DEVELOPMENT OF NOVEL OCDMA CODES FOR FTTH NETWORK

THANAA HUSSEIN ABD

UNIVERSITY MALAYSIA PERLIS

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By

THANAA HUSSEIN ABD

(0940810437)

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Thanaa Hussein Abd
University Malaysia Perlis (UniMAP)

TABLE OF CONTENTS

CHAPTER TWO

LITERATURE REVIEW

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

APD	Avalanche Photo Detector
BER	Bit Error Rate
BS	Brillouin Scattering
CDMA	Code Division Multiple Access
CW	Continuous Wave
DCS	Dynamic Cyclic Shift
EDFA	Erbium Doped Fiber Amplifier
EDW	Enhanced Double Weight
FBG	Fiber Bragg Grating
FSO	Free Space Optics
FTTH	Fiber To The Home
FWM	Four Wave Mixing
Gb/s	Gigabit per second
GF	Galois Field
LAN	Local Area Network
LED	Light Emitting Diode
MAI	Multiple Access Interference
Mb/s	Mega bit per second
MD	Multi Diagonal
MDW	Modified Double Weight
MFH	Modified Frequency Hoping
MQC	Modified Quadratic Congruence
MZ	Non Return to Zero

NDSF	Non Dispersion Shift Fiber
NRZ	Non Return to Zero
OCC	Optical Orthogonal Code
OCDMA	Optical Code Division Multiple Access
OOK	On-Off Keying
PIIN	Phase Induced Intensity Noise
PIN	Positive Intrinsic Negative
PMD	Polarization Mode Dispersion
PON	Passive Optical Networks
PRBS	Pseudo Random Binary Sequence
PSD	Power Spectral Density
RD	Random Diagonal
RF	Radio Frequency
ROF	Radio Over Fiber
RS	Raman Scattering
RZ	Return to Zero
SAC	Spectral Amplitude Coding
SBS	Stimulated Brillion Scattering
SCM	Subcarrier Multiplexing
SLD	Super Luminescent Diode
SMF	Single Mode Fiber
SNR	Signal to Noise-Ratio
SPC	Spectral Phase Coding
SPM	Self Phase Modulation
TDM	Time Division Multiplexing

TDMA	Time Division Multiple Access
TPC	Temporal Phase Coding
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WDMA	Wavelength Division Multiple Access
WHTS	Wavelength-hopping Time-spreading
ZCC	Zero Cross-cross

PEMBANGUNAN NOVEL OCDMA KOD BAGI RANGKAIAN FTTH

ABSTRAK

Teknik Kod Pembahagi Pelbagai Capaian Optikal (OCDMA) membolehkan banyak pelanggan berkongsi rangkainan secara serentak and tak segerak dengan menetapkan kod yang spesifik kepada setiap pelanggan. Gangguan akses yang pelbagai, iaitu Multiple Access Interference (MAI) dianggapkan sebagai factor penurunan yang dominant di dalam system OCDMA. Rekaan jujukan kod yang pintar adalah penting untuk mengurangkan sumbangan MAI. Sejak sedekad yang lalu, banyak kod telah dicadangkan untuk OCDMA. Walau bagaimanapun, kod-kod ini mempunyai beberapa kekangan dalam pemilihan parameter-parameter kod (panjang kod, berat , korrelasi rentangan). Tambahan pula, jumlah pengguna yang boleh ditampung adalah sangat terhad. Di dalan tesis ini, dua kod yang novel, iaitu Multi Diagonal (MD) dan Dynamic Cyclic Shift (DCS) kod telah dicadangkan untuk system OCDMA, bagi menindaskan MAI, seterusnya memitigasikan hingar fasa keamatan teraruh, atau phase induced intensity noise (PIIN), memenuhi jumlah pengguna yang tinggi serta menambah kapasiti rangkaian optik. Kod DCS telah dibangunkan berdasarkan kaedah anjakan kitar dan bidang Galois untuk mendapatkan korrelasi rentangan yang rendah dan meminimumkan panjang kod dengan berat kod yang rendah. Sebaliknya, kod MD telah dibangunkan berdasarkan matrik pelbagai pepenjuru bagi mendapatkan korrelasi rentangan sifar yang mana sangat signifiken dalam menyumbangkan pemansuhan MAI, dan dengan itu memperbaiki prestasi sistem rangkaian OCDMA. Kajian mengenai kedua dua kod ini, pada permulaannya adalah diterbitkan secara matematik, dan seterusnya dijalankan melalui eksperimen simulasi menggunakan simulator optikal Optisystem versi 9.0. Kajian ini memfokuskan kepada kesan jarak, kadar bit, format modulasi data, kuasa input, luang cip, dan nisbah penguat terhadap prestasi sistem. Kod DCS telah dibandingkan dengan kod-kod yang mempunyai nilai korrelasi rentangan di antara kod-kod mereka, seperti kod Modified Quadratic Congruence, (MQC), Modified Frequency Hopping (MFH), Enhanced Double Weight (EDW) and Modified Double Weight (MDW). Kod DCS telah mempamerkan kebolehan untuk menampung jumlah pengguna yang lebih tinggi secara serentak. Kod ini boleh menyokong 160 pengguna yang membawa 622Mb/s secara serentak dengan kadar kesilapan bit yang dibenarkan pada 10^{-11}. Dengan mengaplikasikan kod DCS, kuasa yang diperlukan di foto pengesan adalah lebih rendah, bererti sistem pengesan juga memerlukan kuasa yang lebih rendah. Seumpama dengan itu, sistem kod MD juga mempamerkan prestasi yang lebih baik berbanding kod- kod terdahulu yang mempunyai korrelasi rentangan sifar seperti kod Zero Cross Correlation (ZCC) dan Random Diagonal (RD). Ia boleh menampung 240 pengguna membawa 2.5Gb/s pada kuasa menghantar yang lebih rendah berbanding 160 pengguna aktif oleh kod ZCC dihantar kadar data yang sama. Pembangunan kod DCS dan MD telah menyumbangkan kepada pembaikan sistem OCDMA dengan mengurangkan nilai korrelasi rentangan di antara kod dan dengan itu, memitigasikan PIIN. Dengan mengadaptasikan kod-kod ini ke dalam rangkaian OCDMA, jumlah pengguna yang lebih besar boleh ditampung dengan kekompleksan sistem yang lebih rendah.

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ABSTRACT

Optical Code Division Multiple Access (OCDMA) technique enables many subscribers to share a network simultaneously and asynchronously by allocating a specific code to each subscriber. The Multiple Access Interference (MAI) is considered as the dominant degradation factor in the OCDMA system. Intelligent code sequence design is important to reduce the contribution of MAI. Over the last decade, many codes were proposed for the OCDMA. However, these codes have several restrictions on choosing the code parameters (code length, weight, cross-correlation properties). In addition, the number of accommodating users is severally limited. In this thesis two novel codes, namely Multi Diagonal (MD) and Dynamic Cyclic Shift (DCS) code have been proposed for the OCDMA system, to suppress the MAI consequently mitigate the phase induced intensity noise (PIIN), accommodate large number of users and enhanced the optical network capacity. The DCS code have been developed based on cyclic shift and Galois field method to obtain low cross-correlation property and minimise the code length with low weight value. On the other hand, MD code was developed based on multi diagonal matrixes to achieve zero cross-correlation property which significantly contributes to the elimination of the MAI and thus improved system performance of OCDMA network. The study of both codes, firstly derived mathematically, and subsequently carried out using simulation experiment utilizing optical simulator Optisystem^{TM} version 9.0. The study focused on the effect of distance, bit rate, data modulation format, input power, chip spacing and amplifier ratio on the systems performance. The DCS code has been compared with codes that have cross-correlation value between their code words such as Modified Quadratic Congruence, (MQC), Modified Frequency Hopping (MFH), Enhanced Double Weight (EDW) and Modified Double Weight (MDW) codes. The DCS code showed the ability to accommodate a higher number of simultaneously users. This code could support 160 users simultaneously, carrying out 622Mb/s with a permissible bit error rate of 10^{-11}. Power required was lower at the photo detector which means the detection system required less power by applying DCS code. Accordingly, the MD code system showed better performance than the former codes with zero cross-correlation property such as Zero Cross-correlation (ZCC) and Random Diagonal (RD) codes. It could accommodate 240 simultaneous users with 2.5 Gb/s at low transmitting power comparing to the 160 active user of the ZCC code at the same transmitting date rate. The development of the DCS and MD code has contributed to the OCDMA system improvement by reducing the cross-correlation value between code words and thus mitigating the PIIN. By adapting these codes in the OCDMA network, larger number of users can be accommodated with lower system complexity.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

As telecommunication systems and networks are expended to provide a variety of multimedia applications such as video streaming, voice-over-IP and gaming, there is a demand for bandwidth forces network infrastructure to be of a large capacity and to be reconfigurable. Fiber optics communication systems are able to accommodate this growth of bandwidth by transmitting at terabits per second over a long distance. Fiber optics offers almost unlimited bandwidth and is considered as the ultimate solution to deliver broadband access to the last mile (Guu-Chang & Kwong, 2002; Keiser, 2000). It also offers a much lower attenuation factor, where optical signals can be transmitted over long distances without signal regeneration or amplification. Many channels can be multiplexed to share the same fiber-optic medium, thus reducing the number of links required and the cost to end users.

As a result, the efficient utilization of bandwidth is the major design issue for ultrahigh-speed optical communication systems. Utilizing the exhausting bandwidth offers a variety of multimedia applications over the same optical networks, multiplexing techniques potentially allow for aggregate traffic of many terabits per second per fiber (Kartalopoulos, 2002). Multiple access techniques are necessary to meet the demand for ultrahigh-speed and large capacity optical communication systems.