UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF MULTI-SERVICE CODE FAMILY FOR SPECTRAL AMPLITUDE CODING - OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEMS

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By

MAJID HAYAS KAKA

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

September 2013

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DEDICATION

To my:

Beloved parents,

Sisters and brothers,

Beloved wife, Shawnim, and

Daughter and son, Yara and Yar

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

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Chairman: Makhfudzah Bt Mokhtar, PhD.

Faculty: Engineering

In recent years Optical Code Division Multiple Access (OCDMA) technique received research attention due to its advantages including high-speed asynchronous low-latency access networking, dynamic bandwidth assignment and secured transmission. Among several encoding techniques developed for OCDMA systems, Spectral Amplitude Coding (SAC) is known as a suitable option to provide the Quality of Service (QoS) in optical communication networks by varying the code length, weight or both. SAC also has other advantages such as simplicity and lower cost of system components.

In this thesis, a family of novel spreading sequences is constructed, called a Multi-Service (MS) code have been proposed for SAC-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 as well as offering service differentiation in optical domain. This proposed code has its own advantage because it could generate code-words in flexible way by setting variable basic codes at fixed code weight.

The performance of the proposed code is demonstrated via mathematical simulation and it is shown that with 3.75 THz line width Broadband Source, MS code supports up to 10 users simultaneously at satisfactory Bit Error Rate (BER) of 10^{-9}, choosing code weight of 4 and optimizing number of users per sequence when the bit-rate is 622 Mbps. Furthermore, the results showed that in higher bit-rate e.g. 5 and 10 Gbps, MS with code weight of 4 supports up to 15 and 7 active users respectively. Thus, from the results it indicates that MS code does not only preserve the capability of suppressing MAI, but also improves BER performance due to low cross-correlation (λ_c) between code sequences. (i.e. $0 \leq \lambda_c \leq 1$).

Moreover, in the simulation analyses the software, OptiSystem™ version 10 was utilized to simulate the MS code system. The effects of various parameters such as fiber distance, bit rate, received optical power on the SAC-OCDMA system have been studied and compared, using the MS, Modified Quadratic Congruence (MQC), Khazani Syed (KS) and Random Diagonal (RD) codes. Based on the simulation results, performance of MS code outperformed former codes when the number of basic codes, N_B was optimally chosen.

Finally, the MS code was applied to one of the OCDMA applications which is Triple-Play services (audio, data, and video) with different QoS requirements. The proposed system used the dynamic basic codes (N_B) feature of MS code to provide different QoS metrics for different users with fixed code weight. It is shown that optimum performance of specific N_B can be obtained with a proper choice of supportable users. Codes that used lower value of N_B always have smaller error probability. Hence, overall network performance can be improved if the number of lower N_B users is larger in the multimedia applications. Due to the major advantages of the MS code, with a fewer number of weights, the cost and the complexity of the system is reduced comparing with other QoS codes. Hereby, MS code seems to be a good candidate for providing QoS applications.

Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PEMBANGUNAN PERKHIDMATAN-PELBAGAI KOD KELUARGA UNTUK PENGEKODAN AMPLITUD SPEKTRAL - PEMBEHAGI KOD AKSES PELBAGAI OPTIK

Oleh

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Sejak kebelakangan ini Pembehagi Kod Akses Pelbagai Optik (OCDMA) teknik mendapat perhatian dalam bidang penyelidikan kerana kelebihannya iaitu akses rangkaian kependaman rendah dan tak segerak dengan kelajuan tinggi, pembahagian jalur lebar yang dinamik dan penghantaran yang terjamin. Antara teknik pengekodan yang dihasilkan untuk sistem OCDMA ialah Pengkodan Amplitud Spektral (MPS) yang merupakan pilihan sesuai dalam menyediakan QoS rangkaian komunikasi optik dengan mengubah panjang kod, pemberat atau kedua-duanya. MPS juga mempunyai kelebihan lain seperti lebih ringkas dan kos komponen sistem yang lebih rendah. Dalam tesis ini, keluarga sebaran urutan yang baru telah dibina iaitu kod perkhidmatan-pelbagai (MS) dan telah dicadangkan untuk sistem SAC-OCDMA, bagi menahan MAI seterusnya mengurangkan Fasa Intensiti Teraruh Bunyi (PIIN), untuk menampung jumlah pengguna yang tinggi dan meningkatkan kapasiti rangkaian optik serta menawarkan perbezaan dalam perkhidmatan domain optik. Kaedah kod yang dicadangkan ini mempunyai kelebihan tersendiri kerana ia boleh menjana kod-perkataan dalam cara yang fleksibel dengan menetapkan kod asas berubah pada pemberat kod tetap.

Prestasi kod yang dicadangkan ini ditunjukkan melalui simulasi matematik dan ia menunjukkan bahawa, dengan memilih pemberat kod 4 dan mengoptimumkan bilangan pengguna setiap urutan pada kadar bit 622 Mbps, MS kod menyokong sehingga 10 pengguna serentak pada kadar ralat bit (BER) yang memuaskan iaitu 10^{-9}. Selain daripada itu, keputusan menunjukkan bahawa pada kadar bit yang lebih tinggi seperti 5 dan 10 Gbps, MS dengan pemberat kod 4 menyokong sehingga 15 dan 7 pengguna aktif. Oleh itu, dari keputusan ini menunjukkan bahawa kod MS bukan sahaja mengekalkan keupayaan menahan MAI , tetapi juga meningkatkan prestasi BER disebabkan silang korelasi (λ_c) yang rendah antara urutan kod. (i.e. $0 \leq \lambda_c \leq 1$).

Selain daripada itu, OptiSystem™ versi 10 telah digunakan untuk mensimulasikan sistem kod MS. Kesan daripada pelbagai parameter seperti jarak gentian, kadar bit dan kuasa optik yang diterima pada sistem SAC-OCDMA telah dikaji dan dibandingkan dengan menggunakan MS, Modified Quadratic Congruence, (MQC), Syed Khazani (KS) dan Random Diagonal (RD) Kod. Berdasarkan keputusan simulasi, prestasi kod MS mengatasi kod terdahulu apabila bilangan pengguna dalam kod asas, N_B telah dipilih secara optimum.

Akhirnya, kod MS telah diaplikasikan kepada salah satu daripada aplikasi OCDMA iaitu perkhidmatan Triple-Play (audio, data, dan video) dengan keperluan QoS berbeza. Sistem yang dicadangkan menggunakan ciri kod MS iaitu kod asas dinamik (N_B) untuk menyediakan metrik QoS yang berbeza bagi pengguna yang berbeza dengan pemberat kod tetap. Selain daripada itu, ia menunjukkan bahawa prestasi optimum N_B boleh dicapai dengan membuat pilihan yang betul dari pengguna yang dikekalkan. Kod yang menggunakan nilai (N_B) yang lebih rendah sentiasa mempunyai ralat kebarangkalian yang lebih kecil. Oleh itu, prestasi keseluruhan rangkaian boleh diperbaiki jika bilangan pengguna dengan nilai (N_B) yang lebih rendah adalah lebih ramai di dalam aplikasi multimedia. Dengan bilangan pemberat yang rendah, jumlah kos dan tahap kekompleksan dapat dikurangkan berbanding dengan kod QoS yang lain. Oleh yang demikian, MS kod merupakan calon yang sesuai untuk menyediakan aplikasi QoS.

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I certify that a Thesis Examination Committee has met on 20 September 2013 to conduct the final examination of Majid Hayyas Kaka on his thesis entitled "Development of Multi-Service Code Family for Spectral Amplitude Coding-Optical Code Division Multiple Access Systems" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I declare that the thesis is my original work except for 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 institutions.

_____

MAJID HAYAS KAKA

Date: 20 September 2013

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