Comparative Analysis of BER performance of IDMA with OFDM-IDMA

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Abstract:

The popular OFDM(Orthogonal frequency division multiplexing)-CDMA(Code division multiple access)scheme also referred as MC-CDMA scheme is a spread-spectrum transmission technique introduced in 1993 by researchers. Moreover, OFDM-CDMA is considered to be a promising candidate for the air interface of the fourth generation (4G) wireless communication systems.In the thesis, initially the basic principles of OFDM-IDMA transmitter and receiver have been presented. Later, comparative studies between tree based interleaver and random interleaver with OFDM-IDMA scheme has been carried out. In addition to it, the simulation of OFDM-IDMA scheme has also been done in various other conditions demonstrating its effectiveness in the performance. Thanks to the independent processing of ISI and MAI, OFDM-IDMA offers better performance than plain IDMA with LLRC in terms of both BER and complexity.

The comparative study of both the interleavers in OFDM-IDMA scheme environment provides a conclusion regarding upper hand of tree based interleaver over random interleaver. It also confirms claim of tree based interleaver to be optimal one for its utilization in OFDM-IDMA scheme for future high-rate multiuser communications over multipath fading channels in various wireless communication environments.

Keywords:-OFDM,CDMA,IDMA,Wireless Communication.

I Introduction:

The IDMA receiver complexity over multi-path channels is related to the channel length. Recently, OFDM-IDMA was proposed as an alternative to plain IDMA over multi-path channels. OFDM-IDMA inherits most of the merits of OFDM and IDMA. The key advantage of OFDM-IDMA is that MUD can be realized efficiently with complexity per user independent of the channel length and the number of users, which is significantly lower than that of other alternatives.
The OFDM-IDMA scheme presented in combines most of the advantages of the multiple access schemes mentioned above (such as OFDMA, CDMA, OFDM-CDMA, and IDMA) and avoids their individual disadvantages. With OFDM-IDMA, ISI is resolved by an OFDM layer and MAI is suppressed by an IDMA layer, both at low cost. With these two main obstacles removed, OFDM-IDMA offers many attractive features including

• The achievable throughput of OFDM-IDMA is considerably higher than that reported for CDMA and OFDM-CDMA in the literature.

• If the entire bandwidth resource in a cell can be allocated to a single user, OFDM-IDMA can achieve a very high single-user throughput using a superposition coding technique. This property is crucial for packet mode transmission. It is difficult to achieve very high single- user throughput with the existing CDMA or OFDM-CDMA techniques.

• The power efficiency of OFDM-IDMA can be greatly enhanced by use of an unequal power control strategy inherited from IDMA.

• In fading environments, OFDM-IDMA can offer the so-called multi-user gain which is an interesting concept from information theory. The power efficiency of OFDM-IDMA is potentially much higher than that of orthogonal schemes such as FDMA, TDMA, or OFDMA. The difference can be very significant at high rates.

II. OFDM (Orthogonal Frequency Division Multiplexing)

OFDM is a combination of modulation and multiplexing. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier.

OFDM is especially suitable for high-speed communication due to its resistance to ISI. As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. Since the delay time caused by multipath remains constant, ISI becomes a limitation in high-data-rate communication. OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, Figure 2 shows two ways to transmit the same four pieces of binary data.

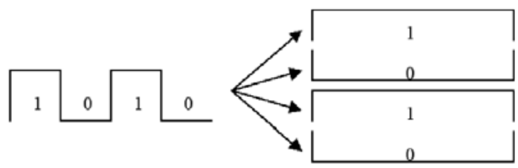

Figure 2: Traditional vs. OFDM Communication

Suppose that this transmission takes four seconds. Then, each piece of data in the left picture has duration of one second. On the other hand, OFDM would send the four pieces simultaneously as shown on the right. In this case, each piece of data has duration of four seconds. This longer duration leads to fewer problems with ISI. Another reason to consider OFDM is low-complexity implementation for high-speed systems compared to traditional single carrier techniques.

III. IDMA (Interleave Division Multiple Access)

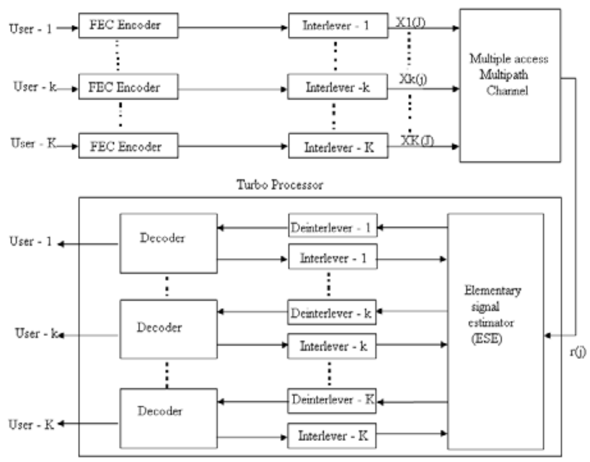

Figure 3: IDMA transmitter and receiver structures

IDMA is one such alternate and highly effective approach that retains most of the positive features of CDMA without spreaders. In this scheme interleavers are employed to distinguish signals from different usersThe upper part of the figure shows the transmitter structure of multiple access schemes under consideration with N simultaneous users. The input data sequence dn of user of user n is encoded generating a coded sequence cn = [cn (1), cn (2),….cn (j),.... cn (J)]T, where J is the frame length. The elements of cn are referred to as coded bits. cn is now permutated by an interleaver to produce xn = [xn (1), xn (2),….. xn (j),….. xn (J)]T . The interleavers for all the users should have following three distinguishing properties, first they should be different for different users, second they should be generated independently and third they should be generated randomly. The interleavers should disperse the coded sequence such that adjacent hips are uncorrelated and the chip-by-chip detection can thus be done.

The figure 3 is a special case in which signature spreading sequence have been reduced to a single chip, thus making spreader and correlator trivial. It is assumed that all the encoders are identical with rate R with total throughput of the system as NxR information bits per chip. Each user is assigned a unique sequence of interleaving indexes. This can be considered as a special case of CDMA where each uniquely interleaved version of a code is a different code.There is an elementary signal estimator (ESE) and K single user a posteriori probability (APP) decoders. The multiple access and coding constraints are considered separately in the ESE and DECs. The outputs of the ESE and DECs are log-likelihood ratios (LLRs) about {xn (j)} defined below

$e(x_n(j)) = \log(\Pr(x_n(j)=+1)/\Pr(x_n(j)=+1))$ for all n, j.

The proposed IDMA scheme is thus aimed at achieving high spectral efficiency and improving performance with low receiver complexity while inheriting many advantages from CDMA, in particular dynamic channel sharing, high flexibility in transmission rates, soft handoff and diversity against fading.

IV. OFDM-IDMA(Orthogonal Frequency Division Multiplexing – Interleave Division Multiple Access

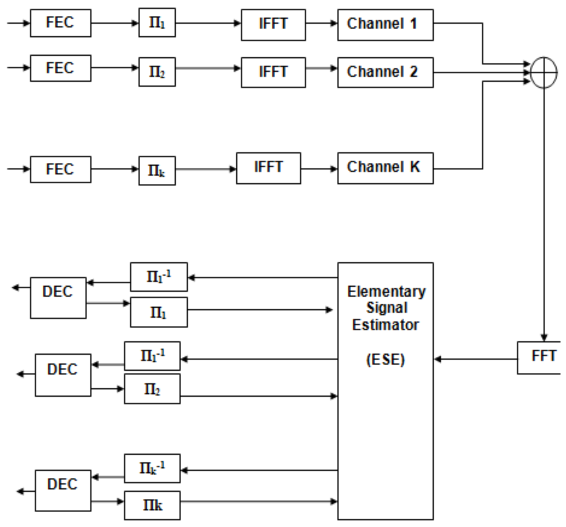

Figure 4: Transmitter and receiver structures of the OFDM-IDMA scheme with K Simultaneous users, where Πk is the interleaver of user-k.

The coded signals are first interleaved by user-specific interleavers {p*k*}. Then the resultant signals, again denoted by {*xk*(*n*)}, are modulated onto subcarriers by using IDFT. Each subcarrier can be occupied by several users, so users are solely distinguished by their interleavers.

Let *dk*be the data stream of user-*k*. This data stream is encoded by a forward error correction (FEC) code, generating a chip sequence *ck*. (Here, "chip" is used instead of "bit" as the FEC encoding may include spreading or repetition coding.) Then *ck* is permutated by a user-specific interleaver-*k*. After symbol mapping, the symbol sequence *xk*= [*xk*(1)*; ¢ ¢ ¢ ; xk*(*j*)*; ¢ ¢ ¢ ; xk*(*J*)]*T* is produced, where *J* is the frame length. Then these symbols are modulated onto different subcarriers by IFFT.
Consider QPSK signaling

$$x_k(j) = x_k^{Re}(j) + ix_k^{Im}(j).$$

After OFDM modulation, the transmitted sequence can be expressed as *vk*= W*Hxk*. (*xk*26
is divided into blocks with length of *Nc*for OFDM transmission, where *Nc*is the number of subcarriers.) W is DFT matrix and the superscript "*H*" indicates Hermite transpose. The (*m; n*)-th entry of W is

$$\mathbf{W}[m,n] = \frac{1}{\sqrt{N_c}} e^{-i2\pi mn/N_c}.$$

We assume an *L*-path channel model with fading coefficients *hk*= [*hk*(0)*; hk*(1)*; ¢ ¢ ¢ ; hk*
(*L ¡* 1)] for user-*k*. The output of multipath channel can be written as

$$y = \sum_k y_k + z = \sum_k h_k * v_k + z$$

where ¤ denotes the convolution and the elements of z are samples of additive noise.At the receiver side, OFDM demodulation is carried out before iterative MUD processas show in lower half of Fig. 7. Assuming that the duration of cyclic prefix is longerthan the maximum channel delay, the received signal after OFDM demodulation can be expressedaThen the CBC detection algorithm for complex single-path channel can be applied[31]. The main difference between the detection process described in Section 2.4 anddetection algorithm proposed here is that the fading coefficients of OFDM subcarriers*fHk*(*j*)*g* are different for different *j* in a frequency selective channel in the OFDMIDMA scheme, while in Section 2.4 we consider multipath quasi-static fading channelsand the fading coefficients *fhk*(*l*)*g* are identical for all chips of user-*k* during one frame.
(*l*is the path index.)

The optimized OFDM-IDMA scheme possesses several attractive properties, including
• Very high spectral efficiency
• Flexibility in multi-user as well as single-user mode transmission,
• Multi-user gain in fading channels

V.Simulations and Results (BER vs. Eb /No):

We have illustrated the data transmission and reception through MATLAB. Firstly we have taken digital data then we have used functions for FFT, IFFT corresponding to each block of ODDM trans-receiver. Then at output we are getting almost the same input.

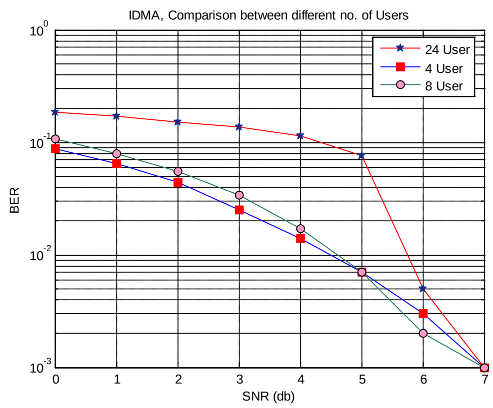

Figure 5: IDMA (Without Coding), BER vs. Eb /No (db) Comparison between different numbers of Users with Random Interleaver.

Data Length -1024
Spread Length -16
Iteration -30

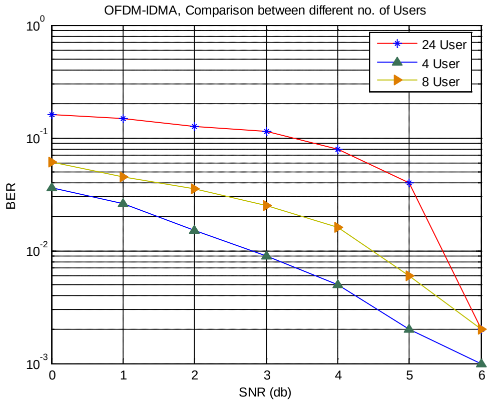

Figure 6: IDMA (With Coding), BER vs. Eb /No (db) Comparison between different numbers of Users with Random Interleaver.

Data Length -1024
Spread Length -16
Iteration -30

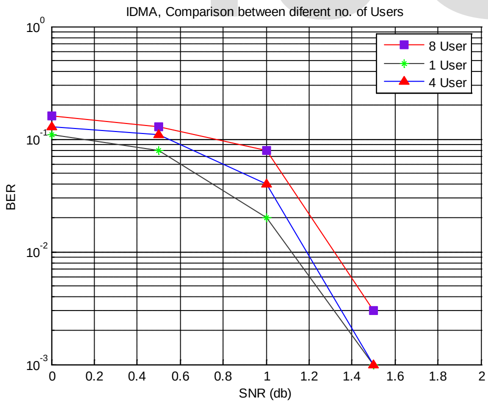

Figure 7: OFDM-IDMA (Without Coding), BER vs. Eb /No (db) Comparison between different numbers of Users with Random Interleaver.

Data Length -1024
Spread Length -16
Iteration -30

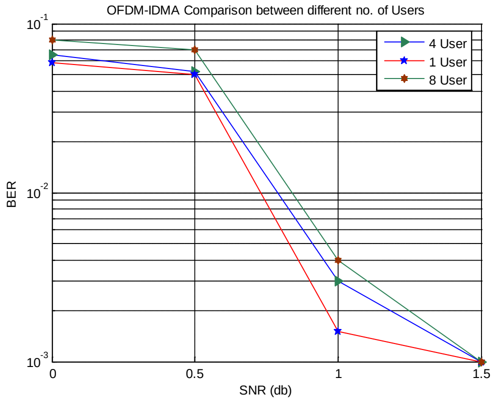

Figure 8:- OFDM-IDMA (With Coding), BER vs. Eb /No (db) Comparison between different numbers of Users with Random Interleaver.

Data Length -1024
Spread Length -16
Iteration -30

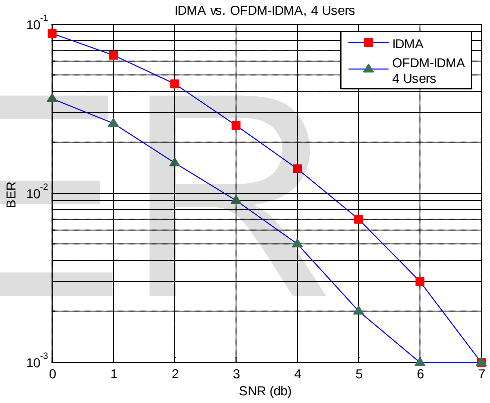

Figure 9: IDMA vs. OFDM-IDMA Comparison for 4 Users (without Coding)

Data Length -1024
Spread Length -16
Iteration -30

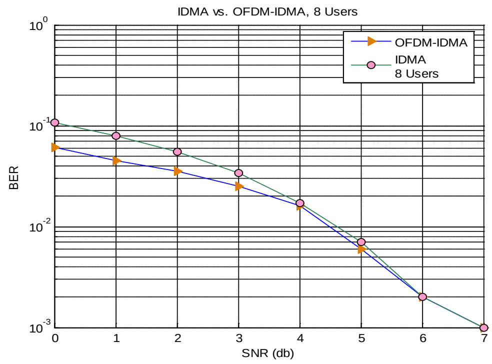

Figure 10: IDMA vs. OFDM-IDMA Comparison for 8 Users (without Coding)

Data Length -1024
Spread Length -16
Iteration -30

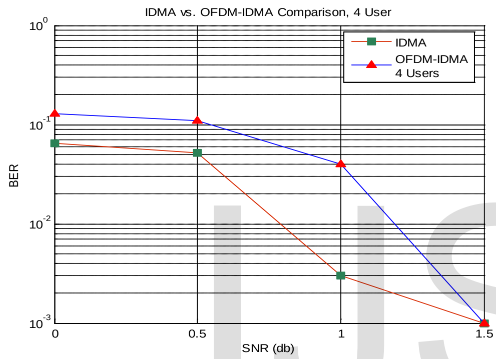

Figure 11: IDMA vs. OFDM-IDMA comparison for 4 User (with Coding)
Data Length -1024
Spread Length -16
Iteration -30

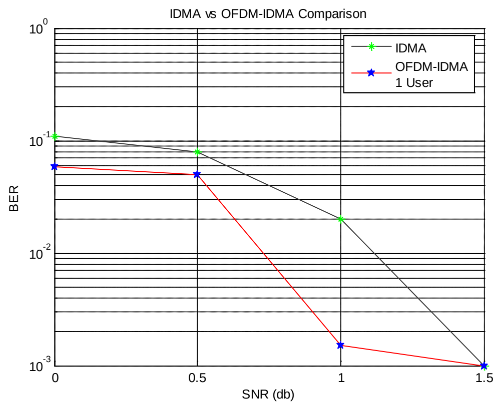

Figure 12: IDMA vs. OFDM-IDMA comparison for single User (with Coding)
Data Length -1024
Spread Length -16
Iteration -30

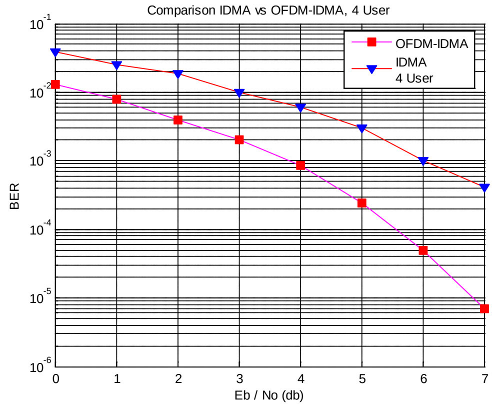

Figure 13: IDMA vs. OFDM-IDMA comparison for 4 Users with Tree-Based Interleaver.
Data Length -1024
Spread Length -16
Iteration -30

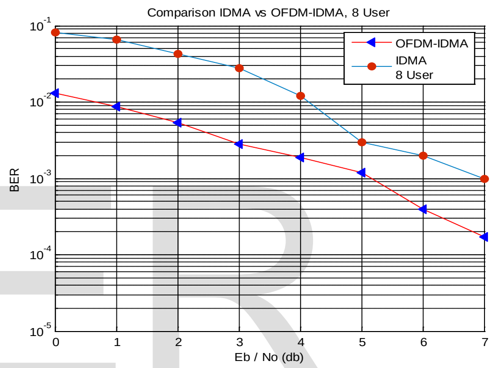

Figure 14 IDMA vs. OFDM-IDMA comparison for 8 Users with Tree-Based Interleaver.
Data Length -1024
Spread Length -16
Iteration -30

VI. Conclusion:

The OFDM-IDMA scheme combines the advantages of both OFDM and IDMA and provides effective solutions to ISI and MAI problems. With sufficient guard intervals, OFDM can completely remove ISI. IDMA together with CBC iterative multiuser detection algorithm can overcome both intra-cell and cross-cell MAI problems efficiently.

Comparative studies between OFDM-IDMA and IDMA have shown that OFDM-IDMA outperforms IDMA in terms of BER performance mainly thanks to the effective CBC detection algorithm. We have carried out comparisons between OFDM-IDMA and IDMA with LLRC in multipath fading channels. Since OFDM operation prevents ISI, OFDM-IDMA avoids the joint cancellation of ISI and MAI, which reduces processing burden of CBC multiuser detector. Simulation results show that

OFDM-IDMA surpasses IDMA with LLRC in terms of BER performance. The complexity of ESE part for IDMA with LLRC is approximately L times of that for OFDM-IDMA.

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