Improving Code Word Interference Cancellation (CWIC) Technique in Heterogeneous Network

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ABSTRACT:
This paper first examines performance of (code word interference cancellation) CWIC for downlink non orthogonal multiple access (NOMA) combined with 2-by-4 multi-user (MU)-MIMO, taking into account the disadvantages of the CWIC receiver, such as complex receiver structure, high volumes of network overhead and high delay, we offer a way to improve the efficiency of the CWIC receiver. CWIC receiver detects, decodes and cancels all interference signals in several steps, from large to small, respectively. The number of interference cancellation stages depends on the number of interference signals. The proposed receiver only cancels the intense interference signal. That's why it's called CWIC-II (Intense Interference). Finally, using simulation, we show that CWIC-II receiver reduces latency and improves throughput. The complexity problem of the CWIC receiver structure is also resolved. In the end, a method has been developed to resolve the problems of the proposed receiver.

KEYWORDS: Successive Interference Cancellation, CWIC, MIMO, NOMA, OFDM.

1. INTRODUCTION

The increasing need for increasing the capacity and applications in the existing cellular networks are the main drivers for moving the network towards a new model called heterogeneous networks. These types of networks have their own challenges, including cell association, mobility management, and interference. The most important of them is interference. Because heterogeneous networks allow multiple users to simultaneously use bandwidth. Also, because heterogeneous networks consist of diverse types of small cells, such as femtocells and picocells, inter-cellular and intracellular interference occur. 3GPP in LTE Rel-10 introduced a set of network-centric techniques grouped under the umbrella term of eICIC (Enhanced Inter-Cell Interference Coordination) [1], [2]. Although effective, these techniques usually require precise coordination and incur in relatively high network overhead. Alternatively, interference cancellation (IC) techniques at the mobile user can also be employed. These techniques are basically categorized as time domain-based, frequency domain-based, power control based, and advanced receiver at the terminal. As mentioned the use of advanced receiver is one of interference cancellation techniques. Interference avoidance techniques can also be used on the user's side [3].

These techniques often require precise coordination and also increase network overhead. One of small letter is called successive interference cancellation (SIC), which is implemented using different techniques. CWIC receiver is one of the types of SIC receivers. The SIC receiver has two types of SLIC (symbol-level interference cancellation) and CWIC. Simulation results in [4] indicated that CWIC performs better than SLIC. In the transmitter, the signals must be encoded and modulated before being sent. The receiver to extract its message, demodulate and decode one of the signals from the received compound signal. If the signal is successfully extracted, the message signal is again encoded and then modulated and finally subtracted from the original signal. The process is repeated until all signals have been extracted. In each step, by eliminating the interference, the signal becomes stronger and therefore the SINR increases [5]. The use of the CWIC receiver makes it possible to extract multiple signals that interfere with the receiver. The use of the CWIC receiver makes it possible to extract multiple signals which are interfering each other. The disadvantages of this receiver are: the

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complex structure of the receiver, and that it is not always possible to decode the received signal. Another important disadvantage is that CWIC receiver contains a MMSE bank and the decoding steps impose a high delay on the network, it's not cost-effective to use and, given the high latency, decreases network throughput. Therefore, quality of service is reduced.

In the following, we first consider the concept of the CWIC receiver in downlink NOMA with MU-MIMO. In the next section, a method to improve the design of the CWIC is presented. Then, in the fourth section, we provide and talk about the results of the performance downlink NOMA, when CWIC a CWIC-II receiver are applied for 2-by-4 MIMO. Finally, we will conclude in the last section.

2. DOWNLINK NOMA CWIC WITH MU-MIMO

In order to evaluate the efficacy of the offered receiver (CWIC-II receiver), we assume 4 users. It should be mentioned that, all researches which study CWIC receiver, Only two users have been reviewed, the (UE #1) located in the center of the cell and the other UE (UE #2) at the edge of cell and the (UE #2) does not apply successive interference cancellation as the interference signal from cell-center UE is behaved as noise; thus, only demodulation and decoding are applied to the received signalY2. Clearly, with the lowest number of receiving and transmitting antennas, the channel capacity of a MIMO system is increasing. The reason for the increased channel capacity is the spatial diversity created by multiple antennas. MU-MIMO systems share the increased capacity among multiple users to realize multiple accesses. In MU-MIMO systems to realize multiple access, the increased capacity is shared [6], [7].

NOMA boosts the functionality of the system by increasing the ability to use the existing channel capacity. For this reason, it also creates interference between different users. Accepting NOMA in the MU-MIMO system is the hope of increasing spectral efficiency [7].

In order to combine MU-MIMO communication with NOMA, MU-MIMO is used to any UE (User Equipment) separately with up to 2-layer transmission for each UE. It is well known that till 8-layer transfer is made possible by using 2-by-4 MU-MIMO on top of NOMA with 4UE multiplexing. In the case of OMA combined with MU-MIMO, between transmission layers, the transmit power that allocated to any UE is distributed equally.

In practice, NOMA provides users with lower qualitative channels with more power to make sure that the purpose rates available to these users are guaranteed; in that way interconnection of the network and user justice is established. In addition, NOMA in qualifications of total channel capacity and ergodic total capacity has a definitive advantage over OMA [8].

Fig. 1 indicates the concept of downlink NOMA by using the successive interference cancellation receiver and four user equipment's (UEs) and with MU-MIMO While there is one base station (BS) with two antennas. Fig. 2(a) illustrates the CWIC and CWIC-II receivers and BS transmitter configuration.

The user dropped according to 3GPP configuration 4b [9]. Five different seeds are utilized for simulation. In these seeds, more than 50% of users are dropped near BS and the remaining users are randomly dropped in the layout. As previously mentioned we consider that the number of UE is four, while three UE located at a center of the cell and the other UE at an edge of the cell. Pi is the power that BS sends to send to the UE #i and

$$E[|X_i|^2] = 1, \tag{1}$$

$$p_4 > p_3 > p_2 > p_1, \tag{2}$$

$$P_1 + P_2 + P_3 + P_4 = 1, \tag{3}$$

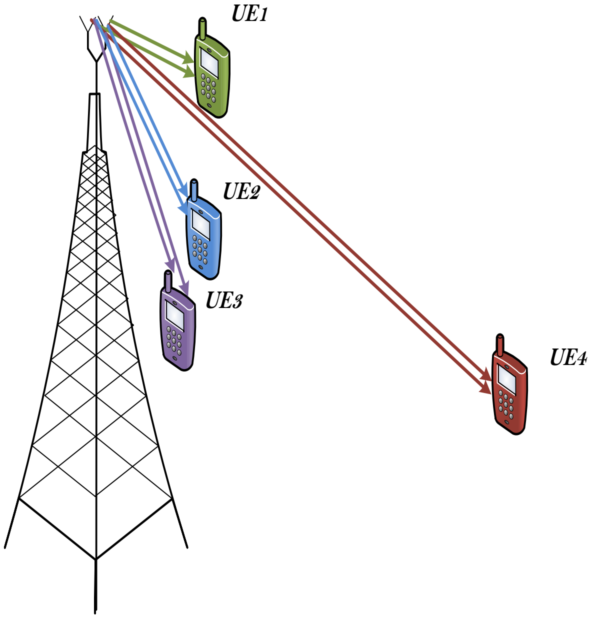


Fig. 1. An overview of the location of users around the base station.

This means that the transmit signals for *UE #i* are multiplexed in the power domain based on the allocated transmit power *Pi* [4]. As shown in Fig. 1, *UE4* causes the strongest interference on other users because it has the maximum distance to BS. In the case of *UE* located on the edge of the cell, the use of the CWIC receiver is not necessary, because of the transmitter. The bandwidth used by all of the UEs is the same. Inevitably, to decode the signal received by the user located at the center of the cell, the successive interference cancellation technique should be used, because the *UE* signals at the cell-center are significantly contaminated by the *UE* edge of the cell.

And assuming we have two transmitter antennas [4]:

$$\begin{bmatrix} x_i(k) & x_i(k+1) \\ -x_i^*(k+1) & x_i^*(k) \end{bmatrix}, \tag{4}$$

In this matrix, *xi (k)* represents the *k-th* signal transmitted by *UE#i*. The vector of the signal X is generated in this way [4]:

$$X = \sum_{i=1}^{N} \sqrt{P_i} \begin{bmatrix} x_i(k) \\ -x_i^*(k+1) \end{bmatrix} W_{Tx,i}, \tag{5}$$

$W_{Tx,i}$is the matrix of preceding weight for each *UE*. So we have:

$$X = \sqrt{p_1} X_1 W_{Tx,1} + \sqrt{p_2} X_2 W_{Tx,2} + \sqrt{p_3} X_3 W_{Tx,3} + \sqrt{p_4} X_4 W_{Tx,4}, \tag{6}$$

Y shows the received signal vector for each *UE* (*i* = 1, 2, 3, 4), At the receiver side:

$$Y_i = HX + N_i, \tag{7}$$

Y unlike X, in each receiver, is distinct. H illustrates the complex channel matrix of *UE#i*, and N_i represents the additive white Gaussian noise (AWGN) vector for each *UE* [4]:

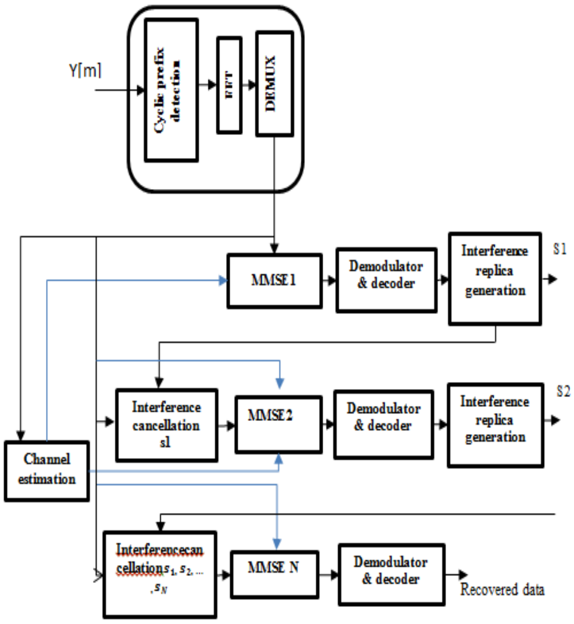
$$\delta^2 I = E\lfloor N_i N_i^H \rfloor, \tag{8}$$

I is the identity matrix [4]. The complex channel matrix H is specified as follows:

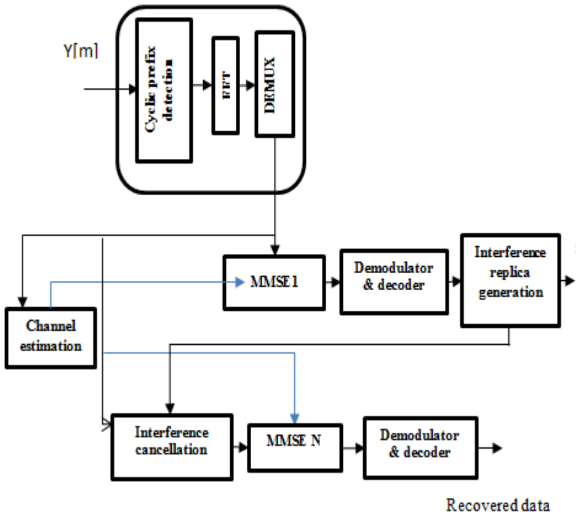
$$H = \begin{bmatrix} h_{11}(k) h_{12}(k) \\ h_{21}(k) h_{22}(k) \\ h_{31}(k) h_{32}(k) \\ h_{41}(k) h_{42}(k) \end{bmatrix}, \tag{9}$$

Where $h_{ij}(k)$ illustrates the complex channel coefficient of *k*-th subcarrier of *i*-th received antenna and *j*-th transmitted antenna [4]. In order to cancel interference, the receiver usually through the pilot signals such as Cell-specific Reference Signals (CRS), estimates the interference covariance matrix. The receiver uses the interference spatial structure to estimate the antenna weight. The parameters of the useful signal are typically known at the terminal receiver through control channel signaling [10]. Signal interference parameters are channel transmission function, power rising, precoding vectors, modulation instruction, and etcetera that in LTE technology should be blindly detected for each resource block (RB) to simplify the receiver's performance [10].

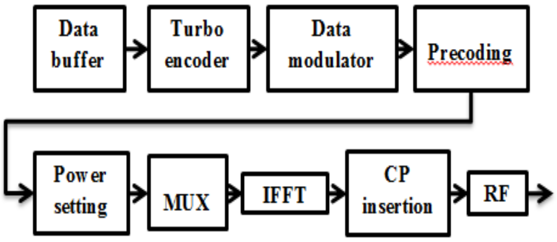
While serving cell parameters should normally be detected from the control channel signaling, the current technical specifications of LTE-A technology do not support signaling of information on interference parameters [10]. As a result, the identification of the interference signal is not possible with the help of channel signaling. Therefore, the calculation of the signal parameter interference must be made using the received signal [10].



(a). CWIC receiver



(b). CWIC-II receiver



(c). BS Transmitter

Fig. 2. Transceiver configuration.

The *UE* receiver first computes the received weight matrix using estimated channel coefficients applying the CRS, taking into account the interference of the user based on the MMSE criterion according to (10) and (11).

Since the number of transmitter antennas is less than the number of receiver antennas, received weight matrix is equal to:

$$W = (H^H H + \sigma^2 I)^{-1} H^H, \tag{10}$$

As a result, the weight matrix received in *UE1* in the first stage of interference cancellation can be represented as:

$$W_{Rx,4} = (\hat{H}_4^H \hat{H}_4 + \hat{H}_1^H \hat{H}_1 + \delta^2 I)^{-1} \hat{H}_4^H, \tag{11}$$

The complex matrix H1 is derived from Eq.(12):

$$H_i = \sqrt{p_i} \begin{bmatrix} h_{11}(k) h_{12}(k) \\ h_{21}(k) h_{22}(k) \\ h_{31}(k) h_{32}(k) \\ h_{41}(k) h_{42}(k) \end{bmatrix} * W_{Tx,i}, \tag{12}$$

For detection the *UE* that is located in the edge of a cell, we determine the channel matrix follow as (12). The vector of the interfering *UE* symbol is calculated in the first step of the removal of the interference according to (13):

$$S_{rep,4} = (W_{Rx,4}) Y_1, \tag{13}$$

The receiver, by means of detecting and decoding the vector of symbols, intercepts *UE*, produces $S_{rep,i}$ and $X_{rep,i}$. After demodulation and decoding the output as a sequence of log-likelihood ratio (LLR), they are actually the same code words. The LLR is given by

$$X_{rep,i} = LLR = lo\, g \frac{(b^m = 1|S_{rep,i})}{(b^m = 0|S_{rep,i})}, \tag{14}$$

That b^m, the *m-th* Symbol bit interferes with the vector of the *UE* symbol. The vector of the received signal after the first step of interference cancellation is equal to:

$$Y_{C,1} = Y_1 - \hat{H}\sqrt{P_4} W_{Tx,4} X_{rep,4}, \tag{15}$$

So in CWIC receiver, the vector $Y_{C,1}$ enters the MMSE. At this stage, there is no other *UE4* interference signal, but *UE3* creates the strongest interference and all the steps mentioned above are performed to detect and cancel the intermittent signal.

The number of interference cancellation stages in the CWIC receiver depends on the number of interfering *UEs*, and finally, after the removal of all interfering signals, to gaining binary trail demodulation and decoding are used.

Generally, for about of CWIC receptor $X_{rep,i}$ is produced via detecting and decoding $S_{rep,i}$. Then producing $X_{rep,i}$ and using successive interference cancellation, the received signal vector, $Y_{C,1}$ is computed follow as

$$Y_{C,1} = Y_1 - \hat{H} \sum_{i=2}^{N} \sqrt{P_i} W_{Tx,i} X_{rep,i}, \tag{16}$$

UE4 which is located at the edge of a cell treats interference signals as noise. So, for its received signal (Y_4), it only demodulation and decode. *UEs* will not receive interference from other UEs which have lower power than themselves. For example, *UE3* does not receive interference from *UE1* and *UE2*.

2.1. CWIC-II receiver design

We described the well-known technique, successive interference cancellation (SIC), in the introduction. Interference cancellation in CWIC takes place at the *UE*, which must decode the interference signal before subtracting it from the total received signal at the codeword level [10]. This decoding restriction imposes a fundamental tradeoff in the studied system since the interfering base station must constrain its transmission rate to a value supported by the interfering link. Both to keep the complexity of the scheme low and minimize the constraints in the system, we propose the case of decoding and cancellation only the intense interferer (II). Therefore, we recommend CWIC-II receiver. SIC receivers generally begin to cancel interference from the largest interfering signal. That is, here, the CWIC receiver used by the UE1 first detects in the first step the interference signal from the *UE4*, and in the second step the interference signal from the *UE3*, and at the last stage, the interference signal entered by the second user, and cancels them respectively. Therefore, the designed receiver performs only one cancellation step. Fig. 2(b) clearly shows the block diagram of the CWIC-II receiver. This means that *UE1* only detects and cancels interference signal *UE4*. Generally, in the proposed method in *UE1*, the received weight matrix is obtained by means of equation (17):

$$W_{Rx,II} = \left(\hat{H}_{II}^{H}\hat{H}_{II} + \hat{H}_{i}^{H}\hat{H}_{i} + \delta^{2} I\right)^{-1}\hat{H}_{II}^{H}, \qquad (17)$$

And the vector of the *UE* symbol is interfered as in (18):

$$S_{rep,II} = \left(W_{Rx,II}\right)Y_{i}, \qquad (18)$$

Finally, the vector of the received signal will be in the form of:

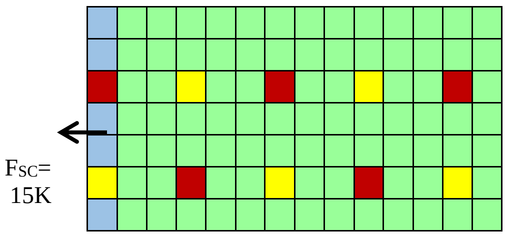
$$Y_{C,i} = Y_{i} - \hat{H}\sqrt{P_{II}}\,W_{Tx,II}X_{rep,II}, \qquad (19)$$

In the CWIC-II receiver after removal of the largest interference, after obtaining the vector $Y_{C,i}$, decoding and modulation are done and the binary signal is generated. In addition, when transmitting the LTE-TM3 open loop MU-MIMO loop, the SFBC (space-frequency block coding) frequency encoding block is applied. The SFBC encodes the same data in different ways and increases SNR in order to obtain the transmission diversity, as well as the Cyclic Delay Diversity (CDD). We will further evaluate the performance of the CWIC and CWIC-II receiver.

3. SIMULATION EVALUATION

A: Simulation evaluations

Simulations at the link level are performed to evaluate the performance of both the CWIC and CWIC-II receivers. Fig. 3 shows the structure of the radio frame that used in this scenario. The radio frame structure is based on LTE release 8 specifications [11]. Assumptions of Simulation is given in Table I. the bandwidth which is applied in this system is 20 MHZ and the number of subcarriers of OFDM is 1200. Separation of the subcarriers 15 kHz is considered as noted previously, the data information is the binary trail, and at the transmitter, data is turbo encoded. The modulation scheme applied is QPSK and 16QAM. For this reason, in this scenario, the UE needs less feedback on channel status. The LTE TM3 transmission design is used for the resultant signal trail of any UE. The third mode, open loop space multiplexing is also referred to as cyclic delay diversity.



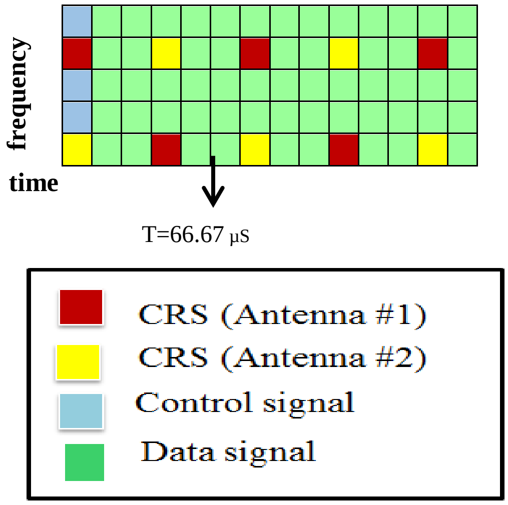


Fig. 3. Radio frame structure.

After the inset of CRS, the signal trail is changed to the OFDM symbol and duration of the symbol is 66.67 μs, then insertion a cyclic prefix (CP) with the duration of 4.69 μs.

The number of multiplexing UEs is four. At the receiver, after receiving the signal, the cyclic prefix is detected and then deleted. The received signal by using the FFT is demultiplexed to each subcarrier component.

Table 1. SIMULATION ASSUMPTIONS

Number of transmitter antenna	2
Number of UE	4
Radius cell	100 m
Symbol duration	Effective data: 66.67 μs + CP: 4.69 μs
Sub frame length	1.0 ms
Subcarrier separation	15 kHz
Number of subcarriers	1200
System bandwidth	20 MHz
Channel coding / decoding	Turbo coding (Constraint length: 4 bits) / Max-Log-MAP decoding (6 iterations)
Receiver type	CWIC and CWIC-II
Channel model	Exponentially decaying 6-path Rayleigh fading

The signal demodulated in order to detect interference is entered in block MMSE. Finally, by using the max-log-map algorithm with six repeats, the trails of likelihood values are turbo decoded and recover the transmitted binary data. The channel model is in accordance with Table I. where the relative path power is decayed by 2dB, the root means squared (RMS) delay spread value of 0.29µs. the maximum of Doppler frequency is considered for Rayleigh fading any path, is 10 HZ. The simulation assumptions in this paper are in accordance with [4] and [12].

The CWIC and CWIC-II receivers only apply to cell-center users and the cell-edge user does not apply the SIC.

4. SIMULATION RESULTS

Figs. (4), (5), (6), (7) show Link-level performance evaluation of the CWIC and CWIC-II receivers for four parameters.

In Fig. (4), the output SINR vs. received SNR for cell-center UEs it has been shown. Obviously, by canceling only the intense interfere signal, the SINR rate decreases and the quality of transmission is reduced. According to users in this scenario and according to Fig. (4), there is no significant decrease in the SINR values for CWIC-II applications compared to the CWIC receiver. As shown in Fig. (4), in SNR=15dB, SINR of CWIC is 17 dB and SINR of CWIC-II is equal to 15.5 dB. In SNR=30 dB, it can be seen that SINR of CWIC is 25 dB and SINR of CWIC-II is 21 dB. Fig. (5) shows the diagram of throughput versus SNR for cell center UEs. As shown in Fig. (5), where SNR is 15 dB rate of throughput in CWIC is 6.5 Mbps and in CWIC-II is 14.5 Mbps. When SNR is equal to 30 dB, throughput rate for CWIC is 13 Mbps and for CWIC-II is equal to 18.7 Mbps. It is clear that the throughput rate for CWIC-II is higher than CWIC.

In Fig. (6), we show the bit error rates for cell center *UEs* for CWIC and CWIC-II receivers. As shown in this figure, the bit error rate (BER) in the CWIC receiver is lower than the CWIC-II which is better. This is obvious because the CWIC receiver cancels all interferences, but the CWIC-II only cancels the intense interference, which can increase the bit error rate. Fig. (7) shows packet delay versus the number of active users employing CWIC or CWIC-II receivers. According to the figure, when two users are simultaneously active, the packet delay for the CWIC is 0.26 seconds and for the CWIC-II is 0.14 seconds, and when 4 users are simultaneously active, the packet delay for the CWIC is 0.43 seconds and for the CWIC-II is 0.25 seconds. These results are achieved when three cell-center *UEs* applied SIC receiver and the cell-edge *UE* (*UE #4*) does not use successive interference cancellation. The cell-edge UE only demodulation and decoding are used to the received signal *Y4* and, this means that the cell-edge treat with interference signal like noise.

As can be seen, CWIC shows higher delay than CWIC-II. This means that the removal of only the most powerful interfering signal has a significant effect in reducing the delay. Because the CWIC receiver needs to spend more time to cancel all interferences, but in CWIC-II there is only one step to cancel the interference.

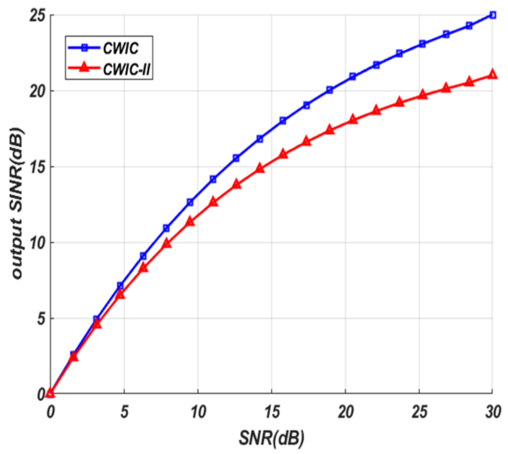


Fig.4. output SINR for cell-center *UE* (dB).

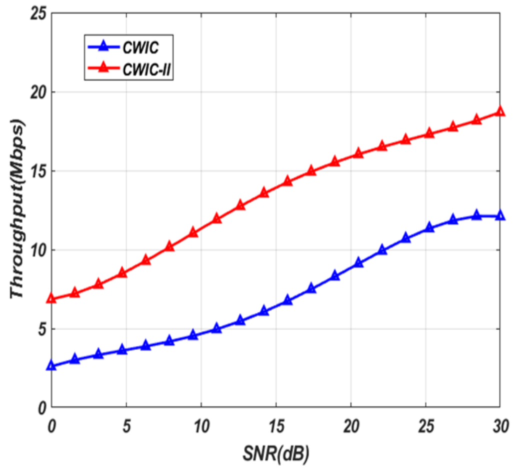


Fig. 5. Throughput performance for cell center *UE* (Mbps)

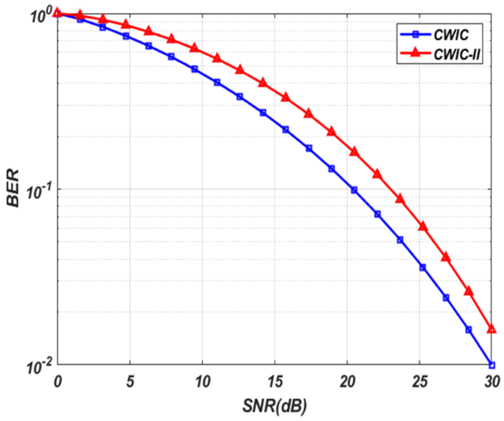


Fig. 6. BER performance for cell center UE.

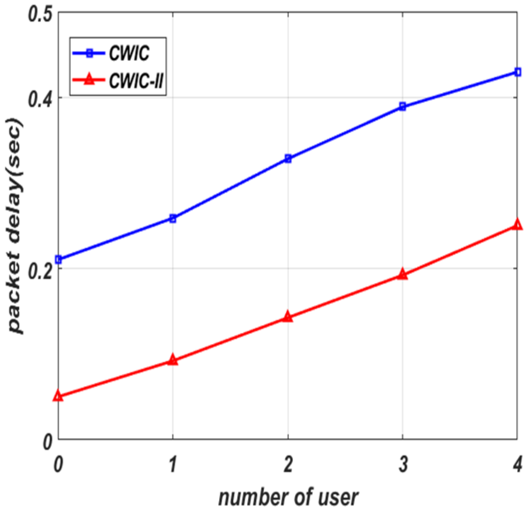


Fig. 7. packet delay

5. CONCLUSION

We showed using simulation that the receiver of the CWIC-II has achieved its goal of reducing the complexity of the receiver structure to simplify decoding steps and decrease network overhead. Therefore, as with all proposed plans and scenarios along with the benefits, there are some disadvantages such as lowering SINR and raising BER.

For this scenario, there is only one user on the edge of the cell. Therefore, in order to overcome the disadvantages in more user scenarios, it is suggested that the CWIC receiver be designed to cancel all interference signals from the cell-edge *UEs*, or consider a threshold for SINR, meaning that *UEs* will have the potential to cancel interference when their SINR outputs are reduced to a desired value.

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