CHAPTER 2

LITERATURE REVIEW

The purpose of this project is to develop a point-to-point OCDMA System for metropolitan area network application using the DW code. Based on simulation design we analyze the performance of the system by evaluating the bit error rate (BER) of different design parameters such as distance, input power, bit rate, chip distance, chip width, and output power.

2.1 Optical Code Division Multiple Access

Optical Code Division Multiple Access (OCDMA) is an alternative multiplexing scheme to the more conventional Wavelength Division Multiple Access (WDMA) and Time Division Multiple Access (TDMA). It has recently attracted significant research interest because of the advantages it offers in terms of network granularity and the flexibility in the management of the system resources. In addition, it is attractive for applications where secrecy in the transmission is important, and also has the potential of supporting burst IP traffic and multi-protocol-based networks [16].

OCDMA is based on allocating each user of the network one particular code; the codes are assigned to the data pulses before transmission; at the receiver the users rely on correctly decoding the signal intended for them in order to establish communication, while rejecting all other coded data intended for other users at the same time. Thus, unlike WDMA and TDMA, in general, each user is allowed to use the entire available spectrum for all of the time. The earliest pulse encoding implementations used arrays of discrete optical fibers of different path lengths appropriately coupled together using fiber couplers, in order to temporally split the input pulses in a predefined manner. The decoder used the same configuration, which served as a correlator for the encoded signals. However, this simplified scheme introduces several issues associated to its scalability as well as its sensitivity to environmental conditions. Since then several other technologies have been investigated, which apply encoding/decoding either in the time (direct-sequence-) or the frequency domain (frequency-encoded-OCDMA). Hybrid (also called two-dimensional or frequency-hopping) approaches have also been demonstrated [16].

2.2 OCDMA codes

Many codes have been proposed for optical CDMA system [17], [18]. However only a few of them [19], [20] have been shown actually support multi-rate transmissions. The multi-rate transmission is one of the main advantages of OCDMA systems which provide asynchronous transmission as opposed to the synchronous time division multiplexing (TDM) systems.

2.2.1 Double Weight Code

The Double Weight (DW) code has fixed weight of 2. The main reason we implement the DW code are efficient code construction, simple encoder/decoder design, existence for every natural number n, ideal cross-correlation $\lambda=1$ and high signal to noise ratio (SNR) [21]. The DW code can be constructed using the following steps:

Step 1:

The DW code can be represented by using $K \times N$ matrix. In DW codes structures, the matrix K rows and N columns will represent the number of user and the minimum code length respectively. A basic DW code is given by a 2×3 matrix, as shown below:-

$$\begin{matrix} 1 & 2 & 1 \\ \downarrow & \downarrow & \downarrow \end{matrix} \qquad (1)$$

$$H_1 = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

Notice that H_1 has a chips combination sequence of 1,2,1 for three columns (i.e 0+1, 1+1, 1+0).

Step 2:

A simple mapping technique is used to increase the number of codes as shown below:-

$$H_2 = \left| \begin{array}{ccc:ccc} 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ \hdashline 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 \end{array} \right| = \left| \begin{matrix} 0 & H_1 \\ H_1 & 0 \end{matrix} \right| \qquad (2)$$

Note that as the number of user, K increase, the code length, N also increases. The relationship between the two parameters, K and N is given by the equation (3) and (4):

When K is even

$$N = \frac{3}{2} K$$

But if K is odd

$$N = \frac{3K}{2} + \frac{1}{2}$$

In general the equation can be re-written as in equation (5) for both odd and even numbers.

$$N = \frac{3K}{2} + \frac{1}{2}\left[\sin\left(\frac{K\pi}{2}\right)\right]^2 \quad (5)$$

Some DW code sequences are list in table 2.1

Table 2.1: Example of DW Code sequences [21].

C_6	C_5	C_4	C_3	C_2	C_1	*K*th
0	0	0	0	1	1	1
0	0	0	1	1	0	2
0	1	1	0	0	0	3
1	1	0	0	0	0	4

Note that is the column number of the codes which also represents the spectral position of the chips where *i* is 1,2,3….*N*. In DW code sequence construction, the spectral positions of the two weights, $C_{1,K}$ for the first weight and $C_{2,K}$ for the second weight for the *K*th user are given by:

$$C_{2,K} = C_N \quad (6)$$

and

$$C_{1,K} = C_{N-1} \quad (7)$$

where *N* is as in equation (3) and (4).

Notice that the spectral position of the second weight $C_{2,K}$ is always the same as the minimum code length, *N* while the first weight is always one position before. This makes the DW code construction simple. For instance, if *K*= 4, the minimum code length, *N* is equivalent to six using equation (3), and the spectral positions $C_{1,4}$ and $C_{2,4}$ are C_5 and C_6 as obtained using equation (6) and (7) respectively. It is important that the weight positions are maintained in pairs, so that less filters can be used in the encoder and decoder. This way, a filter with the bandwidth twice of the chip width can be used, instead of two different filters, making the systems easier and less costly to implement.

2.3 OCDMA Equipment

OCDMA equipment is a subsystem that consists of light source, splitter, encoder, decoder, external modulator and multiplexer at the transmit side and splitter, decoder and receiver at the receive side. The configuration is shown in Figure 2.1.

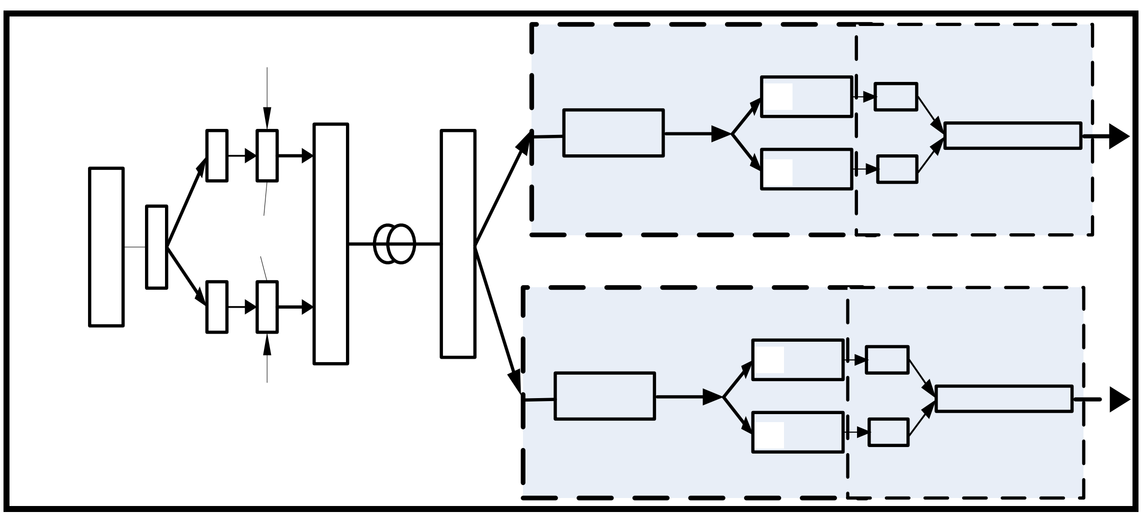

Figure 2.1: Optical CDMA Equipments.

The encoder/decoder is a pair of devices or sub-systems required in an OCDMA transmission system, where is the encoder implement at the transmitter part, and decoder at the receiver side. The function of the encoder is to amplitude-spectrally encode the source according to the specific code it uses. One unique encoded spectrum represents one channel. While a decoder consists of a set of filters and/or reflectors arranged in unique configurations with other components, the decoder has two sets of filters. Encoders and decoders can be implemented using any types of optical filtering technology, including thin-film filters, fiber Bragg gratings or free-space diffraction gratings. The same types of components used in WDM systems are useful, with suitable adjustment of the specifications to optimize their performance in an OCDMA system.

In this study, the encoders/decoders are using parallel-configured design as shown in Figure 2.1. The encoders/decoders used of fixed and passive type.

2.4 OCDMA Application

Code Division Multiple Access (CDMA) has been investigated over the past 15 years for applications in optical fiber networks [22]. As the name suggests, CDMA is a multiple access scheme based on the principle of message encoding and decoding by authorized receivers only and in the presence of interfering signals from network co-users. The main reasons which have motivated the communications community to examine the potential of CDMA in optical networks are the asynchronous access capability and the inherent security in transmission offered by CDMA. These characteristics distinguish CDMA from other more standard multiplexing schemes such as TDM or FDM, which are based on time or frequency allocation as discussed previously. Additionally the prospect of performing the encoding/decoding functions all-optically, and therefore achieving real transparent networks, could potentially lead to network throughput of the rate of Tbps. An example of the OCDMA system application is in Metropolitan Area Network (MAN) environment. This will be elaborated further detail in the following section.

2.4.1 Other Research

2.4.1.1 The Role of Optical CDMA in Access Network

By Andrew Stok and Edward H. Sargent, University of Toronto.

We investigate the possible role of optical CDMA (O-CDMA) in future access networks. We begin with a short review of the O-CDMA technique for those unfamiliar with the technology. Next, we investigate in detail those characteristics of O-CDMA that make it an attractive technology for application in metro access networks: fairness, flexibility, simplified network control and management, service differentiation, and increased security. Although O-CDMA has many favorable attributes, it also has several actual or perceived drawbacks. We discuss the technical, economic, and perception barriers that may have limited the widescale deployment of O-CDMA access networks. We try to determine which of these drawbacks may be surmountable in the near future and which may be true “showstoppers.”

2.4.1.2 System Performance Comparison of Optical CDMA and WDMA in a Broadcast Local Area Network.

By Andrew Stok and Edward H. Sargent, Member, IEEE

The performance of optical code-division multiple access (CDMA) systems with wavelength-hopping/time-spreading codes is compared to that of a wavelength-division multiple-access (WDMA) system. The multiple-access techniques are applied in a time-slotted broadcast local area network. The utilization, defined as the throughput per unit of time-domain bandwidth expansion, and packet delay are used as metrics of performance. When more than seven wavelengths are available, optical CDMA systems using asymmetric prime-hop codes and all-optical signal processing are shown to have higher peak utilization and lower corresponding delay than a WDMA system with the same number of wavelengths. When the encoders/decoders operate at the chip rate, the utilization of optical CDMA exceeds that of WDMA at high offered loads; however, the peak utilization of the WDMA system is still superior.

2.4.2 Metropolitan Area Network

A MAN is a high-speed communications network providing distributed switching between nodes for multiple services such as data, voice, and video over extended geographical areas. Geographically, the metropolitan area networks (MAN) cover an area between 10 and 50 km in diameter. A MAN may also be regarded as a network that spans a larger geographical area than a LAN, but smaller than a WAN.

The development of MAN is to poses some challenging problems likes support of a large number station, coverage of a large geographical area, real-time traffic (voice, video) support, and very high bandwidth requirements.