IDMA based Communication for Next Generation (4G)

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ABSTRACT
This paper outlines the operational concepts of recently proposed Interleaved Division Multiple Access (IDMA) scheme. Some interesting features of Interleaved Division Multiple Access (IDMA) over conventional Code Division Multiple Access (CDMA) are explained including its performance, simple receiver structure as well as spectral efficiency. The basic principle of IDMA is that interleaver is different for each user whereas CDMA employs different signatures. IDMA inherits many advantages of CDMA such as robust against fading, easy cell planning and dynamic channel sharing. Further IDMA increase the spectral efficiency and reduce the receiver complexity.

General Terms
Spectral efficiency, PN Sequences

Keywords: **IDMA, CDMA, Interleaver, Digital signatures**

1. INTRODUCTION
In modern wireless communication systems, the ultimate objective is to enhance the Throughput of an overall system. It may be done by employing following process,

- Increasing the Effective Isotropic Radiated power (EIRP)
- Using more spectrums.
- Reducing system losses.
- Efficient utilization of channel resources.

Of these, increasing EIRP and Bandwidth costs high to the service provider but by using effective multiple access techniques we can gain Throughput by using simple receiver. Hence many researches mainly focus on various multiple access techniques since the origin of multi user communication. Based on the working principle the access techniques can be classified into two categories,

- Conflict free Multiple Access Techniques
- Contention based Multiple Access Techniques.

The Contention based Multiple Access Techniques includes Carrier Sense Multiple Access (CSMA), ALOHA.etc. Contention based Multiple Access Techniques covers three most commonly used access methods Frequency Division Multiple Access

(FDMA), Time Division Multiple Access (TDMA), Code Division multiple access (CDMA), Space Division Multiple Access (SDMA), Polarization Division Multiple Access (PDMA)...etc [7].

First Generation (1G) communication used analogue AMPS, TACS etc. which are mainly for voice communication with low data rates with circuit switching. Second Generation (2G) use digital GSM, CDMA (IS-54, 95,136), DECT etc for voice and data communication with packet switching Presently (3G) techniques are advanced CDMA (cdma2000, W-cdma) [8] are used for broadband applications with high data rate.. Beyond 3G (B3G) we need better technique with simple receiver structure which should also mitigates multiple access Interference (MAI) and Intersymbol Interference (ISI) which is infeasible in present W-CDMA [1]. We can mitigate such interferences which lead to complex receiver and high cost.

Aaccording to various researches, it may be achieved by using Orthogonal Frequency multiple access (OFDMA) where multiple carriers are used for user separation or Interleaved Division multiple access (IDMA) where different interleavers are used for user separation. This work mainly focuses on IDMA [3].

2. CDMA VS IDMA

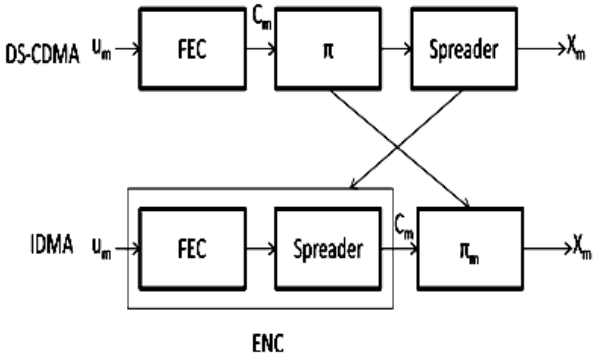

Fig 1. CDMA Vs IDMA

IDMA is special form of CDMA in which different interleavers are used for user separation. In CDMA encoding and spreading are done separately but in IDMA both operations are combined as shown in Figure 1.

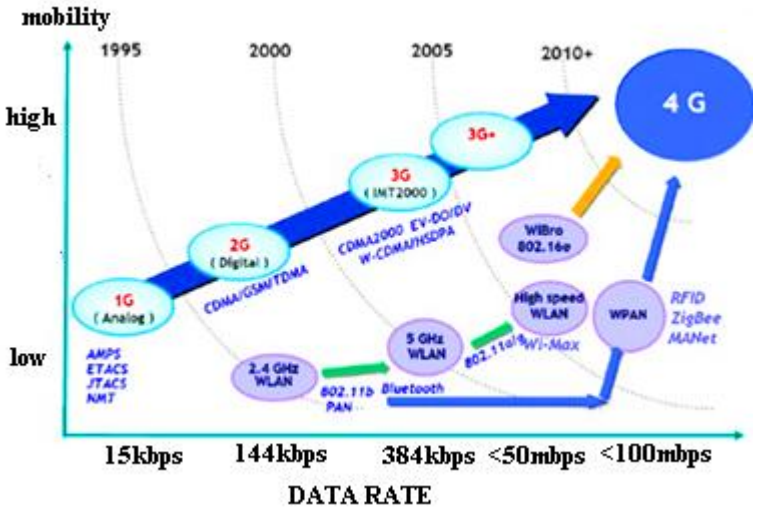

Fig 2. Evolution of wireless communication

The main difference between CDMA and IDMA is simple as shown in which user data is interleaved and then spread in CDMA whereas in IDMA the data is spread first and then it is interleaved with different interleaver for different user.

The CDMA technique use different signature (sequence) for user separation in a multiuser environment whereas in Interleaved Division multiple access (IDMA) different interleavers are used for user separation. Further the process of forward error control coding (FEC) and spreading are combined which is done separately in CDMA [1]. In the receiver side correlator with matched filter has been used.

3. PERFORMANCE OF CDMA

The efficiency of CDMA system is non linear with user number. The effect of increasing user number is shown in Figure 3. It is totally dependent on length of the PN sequence and user number. Though the conventional CDMA provides many advantageous like diversity against fading, ease of cell planning, secure data transmission.etc it is limited by Multiple access Interference (MAI) and Intersympol Interference (ISI) [1]. Hence when number of user increases the BER performance also increased as in fig2. Which is simulated for input sequence of length 5 for 31 user. The main limitation in CDMA is that it involves separate coding and spreading operations. But to achieve Multiple Access Channel (MAC) Capacity the entire Bandwidth expansion is devoted to coding gain. Hence we have to use low rate code to maximize coding gain. This can be overcome in IDMA by repetition code. To mitigate MAI and ISI, turbo type iterative MUD (Multi User Detection has been introduced which increases the receiver complexity [7].

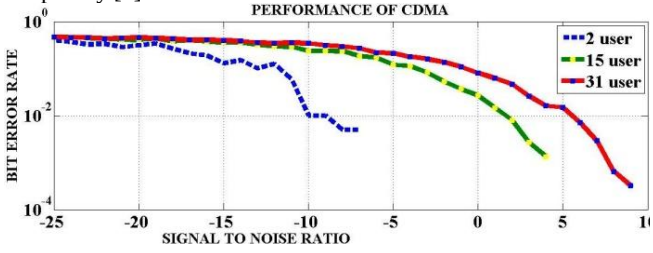

Fig 3. CDMA Performance

4. IDMA SYSTEMS

4.1 IDMA transmitter

The IDMA transmitter system is shown in Figure 4 with K simultaneous user. the input data sequence d_k of length n is encoded with Repetition code having bit rate of 1/s and spreading sequence have length 'j' (j=1,2.....J) J=ns. The spreader sequence $C_k(j)$ is interleaved with interleaver $\pi_{k)}$ and get the signal x_k (j) represents the 'j^{th}' bit of 'k^{th}' user. Hence the data is transmitted to Multiple Access Channel (MAC).

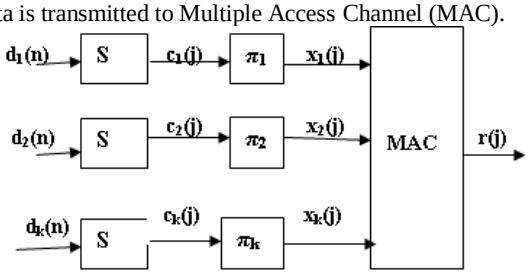

Fig 4. IDMA Transmitter

The key principle of IDMA is that the interleaver (π_k) should be generated independently and randomly. These interleavers disperse the coded sequences so that the adjacent chips are approximately uncorrelated, which facilitates the simple chip by chip detection scheme to be discussed. For a input data (d_k) of length 'n' and FEC code rate 's'. The spread sequence ($c_k(j)$) must have length 'j' where j=ns. The spread sequence is then interleaved with interleaver (π) of length 'j'. The interleaved data is transmitted through Multiple Access Channel (MAC).

4.2 Interleaver

Interleaving is a technique commonly used in communication systems to overcome channel noise such as burst error or fading. The interleaver rearranges input data such that consecutive data are spaced apart. At the receiver end, the interleaved data is arranged back into the original sequence by the de-interleaver. As a result of interleaving, correlated noise introduced in the transmission channel appears to be statistically independent at the receiver and thus allows better error correction. But in IDMA interleaver are mainly used for user separation. The analysis on various interleaver are done in [15] as shown in Figure 5.

In this paper we use Random interleaver for user separation because the interleaver should be independent and random.

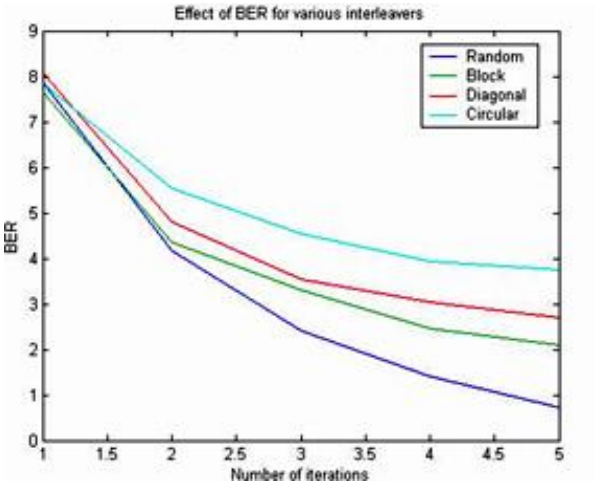

Figure 5. Comparison of various interleavers

4.3 IDMA Receiver Structure

The received signal (r(j)) over AWGN channel for 'K' user is written as,

$$r(j) = \sum h_k x_k(j) + n(j) \quad , \qquad j=1,2.....J$$

Where h_k is the channel coefficient for user k and {n(j)} are samples of an AWGN with variance $N_0/2$. We assume that channel coefficients (h_k) are known a priori at the receiver.

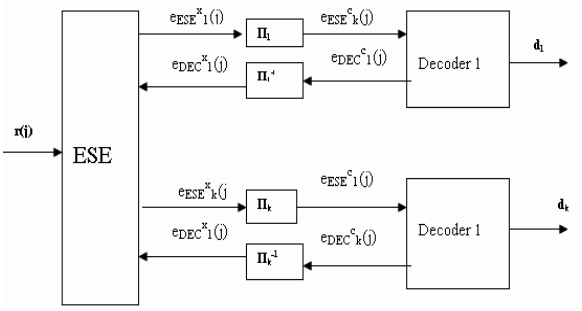

Fig 4 IDMA Receiver

The receiver consists of an Elementary Signal Estimator (ESE) and a posteriori probability (APP) decoders (DECs). The received signal r(j) which is to be deinterleaved and decoded with appropriate interleaver. For any receiver it is complex to retrieve the transmitted information by using various Multi User Detection (MUD) algorithms. In this IDMA receiver Elementary Signal Estimation (ESE) is used as detection algorithm

The ESE function is done as follows,

1. Initialize $e_{DEC}(x_k(j)) = 0$
2. Set $E(x_k(j)) = \tanh(e_{DEC}(x_k(j))/2)$
3. $\mathrm{Var}(x_k(j)) = 1 - (E(x(j)))^2$.
4. Find $E(r(j) = \sum h_{k'} E(x_{k'}(j))$
5. Next find variance as,

$$\mathrm{Var}(r(j)) \Leftarrow \sum_{k'=1}^{K} |h_{k'}|^2 \mathrm{Var}(x_{k'}(j)) + \sigma^2$$

6.Finally find ESE function as,

$$e_{ESE}(x_k(j)) \Leftarrow 2h_k \cdot \frac{r(j) - \mathrm{E}(r(j)) + h_k \mathrm{E}(x_k(j))}{\mathrm{Var}(r(j)) - |h_k|^2 \mathrm{Var}(x_k(j))}$$

This is a simplified form of [7]. The detail study of ESE is in[7].The function is iterated for user defined number. During the turbo-type iterative process, the extrinsic information generated by the ESE is used (after de-interleaving) as the a priori information in the DECs, and vice versa.

5. SIMULATION RESULTS

Figure shows the performance comparison of CDMA and IDMA. CDMA system with PN sequence of length 5 and for 31 users is simulated for conventional (non-iterative) receiver. For IDMA system it is simulated for data length of 100 bits, repetitive code rate of 1/4 and for 3 iterations in turbo type receiver.

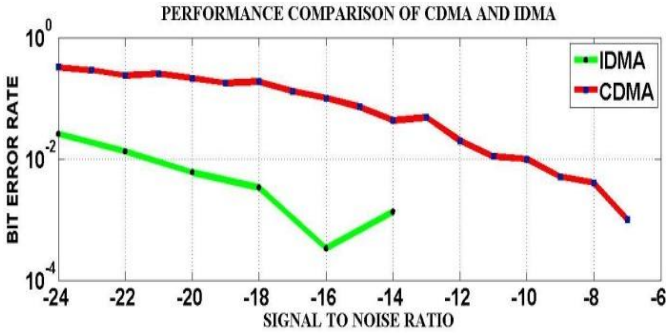

Figure 6. CDMA AND IDMA comparison

In a IDMA systems the interleaved data is again spreaded with PN sequence to get better Bit Error Rate (BER) performance which is called as Coded IDMA. The performance of coded and uncoded IDMA is shown in fig

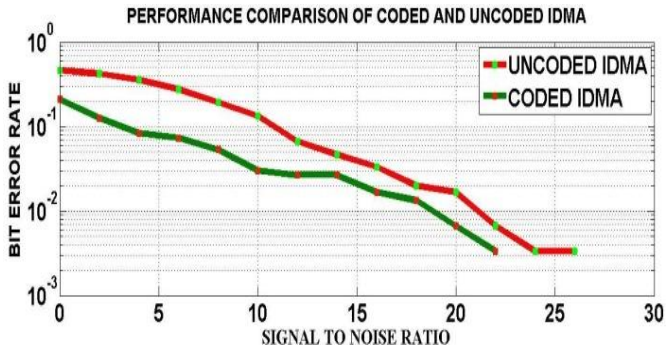

Figure 7.Comparison of Coded and Uncoded IDMA

6. CONCLUSIONS AND FUTURE WORK

From the simulations results it is inferred that increasing user number the BER also increased. The performance of CDMA and IDMA can be compared for unique number of user and data to get expected result, and the receiver structure can be modified with different Multi User Detection (MUD) algorithm. Further IDMA performance can be evaluated for various types of interleaver which plays vital role in IDMA.

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