Multiple Access Scheme for Future (4G) Communication: A Comparison Survey

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ABSTRACT
The demand for wireless broadband communication services has been growing steadily for last several years. Over the last two decades, wireless communications have gained enormous popularity in all over the world. It offers an attractive option for many personal as well as organizational communication requirements due to various parameters including cost, effectiveness, and mobility. The next generation mobile communication systems i.e. fourth generation (4G) are needed to support multiple services in different types of environments. 4G is being developed to accommodate the QoS (quality of service) and required data rate such as wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV. This paper focuses the light on various multiple access techniques proposed in 4G communication systems. Among all the multiple access (MA) techniques, it is attempted to demonstrate that IDMA (Interleave Division Multiple Access) technology can efficiently mitigate the interference among users and support high data rates without compromising the required quality of service.

Keywords:
CDMA, IDMA, Multiple access Interleavers, Multi user detection.

1. INTRODUCTION
With the tremendous increment in the users count and introduction of new features including web browsing. In the past few years, the request for bandwidth has started to surpass the availability in wireless networks. Different techniques have been studied to improve the bandwidth, efficiency and increase the number of users that can be accommodated within each cell [1].
The International Telecommunication Union (ITU) also defined recommendations for mobile communication system for fourth generation (4G).In these recommendations, data rates up to 100 Mbps for high mobility and up to 1 Gbps for low mobility or local wireless are predicted. Systems fulfilling these requirements are usually considered as fourth generation (4G) systems. But 3G systems provide data rate of around 3.6-7.2 Mbps. Existing multiple access techniques used in 1G/2G/3G systems (such as FDMA/TDMA/CDMA respectively) are basically suitable for voice communication only and unsuitable for high data rate transmission and burst data traffic which would be the dominant portion of traffic load in 4G system [1].

In modern communication system Code-Division-Multiple –Access (CDMA) has made its impact in wireless communication. It offers well known features such as dynamic channel sharing ,soft capacity, reuse factor of one, low dropout rate and large coverage (due to soft handover),ease of cellular planning, robustness to channel impairments and immunity against interference etc. These advantages are available due to spreading the information over a large bandwidth. The performance of conventional CDMA system is limited by multiple access interference (MAI) as well as Inter symbol Interference (ISI) [3]. Also, the complexity of CDMA multiuser detection has always been a serious concern for large no. of users. A 4G system is expected to provide a comprehensive and secure all possible solution where facilities such as IP telephony, ultra-broadband internet access, gaming services and streamed multimedia may be provide to users[1][3].

There are various numbers of multiple access techniques which are proposed for 4G system named as DS-CDMA (Direct Spread- Code Division Multiple Access), MC-CDMA (Multicarrier-CDMA), OFDMA (Orthogonal FDMA), IDMA (Interleave Division Multiple Access) etc. So, in section II introduction of all mentioned multiple access techniques are given. In section III comparative analysis of all M.A. techniques are discussed, and at the last in section IV conclusion is provided with the glimpse of future scope.

2. MULTIPLE ACCESS SCHEMES
2.1 CDMA
In Frequency Division Multiple Access (FDMA), the total system bandwidth is divided into frequency channels that are allocated to the users. In Time Division Multiple Access (TDMA), each frequency channel is divided into time slots and each user is allocated a time slot. But in CDMA each user
is assigned a unique code sequence that it uses to encode its information-bearing signal. The receiver, knowing the code sequences of the user, decodes a received signal after reception and recovers the original data. This is possible since the cross correlations between the code of the desired user and the codes of the other users are small. Since the bandwidth of the code signal is chosen to be much larger than the bandwidth of the information-bearing signal, the encoding process enlarges (spreads) the spectrum of the signal and is therefore also known as spread spectrum [3].

One of the main advantages of CDMA systems is the capability of using signals that arrive in the receivers with different time delays. This phenomenon is called multipath. FDMA and TDMA, which are narrow band systems, cannot discriminate between the multipath arrivals, and resort to equalization to mitigate the negative effects of multipath. But the performance of CDMA system is mainly limited by multiple access interference (MAI) and Inter symbol Interference (ISI) and it also does not provide much high data rate as user expect for the transmission. So, all these problems lead to the fourth generation (4G) system [3].

2.2 DS-CDMA

DS-CDMA is the most popular technique of CDMA techniques. The DS-CDMA transmitter multiplies each user's signal by a distinct code waveform. The detector receives a signal composed of the sum of all users' signals which overlap in time and frequency [1] [4].

DS-CDMA shows some advantages which are easy frequency planning, high immunity against interference if a high processing gain is used, flexible data rate adaption etc. But there are also some problems with DS-CDMA which are MAI and its receiver complexity. Basically as the number of simultaneously active user increases, performance of DS-CDMA decreases rapidly. Since, the capacity of DS-CDMA system with moderate processing gain (limited spread bandwidth) is limited by MAI, and in order to exploit all multipath diversity it is necessary to apply a matched filter approximated by a rake receiver with sufficient number of arms. This leads to additional receiver complexity with adaptive receiver filters and a considerable signaling overhead.

2.3 MC-CDMA

In DS spread spectrum transmission, the user data signal is multiplied by a code sequence. Mostly, binary sequences are used. The duration of an element in the code is called the chip time. The ratio between the user symbol time and the chip time is called the spread factor. DS-CDMA with a spread facto N can accommodate N simultaneous users only if highly complex interference cancellation techniques are used. In practice, this is difficult to implement.MC-CDMA can handle N simultaneous users with good BER (bit error rate) using standard receiver techniques. This is the main advantage of MC-CDMA over DS-CDMA [5].

Multi-Carrier Code Division Multiple Access (MC-CDMA) is a multiple access scheme used in OFDM based telecommunication systems, allowing the system to support multiple users at the same time.MC-CDMA spreads each user symbol in the frequency domain. That is, each user symbol is carried over multiple parallel subcarriers, but it is phase shifted (typically 0 or 180 degrees) according to a code value. The code values differ per subcarrier and per user. The receiver combines all subcarrier signals, by weighing these to compensate varying signal strengths and undo the code shift. The receiver can separate signals of different users, because these have different (e.g. orthogonal) code values.

However, MC-CDMA system suffers from high complexity in receiver and transmitter and the extreme requirement for changing the spreading codes at high rates which make the system impractical at high traffic.

2.4 OFDMA

OFDMA is an orthogonal multiple access scheme directly based on OFDM techniques, which is formed by dividing the available subcarriers in OFDM into non-overlapping subsets and assigning each user a unique subset. Some properties of OFDMA are listed below each subcarrier is occupied by at most one user [6]. Orthogonality among subcarriers can be maintained in multi-path channels provided that the cyclic prefix length is longer than the channel length. Clearly, this also guarantees the orthogonality among users. In practice, DFT and IDFT can be implemented using the fast Fourier transform (FFT) and its inverse IFFT with greatly reduced cost. Each coded bit is modulated onto a subcarrier by IFFT. All of the modulated sub-carries are transmitted in parallel. OFDMA also possesses some features such as- Bandwidth options 1.25,5,10 or 20 MHZ .Entire bandwidth is divided into 128, 512, 1024 or 2048 sub carriers 20 MHZ bandwidth with 2048 subcarriers has 9.8 MHZ spacing between subcarriers [6] [7].

Major advantages of OFDMA are-broadband signal experience frequency selective fading, BER performance is better only in fading environment, it allows different users to transmit over difficult portions of the broadcast spectrum(traffic channel).But there are also some problems in OFDMA which are the large amplitude variation increases in-band noise and increases the BER when the signal has to go through amplifier non-linearity's and there is tight synchronization between users are required for FFT in receiver.

So, this technique also required some improvement such as timing and frequency synchronization, efficient digital signal processing implementation of OFDMA etc. for the efficient processing of fourth generation (4G) [6].

2.5 IDMA

Various multiple access (MA) technologies have been proposed for broadband wireless networks to support multiservice transmissions over the shared wireless link. Extensive studies have been made on MA technologies such as time-division multiple-access (TDMA), frequency division multiple-access (FDMA), orthogonal-frequency division multiple-access (OFDMA) and code-division multiple-access (CDMA) [1]. However, as the demand for high data rate services grows in wireless networks, various challenging problems arise when the above-mentioned MA technologies are used. For orthogonal MA technologies such as TDMA, FDMA and OFDMA, the major problems include their sensitivity to inter-cell interference and frame synchronization requirement for maintaining orthogonality. For non-orthogonal MA technologies such as random waveform CDMA, although it mitigates inter cell interference and supports asynchronous transmission, the challenge is to combat intra-cell interference. So, there is a new technique known as IDMA (Interleave Division Multiple Access) which seems to be the solution

of all the problems of other techniques[8].

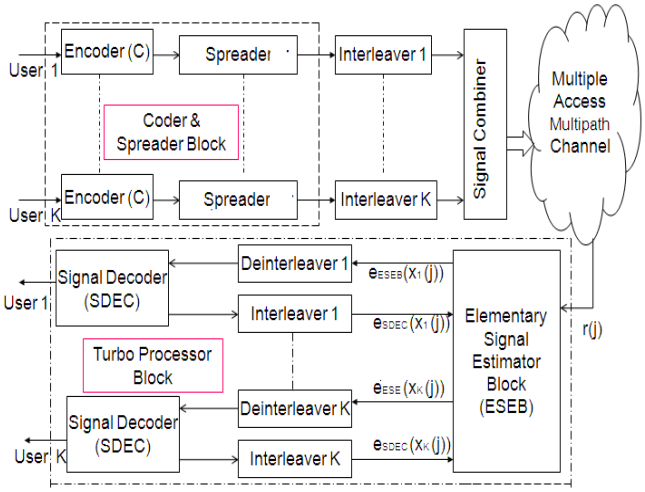

Figure 1. Transceiver structures of IDMA scheme With K simultaneous users.

Interleave-Division Multiple-Access (IDMA) is a recently proposed multi-access scheme, in which users are distinguished by different interleaving patterns. An interleaver is used as a component of a channel encoder to enhance the coding gain, or as a channel interleaver to combat the time/frequency coherent fading by scrambling burst errors into random errors. However, cell-specific interleaving can also be used to randomize the inter-cell interference.

Cell specific interleaving brings more robust performance than cell specific scrambling. The advantages of interleaving over scrambling seems very important for cell edge subscriber stations to receive broadcast services such as common signaling broadcasting because some advanced transmitting techniques for uni casting cannot be used for broadcasting [9]. The block diagram of IDMA scheme is shown in figure 1 for K users. The principle of iterative multi user detection (MUD) which is a promising technique for multiple access problems (MAI) is also illustrated in the lower part of Fig. 1. The turbo processor involves elementary signal estimator block (ESEB) and a bank of K decoders (SDECs). The ESEB partially resolves MAI without considering FEC coding. The outputs of the ESEB are then passed to the SDECs for further refinement using the FEC coding constraint through de-interleaving block. The SDECs outputs are fed back to the ESEB to improve its estimates in the next iteration with proper user specific interleaving. This iterative procedure is repeated a preset number of times (or terminated if a certain stopping criterion is fulfilled). After the final iteration, the SDECs produce hard decisions on the information bits [1]. The complexity involved (mainly for solving a size KxK correlation matrix) is O (K2) per user by the well-known iterative minimum mean square error (MMSE) technique in CDMA, while in IDMA, it is independent of user. This can be a major benefit when K is large.

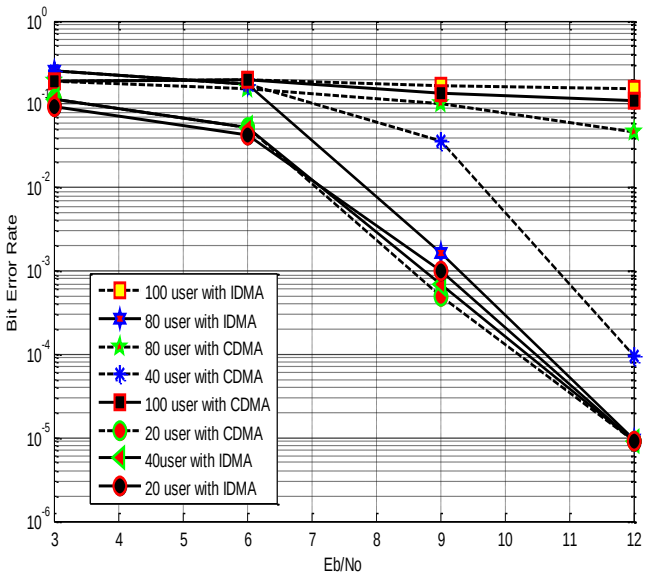

Figure 1:- Comparison between CDMA and IDMA

3. COMPARATIVE ANALYSIS

Important features of all named multiple access are compared IDMA have been compared with the existing MA technologies [Table 1]. With the existing CDMA, high data rates can be achieved by reducing spreading factor or adopting multi-code CDMA, but the former leads to reduced spreading gain against fading and interference, and the latter needs to overcome the interference among spreading sequences. In contrast, high data rate transmission can be achieved in IDMA systems by assigning the FEC codes with high coding rates.

Neglecting intra-cell interference at low computational cost the multiple access interference (MAI) is a major concern for both CDMA and IDMA cellular networks. The existing CDMA mitigates the MAI by multi-user detection (MUD). However, the high computational Cost involved in MUD which limits the high number of user- application in practical systems.

In contrast to CDMA, IDMA uses the iterative chip-by-chip (CBC) detection algorithm to combat intra-cell interference. The per-user computational complexity of the CBC is independent of the number of users involved. It achieves multi-user gain in the case of each user with a rate constraint. This means that given the same sum-rate, the more users in a system, the less average transmitted sum-power is required. The features of IDMA distinguished from the other MA techniques must be considered in MAC design for IDMA based networks. IDMA involves dynamic power control to improve link capacity and guarantee QoS for users [table 2].

So, IDMA can perform better for large number of users. It supports asynchronous transmission. The orthogonal MA technologies, such as time-division multiple-access (TDMA), frequency-division multiple-access (FDMA) and orthogonal-FDMA (OFDMA), require frame synchronization to maintain orthogonality. In IDMA networks, there is no sophisticated synchronization requirement on data transmission [table 1].

Parameters	TDMA	FDMA	OFDMA	CDMA	IDMA
Parameter which distinguish the users in single channel scenario	Time slot	Frequency	Orthogonal Frequency	Signature sequence	Interleaver
ISI elimination	Equalization	Cyclic prefix	Cyclic prefix	Rake receiver	Iterative CBC detection
Solutions to high single user rate	High order modulation	High order modulation	High order modulation	Multi code CDMA	Variable coding rate
Intra-cell interference cancellation	Not necessary	Not necessary	Not necessary	MUD	MUD
Inter-cell interference	Sensitive	Sensitive	Sensitive	Mitigated	Mitigated
Synchronization required	Yes	Yes	Yes	No	No

Table 1 Comparison between IDMA and Other Existing MA Technologies [9].

MAC Protocol	Resource allocation	Access method	QoS support	Priority Access
TD/CDMA based MDPRMA BB	Code slots are allocated according to traffic class and required traffic rate	Full sized slots contention	Data rate and relay	Different transmission probability
TD/CDMA based WISPER	Code slots are allocated according to required BER and traffic class	Piggy backed requests	BER and relay	Prioritized packet transmission
WCDMA	According to load, traffic class and rate	ALOHA, contention based request packets	BER and delay	Different transmission format
IDMA	Allocation of data rate and transmitted power with power control	Interleave division slotted-ALOHA contention based request packets	BER data rate and delay	Traffic class

Table 2 Comparisons between MAC Protocols of IDMA and CDMA [9].

4. CONCLUSIONS

In this paper, comparisons between different MA techniques have been made on the basis of parameters like user separation, inter and intra-cell interference cancellation, MAC protocols etc. Among all the comparisons discussed so far, the features of IDMA shows its suitability for the applications to support multimedia services in broadband wireless network for fourth generation communication. In fig 1 the comparison between CDMA and IDMA is also given to show the performance gain of this technique over CDMA. Hence it can be the representative for future communication services Although the performance IDMA technique is well suited for next generation, but still there are some challenging issues in this scheme such as interleaver design, coding scheme, channel behavior, optimum signaling scheme etc., in which research is going on in all over the world.

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