Major Technical Concerns in the Practical Realization of FO-OCDMA Networks

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Abstract—In this paper latest trends and techniques have been discussed for the practical realization of optical CDMA networks. The work is basically an overview of optical CDMA and optical coding and their major technical concerns. Comparison has been done for various OCDMA concerns such as optical coding techniques, Encoders/Decoders, multiple user interferences, optical sources, optical noises and optical threshold techniques.

Keywords- OCDMA, FOLD, MEMS, SSFBG, AWG, SLM, OG, PLC, MLLD, FPL-LD, ASE, DFB.

I. Introduction

Interest in optical CDMA has been increased many folds from past few decades. The technique was initially urbanized for wireless networks. The notion was introduced to optical networks firstly by Prucnal in mid 80's. These systems had the advantages of complete asynchronous transmission without any delay and central control [1]. Preliminary work on OCDMA systems considered codes having pulses only in the time dominate one dimension codes. However, they performed very inefficiently as compared to well establish multiple access techniques like WDMA and TDMA. To conquer severe limitations of 1-D, 2-D codes were projected in which active code chips are not only defined by their temporal positions in sequence but also by their wavelengths, which trim down interferences between two users appreciably [2].

The most basic CDMA system architecture is shown in fig 1. In which signal from each user is delivered to every receiver. The decision at receiver is made by correlating with the specific code sequence and then passing the total energy through a threshold device. The main advantages of OCDMA are

(a) Asynchronous data transmission
(b) Dynamic bandwidth allocation
(c) Decentralized architecture
(d) Graceful degradation of system performance with increase in data traffic
(e) Robust information security
(f) Soft capacity on demand
(g) Self Routing

All above said features make OCDMA technology a very promising contender for next generation all optical networks [3].

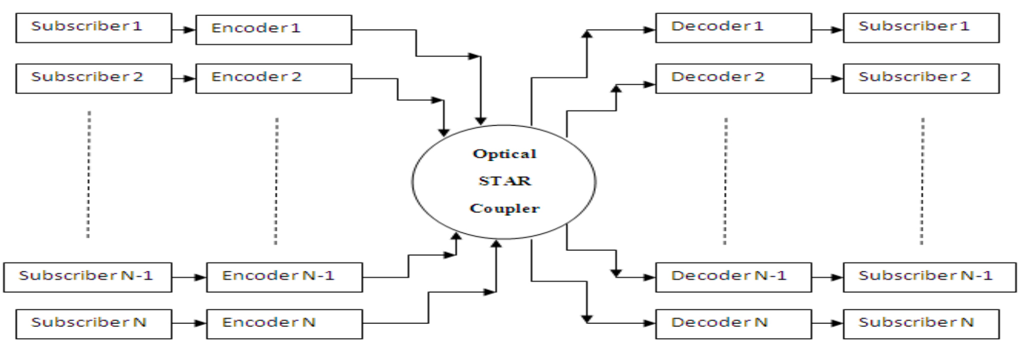

Figure 1: OCDMA Network Architecture

Number of optical CDMA schemes has been proposed by researchers time to time. They can be broadly classified as

(i) Coherent OCDMA Scheme

(ii) Incoherent OCDMA Scheme

In coherent OCDMA, the phase information of the optical carrier is crucial for the de spreading process. Due to the nature of optical fiber transmission and its phase noise limitations, such as nonlinear effects of Self Phase Modulation (SPM), Four Wave Mixing (FWM) and random phase fluctuations, the complexity of the coherent OCDMA receiver makes this approach more difficult to realize [3].

Incoherent systems are based on intensity Modulation-Direct Detection (IM-DD) scheme uses unipolar codes and incoherent passive matched filtered detection (MFD). The operation of direct detection makes the procedure simple and the receiver is cost effective. Because of the way optical signals are detected in IM-DD systems using the photodiode, optical systems are considered as positive or unipolar systems[4]. The photo detector detects the power of the optical signal but not the instantaneous phase variations of the optical signal. Thus, only incoherent signal processing techniques can be used to process the signature sequences composed of only ones and zeros restricting the type of codes that can be used in incoherent OCDMA systems. The assessment of these two coding techniques is given in Table I.

TABLE I OVERVIEW OF OCDMA TECHNIQUES

S. No.	Parameter	Coherent OCDMA	Incoherent OCDMA
1.	Code	Bipolar	Unipolar
2.	Parameter used for coding	Optical pulse amplitude	Optical power
3.	Encoder/decoders	SSFBG,PLC,SLM,AWG	FODL, FBG,SLM,,MEMS
4.	Coding schemes	Time spread, spectral coding	Time spread, spectral coding, 2 D
5.	Data rates	High	Low
6.	code cardinality	High	Low
7.	Multiple user interface	Low	High
8.	Beat Noise	High	low

II. NOISE PERFORMANCE COMPARISION FOR VARIOUS OCDMA TECHNIQUES

Table II gives a brief comparison of various OCDMA schemes. It has been assumed that all the codes are of same length and their optical power efficiency will be given by the ratio of chips with optical signal to the total bits in one encoded bit of electrical data [4]. The term spectral efficiency has its usual meaning that is no. of bits per unit bandwidth [5].

TABLE II. COMPARISON OF VARIOUS OCDMA SCHEMES

S.No.	OCDMA Schemes	Incoherent			Coherent	
		Time spread	Spectral coding	2 D	Time spread	Spectral coding
1.	Correlation Property	Worst	Medium	Good	Good	Medium
2.	Code cardinality	Small	Medium	Large	Large	Large
3.	MUI	High	Medium	Medium	Low	Low
4.	Beat noise	Low	Medium	Medium	High	High
5.	Spectral Efficiency	Low	Low	Medium	Medium	
6.	Data Rates	Low	Low	Medium	High	High

Based on the comparison given, we can conclude that Incoherent coherent time spreading and spectral coding techniques are the promising candidate for futures all optical networks.

III. CRITICAL HARDWARE CONSIDERATIONS FOR OCDMA NETWORKS IMPLEMENTATION

A. Encoder/Decoders

The most decisive components in an OCDMA network are the en/decoder, which have been regarded as one critical concern of the practicality of OCDMA network in terms of cost, reconfigurable ability, and knack of generating long orthogonal codes. Table III compares most of the coding techniques in terms of the ability of generating long orthogonal codes; the SSFBG is the best so far, while SLM also has the potential by using high resolution component. In terms of reconfigurable ability, the FODL could be pulled off by means of optical switches, MEMS itself is the high performance optical switch.

TABLE III. CODE GENERATION PROPERTIES OF VARIOUS OCDMA SCHEMES

S.No.	Encoders	AWG	FBG	MEMS
1.	Code generation capability	Medium	High	Medium
2.	Reconfigurability	Available	Available	Easy
3.	Insertion Loss	High	Low	Medium
4.	Integration	Medium	High	Medium
5.	Reliability	Medium	High	High
6.	Complexity	High	Low	High
7.	Cost	High	Low	Medium
8.	Applications	Incoherent TS, 2D, coherent spectral coding	Incoherent and coherent TS, spectral and 2D	2D

B. Optical Sources

Another vital fragment in OCDMA system is the suitable optical sources. The prerequisite for the optical sources differs with different OCDMA schemes. For incoherent TS, the source should be high speed (chip-rate) and high power as the code is very sparse of "1"s, and high TB product for incoherent superimposing, while for 2-D scheme, the sources should be with broad bandwidth or multi wavelength in addition. For incoherent spectral coding, the source should be broadband incoherent light source with high spectral power density. In coherent schemes, the sources should be coherent that the generated optical pulses are transform limited. For TS scheme, short pulse source(≤10 ps) is preferred, while in spectral coding scheme, ultra -short (<1ps) light sources is needed.

TABLE IV. COMPARISON OF OPTICAL SOURCES FOR OCDMA SCHEMES

Scheme	*Requirements*	*Sources*	*Data Rate*	*Chip*
TS	*High Speed, High Power, Incoherent*	*DFB-LD, FP-LD*	*Upto 1 Gbps*	*<100ps*
Spectral Coding	*Broadband , incoherent*	*LED,SLD, ASE*	*155Mbps*	*-*
2D	*High Speed, Broadband, Incoherent*	*LED,SLD, ASE*	*2.5 Mbps*	*<100ps*
		DFB LD	*10 Gbps*	*>100ps*
		SC Source	*2.5 Gbps*	*<10ps*
		FP-LR (Free Running)	*250 Mbps*	*<100ps*
		FP-LR (Self Seeding)	*1 Gbps*	*<100ps*
TS	*High Speed, Coherent*	*MLLD*	*2.5Gbps*	*<10ps*
Spectral Coding	*Ultra high Speed, coherent*	*MLLD*	*2.5 Gbps*	*<1ps*

The optical sources that have been used in OCDMA schemes include light emitting diode (LED), super luminescent diode (SLD), amplified spontaneous emitting (ASE) source , broadband super fluorescent (SFS)fiber source, gain-switched (GS) distribution feedback (DFB) and Fabry-Perot (FP) laser diode (LD), super continuum (SC) light sources and mode locked laser diode (MLLD). The applications and some experimental performance of them are compared in Table IV.

C. Thresholding Techniques

In an ideal OCDMA network, chip-rate detection is assumed. For coherent TS OCDMA employing long OC with chip rate as high as several hundred Gchip/s, or the coherent spectral coding scheme that employs ultra-short optical pulse, the bandwidth of the receiver cannot match the chip-rate detection requirement. Therefore, the BER degradation will be resulted due to the receiver's bandwidth limit. Using of time gating technique could improve the BER performance by eliminating the MAI noises outside the gating window, however, austere synchronization (chip level) is needed that makes it not suitable in asynchronous OCDMA.

TABLE V. COMPARISON OF VARIOUS THRESHOLD TECHNIQUES

S. No.	Scheme	Repetition Rate	Pulse width	Contrast Ratio
1.	DSL	31.2Mhz	600-800 fs	30dB
2.	HNLF	10GHz	400fs	7 dB
3.	Holy fiber	1.25 Ghz	2.5ps	
4.	NOLM	1.25G-2.5G	2.5ps	
5.	PPLN	2.5G	400fs	20dB

Optical threshold is a crucial device in such system to carry out chip rate MAI noise elimination without synchronization. The optical threshold techniques that have been proposed for OCDMA application include: using intensity dependent nonlinear frequency shift in DSF, holly fiber, or high nonlinear fiber (HNLF), nonlinear optical loop mirror (NORM), and periodically-poled lithium niobate (PPLN) waveguide. Table V lists the reported parameters of these techniques. For practical OCDMA application, the most desired technique should have a high contrast ratio with low operating power. This still is a challenge for current techniques.

IV. CONCLUSION

Having had the mature optical devices and technologies, the OCDMA exhibits a good prospect for practical applications in future broadband access networks. In this paper, we will be in favour of the coherent 1-D time-spreading and spectral coding schemes and incoherent 2-D scheme. The issues with practical OCDMA networks are discussed in terms of encoder/decoder, optical sources, optical threshold as well as multiple access interferences and beat noise suppression. Predominantly, in terms of encoder/decoder, the SSFBG that can easily generate ultra-long OC with low insertion loss is highlighted. Another crucial segment for practical OCDMA network is the optical threshold, which has been demonstrated by a number of nonlinear optical devices. However, the OCDMA networks are mainly limited by the beat noise. The multiple users' OCDMA experiments are also reviewed in this paper.

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