Overloaded Spread spectrum OFDMA in indoor environment (Low Interleaving)

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***Abstract*—**Development of any mobile communication technology starts with invention or modification of new Radio Access Technique which can meet the user requirements and enhance the capacity. The main objective of this paper is to enhance spectral efficiency and hence average throughput of the system using OFDM based multiple access technique. Here we have chosen Overloaded Spread spectrum OFDMA. We have observed that for 24% overloading approximately 33% rise in Spectral efficiency.

Keywords*—overloaded; spread spectrum; indoor; interleaving; Spreading gain (SG)*

I. INTRODUCTION

Current boom in the wireless communication is because of increasing need of end users to access faster INTERNET even in higher mobility condition. There is no doubt, wireless data rate will reach somewhere near to wire-line that we have achieved today. Also, shape of the evolution curve is similar in both wire-less and wire-line domains with relative difference of approximately 30 times [1]. An application of Moore's law predicts, "Data rate doubles every 18 months". Currently, we are getting data-rate more-than 100 Mbps in case of wire-line system with copper or fiber based solution. With increasing number of mobile phone users, which exceeded 4th billion landmark at the end of 2008 [1], it's necessary to go beyond the currently available technologies and provide user all the services they demand with sufficient quality of service, with maximum data rate. "It is always dangerous to put any limit on the increasing data rate" and hence we have to look into future generation wireless systems i.e. beyond 4G.

II. SPREAD SPECTRUM OFDMA

A. Motivation

In this Spread Spectrum-Orthogonal Frequency Division Multiple Access (SS-OFDMA), a symbol to be mapped on a carrier is instead spread over spreading gain amount of carriers. This gives the advantage of frequency diversity and hence even channel condition is not good for certain carriers, symbol mapped can be decoded easily. Hence this kind of technique gives benefit of OFDMA and CDMA. Depending on correlation properties, system performance of Spread Spectrum OFDMA varies. Hence, receiver has to use Multiuser Detection techniques to mitigate interference.

B. Fundamentals of Overloaded Spread Spectrum OFDMA

One of the merits of CDMA based technique is Soft Capacity i.e. it can be overloaded with certain degradation in probability of error. Overloading is term used in Cellular CDMA technique. Generally, CDMA allocates every sequence of length N to maximum N number of users. I.e. $N = T/T_c$ is the processing gain or spreading gain of CDMA. Where, T: Symbol Duration and T_c: Chip Duration. If less than N number of users is allocated using chip sequence of length N, then system is called Under-loaded System. In this case, Orthogonality of the codes is not violated and hence their performance is not affected. When Number of users exceed N, system is Overloaded. So, in this case, it is necessary to assign more number of sequences than the spreading factor. Hence, the sequences become no more orthogonal and in effect, it increases the Multiple Access Interference (MAI). This kind of scheme makes system performance worse.

In literature, different approaches are described to mitigate this effect of overloading and hence enable more number of users to share bandwidth simultaneously. Several approaches include the use of Multi User Detection (MUD) at Base Station[14] has shown CDMA Overloading performance using Iterative Interference Cancellation Receiver. Several approaches [15] also suggest use of Orthogonal Codes such as Quasi Orthogonal Sequences (QOS) and Orthogonal Gold (OG) Codes can enhance system performance.

Recently, OFDMA based access technique is been dominant and suitable for multi-path environment. For next generation wireless network, we can still think about combination of CDMA and OFDMA. One of these kinds of technique which is used in 3GPP-LTE standard is SC-FDMA [11]. It consists of DFT spreading which enables the Code Division Multiplexing of the symbols. This Concept of Overloading in CDMA can be extended further to OFDM based access technique to increase the capacity. This can be possible using different kinds of spreading codes, such as OG Codes or QOS. These Codes must have very little or no performance degradation as compared to under loaded system and should possess good correlation properties. Further, it is also necessary to use a Multi Stage Detector [16] for the interference cancellation. Keeping all this in mind, performance of this new scheme is evaluated using Rayleigh channel in the indoor environment and each user data is interleaving and transmitted (Low interleaving).

III. TRANSCEIVER DESCRIPTION

One of the advantages of Overloaded OFDMA is, it increases the capacity of OFDM system in proportion to the increase in amount of Overload. Also, Symbols are spread over carriers' equivalent to the amount of spreading gain. So it also brings in advantage of Diversity Gain. But, this novel Access technique has to deal with PAPR issue as it mainly depends on kind of spreading sequences we are using [17].

Following Fig.1 (a) shows the transmission of data to individual user from Base station (BS). Fig. 1(b) shows the reception of data from Base Station to individual User. Hence, in this case BS Spreads the data of individual user over allocated sub-carriers. Consider Base Station has K = U * N number of useful sub-carriers with it and a maximum of N sub-carriers can be allocated to one user. Hence, in total, U =K/N is the total number of users supported by the system. In this way, a particular user data is transmitted over allocated sub-carriers only. U number of user's data transmitting over whole system bandwidth. Hence, each user is mapping M > N number of symbols over N number of allocated carriers, which makes the system overloaded. Hence at the Base-Station (transmitter) if overloaded SS-OFDMA is used, BS will spread M >N data symbols of each user over allocated N carriers.

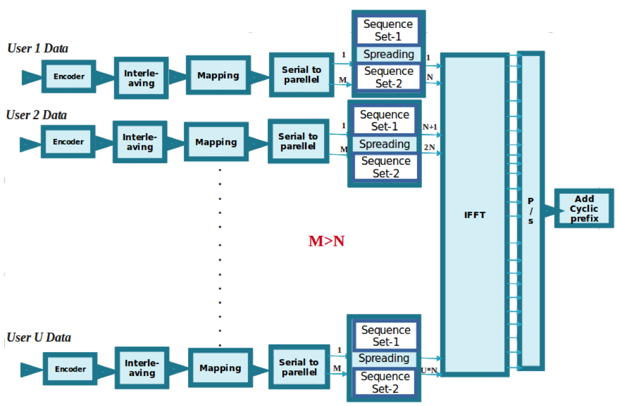

Fig 1(a) Transmitter Block diagram

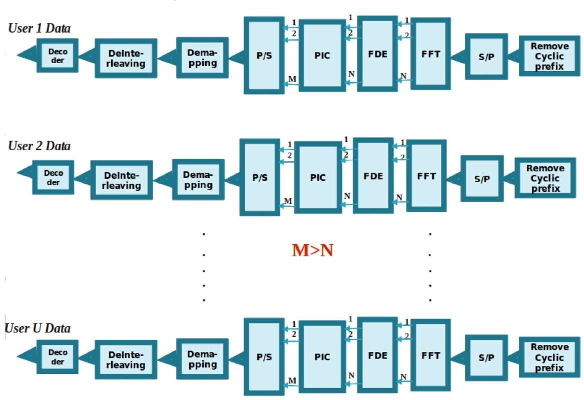

Fig 1(b) Receiver Block diagram

To decode the same data at particular user, they already have information regarding what carriers allocated by BS. Hence, every User decodes the information from allocated carriers only. This way, capacity of existing system is increased with proportion of amount of overload.

A. BER performance

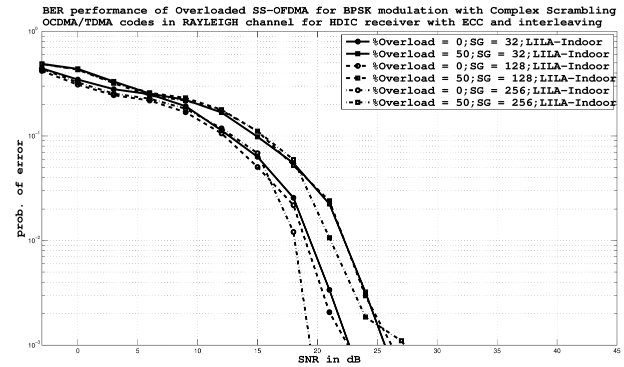

Fig 2(a) BER performance of Overloaded Spread spectrum OFDMA for BPSK modulation

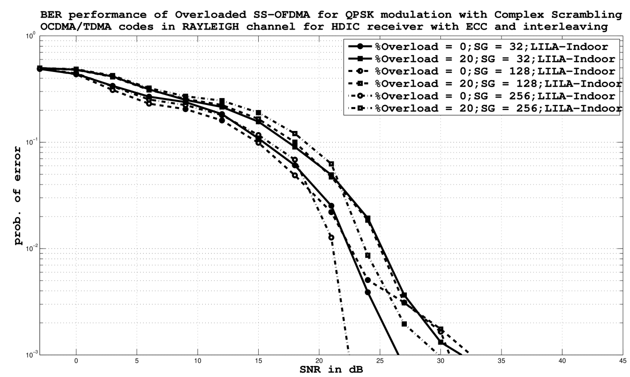

Fig 2(b) BER performance of Overloaded Spread spectrum OFDMA for QPSK modulation

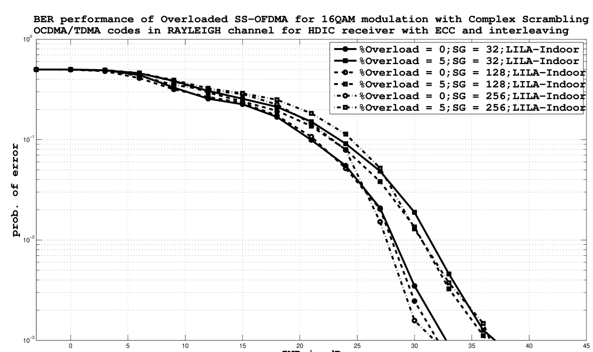

Fig 2(c) BER performance of Overloaded Spread spectrum OFDMA for 16-QAM modulation

Fig 2(a) shows the BER performance of Overloaded Spread spectrum OFDMA for BPSK modulation, Fig. 2(b) shows the BER performance of Overloaded Spread spectrum OFDMA for QPSK and Fig 2(c) for 16QAM with complex scrambling OCDMA/TDMA codes. The performance is done in Rayleigh channel for HDIC receiver with spreading gains 32,128 and 256 with Error Correction Coding (ECC) 1/2 in indoor and outdoor case respectively(FFT size = 2048). Results show that there is degradation in SNR requirement with overloading. This degradation is more for higher modulation. This is because, as we increase the number of symbols in set-2, interference increases with that respect. Hence make performance worse. As we increase the SG, performance improves because Cross-correlation decreases as we increase the Spreading gain.

B. Analytical Model for Throughput performance

Previous section gives performance for establishing better link between user and base-station. Hence, probability of error simulation for the various schemes of overloading is carried out. It gives the idea of how much BER we can lose to switch over to overloading scheme from basic OFDMA system. But, this loss in BER at the other side is compensated by gain in capacity of system. Hence, to measure, what extent capacity is being improved, we are carrying out throughput simulation. Following equation gives normalized throughput which depends on SNR of the system,

$$\text{Throughput} = C/W = \log_2 (1+\text{SNR})$$

Where, C is capacity, W is system Bandwidth. Hence C/W, which is nothing but normalized throughput which can be a measure of number of bits per second that can be transmitted over a Hz of bandwidth or in other words, number of bits that can loaded in a symbol of duration and SNR is signal to noise ratio at the receiver.

Also, if P_e is the probability of erroneously received symbols then again we can express Throughput relation as[6]

$$\text{Throughput} = (1-P_e)Lr(1+ [\text{Percent Overload}/100])$$

Where, L is number bits carried over a symbol, r is rate of error control coding and Percent Overload is amount of overload applied. Thus we can say, for approximately, zero probability of error, Throughput is more than no overload case by amount of percentage overload applied.

Fig 3 shows Throughput performance of Overloaded SS-OFDMA for different modulation schemes with complex scrambling OCDMA/TDMA codes in Rayleigh channel for HDIC receiver with Low interleaving and Localized Access (LILA).We have observed that %overload increases the spectral efficiency for different modulations like BPSK,QPSK and 16 QAM.

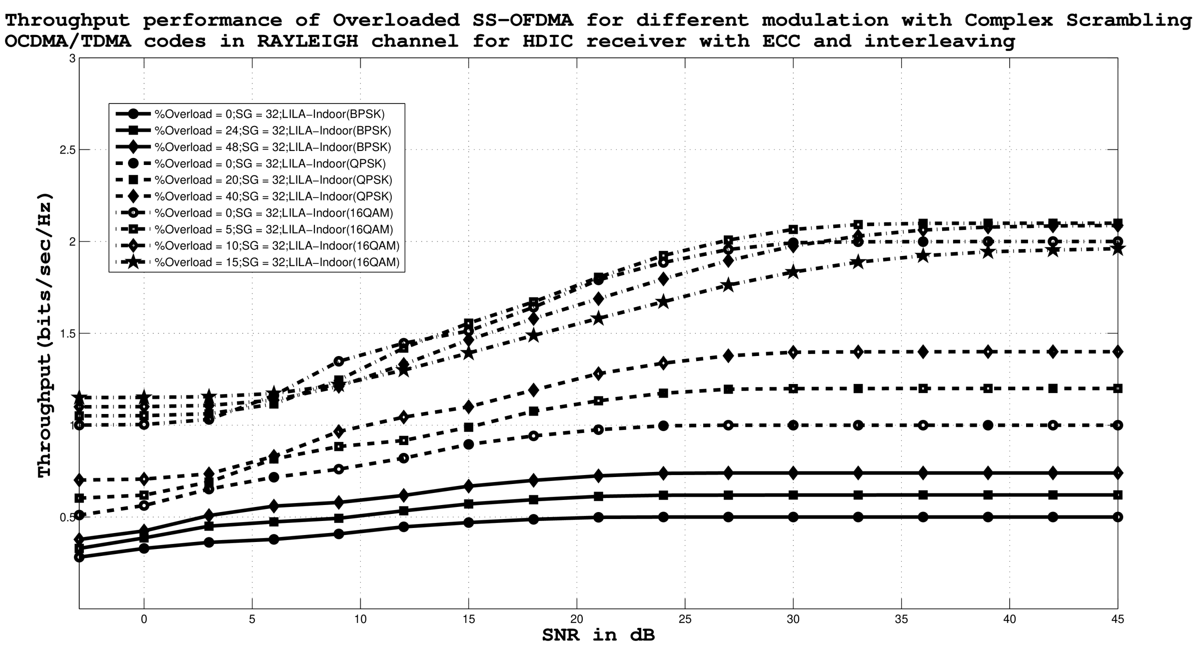

Fig 3: Throughput performance of Overload SS-OFDMA in Indoor environment

C. Conclusions

i) BER performance

The following Table1.1 shows the SNR in dB requirement at BER 10^{-2} for different modulation with Complex Scrambling OCDMA/TDMA codes for Spreading Gains 32,128 and 256 with ECC 1/2.

Observation: With the increase in SG the BER performance improves for different modulation.

ii)Throughput performance

The following Table1.2 shows the SNR requirement to achieve the maximum throughput for different modulation with Complex Scrambling OCDMA/TDMA codes for Spreading Gain 32 with ECC 1/2(for BER>10^{-2} throughput is taken as zero).

Table 1.1. SNR requirement of Overloaded SS_OFDMA for SG 32,128,256 in LILA indoor Scenario

BPSK						QPSK						16-QAM					
0% Overload			5 % Overload			0% Overload			5 % Overload			0% Overload			5 % Overload		
32	128	256	32	128	256	32	128	256	32	128	256	32	128	256	32	128	256
19.4	19	18.1	22.3	22.3	21.1	22.5	22.6	21.2	25.2	25	23.8	28.2	28	27.6	31.4	30.7	30.6

Table1.2 SNR requirement of Overloaded SS-OFDMA to achieve maximum Throughput in LILA indoor scenario

BPSK			QPSK			16-QAM		
0%	24%	48%	0%	20%	40%	0%	5%	10%
22.1	25.1	25.8	26.3	29.7	32.2	34.5	37	

REFERENCES

[1] A. T. Harri Holma, "LTE for UMTS OFDMA and SC-FDMA based radio access," John Wiley and Sons, 2009.

[2] K.K. Carl Wijting, Klaus Doppler, "Key technologies for IMT-advanced mobile communication systems,"IEEE, Tech. Rep., June 2009.

[3] "Requirements related to technical performance of IMT-A radio interface(s),"ITU-R, Tech.Rep.

[4] T. W. Abbas J., "A tutorial on multiple access technologies for b3g mobile networks," IEEE communication Magazine, Feb. 2005.

[5] H.S. Prasad R.,"An overview of multi-carrier cdma,"IEEE communication Magazine, Dec 1997.

[6] K.Fazel, "Performance of cdma/ofdma for mobile communication system, "in International Conference on Universal Personal Communicatons, 1993.

[7] X. Y. Hwa Chen H., "The occ-cdma/os for 4g wireless, "IEEE Vehicular Technology Magazine,Sept 2008.

[8] "Beyond 3g/4g radio access technology and standards roadmap," eMobility, Tech. Rep., Dec 2007.

[9] "Guidelines for evaluation of radio interface technologies for imt-advanced,"ITU-R, Tech.Rep.M.2135, 2008.

[10] "Supekar Vishal Rameshrao,"Overloaded Spread Spectrum OFDMA for Next Generation Wireless Standard,"M-Tech Thesis,IIT Kharagpur,April 2010.

[11] J. L. Hyung G. Myung and P. U. David J. Goodman, "Single carrier fdma for uplink wireless transmission,"IEEE Vehicular Technology Magazine, Sept 2006.

[12] S.F.M.I.R. Gilberto Berardinelli et al., "Ofdma vs sc-fdma : Performance comparison in local area IMT-A scenarios,"IEEE Wireless Communications,Oct 2009.

[13] B. E. P. Gilberto Berardinelli, "Improving sc-fdma performance by turbo equalization in utra LTE uplink," in Vehicular Technology Conference. IEEE, May 2008.

[14] P.Kumar, "Overloading with iterative interference cancellation receiver,"Ph.D. dissertation,IIT Kharagpur, July 2008.

[15] M.F. Vanhaverbeke, "Sequences for Oversaturated cdma channels,"in International Symposium on Spread Spectrum Techniques and Applications. IEEE, Aug 2008.

[16] S. Verdu "Multiuser Detection," Cambridge University press,1998.

[17] E. H. Dinan and B. Jabbari, "Spreading codes for ds-cdma and wideband cdma cellular networks,"IEEE Communication Magazine, Sept 1998

[18] M. M. Frederic Vanhaverbeke,"Ds/cdma with two set of Orthogonal spreading sequences and iterative detection,"IEEE Communication Letters. Vol.4,no. 9, Sept 2000.

[19] Muhammad Imadur Rahman,"Channelization, Link Adaptation and Multi-antenna Techniques for OFDM (A) Based Wireless Systems, "Ph.D.Dissertation, Aalborg University, pp.47-55, Sept 2007.

[20] Priyanto, B.E.; Codina, H.; Rene, S.; Sorensen, T.B.; Mogensen, P.; "Initial Performance Evaluation of DFT-Spread OFDM Based SC-FDMA for UTRA LTE Uplink ,"VTC 2007-spring.IEEE 65th,pp.3175 - 3179 ,2007.

[21] Nisar, M.D.; Nottensteiner, H.; Hindelang, T.;"On performance limits of dft-spread ofdm systems,"Mobile and wireless communications summit 16th IST, pp.1-4, 2007.

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