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Simulation Analysis of Enhancing O-CDMA

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Abstract:
The spread spectrum communications utilizes transmission bandwidth which has potential higher than the desired signal bandwidth. Optical fibers are broadly used in fiber-optic communications, as it affirms transmission over longer distances than other forms of communication. So O-CDMA has become encouraging applicant for communications, due to its: fairness, flexibility, simplified network control and management and increased security. After going through so many researches, in this paper, we discuss how the network performance can be improved using PN sequence code, Walsh Hadamard code and Padded codes and will compare their results by knowing signal to noise ratio (SNR) v/s Bit error rate (BER) graphs, which one is more effective based on their BER v/s number of users plot and which code will be more useful to enhance the network capacity.

Key words: *BER, SNR, PN sequence, Walsh Hadamard Code, Padded code, OCDMA.*

1.Introduction

Optical code-division multiple-access (O-CDMA) systems have shown growing interest in the latest years due to the ample bandwidth ascribed by the optical links and the extra-high optical signal processing speed provided by the optical components. The fundamental conception in data communications is to permit several transmitters to deliver information concurrently over a single communication channel. This allows many users to share a band of frequencies (bandwidth). This concept is called multiple access. O-CDMA is adapted from spread spectrum techniques has appeared as an encouraging choice over time-division multiplexing (TDM) and wavelength division multiplexing (WDM) technologies [1], [2]. Spread spectrum techniques are the methods by which a signal generated in a particular bandwidth is intentionally spread in the frequency domain, resulting in signal with wider bandwidth.

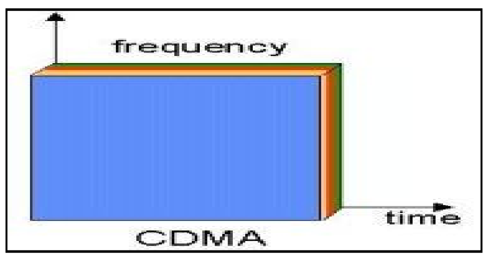

Figure 1: Illustration of CDMA

1.1. CDMA

CDMA is one of the attractive multiple-access schemes for optical networks because it permits concurrent users to access the identical optical channel without hindering with one another. CDMA is a spread spectrum multiple access (SSMA) method. Spread spectrum techniques are the methods by which a signal generated in a particular bandwidth is intentionally spread in the frequency domain, resulting in signal with wider bandwidth. In CDMA each transmitter is assigned a code to permit multiple users to be multiplexed over the same physical channel.

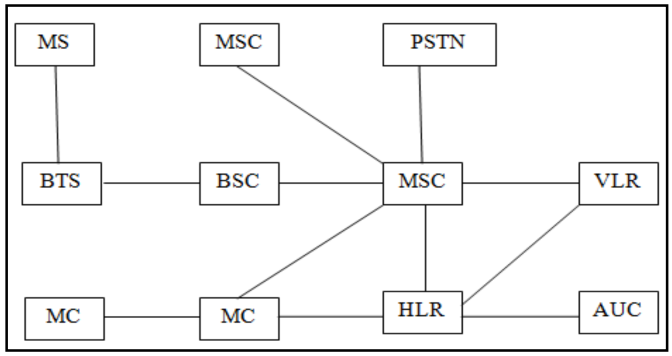

Figure 1.1: Architecture of CDMA

MS: Mobile Station
BSC: Base Station Controller
BTS: Base Transceiver Station
MSC: Mobile Switching Centre
VLR: Visitor Location Register
HLR: Home Location Register
AUC: Authentication Centre
OMC: Operation and Maintenance Centre
MC: Message Centre

The orthogonality condition for signals in CDMA is given by:

$$\int_c S_i(t)\, S_j(t)\, dt = \begin{cases} 1, & i = j, \quad i,j = 1,2\ldots,k \\ 0, & i \neq j \end{cases}$$ [10]

The above equation indicates that there is no overlapping of signals and implies that the signals do not have any common code.

Each user in a CDMA system uses a different code to modulate their signal. Choosing the codes used to modulate the signal is very important in the performance of CDMA systems. The best performance will occur when there is good separation between the signal of a desired user and the signals of other users. In a CDMA system the same frequency can be used in every cell because channelization is done using the pseudorandom codes.

1.2.Optical Fiber

An optical fiber is a flexible, transparent fiber which acts as a waveguide to transmit light between the two ends of the fiber. Optical fibers are broadly used in fiber-optic communications, as it affirms transmission over longer distances and at higher bandwidths (data rates) than other forms of communication. Fibers are employed over metal wires because signals travel along them with less loss and are also immune to interference or noise. It is favored for long-distance communications, because light propagates through the fiber with minimum diminution contrasted to cables.

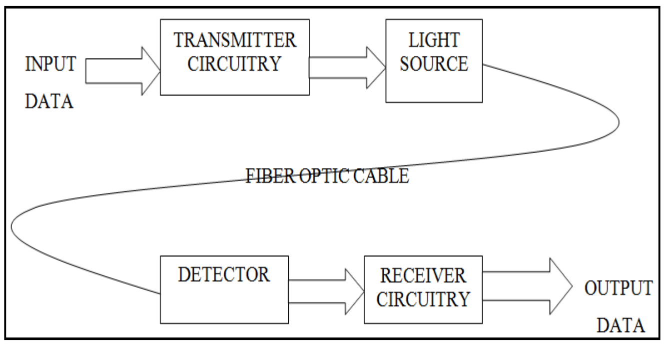

Figure1.2: Basic block diagram of fiber optical communication [6]

1.2.1.Principle Of Optical Fiber

It is based on principle of Total internal reflection (TIR) which occurs when a ray of light strikes a boundary of medium at an angle larger than a particular critical angle (it is the angle of incidence above which the total internal reflection occurs) with respect to the normal to the surface. If the refractive index is lower on the other side of the boundary, then no light can pass through and all of the light is reflected.

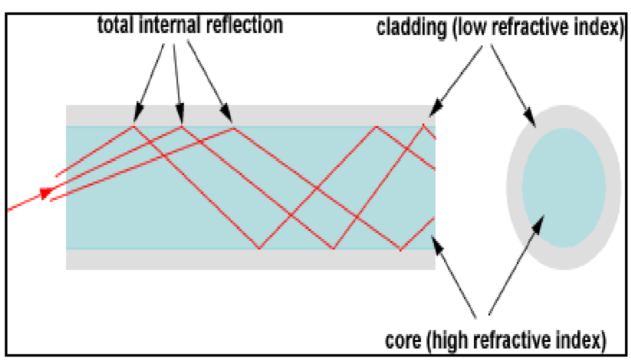

Figure1.3: Illustration of TIR

1.3.O-CDMA

Optical code-division multiple-access (CDMA) systems have been given an increasing interest in the recent years. This is due to the vast bandwidth offered by the optical links and the extra-high optical signal processing speed offered by the optical components. As a result, Optical CDMA can accommodate a larger number of simultaneous users than the radio-frequency techniques. Recently, optical code-division multiple-access (O-CDMA), adapted from spread spectrum techniques, has emerged as a promising alternative scheme to time-division multiplexing (TDM) and wavelength division multiplexing (WDM) technologies because in optical CDMA, each user (or station) is assigned a unique binary unipolar signature sequence (or codeword) as its own address. Each user sends a signature sequence, corresponding to the address of its intended destination, if the data bit is one, and transmits nothing if data bit is zero.

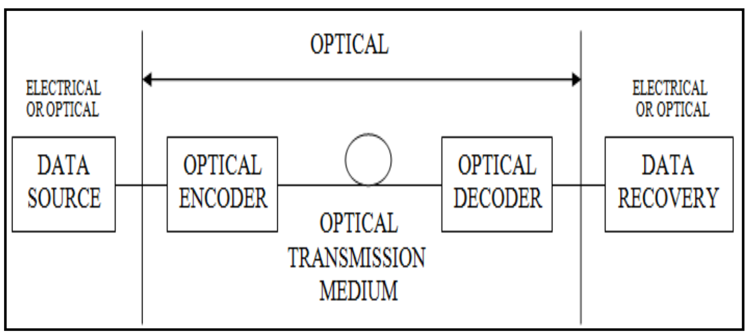

Figure 1.4: Fiber optic communication using encoder and decode

2. Codes To Be Employed

2.1.Pseudo-Noise Sequence

The signals in spread spectrum are pseudorandom in nature and have noise like properties in them. The pseudo-noise sequence is a binary sequence which is not continuous but can be generated by desired receiver. Its autocorrelation is similar to autocorrelation of band-limited white noise. The PN sequence is executed using sequential logic circuits. The PN sequence helps to convert a narrowband signal to wideband noise-like signal before transmission. [1]

2.2.Walsh Hadamard Code

The Walsh Hadamard Transform (WHT) is a suboptimal, non-sinusoidal, orthogonal transformation that decomposes a signal into a set of orthogonal, rectangular waveform called Walsh function. WHT are used in many different applications such as power spectrum analysis, filtering, processing speech and medical signals etc. Walsh Hadamard codes are widely used as signature codes in the current CDMA technology due to their orthogonal property and simplicity of implementation. These codes also offer better correlation properties and their BER performance is comparable with Walsh codes. Walsh codes do not have the properties of m-sequences regarding cross correlation. Walsh codes are created out of hadamard matrices and Transform. Hadamard is the matrix type from which Walsh created these codes. In a family of Walsh codes, all codes are orthogonal to each other and are used to create channelization within the 1.25 MHz band. Here are first four Hadamard matrices. The code length is the size of the matrix. Each row is one Walsh code of size N. The Hadamard matrices of dimension 2^k for $k \in N$ are given by the recursive formula. The lowest order of Hadamard matrix is 2. [7]

$$H(2^1) = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

$$H(2^2) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix},$$

and in general

$$H(2^k) = \begin{bmatrix} H(2^{k-1}) & H(2^{k-1}) \\ H(2^{k-1}) & -H(2^{k-1}) \end{bmatrix} = H(2) \otimes H(2^{k-1}),$$

2.3.Padded Codes

These MOLS classes do not have fixed CC and cannot be used for a conventional balanced detection optical spectral-amplitude system. Therefore, a flexible padding method is employed to make the entire code family have unity CC and to enlarge the code cardinality.

The bit error rate for the padded codes may be derived as [5]:

$$P_E \leq 0.5\,\mathrm{erfc}\left(\sqrt{SNR_{min}/8}\right)$$

$$SNR_{min} = \frac{Q^2R^2P_{sr}^2/(Q^2+Q+1)^2}{\dfrac{BR^2P_{sr}^2(Q+1)K}{2\,\Delta v\,(Q^2+Q+1)^2}\left(\dfrac{K-1+Q+K}{Q}\right) + eBRP_{sr}\left(\dfrac{2K-1+Q}{Q2+Q+1}\right) + \dfrac{4kT_rB}{R_L}}$$

where

R is the receiver photodiode responsivity

P_{sr} is the effective power of the broadband source at the receiver

B is the electrical noise equivalent bandwidth of the receiver

K is the number of active users

$\Delta\nu$ is the optical source bandwidth

e is the electronic charge; k is Boltzmann's constant

Tr is the receiver noise temperature

R_L is the load resistance

3.Simulation Analysis

3.1.Simulation1- Result for PN Sequence

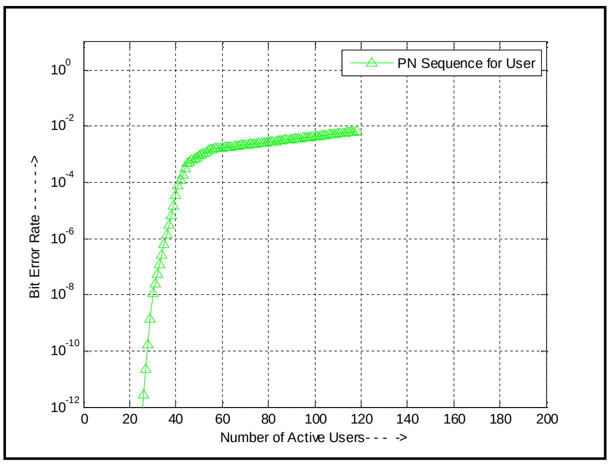

Figure 4.1: Implementation Result of Pseudo-Noise Sequence

Figure obtained after simulation of PN sequence illustrates the graph between BER and No. of active user. Initially for small number of users the value of BER is increasing linearly then after sometime the increase in number of users the BER is moving to attain constant value (as the users are increasing the BER attains value at 10^{-2}).

3.2.Simulation2- Result For Walsh Hadamard Code Generation

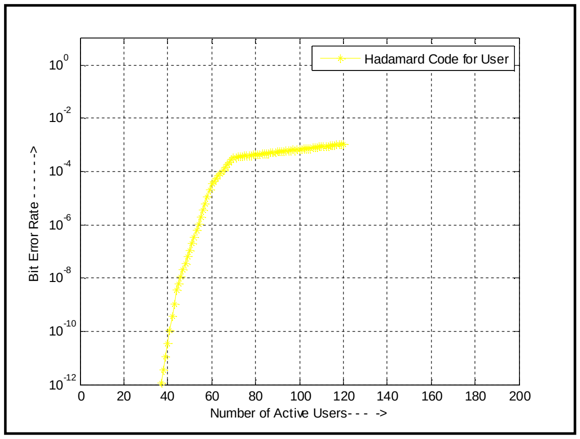

Figure 4.2: Implementation Result of Walsh Hadamard Code

Figure obtained after simulation of Walsh Hadamard Code illustrates the graph between BER and No. of active user. Initially for small number of users the value of BER is increasing linearly then after some time the value of BER attains constant value (as the users are increasing the BER attains value between 10^{-4} and 10^{-2}).

3.3.Simulation3- Result For Padded Codes

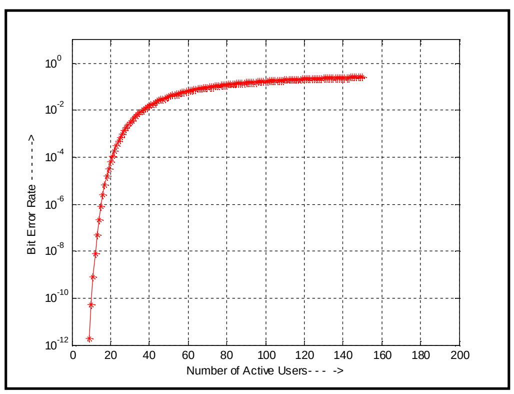

Figure 4.3: Implementation Result of Padded Codes

Figure obtained after simulation of Padded Codes illustrates the graph between BER and No. of active user. Initially for small number of users the value of BER is increasing linearly then after some time the value of BER attains constant value (even with the decrease in users BER attains value above 10^{-2}).

4.Performance Analysis

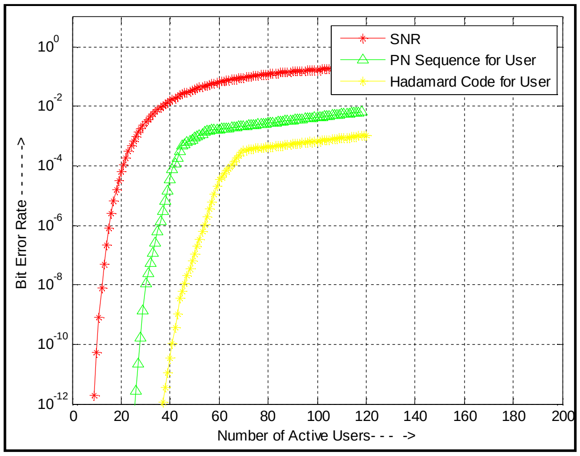

Figure 5: Comparative Result

5.Conclusion

System performance has been found to be one of the limiting factors for communication systems as channel capacity requirement continues to grow. Using the above mentioned codes it should be observed which code will result in lower bit error rate and offer much larger flexibility in code compared with the other sequences.

For the system to perform better BER value must vary between 10^{-3} to 10^{-4}.

On comparing the response of 3 different codes employed, it is clear that the system employing "Walsh Hadamard Code" is better compared to PN Sequence and Padded codes, as its BER value is varying exactly between 10^{-3} to 10^{-4}.

Moreover, the resulting code allow us accommodating more subscribers to be supported for a given bit error rate.

At the end it is concluded that the O-CDMA sphere is vast and has huge space for newer explorations and application.

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