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Overloaded Spread Spectrum OFDMA in Outdoor Environment in the More Interleaving Scenario

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Abstract*: The advancement of mobile communication technology is driven by innovations or modifications in the latest Radio Access Techniques to meet user demands and enhance capacity. This paper focuses on improving spectral efficiency and average throughput using an OFDM-based multiple access technique. Specifically, we have chosen Overloaded Spread Spectrum OFDMA for this study. Our research findings indicate that implementing a 24% overload leads to an approximate 33% increase in spectral efficiency. This significant improvement demonstrates the potential of Overloaded Spread Spectrum OFDMA in optimizing the performance of mobile communication systems. By increasing spectral efficiency, we can support a larger number of users and higher data rates, which are crucial for the evolving demands of modern mobile networks. This study highlights the importance of adopting advanced access techniques to sustain the growth and efficiency of mobile communications*

Keywords: overloaded; spread spectrum; outdoor; interleaving; Spreading gain (SG)

I. INTRODUCTION

The rising demand for faster internet access, especially in high-mobility scenarios, is driving the current growth in wireless communication. Despite significant progress, wireless data rates still trail behind wire-line systems by roughly 2 to 3 times. Moore's Law suggests that data rates will double every 18 months, further emphasizing the need for rapid advancements in wireless technology. At present, wire-line systems can achieve data rates exceeding 10 Gbps, while wireless systems can exceed 5 Gbps. It is anticipated that by the end of 2027, the number of mobile phone users will surpass 8 billion, highlighting the pressing need to overcome existing technological barriers and provide services with optimal quality and maximum data rates. As the demand for higher data rates continues to grow, the development of next-generation wireless systems beyond 5G becomes imperative. These innovations are essential to ensure that users receive the high-speed, reliable connectivity necessary in today's mobile-centric world.

II. SPREAD SPECTRUM OFDMA

2.1 Motivation

In Spread Spectrum-Orthogonal Frequency Division Multiple Access (SS-OFDMA), a symbol is spread across multiple carriers according to the spreading gain, rather than being mapped to a single carrier. This approach leverages frequency diversity, allowing symbols to be decoded accurately even if some carriers experience poor channel conditions. SS-OFDMA combines the benefits of OFDMA and CDMA, enhancing system performance through improved frequency diversity. The effectiveness of SS-OFDMA varies based on correlation properties, necessitating the use of Multiuser Detection techniques at the receiver to mitigate interference. This combination of spreading and detection techniques enables robust data transmission, making SS-OFDMA a valuable method for increasing spectral efficiency and system throughput in modern wireless communication environments. By spreading the symbols across multiple carriers and utilizing advanced detection methods, SS-OFDMA ensures reliable communication even in challenging channel conditions.

2.2 Fundamentals of Overloaded Spread Spectrum OFDMA

One of the benefits of CDMA-based techniques is their Soft Capacity, which allows the system to handle overloading with some degradation in error probability. Overloading in CDMA occurs when the number of users exceeds the system's spreading factor. Typically, CDMA allocates each sequence of length NN to a maximum of NN users, where N=T/TcN=T/Tc is the processing gain, TT is the symbol duration, and TcTc is the chip duration. If the number of users is less than NN, the system is considered Underloaded, maintaining code orthogonality and optimal performance. However, when the number of users exceeds NN, the system becomes Overloaded, necessitating more sequences than the spreading factor. This results in a loss of orthogonality, increasing Multiple Access Interference (MAI) and degrading system performance.

Various strategies have been proposed to address the challenge of overloading in CDMA systems, thereby enabling a greater number of users to share bandwidth simultaneously. One effective approach involves utilizing Multi User Detection (MUD) at the base station. MUD techniques, such as Iterative Interference Cancellation Receivers, have shown significant improvements in handling CDMA overloading by effectively reducing interference. Additionally, the use of orthogonal codes, like Quasi Orthogonal Sequences (QOS) and Orthogonal Gold (OG) Codes, has been suggested to further enhance system performance. These orthogonal codes help maintain the integrity of signal separation, thereby minimizing the impact of interference and improving overall system efficiency. By implementing these methods, it is possible to support more users in a CDMA system without severely degrading performance, ensuring reliable and efficient communication even under high user loads.

In recent times, OFDMA-based access techniques have emerged as dominant and well-suited for multi-path environments. However, for the next generation of wireless networks, there is still consideration for integrating CDMA with OFDMA. An example of this hybrid approach is Single Carrier Frequency Division Multiple Access (SC-FDMA), utilized in the 3GPP-LTE standard. SC-FDMA employs Discrete Fourier Transform (DFT) spreading, facilitating Code Division Multiplexing of symbols. The concept of overloading, commonly associated with CDMA, can be extended to OFDM-based access techniques to enhance capacity. This extension can be achieved through the utilization of various spreading codes, such as Orthogonal Gold (OG) Codes or Quasi Orthogonal Sequences (QOS), which must exhibit minimal performance degradation compared to underloaded systems and possess favorable correlation properties. Additionally, employing a Multi-Stage Detector for interference cancellation becomes necessary. Evaluation of this hybrid scheme's performance is conducted in an indoor environment using a Rayleigh channel, with each user's data interleaved and transmitted with more interleaving.

III. TRANSCEIVER DESCRIPTION

An advantage of Overloaded OFDMA is its ability to enhance the capacity of OFDM systems in proportion to the level of overload applied. This increase in capacity is achieved by spreading symbols across carriers, corresponding to the amount of spreading gain utilized. As a result, Overloaded OFDMA also introduces the advantage of Diversity Gain, improving system robustness in challenging channel conditions. However, this innovative access technique faces challenges related to Peak-to-Average Power Ratio (PAPR) issues, primarily influenced by the type of spreading sequences employed. Managing PAPR is essential for ensuring efficient signal transmission and minimizing signal distortion, highlighting the importance of selecting appropriate spreading sequences to mitigate this issue in Overloaded OFDMA systems.

Figures 1(a) and 1(b) illustrate the transmitter and receiver block diagrams of Overloaded SS-OFDMA in the More Interleaving Localized Access (MILA) configuration. Here, interleaving aggregates U×M×L bits at the transmitter, where L denotes the bits per symbol and MM signifies the symbols transmitted by each of the U users, as shown in Figure 1(a). Conversely, at the receiver, each user receives the collective U×M×L bits transmitted by the transmitter and de-interleaves them. Subsequently, each user extracts only M×L bits of their data, discarding the surplus. Thus, the More Interleaving Localized Access (MILA) setup entails heightened complexity compared to the Low Interleaving Localized Access (LILA) alternative.

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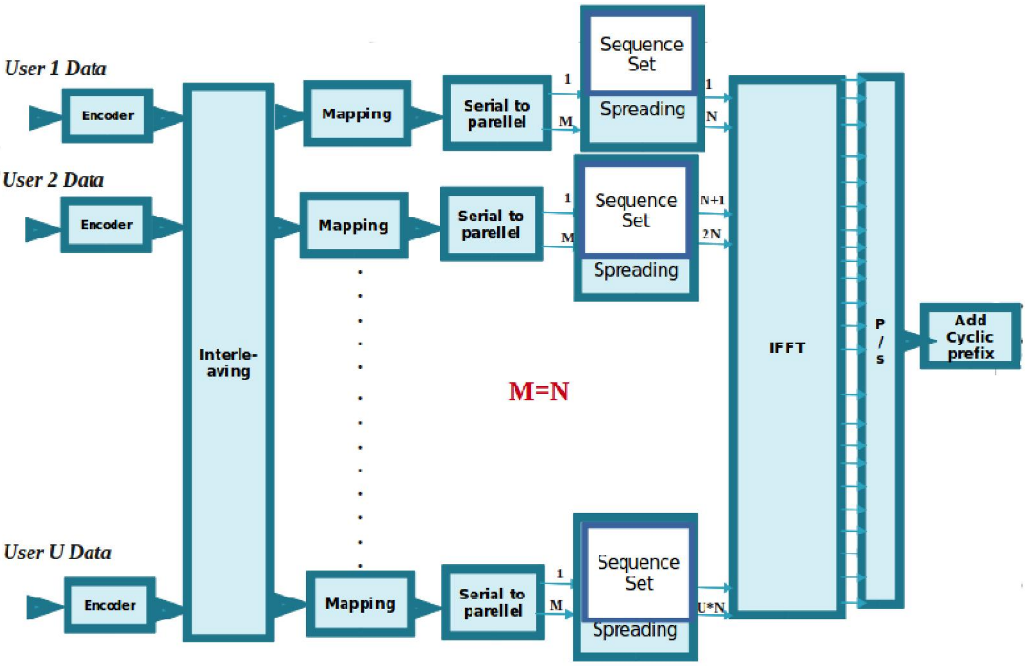

Fig. 1(a) Transmitter Block diagram

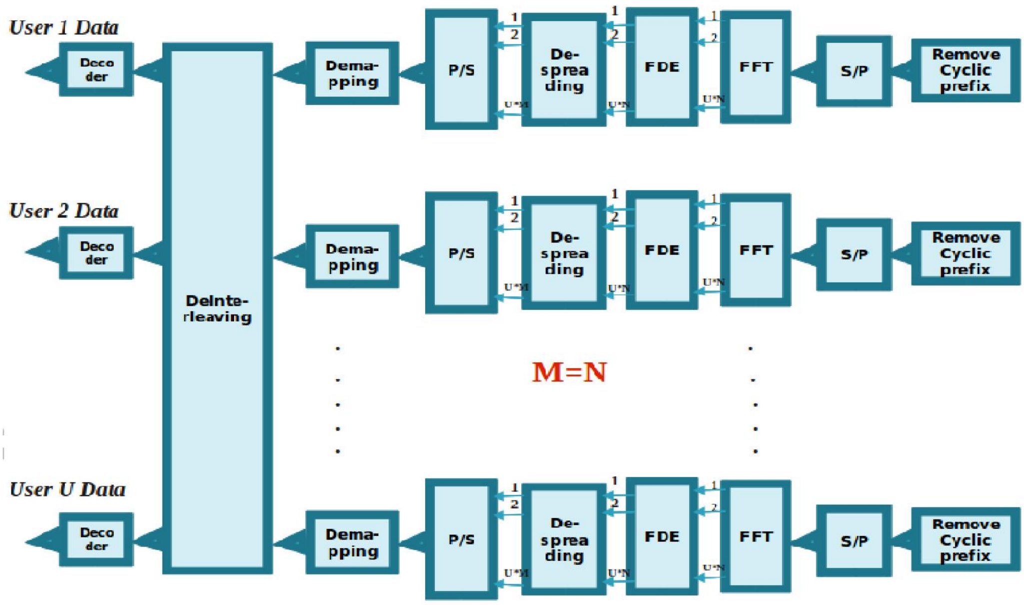

Fig. 1(b) Receiver Block diagram

IV. FINDINGS

4.1 BER Performance

Figure 2(a) illustrates the Bit Error Rate (BER) performance of Overloaded Spread Spectrum OFDMA using Binary Phase Shift Keying (BPSK) modulation, while Figures 2(b) and 2(c) show BER performance for Quadrature Phase Shift Keying (QPSK) and 16-Quadrature Amplitude Modulation (16QAM) respectively, all employing complex scrambling OCDMA/TDMA codes. Evaluation occurs within a Rayleigh channel setting, employing a High-Definition Iterative Cancellation (HDIC) receiver with spreading gains of 32, 128, and 256 and Error Correction Coding (ECC) set at 1/2. The assessment covers both indoor and outdoor scenarios with an FFT size of 2048.

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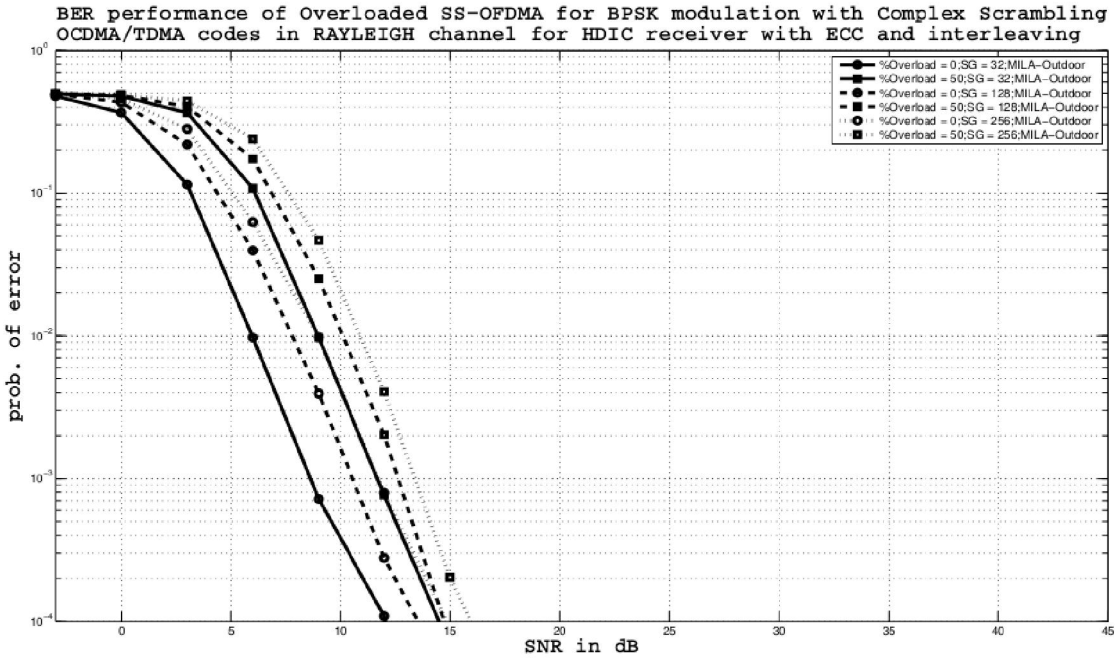

Fig. 2(a) BER performance of Overloaded Spread spectrum OFDMA for BPSK modulation

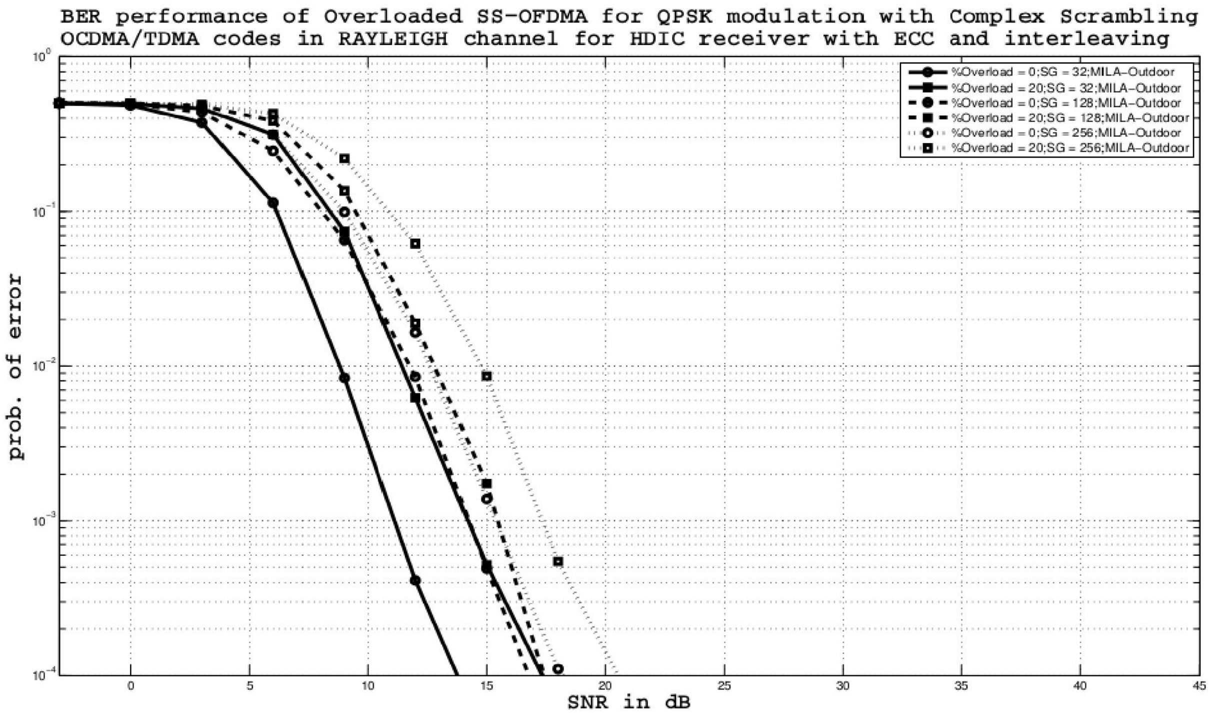

Fig. 2(b) BER performance of Overloaded Spread spectrum OFDMA for QPSK modulation

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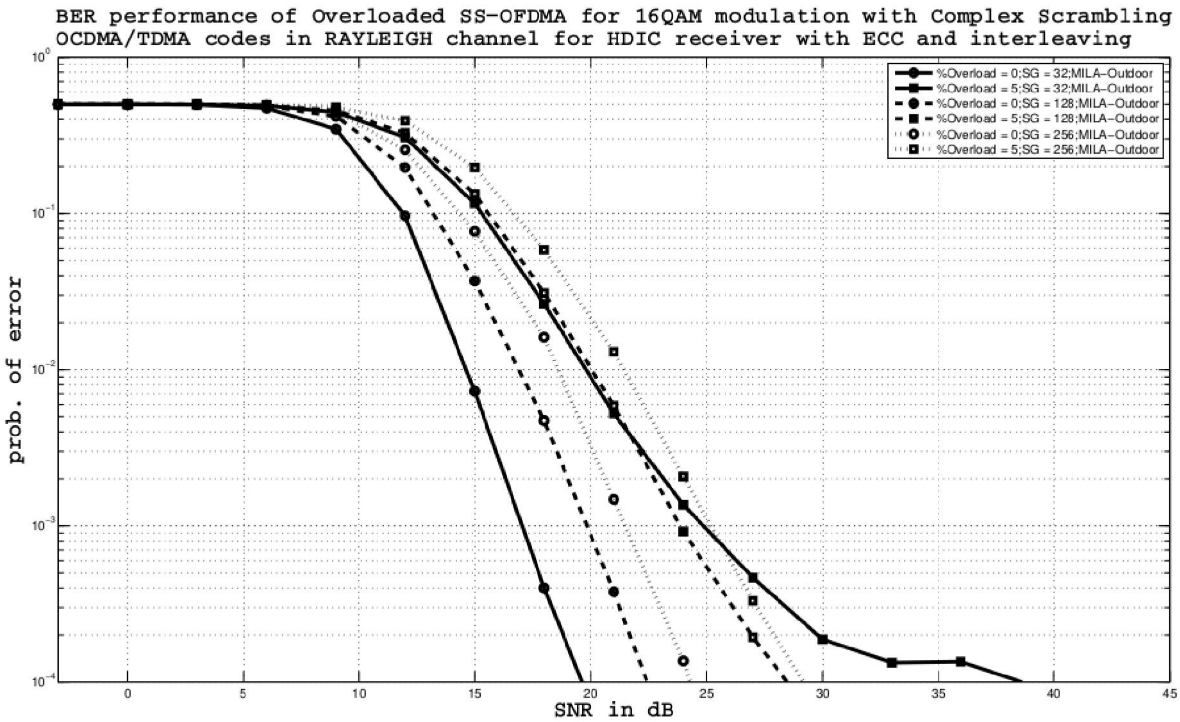

Fig. 2(c) BER performance of Overloaded Spread spectrum OFDMA for 16-QAM modulation

Results indicate a degradation in Signal-to-Noise Ratio (SNR) requirement with overloading, mirroring the Low Interleaving Localized Access (LILA) case. However, BER performance improves compared to LILA due to enhanced interleaving gain among users' data. This degradation is particularly notable for higher modulation schemes, attributable to increased interference as the number of symbols in set-2 escalates, thereby worsening overall performance. Conversely, augmenting the spreading gain enhances performance by mitigating cross-correlation effects. These findings underscore the intricate trade-offs between modulation schemes, spreading gains, and interleaving techniques in achieving optimal performance in Overloaded Spread Spectrum OFDMA systems across varying channel conditions.

4.2 Analytical Model for Throughput performance

The following equation provides the normalized throughput, which is contingent upon the Signal-to-Noise Ratio (SNR) of the system.

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

In the equation, C signifies system capacity, W represents system bandwidth. C/W, termed as normalized throughput, measures the number of bits transmitted per second over one Hertz of bandwidth. It quantifies the bits loaded within a symbol duration. The variable SNR denotes Signal-to-Noise Ratio at the receiver, reflecting the quality of the received signal relative to background noise.

Moreover, if Pe denotes the probability of erroneously received symbols, the throughput relation can be expressed as indicated in reference [6].

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

In this context, L refers to the quantity of bits conveyed within a symbol, while r stands for the error control coding rate. The variable "Percent Overload" denotes the extent of overload imposition. Hence, it can be deduced that when the probability of error is nearly zero, the Throughput exceeds that of the no overload scenario by the percentage of overload applied.

In scenarios where the probability of error approaches zero, the throughput surpasses that of the no overload situation by the percentage of overload applied. Figure 3 depicts the throughput performance of Overloaded SS-OFDMA across

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different modulation schemes, utilizing complex scrambling OCDMA/TDMA codes within a Rayleigh channel. The system employs an HDIC receiver with More interleaving and Localized Access (MILA). Notably, an escalation in the overload percentage enhances spectral efficiency across diverse modulations like BPSK, QPSK, and 16 QAM. This finding underscores the advantageous impact of overloading on system performance and spectral efficiency across a range of modulation schemes.

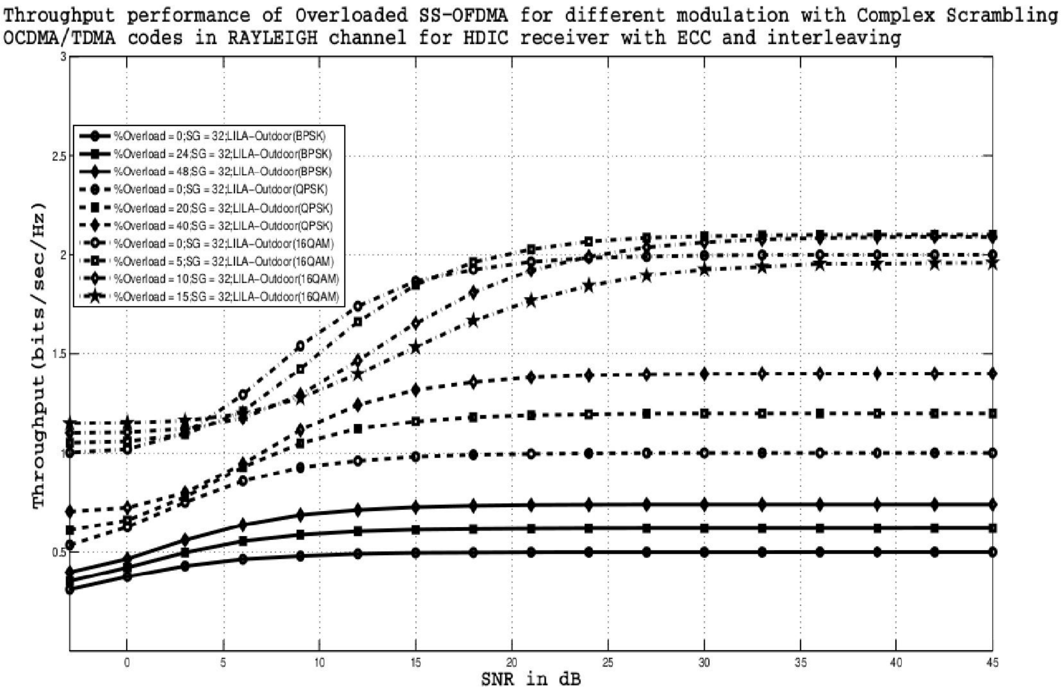

Fig. 3: Throughput performance of Overload SS-OFDMA in Outdoor environment

V. CONCLUSION

5.1 BER performance

Table I displays the Signal-to-Noise Ratio (SNR) requirements, measured in decibels, necessary to achieve a Bit Error Rate (BER) of 10^-2 across different modulation schemes. The evaluation is conducted using Complex Scrambling OCDMA/TDMA codes with varying Spreading Gains (32, 128, and 256) and Error Correction Coding (ECC) set at 1/2. Observation:-with the increase in SG BER performance is becoming worse.

TABLE I: SNR REQUIREMENT OF OVERLOADED SS-OFDMA FOR DIFFERENT MODULATION WITH VARIOUS SPREADING GAIN IN MILA OUTDOOR

BPSK						QPSK						16 QAM					
0% Overload			50% Overload			0% Overload			20% Overload			0% Overload			5% Overload		
32	128	256	32	128	256	32	128	256	32	128	256	32	128	256	32	128	256
6	7.8	9	9	10.1	10.8	8.8	11.7	12.6	11.5	12.8	14.7	14.6	16.9	18.6	19.8	20.1	21.4

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5.2 Throughput performance

Table II outlines the Signal-to-Noise Ratio (SNR) required to achieve maximum throughput across different modulation types. This assessment utilizes Complex Scrambling OCDMA/TDMA codes with a Spreading Gain set at 32 and Error Correction Coding (ECC) at 1/2.

TABLE II: SNR REQUIREMENT OF OVERLOADED SS-OFDMA FOR DIFFERENT MODULATION TO ACHIEVE THE MAXIMUM THROUGHPUT IN MILA OUTDOOR

BPSK			QPSK			16 QAM		
0%	24%	48%	0%	20%	40%	0%	5%	10%
8.7	9.8	11.7	12.1	14.9	17.8	19.6	26.3	36

REFERENCES

[1]. 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.
A. Dogra, R. K. Jha and S. Jain, "A Survey on Beyond 5G Network With the Advent of 6G: Architecture and Emerging Technologies," in *IEEE Access*, vol. 9, pp. 67512-67547, 2021.
[4]. H.S. Prasad R.,"An overview of multi-carrier cdma,"IEEE communication Magazine, Dec 1997.
[5]. K.Fazel, "Performance of cdma/ofdma for mobile communication system, "in International Conference on Universal Personal Communications, 1993.
[6]. X. Y. Hwa Chen H., "The occ-cdma/os for 4g wireless, "IEEE Vehicular Technology Magazine,Sept 2008.
[7]. "Beyond 3g/4g radio access technology and standards roadmap," eMobility, Tech. Rep., Dec 2007.
[8]. "Guidelines for evaluation of radio interface technologies for imt-advanced,"ITU-R, Tech.Rep.M.2135, 2008.
[9]. "Supekar Vishal Rameshrao,"Overloaded Spread Spectrum OFDMA for Next Generation Wireless Standard,"M-Tech Thesis,IIT Kharagpur,April 2010.
[10]. "Y.Arun Kumar Reddy, " Overloaded Spread spectrum OFDMA in indoor environment (Low Interleaving) ", IJRECE , V OL . 7 ISSUE 1 , JANUARY - MARCH 2019, pp.689-693.
[11]. "Y.Arun Kumar Reddy, " Overloaded Spread spectrum OFDMA in indoor environment (More Interleaving) ", IJRECE , V OL . 7 ISSUE 1 , JANUARY - MARCH 2019, pp.684-688.
[12]. "Y.Arun Kumar Reddy, " Overloaded Spread Spectrum OFDMA in Outdoor Environment in the Low Interleaving Scenario", IJARSCT, Vol. 4 Isuue 4, May 2024, pp.596-602
[13]. J. L. Hyung G. Myung and P. U. David J. Goodman, "Single carrier fdma for uplink wireless transmission,"IEEE Vehicular Technology Magazine, Sept 2006.
[14]. 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.
[15]. E. P. Gilberto Berardinelli, "Improving sc-fdma performance by turbo equalization in utra LTE uplink," in Vehicular Technology Conference. IEEE, May 2008.
[16]. P.Kumar, "Overloading with iterative interference cancellation receiver,"Ph.D. dissertation,IIT Kharagpur, July 2008.
[17]. M.F. Vanhaverbeke, "Sequences for Oversaturated cdma channels,"in International Symposium on Spread Spectrum Techniques and Applications. IEEE, Aug 2008.
[18]. S. Verdu "Multiuser University press,1998.
[19]. E. H. Dinan and B. Jabbari, "Spreading codes for ds-cdma and wideband cdma cellular networks,"IEEE Communication Magazine, Sept 1998.
[20]. M. M. Frederic Vanhaverbeke,"Ds/cdma with two sets of Orthogonal spreading sequences and iterative detection,"IEEE Communication Letters. Vol.4,no. 9, Sept 2000.

[21]. 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.

[22]. 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.

[23]. 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.

[24]. M. C. Chang and Y. T. Su, "Overloaded multiple access systems: A generalized model and a low-complexity multiuser decoder," *2016 9th International Symposium on Turbo Codes and Iterative Information Processing (ISTC)*, Brest, France, 2016, pp. 231-235