

ABSTRACT

This paper evaluate performance of Optical CDMA network using 3-D Optical Orthogonal Codes in a frame work called “ time-slotted broadcast local area network” . In this framework, with suitable multiple access schemes, a number of packets from different sources can be transmitted over the optical fiber in a single slot simultaneously. Performance is evaluated in term of offered load vs. throughput for various classes and it is compared with 2-D OOCs.

KEYWORDS: OCDMA, OOCs, 2-D OOCs, 3-D OOCs

INTRODUCTION

In order to make full use of the available bandwidth in optical fibers and to satisfy the bandwidth demand in future information networks, it is necessary to multiplex low rate data streams onto optical fiber to increase the total throughput. There are varieties of Optical CDMA schemes. They all share a common strategy of distinguishing data channels not by wavelength or time slot but by distinctive spectral or temporal code (or signature) impressed onto the bits of each channel [03]. Suitably designed receivers isolate channels by code-specific detection. Optical orthogonal codes such as 1-D, 2-D, Multiclass Optical Orthogonal Codes and 3-D are used as signature codes.

3-D OPTICAL ORTHOGONAL CODES (OOCs)

Space/wavelength/time 3-D codes can be constructed by extending 2-D codes—space/time codes or wavelength/time codes. Let us assume $(S \times T, S, 0, 1)$ space/time 2-D codes. If multi wavelength light sources (W) are available for each spatial channel, we have another degree of freedom to choose the wavelength of each spatial channel in code construction. For a given temporal distribution of pulses over spatial channels, i.e., one codeword of the space/time 2-D code, many different code words can be generated by changing the wavelength of pulse in each spatial channel. In assigning wavelength to each spatial channel, we need to keep the orthogonality by constraining cross-correlation between any two code words with different temporal distributions of pulses over spatial channels less than or equal to 1. To extend 2-D codes to 3-D codes without losing orthogonality, we only need to assign wavelengths to each spatial channel such a way that any two distinct code words have no more than one spatial channel of the same wavelength. In other words, we can construct space/wavelength/time 3-D code by applying 2-D construction algorithm separately to space/wavelength plane and space/time plane [01]. For example, the prime sequence algorithm for space/wavelength and the Reed–Solomon algorithm for space/time can be employed. We can generate distinct codewords for each temporal distribution of pulses over space channels by applying the 2-D prime code algorithm for assigning W wavelengths over spatial channels. Table 1 shows 9 codewords in $(3 \times 3 \times 3, 3, 0, 1)$ 3-D code constructed by employing the prime code algorithm, these codes are generated from by assigning wavelengths to spatial channels in different ways with the same allocation of optical pulses in time. Moreover, if the number of wavelength is greater than or equal to that of spatial channels $(W \geq S)$, due to the orthogonality of the 2-D prime code construction algorithm, every cyclic shift in wavelength domain also generates another codeword that is orthogonal to others. For the code words shown in Table 1 each codeword will generate two more codewords by shifting pulses in wavelengths. Consequently, we have 27 codewords in $(3 \times 3 \times 3, 3, 0, 1)$ 3-D prime code. Therefore, we can generate W^2T codewords by extending $(S \times T, S, 0, 1)$ code to $(S \times W \times T, S, 0, 1)$ code if $W \geq S$. If $W \leq S$, cyclic shift of codewords in wavelength domain coincide with other codewords, and thus, we have WT codewords for $(S \times W \times T, S, 0, 1)$ 3-D code [02].

C ₀	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈
$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$
$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 010 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 001 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 100 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 010 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 001 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 000 \\ 100 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 000 \\ 010 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 000 \\ 001 \end{bmatrix}$
$\begin{bmatrix} 100 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 001 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 010 \\ 000 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 000 \\ 100 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 000 \\ 001 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 000 \\ 010 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 100 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 000 \\ 001 \\ 000 \end{bmatrix}$	$\begin{bmatrix} 001 \\ 010 \\ 000 \end{bmatrix}$

Table 1 : Visualization of 3 x 3 x 3 matrices. Each stack of 3 x 3 matrices represents a codewords of (3 x 3 x 3, 3, 0, 1) 3-D code. Each column and row of 3 x 3 matrices represent a time chip and a wavelength, respectively. Each 3 x 3 matrix represents a spatial channel or wavelength/time plane.

ANALYTICAL FRAME WORK FOR PERFORMANCE EVALUATION

The multiple-access techniques are applied in a time-slotted broadcast local area network. With a suitable multiple-channel multiple-access scheme (WDM or CDMA), a number of packets from different sources can be transmitted over the optical fiber in a single slot. We denote the number of simultaneous packets on the channel during a slot interval by M . Due to multiple-access interference, some of the packets will arrive at the receiver with bit errors. We let $P_B(m)$ be the probability of a bit error when there are simultaneous transmissions on the channel. The form of $P_B(m)$ will depend upon the type and parameters of the specific multiple-access scheme. The probability of receiving a packet without errors when simultaneous transmissions are on the channel is given by following equation [05].

$$P_C(m) = [1 - P_{B(m)}]^L$$

With suitable error-detection capability, the receiver can determine if one or more errors have occurred in a packet. All packets with errors are dropped by the receiver. For simplicity, we neglect the overhead required for this error-detection. In a broadcast network, the sender can independently determine the success or failure of the transmission and schedule the packet for retransmission after a random delay.

Let M be a random variable that represents the number of simultaneous transmissions in a time slot. The conditional distribution of the number of successfully received packets S is then given by following equation.

$$P[S = s | M = m] = \binom{m}{s} P_C^s(m) [1 - P_C(m)]^{m-s}$$

The steady-state throughput $\hat{\alpha}$ can be shown equal to:

$$\beta = E[S] = E[E[S/M]] = \sum_{m=1}^{\infty} m P_C(m) f_M(m)$$

where $f_M(m)$ is the steady-state probability distribution of composite arrivals (new and retransmitted packets).

We assume that composite arrival distribution is Poissonian with arrival rate λ then $f_M(m)$ is given by:

$$f_M(m) = \frac{(\lambda t)^m e^{-\lambda t}}{m!}$$

This choice of arrival distribution corresponds to an infinite user population. Defining

$\gamma = \lambda T$ to be the offered load (average number of attempted transmissions per time slot), the throughput becomes:

$$\beta = e^{-\gamma} \sum_{m=1}^{\infty} (m P_C(m) \gamma^m) / m!$$

METHODOLOGY

To analyze system performance under multiple user circumstance, we need the probability, P , that we will get 1 in cross-correlation between two distinct codewords at the time of detection. In other words, P is the probability that we will get a small optical pulse from an unwanted sender at the time of detection, where the power of the pulse is $1/(\text{code weight})$ times of a signal pulse. Let us call the P cross-correlation probability. In the 2-D prime codes, there is one pulse per row and $P = (1/2T) \times \text{number of rows}$. In the 3-D codes with multiple (W) pulses per plane, P is given by $(1/2T) \times SW$ since the code is equivalent to the 2-D code with SW rows. In the space/wavelength/time 3-D codes w/SPP, for the pulse in a spatial channel from an unwanted sender to contribute to noise at the time of detection, it should be of the same wavelength with the pulse from the wanted sender in that spatial channel. Therefore, P is given by $(1/2T) \times (1/W) \times S$.

Once P is given, the error probability of the system is given by

$$P_B = \frac{1}{2} \sum_{i=Th}^{N-1} \binom{N-1}{i} (P^2)^i (1-P)^{N-1-i}$$

where Th is a threshold in detection, N is the number of simultaneous users, and the factor $1/2$ accounts for the probability that the wanted sender transmits 0 assuming equiprobable on-off data bit transmission. Note that when the sender transmits 1, no error occurs [06].

Probability of bit error for the OCDMA networks using 3-D Optical Orthogonal Codes is employed in the framework called “time-slotted broadcast local area network” as described above. Using the equations derived required Matlab codes are written and on executing the Matlab codes graph between Throughput and Offered load is obtained.

RESULT AND CONCLUSION

In this scheme, the code length is considerably reduced because each codeword is reusable at different wavelength. For the analysis, we have taken the code length $T = 48$, wave length $W = 2$ and number of spatial channel $S = 8$. The maximum number of users supported in each wavelength is equals to:

1. W^2T codewords if $W \geq S$.
2. WT codewords if $W \leq S$.

So the total number of users supported by this scheme is $48 \times 2 = 96$, but for comparison we will consider only 50 users. By writing Matlab code for the equations we have plotted graphs for throughput vs. offered load as shown in Figure 1

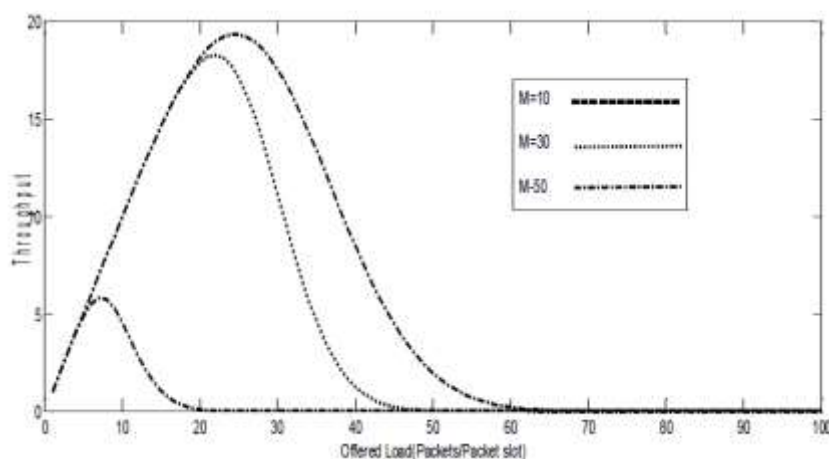


Figure 1 : Throughput vs. Offered load for 3-D OOCs

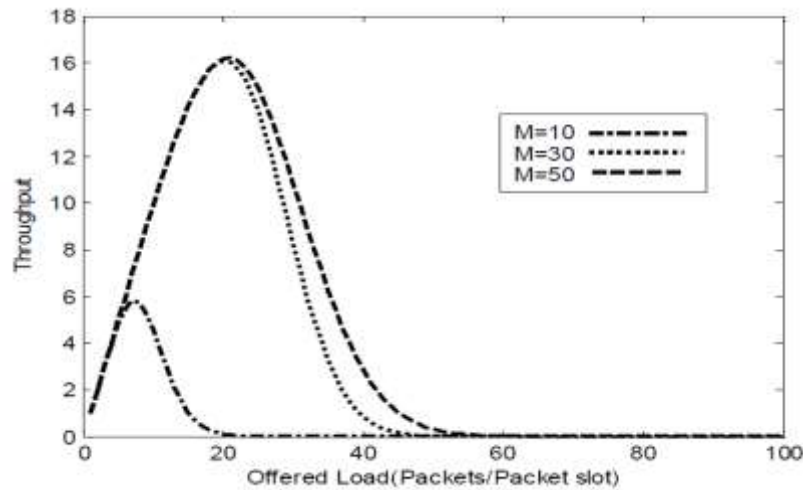


Figure 2 : Throughput vs. Offered load for 2-D OOCs

FO-CDMA employing 2-D OOCs is two dimensional coding. Figure 2 shows Throughput vs. Offered load for 2-D OOCs. It is compared with 3-D codes by fixing maximum users 96. By comparing Figure 1 and Figure 2 in both cases and it is clear that throughput is much more in OCDMA using 3-D codes. Multi Access Interference (MAI) is more dominant in OCDMA using 2-D codes.

ACKNOWLEDGEMENT

I am indebted to Prof. (Dr.) Anil Kumar Sharma, Principal, Institute of Engineering & Technology North Extn., M.I.A., Alwa, Rajasthan, for his stimulating suggestions, untiring help and constructive criticism. It is my pleasant duty to acknowledge, with a great sense of gratitude, to the staff of Library of Sunrise University, Alwar and the assistance I received from individual of Electronics and Communication Department while working in the laboratory. I would like to express my gratitude to the authors of all references.

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