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Performance analysis for Adaptive Subcarriers Allocation in Coherent Optical OFDM System

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Abstract: *The constraint to satisfy the need of increased bandwidth requirement for high speed applications with higher performance has been a motivation to work on Optical Orthogonal Frequency division multiplexing (OOFDM) technique with coherent detection. We implement the coherent optical OFDM (CO-OOFDM) technique and investigate the effect of the number of sub-carriers on performance over single mode fiber (SMF) links. To explore improvement in performance adaptive subcarriers has been selected by assigning subcarriers to user according to the conditions of channel. An adaptive subcarrier allocation has been investigated and performance comparison for proportional and equal allocation has been carried over.*

Keywords: *OOFDM, BER, SNR, Subcarriers.*

I. Introduction

Orthogonal Frequency division multiplexing (OFDM) has been the most attractive multiple access technique to meet the demand of high data rate applications due to its robustness and flexibility in resource allocation. OFDM divides wideband channel into multiple parallel narrowband sub-channels by using fixed number of orthogonal sub-carriers which has been splitting high data rate signal into parallel low data rate signals. As OFDM modulation scheme has been using partially overlapped subcarriers, it provides high spectral efficiency [1]. Orthogonal Frequency division multiple access (OFDMA) has motivated the researchers due to less complexity [2, 3]. It has been proposed that Coherent Optical OFDM (CO-OFDM) is a promising technique for next generation optical networks to achieve high spectral efficiency while maximising SNR, as it holds the advantages of both a coherent technique and an OFDM technology [4,5]. Coherent detection provides is linearity in recovering the input signal to reduce noise [6]. Coherent transmissions for increasing the system capacity by sub-carriers modulation with dual polarized Quadrature phase shift keying (DP-QPSK) in multi-input multi-output (MIMO) configurations has been studied [7]. Equalizers play vital role to combat dispersion effects leading to Inter symbol Interference (ISI) during transmission [8]. But complexity of system increases as we add equalizers in system. OFDM has been an effective technique to lessen the ISI [9]. Requirement of equalizers can be reduced using careful design in OOFDM system. Although due to inherited features like resilience to noise CO-OFDM transmission had gained increased interest of optical research community but performance system is degraded due to certain linear and non linear impairments [10]. For increasing system performance various methods has been proposed including Digital signal Processing (DSP) based Electronic Dispersion Compensation(EDC), Optimization of network parameters [11]. Adaptation of network parameters based on channel conditions can considerably improve transmission performance. Implementation of adaptive technique for adapting network parameters demands transmitter to estimate the response of channel whose knowledge could be achieved from past channel quality estimations [12]. Static resource allocation schemes results in poor spectral efficiency, whereas in dynamic resource allocation distribution of resources could be carried over according to the channel state and the demand of user leading to improved spectral efficiency. Subcarriers are among most important resources of a network whose allocation is very important issue for spectral efficiency. The effect of adaptive cyclic prefix (ACP), the number of subcarriers, has been investigated for IM-DD (intensity modulated direct detection) OOFDM [13-17] but these effects are not been much explored on CO-OFDM for single mode fiber (SMF) for performance improvement. In section II adaptive subcarriers allocation schemes has been investigated to study performance improvement of CO-OFDM system in multiuser environment.

II. System Model

Fig. 1. represents simulation model using CO-OFDM transmission. Transmitter is passing complex valued data stream through serial to parallel converter producing Nx1 vector which is further mapped using modulation scheme Quadrature Amplitude Modulation with varying modulation index M to 16, 64,256.

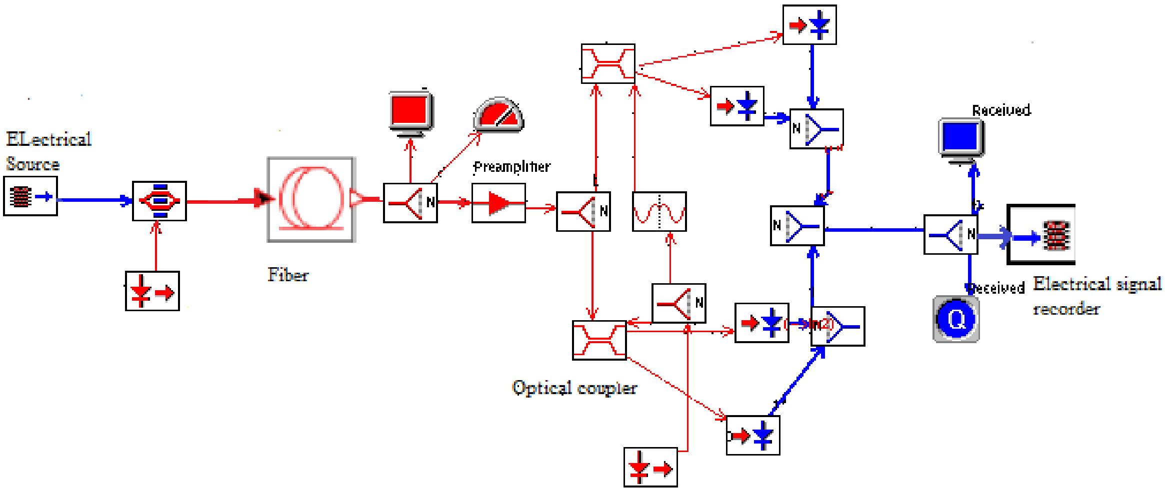

Fig. 1: System Model for CO-OFDM system

Matlab has been used for OFDM coding and decoding, Optsim has been used for modelling the optical OFDM transmission system. Matlab generated OFDM modulated data has been given to Optsim for optical transmission. Binary data generated by random generator has been mapped to M-QAM symbol. Simulation has been carried over an optical communication system with data rates 10 Gb/s at 1550 nm over single-mode (SM) fiber of length 1000(10x100 km) with fiber average beat length 5m [20]. On the assumption that transmitter has perfect knowledge about channel resource allocation has been executed at the transmitter side.

III. Principle Of Adaptive Subcarrier Allocation Technique

For maximising system capacity, achieving desired transmission performance and increasing performance robustness the usage of adaptation techniques in multicarrier OFDM system has been a solution. Among various adaptive loading algorithms adaptive subcarrier allocation technique helps in performance improvement in which subcarriers may be assigned to user according to channel conditions. Depending upon the frequency response of fiber link the subcarriers of CO-OFDM signals faces distortion leading to degraded performance. To tackle this hurdle for achieving spectrally efficient high performance CO-OFDM system, this paper presents an adaptive subcarrier allocation method. Allocation of subcarriers has been carried over following two different strategies proportional allocation and equal allocation. Applicability of each scheme depends on the requirement of network like network may demand fair distribution of data rate among all users or it may demand high throughput. Although the subcarrier assignment along with power distribution has been great interest for researchers for OFDMA wireless networks but it has not been much explored for optical networks.

1. Proportional Allocation

For proportional allocation a method has been presented for allocating subcarriers in CO-OFDM system on the basis of channel conditions monitored by Signal to Noise ratio (SNR) with condition to attain fair allocation amongst users and maximize data rate. The target of achieving fairness and data rate maximization is obtained by devising solution in which fairness among users has been obtained by adding set of non linear constraints. To achieve this, maximized data rate is used as objective function and set of non linear constraints are added for getting fairness. In the proposed solution for proportional allocation, the subcarrier allocation has been determined by permitting each user to select subcarrier with priority for those having highest Signal to noise ratio (SNR) and minimum proportional data rate. Algorithms proceeds for maximization of data rate.
It has been proposed that data rate for M- level QAM can be approximated in terms of BER as eq.1 . r_k corresponds to data rate of k^{th} user represented as :

$$r_k = \log_2\left(1 + \frac{SNR_{k,n}}{\acute{\Gamma}}\right) \qquad (1)$$

Where constant $\acute{\Gamma}$ is calculated in terms of Bit error rate for M-QAM as $-\ln(5BER)/1.6$ [18]. Mathematically, the problem for proportional subcarrier allocation could be represented as eq.2:

$$max_{c_{k,n}} \sum_{k=1}^{K} \sum_{n=1}^{N} \frac{b_{k,n}}{N} \log_2 \left(1 + \frac{SNR_{k,n}}{\acute{\Gamma}}\right)$$

Subject to Condition 1 $b_{k,n} = \{0,1\}$ for all k, n

Condition 2 $\sum_{k=1}^{K} b_{k,n} = 1$ for all n

Condition 3 $r_1 : r_2 : r_3 : \ldots \ldots r_K = \gamma_1 : \gamma_2 : \gamma_3 : \ldots \ldots \gamma_K$ (2)

Where K represents total number of users, N is total number of subcarriers, $SNR_{k,n}$ is Signal to noise ratio for k^{th} user n^{th} subcarrier, According to condition 1 $b_{k,n}$ can have value either 0 or 1 depending if n subcarrier is used by user k or not. Condition 2 illustrate that each subcarrier can be used by only one user. In the last as per condition 3 $\{\gamma_k\}_{k=1}^{K}$ is predetermined values for ensuring fairness in subcarrier allocation.
The desired target of maximizing data rate and proportional allocation among users with assumption of equal power distribution has been attained in presented method in two steps. First involves determination of minimum number of subcarriers to be allocated to each user and second includes assignment of subcarriers to each user so as to maximize data rate while achieving fairness in allocation. After determining the minimum number of subcarriers to be assigned to each user, algorithm proceeds by initializing all variables, then in next step followed by determination of highest value of $SNR_{k,n}$. Next step proceeds to achieve fairness in subcarrier allocation where assignment is base on greedy approach i.e user having least data rate divided by proportionality constant has been selected as most needy user for subcarrier assignment. During this step each user can gets the allocation of N_k subcarriers. In next step the allocation of remaining subcarriers has been carried over. This step takes care that each user can achieve at the maximum of one unassigned subcarrier so as to avoid that user with maximum SNR should not get all the unallocated subcarriers. This strategy achieves proportional fairness among subcarriers while maximising data capacity.

2. Equal allocation

If in eq. 2 condition 3 the value of rate constants γ_K is made unity it become the condition where all users have all users have the same capacity and the data rate has been maximized. In order to make comparison a special case of maximum fairness has been considered where the value of proportional constants has been made equal and unity i.e $\gamma_1 : \gamma_2 : \gamma_3 : \ldots \ldots \gamma_K = 1 : 1 : 1 : \ldots \ldots 1$.
Performance comparison has been carried in this paper for proportional fairness and maximum fairness for subcarrier allocation in the form of Bit error rate (BER) and SNR to emphasize the better conduct of proposed scheme.

IV. Simulation Results

In this section the simulation results for performance of adaptive subcarrier allocation has been presented over CO-OFDM. In particular the performance comparison between proportional subcarrier allocation and equal allocation has been presented.

The modulation schemes considered during analysis includes 16 QAM, 64 QAM and 256 QAM. Figure 2(a), 2(b), 2(c) presents the performance comparison of proposed proportional allocation and equal subcarrier allocation for 16 QAM, 64QAM and 256 QAM by considering maximum number of subcarriers as 16 where bit error rate has been evaluated for different values of SNR. The proportional allocation allocates subcarriers by monitoring channel conditions to maximize capacity along with achievement of fairness in subcarrier allocation by allocating number of subcarriers which is proportional to data rate, whereas in equal subcarrier allocation all users are allocated same number of subcarriers. This equal subcarrier allocation results in inefficient utilization of resources as users with poor channel conditions and low data rate requirement may achieve more than required number of subcarriers leading to poor system performance. On comparing these results it could be clear inferred that adaptive subcarrier allocation instead of fixed equal subcarrier allocation can improve the system performance. Improvement of 9-11 db in terms of SNR for achieving same BER has been observed between adaptive subcarrier allocation and equal allocation. For evaluating the simulated results reference optimum has been selected using analytical expression of Eq. (3) [19] for theoretical BER.

$$\text{BER} = 1 - \left(1 - \frac{2}{\log_2 M}\left(1 - \frac{1}{\sqrt{M}}\right) Q\left(\sqrt{SNR \frac{3}{M-1}}\right)\right)^2 \qquad (3)$$

In Eq. (3) M represents modulation order, Q quality factor; SNR as Signal to Noise Ratio. Simulated results are achieving quite optimum results when compared with theoretical expectations using adaptive subcarrier allocation strategy. Achievement of BER 10^{-9} has been obtained by 16 QAM system with SNR value 24.5 dB, 64 QAM system with SNR value 29 dB , 256 QAM system with SNR value 30 dB using maximum number of subcarriers 16.

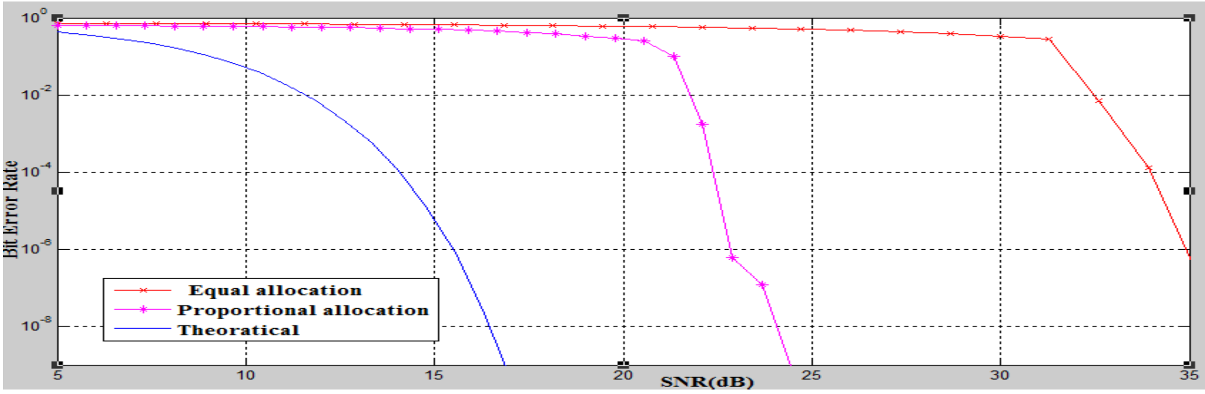

Fig. 2(a): BER comparison for two subcarrier allocation using 16 QAM with 16 subcarriers.

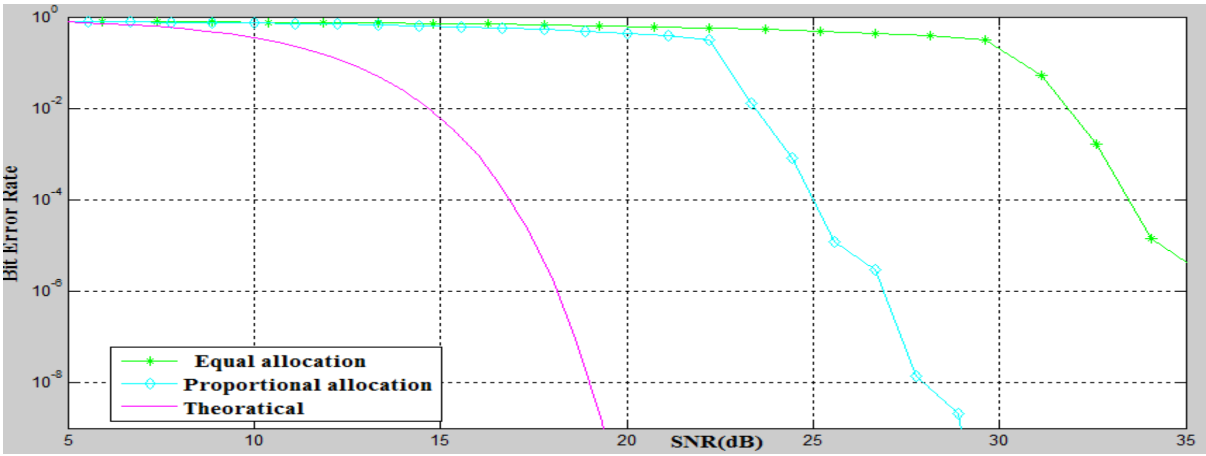

Fig. 2(b): BER comparison for two subcarrier allocation using 64 QAM with 16 subcarriers

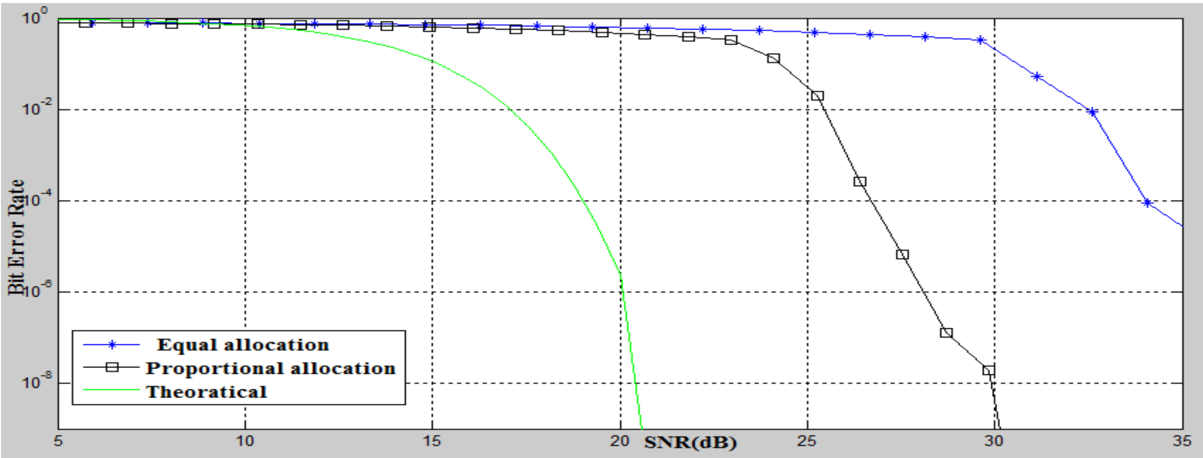

Fig.2(c): BER comparison for two subcarrier allocation using 256 QAM with 16 subcarriers.

V. Conclusion

For CO-OFDM system in comparison to usage of long CP for combating with dispersion effects increasing the number of subcarriers has been more effective. For static subcarrier allocation optimum number of subcarriers over SMF link of 1000 km with 16 QAM CO-OFDM transmission has been identified to be 64. Further, this paper presents usage of resources like subcarriers in adaptive manner. In particular comparison of proportional subcarrier allocation with equal subcarrier allocation has been carried over. An improvement of improvement of 9-11 dB in terms of SNR for achieving same BER has been observed between adaptive subcarrier allocation and equal allocation. The proposed subcarrier allocation is based on estimation of channel conditions along with fair allocation strategy to maximize channel capacity, whereas the equal subcarriers allocation is based on equal number of subcarrier assignment. The proposed proportional subcarrier assignment provides better performance in terms of BER and throughput.

References

[1]. W. Shieh, H. Bao, and Y. Tang, 2008, "Coherent Optical OFDM: Theory and Design", Opt. Express, 16, pp.842-859.
[2]. M. Ergen, S. Coleri, and P. Varaiya, 2003, "QoS aware adaptive resource allocation technique for fair scheduling in OFDMA based broadband wireless access systems", IEEE Trans. Broadcast, 49(4), pp. 362–370.
[3]. Z. Han, Z. Ji, and K. J. R. Liu, 2005, "Fair multiuser channel allocation for OFDMA networks using nash bargaining solutions and coalitions", IEEE Trans. Commun., 53(8), pp.1306–1376.
[4]. W. Shieh, H. Bao, and Y. Tang, 2008, "Coherent Optical OFDM: Theory and Design", Opt. Express, 16, pp.842-859.
[5]. M. Cavallari, C. R. S. Fludger, and P. J. Anslow, 2004, " Electronic signal processing for differential phase modulation formats", Presented at the Optical Fiber Communication Conference. OFC, pp. 422-425.
[6]. W. Shieh and I. Djordjevic, 2010, "OFDM for Optical Communications", Elsevier.
[7]. H. Sun, K.-T. Wu, and K. Roberts, 2008, "Real-time measurements of a 40 Gb/s coherent System", Opt. Express, 16, pp. 873-879.
[8]. S. Pachnicke, 2012, "Fiber optic transmission networks efficient design and Dynamic operation", Springer, ch.2,2012.
[9]. Y. H. Kim, 1999, "Performance Analysis of a Coded OFDM System in Time-Varying Multipath Rayleigh Fading Channels", IEEE transactions on vehicular technology, 48(5) pp.1610-1615.
[10]. M. A. Jarajreh, J. L. Wei, J. Tang, Z. Ghassemlooy, and W. P. Ng, 2010, "Effect of number of sub-carriers, cyclic prefix and analogue to digital converter parameters on coherent optical orthogonal frequency division", IET Commun.4, pp. 213- 233.
[11]. A. J. Lowery, 2007, "Fiber nonlinearity mitigation in optical links that use OFDM for dispersion compensation", IEEE Photon. Technol. Letters, 19, pp. 1556-1558.
[12]. T. Keller and L. Hanzo , 2000, "Adaptive modulation techniques for duplex OFDM transmission, Vehicular Technology", IEEE Transactions, 49(5), pp.1893 – 1906.
[13]. X. Q. Jin, J. M. Tang, P. S. Spencer, and K. A. Shore, 2008, "Optimization of Adaptively modulated optical OFDM modems for multimode fiber-based local area networks", J Opt. Netw., 7, pp. 198-214.
[14]. E. Giacoumidis and J. Tang, 2008, "Improved transmission performance of adaptively modulated optical OFDM signals over MMFs using adaptive cyclic prefix", Presented at the OECC/ACOFT, pp. 1-2.
[15]. I. B. Djordjevic, and B. Vasic, 2008, "LDPC-Coded OFDM in Fiber-Optics Communication Systems" , J. Opt. Netw. 7, pp.217-226.
[16]. T. J. Ming, S.K. Allan, 2007, "Maximizing the transmission performance of adaptively modulated optical OFDM signals in multimode-fiber links by optimizing analog-to-digital converters", J. Lightw.Technol., 25(3), pp.787-798.
[17]. J. M. Tang, P. M. Lane, and K. A. Shore, 2006, "Transmission Performance of Adaptively Modulated Optical OFDM Signals in Multimode Fiber Links", IEEE Photon. Technol. Lett. 18(1), pp. 205–207.
[18]. S. T. Chung and A. Goldsmith, 2001, "Degrees of Freedom in Adaptive Modulation: A Unified View", IEEE Trans. Commun., 49(9), pp. 1561.1571.
[19]. R. Noe, 2010, "Essentials of Modern Optical Fiber Communication", Springer.
[20]. H.J. kaur and M. L. Singh, 2013, "Modelling and reporting parameters of Optical OFDM system using different Modulation techniques", Optics and Photonics J., 3(2), pp. 204-210.