiplexing gain, which is significant in high-data traffic (Zhuo et al., 2010).

OCDMA is attractive due to its dynamic capacity and flexible bandwidth management, and the fact that it supports random-access protocols and presents superior security (Martin-Gonzalez, et al., 2012). The asynchronous transmission in OCDMA resulted in more simplified access control to the medium than TDMA (Ghafouri-Shiraz, et al., 2012). Simultaneous and asynchronous access to the network is provided to by the OCDMA system with tight security and systems with WDM presents a high capacity of transmission. OCDMA can be adapted to existing WDM systems to strengthen network protection and increase its capacity (Isaac, et al., 2012). The

research and development efforts between the mid 2008s and 20012 have mostly focused on OCDMA over WDM, as shown in Figure 1.1.

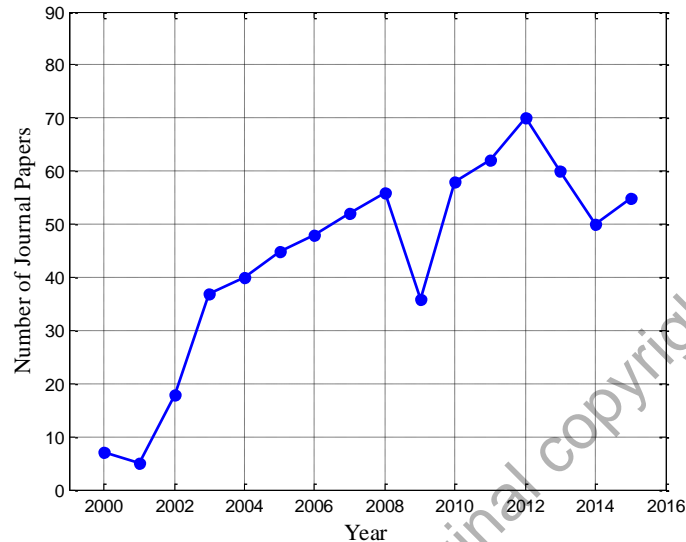


Figure 1.1: Number of published journal articles on OCDMA over WDM system as a function of the year of publication (data obtained from the ISI Web of Science database, 2015).

1.3 Problem Statement

The most important consideration in OCDMA is performance degradation depending on the number of simultaneous users (Prucnal, 2005). This thesis, aims to achieve a network that allows the simultaneous communication of high bit rate clients through long-distance fibre. In a well-designed system without MAI and that address PIIN, users can successfully communicate asynchronously regardless of the network traffic and the number of active users (Bakarman, 2009). WDM systems allocate the available optical bandwidth into distinct wavelength channels which are sent simultaneously by different users to allow multiple access. It is difficult to construct a WDM system for a dynamic set of multiple users due to the significant amount of coordination among the nodes that is required for successful operation. To construct a

WDM network with a dynamic user base, control channels and collision detection schemes, which would waste significant bandwidth, would need to be implemented.

The advanced modulation technique DPSK (differential phase shift keying) does not require absolute phase in which signal is used as a phase reference. The bandwidth requirement in DPSK modulation has been reduced significantly. Moreover, the transferring of data for PSK (phase shift keying) have only one cycle, but an additional half cycles are needed in DPSK modulation (Nazih Hajri, 2009). The influence of DPSK modulation on hybrid system transmission is considered to depend on the bit error rate (BER) and power density of the modulated signal. The advanced modulation technique DPSK is used obtain more authenticated results. The inclusion of advanced modulation technique DPSK in this system is one of the main principles which need to adjust the parameters to appropriate values.

The proposed hybrid system has two main issues, namely, the extraction of clean data by the intended user and the reduction of the PIIN (phase induced intensity noise) effect. By eliminating MAI, the detection scheme should be able to suppress or eliminate completely all overlapping data. Therefore, researchers have proposed various detection techniques, direct detection (Mohamad, Feras, Aljunid, & Sahbudin, 2008), AND subtraction detection (C.M. Negi, 2011), complementary subtraction detection (Muthana.Y.aldouri, 2011) and NAND subtraction detection (Ahmed, et al., 2013). However, all of the proposed detection techniques suffer from various limitations, although, some successfully reduce or eliminate the MAI. However, controlling the power level of the signal is crucial for the use of any detection techniques. This concept is applied in the different detection techniques with different bit rates, which have the main objective of producing sufficient power to entire eliminate any overlapping signal.

Cost effectiveness is always the main factor that influencing the development of multiple access system or other communication systems. This factor cannot be ignore because the system constantly needs to budget for all equipment, consultations, services and maintenance throughout the operating time. However, security issues are one of the factors of concern for any system. Thus, the development of a low-cost and secure multiple access system is easy to operate. A detailed review of the proposed OCDMA over WDM system and its implementation in gigabit-capable passive optical networks (GPONs) is provided in Chapter 2.

1.4 Research Objectives

The main objective of this research study was to design a novel hybrid OCDMA over WDM system based on MDW code. Thus, the objectives of this thesis work are the following:

1. To design and develop a new OCDMA over WDM system using the advanced modulation technique DPSK,
2. To analyse and investigate the performance of the system at different bit rates using different detection techniques, and
3. To implement and analyse the performance of the proposed system for application in Gigabit Passive Optical Network.