Evaluation of the weighted-overlap add model with massive MIMO in a 5G system

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ABSTRACT

The flaw in 5G orthogonal frequency division multiplexing (OFDM) becomes apparent in high-speed situations. Because the doppler effect causes frequency shifts, the orthogonality of OFDM subcarriers is broken, lowering both their bit error rate (BER) and throughput output. As part of this research, we use a novel design that combines massive multiple input multiple output (MIMO) and weighted overlap and add (WOLA) to improve the performance of 5G systems. To determine which design is superior, throughput and BER are calculated for both the proposed design and OFDM. The results of the improved system show a massive improvement in performance ver the conventional system and significant improvements with massive MIMO, including the best throughput and BER. When compared to conventional systems, the improved system has a throughput that is around 22% higher and the best performance in terms of BER, but it still has around 25% less error than OFDM.

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1. INTRODUCTION

With the use of computer networks, it has become feasible to access data from distant locations. These can be wired or wireless networks [1]. Wireless sensor networks have been widely used and are adaptable, therefore a lot of research and development has been published recently [2]-[4]. Wireless network connectivity has seen significant technological advances over the last two decades. For users of second generation 2G mobile technology, the only options were phone calls and text messaging (i.e., SMS). Similarly, video chatting, high-speed web browsing, teleconferencing, and online gaming are just a few of the many applications that 4G technology has enabled [5]. With 5G, the new 5G network is one hundred times faster than the previous 4G network, with a data transfer rate of 10 Gbit/s and a latency of just 1 millisecond. This increases the durability of linked devices by increasing their coverage and decreasing their power consumption [6]-[8].

Massive multiple input multiple output (MIMO) systems are important enablers of 5G wireless communication [9], [10]. MIMO systems encourage the use of multiple antennas at the base station (BS), which results in a number of advantages, such as the use of simple uplink and downlink transmission [11]. Despite the benefits of MIMO systems, major architectural challenges emerge as the number of antennas used for BS increases into the dozens, if not hundreds. Furthermore, before implementing a large MIMO system, a variety of potential approaches must be thoroughly described [12], [13]. Authors have investigated the effectiveness of massive MIMO in channels evaluated in actual propagation settings. Due to certain properties, it has been determined that massive MIMO can be used effectively in actual propagation situations [14]. The various components of a multiuser MIMO approach were investigated. These components included pilot and precoding systems, channel estimates, channel measurement, and many others. Massive MIMO characteristics are demonstrated in [15] for most millimeter-wave mmWave bands, and the measurements have been validated by both the geometry-based stochastic model (GBSM) and the propagation graph model (PG model). These observations and analyses of mm-wave massive MIMO channels indicate that massive MIMO propagation characteristics should be considered when designing mmWave channels for large antenna array systems.

Otherwise, Payami and Tufvesson [16] measured a genuine big MIMO channel model using base stations formed in a cylindrical antenna array layout. High doppler and time delay conditions were used to evaluate and compare orthogonal time-frequency space (OTFS) output with orthogonal frequency-division multiplexing (OFDM) output, with the OTFS multipath (MP) detector serving as the receiver [17]. Despite the fact that the standard for wireless transmission in the frequency band is less than 6 GHz and the use of multiple carriers for modulation during transmissions [18], OFDM has several inherent disadvantages. The rectangular pulse shape causes significant frequency loss. A cyclic prefix (CP) reduces spectral efficiency. Furthermore, precise time and frequency synchronization is required to ensure inter-cell interferences, subcarrier orthogonality, and minimum intra [19], [20]. The high level of complexity of multiuser multiple input multiple output (MU MIMO) systems includes block diagonalization (BD) precoding as a result of the singular value decomposition-based sequential creation of transmitter precoding matrices (SVD). El-Abd *et al*. [21] proposed the consideration of the impact of an additional BS antenna on potential sum rate performance as well as the bit error rate (BER) of the various LP algorithms.

2. TRADITIONAL SYSTEM

Figure 1 depicts a MU-MIMO configuration on the downlink that contains one base station outfitted with L and N broadcast and receiving antennas. Each BS serves Z users with O_Z antennas. We assume that each user receives the same antenna number O_Z, without losing comprehensiveness and for the best possible transmission results, it is assumed that both the BS and the users are in sync and that the transmitter has a thorough grasp of of channel state information (CSI). The zth user group's BS-user channel matrix is depicted as a flat fading MIMO-channel [22], [23].

$$\mathrm{H_Z} = \begin{pmatrix} h_{11} & h_{12} & \dots & h_{1L} \\ h_{21} & h_{22} & \dots & h_{2L} \\ . & . & \dots & . \\ . & . & \dots & . \\ h_{O_Z1} & h_{O_Z2} & \dots & h_{O_ZL} \end{pmatrix} \tag{1}$$

$$H = [\,H_1^T \quad H_2^T \quad \dots \quad H_Z^T]^T \tag{2}$$

The MIMO channel H matrix has a precoding matrix with transmission vectors indicating to Z user, and additive noise n. The precoding matrix utilized in the maximum ratio transmission (MRT) transmit beamforming algorithms is:

$$W = H' \tag{3}$$

The accompanied signal to interference plus noise ratio (SINR) of the zth user is dependant on the values of L and Z:

$$SINR = \frac{p\,L}{Z(p+1)} \tag{4}$$

With ZF, the H matrix of the MIMO channel for the Z user additionally includes transmission symbol vectors and precoding, the precoding matrix utilized by transmit beamforming methods is:

$$W = H'(HH')^{-1} \tag{5}$$

$$SINR = p\,\frac{(L-Z)}{Z} \tag{6}$$

The sent signal is:

$$y_Z = \sqrt{p}H^H W_s + n \tag{7}$$

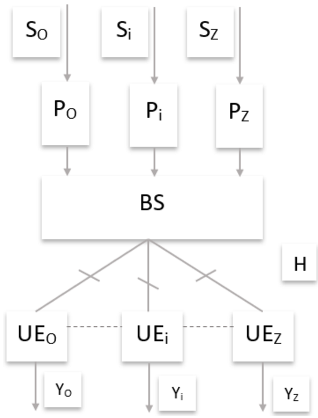

Figure 1. MU-MIMO model

The MIMO channel matrix is denoted as H, Z is the number of users, the P value represents the typical transmit power. W_s, which stands for symbol vector, is the precoding matrix. The letter n stands for additive noise. The perfect channel state is assumed to be known in BS. Before utilizing the transmitter symbol, the acquisition of the pilot open loop time division of the BS is mandatory, which operates well in time division duplex (TDD), in order to support large MIMO schemes such as the frequency division duplex (FDD) scheme [24]. The BS chooses three different precoding techniques. At the user terminal, a unique symbol is assigned to each individual user. Therefore, the terminal is the location where the signal for each user is generated.

$$y_Z = \sqrt{p}\, h_Z^H W_s s_Z + \sqrt{p}\, H_Z \sum_{i=1, i\neq z}^{Z} h_Z^H W_j s_j + n_Z \quad (8)$$

Digital data may be encoded on various carrier frequencies using OFDM. Due to its possession of power efficiency and effectiveness in mitigating frequency-selective fading in wireless channels, OFDM has become standard in wireless broadband systems [25]. As shown in Figure 2, with systems of radio frequency (RF), OFDM is a typical multi-carrier waveform format. It may vastly improve data rates in networks with limited bandwidth because of its superior spectral efficiency and successful MIMO integration [24]–[26]. The subcarrier spacing affects the OFDM’s resistance and determines how well OFDM can handle phase noise as well as channels that are time selective [27]. On the other hand, OFDM’s spectral efficiency is diminished by the inclusion of a CP and huge side lobes, which demand specific null guard tones at the spectrum’s margins [28], [29]. Furthermore, inter-carrier interference (ICI) is an issue for OFDM systems because of carrier frequency deflections [30]. Likewise, non-linearity at the receiver is mostly caused by the high peak-to-average ratio (PAPR) [31].

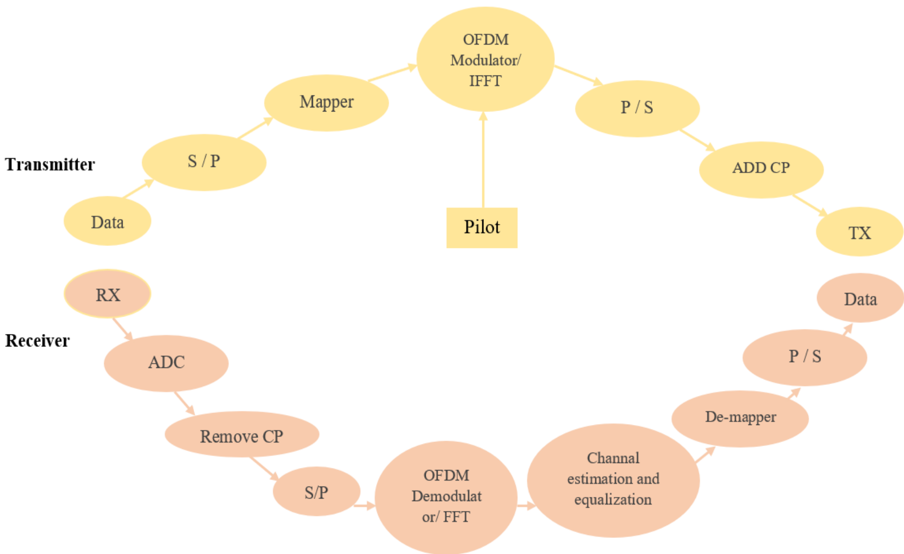

Figure 2. OFDM block diagram

3. THE PROPOSED SYSTEM

The advanced mobile system model and the weighted overlap and add (WOLA) model are both incorporated into the suggested system model. The WOLA-OFDM windowing approach takes into account the overlap with OFDM and adds weight to the resulting windowed OFDM. This method effectively reduces out-of-band (OOB) emissions without much effort. However, a system using OFDM is severely constrained by OOB interference. System performance degradation and ICI come from the propagation of sidelobes from one subcarrier onto adjacent subcarrier [32], [33]. Because the window size is determined by the duration of the CP in the waveform, the level of WOLA-OFDM OOB emissions gradually decreases as the CP length increases. The cyclic prefix can be shortened by utilizing an asymmetrical window rather of the well-known symmetric window. The OOB emissions are affected and diminished when an asymmetric window is used. However, it makes the device far more vulnerable to channel-induced ISI and ICI [34].

In a standard N-subcarrier OFDM system, to ensure compliance with the CP, the inverse fast Fourier transform (IFFT's) last cyclic prefix samples are attached to the beginning of the N samples. Following the application of the aforementioned three sections to the N samples at the IFFT output, the WOLA technique adds N additional samples to the OFDM symbol's start and termination, respectively, using the $(\alpha + \beta + GI)$ samples. At the transmitter, a non-rectangular window is multiplied to produce the initial and final samples. To absorb influence from inter-symbol interference (ISI) as well as ICI, guard interval (GI) samples are utilized. Figure 3 demonstrates the windowing of the relevant $\beta + N$ samples. Likewise, the usage of the WOLA component is seen in Figure 4. The symbol T_0 stands for time and Tw time-windowed stands for TX with RX respectively.

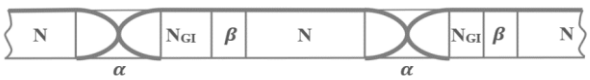

Figure 3. Block diagram for the WOLA symbol

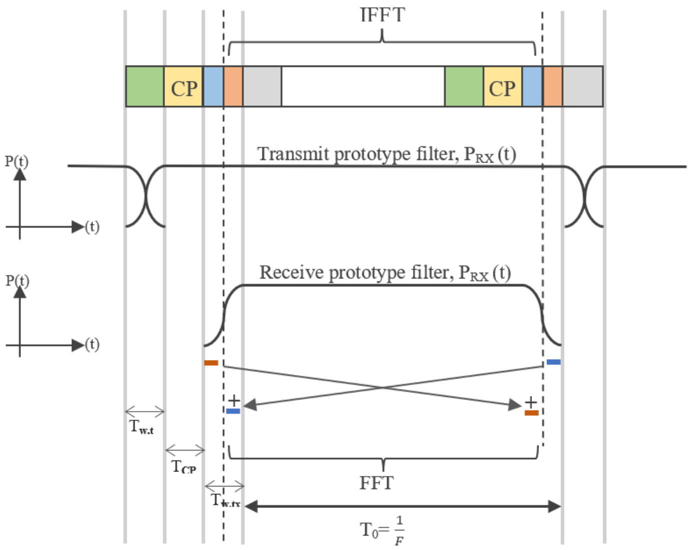

Figure 4. Formulating WOLA parameters

4. SYSTEM SIMULATION

This part provides the numerical outcomes from the MATLAB simulation for the purpose of validating the computed findings. Fair enough, various WOLA and OFDM were used with the same massive MIMO system configuration. The block diagram of the system model simulation stages is shown in Figure 5. With up to 64 antennas and modulation up to 1024, 5G new radio (NR) simulates such huge MIMO. Utilizing MATLAB, the model is implemented and shows data such as the channel coding type, the user nodes and number of BS, the doppler model, and other relevant data. The simulation parameters are shown in Table 1.

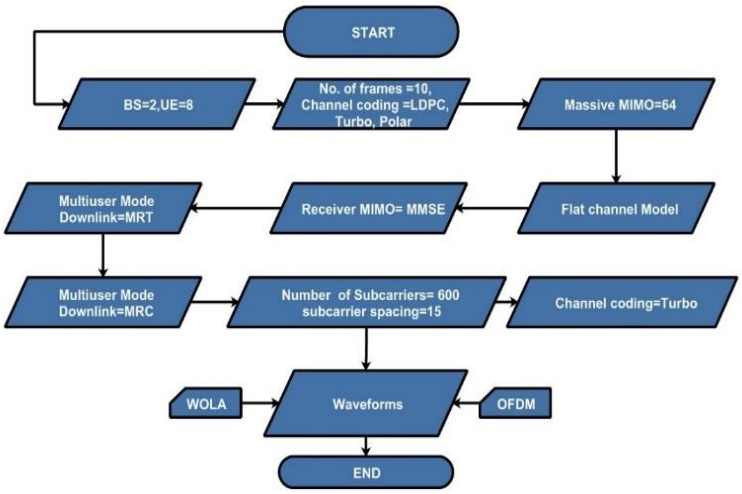

Figure 5. Block diagram of the simulation

Table 1. Parameters for simulation

Parameters	The values
Channel coding	Turbo
Number of frames	10
Doppler model	Jakes
Frame architecture	FDD
Massive MIMO	64
User_velocity (km/h)	15
Channel modulation	QPSK to QAM 1024
Center frequency (GHz)	2.5
Waveform	OFDM, WOLA
Path deterioration (dB)	30
Distance between subcarrier (kHz)	15
The MIMO type of receiver	MMSE
OFDM/WOLA subcarriers	600
WOLA: window size $[\alpha + \beta]$	1 / (14×2×30)

5. RESULTS AND DISCUSSIONS

Figure 6 displays the results of a comparison of the overall throughput gained by two BSs (WOLA and OFDM) utilizing massive MIMO. The proposed model WOLA outperforms OFDM across the MIMO range of 4-64 antennas. The WOLA model likewise has the best throughput when the MIMO is 64, at roughly 89 Mbps, compared to 86 Mbps in the OFDM system, however, the BS2 WOLA performs worse. Figure 7 depicts the throughput that was achieved by the two systems when four user equipment (UEs) were present. The findings indicate that the suggested system offers superior performance because it allowed for an extremely high volume of data flow, which reached 27 Mbps, in comparison to the previous system's maximum of 22 Mbps at UE4. The performance of the proposed system is also superior with regard to the remaining users.

Figure 8 shows a comparison of the BERs at BS1 for the proposed system WOLA and the OFDM system to determine which approach has the lowest BER. This becomes a much more significant factor when there are 64 antennas. While OFDM had a BER of around 0.041, the new system had a BER of about 0.0328 at UE4, making it far more effective than the previous one. When MIMO is 16, WOLA has a lower throughput than OFDM, which is 0.052 compared to 0.036 for WOLA. In addition, Figure 9 illustrates the throughput that was obtained by the two systems when there were a total of four UEs present in the environment. According to the findings, the system using OFDM performs better since it allowed an extraordinarily high amount of data flow, reaching 2.43 Mbps, as opposed to the WOLA system, which could only manage 1.75 Mbps at UE5. The performance of the proposed system was superior in terms of users who were still active in UE6, reaching a maximum of 1.89 Mbps as opposed to the OFDM system, which could only manage 1.61 Mbps.

Schemes of two different model were utilized over MIMO as illustrated in Figure 10, WOLA provided the superior BER. In comparison to the OFDM in UE7, which has an approximate BER of 0.065 when 64 antennas were taken into consideration, it achieved lower BER of about 0.042. A summary of the average throughput results for the WOLA and OFDM over the various BSS was presented in Figure 11 and Figure 12, respectively. The throughput of the proposed system, known as WOLA, is 11.72 Mbps, which was higher than the throughput of the conventional system, which is 11.13 Mbps.

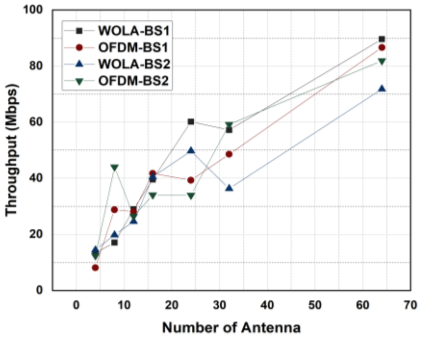

Figure 6. Total throughput in the models of the WOLA and OFDM systems for two BSs

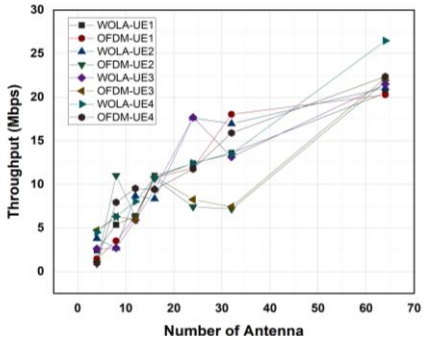

Figure 7. Total throughput of users in the WOLA and OFDM systems at BS1

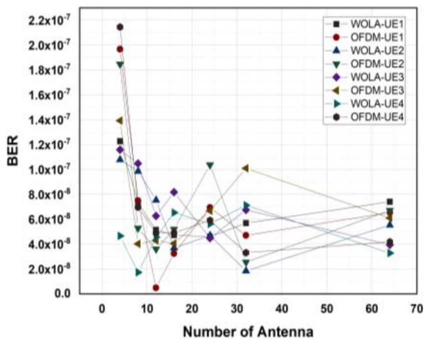

Figure 8. BER of users in the WOLA and OFDM systems at BS1

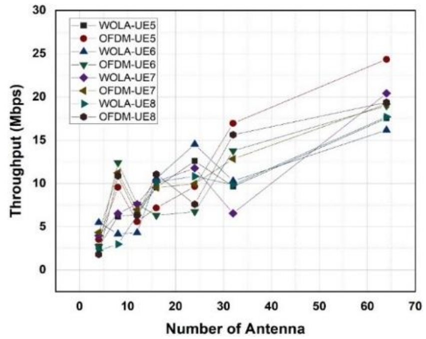

Figure 9. Total throughput of users in the WOLA and OFDM systems at BS2

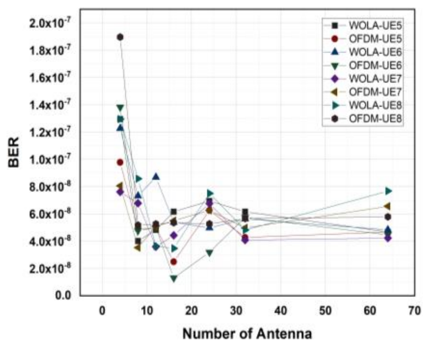

Figure 10. BER of users in the WOLA and OFDM systems at BS2

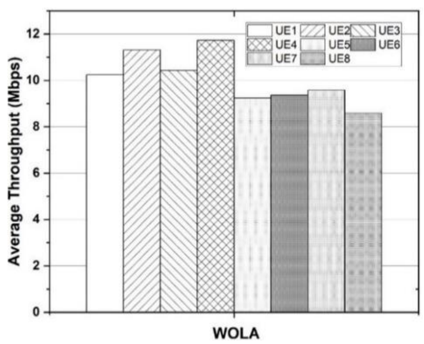

Figure 11. Results of Average throughput user in WOLA system

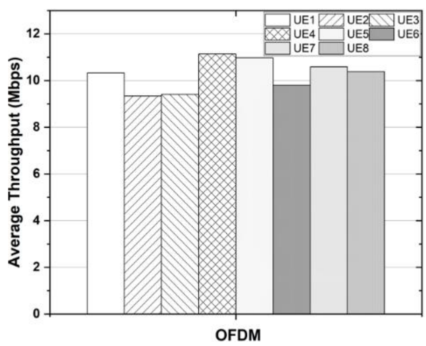

Figure 12. Results of average throughput user in OFDM system

6. CONCLUSION

This paper proposes a new mobile system that addresses some of the long-standing issues with existing mobile platforms. In this regard, WOLA was a possible candidate. Following that, a comparison of WOLA and OFDM in 5G was performed. This plan could be incorporated into a new approach for future mobile networks. The impact of two systems on the mobile system's functionality was investigated.

In order to find the best, each system model must be integrated with the entire mobile system. The simulation results showed that WOLA outperforms OFDM with four UEs. It has the potential to improve the system's throughput and BER performance. As shown by the overall result, the proposed WOLA outperforms OFDM in terms of BS throughput by about 22%. While the suggested system's BER result provided the best performance, it was still approximately 25% less error than OFDM. Because the previous conventional method fails as the number of antennas increases, the new system performs better in these conditions. This discovery will be incorporated into future communication technology iterations.

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