

A Comparison Survey of Multiple Access Scheme for upcoming 4G Communication

Digjaya Dhawan, Dhruv Jindal, Arushi Gupta, Priyanshi Gupta

Under the guidance of: Prof. Manikandan.K. SCOPE, VIT University Vellore

ABSTRACT

Ever since wireless broadband communication services were introduced, its demand has been growing constantly. Over the last twenty years, wireless communications have become popular all across the world. It provides an attractive option for many private as well as administrative communication requirements due to various attributes including cost, effectiveness, and agility. The new generation mobile communication systems i.e. fourth generation (4G) are required to support multiple services in various types of environments. 4G is being developed to accommodate the quality of service and essential data rate like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV. This paper throws light on numerous multiple access techniques anticipated in 4G communication systems. Among all the multiple access (MA) techniques, it is tried to demonstrate that IDMA (Interleave Division Multiple Access) technology can competently alleviate the interference among users and provision high data rates without compromising the quality of service that is required.

1. INTRODUCTION

With a rapid increment in the users count and introduction of new features like web browsing. In the past few years, the demand for bandwidth has started to surpass its availability in wireless networks. Different techniques have been modified

to increase the bandwidth, efficiency and the number of users that can be accommodated within each cell [1]. The International Telecommunication Union (ITU) also made recommendations for mobile communication system for fourth generation (4G). In these references, data rates up to 100 Mbps for high mobility and up to 1 Gbps for low agility or local wireless are expected. Systems fulfilling these requirements are usually fall under the category of fourth generation (4G) systems. However, 3G system provides data rates between 3.6 and 7.2 Mbps. Existing techniques used in 1G/2G/3G systems (such as FDMA/TDMA/CDMA respectively) are suitable for voice communications. However, for high data rate transmission and burst data traffic these techniques fail. High data rate transmission and burst data traffic would be the dominant portion of traffic density in 4G systems [1].

In modern communication system, Code-Division-Multiple-Access (CDMA) has made a strong impact in wireless communication. It provides well known features, dynamic channel sharing, soft capacity, lesser dropout rates and larger coverage, relaxation of cellular planning, robustness to channel defects and immunity against interference, to state a few. The information is spread over a large

bandwidth; hence it offers these advantages. The performance of conventional CDMA system is bound by multiple access interference (MAI) as well as Inter Symbol Interference (ISI) [3]. Also, the complexity of CDMA multiuser detection has always been a thoughtful apprehension for large no. of users. A 4G system is expected to provide an expansive and secure all possible solution where facilities such as IP telephony, ultra-broadband internet access, gaming services and streamed multimedia may be provided to the users [1][3]. There is a large number of multiple access techniques which are proposed for 4G system such as DS-SS (Direct Spread- CDMA), MC-SS (Multicarrier-SS), OFDM (Orthogonal), IDMA (Interleave) etc. In section II, an introduction to all the mentioned multiple access techniques are given. In section III, a comparative analysis of all M.A. techniques is discussed, and at last in section IV conclusion is provided with a just on future scope.

2. MULTIPLE ACCESS SCHEMES

2.1 CDMA

In FDMA, the total system bandwidth is divided into different frequency channels that are assigned to the users. In TDMA, every frequency channel is partitioned into time slots and every user is given a time slot. However, in CDMA each user is assigned a specific code sequence which is used to encode its information-bearing signal. The receiver, knows the code sequences and decodes a received

signal after reception and recovery the original data is performed. This is possible because of the cross correlations amongst the code of the preferred user and the codes of the other users are compact. Since the bandwidth of the code signal is much larger than the information-bearing one, the encoding process broadens (spreads) the spectrum of the signal and is also called spread spectrum [3].

CDMA systems have the capability of using signals which arrive in the receivers having variable time delays. This is one of the main advantages of CDMA systems. This phenomenon is known as multipath. FDMA and TDMA, which are narrow band systems, cannot distinguish between the multipath arrivals, and resort to equalization to alleviate the negative effects of multipath. But the performance of CDMA system is primarily bounded by the MAI and the ISI and it also does not render much high data rate as users require for the transmission. So, all these shortcomings lead to the fourth generation (4G) system [3].

2.2 DS-CDMA

DS-CDMA is the most sought after technique of CDMA techniques. The DS-CDMA transmitter proliferates each user's signal by a unique code waveform. The detector receives a signal possessed of the sum of all users' signals which overlay in time and frequency [1][4]. DS-CDMA shows some advantages such as easy frequency planning, high resistance against interference if a high processing gain is used, bendable data rate adaption etc. But there are also some complications with DS-CDMA which are MAI particularly its receiver's complexity. Basically as the number of concurrently active user increases, performance of DS-CDMA deteriorates rapidly. Since, the scope of DS-CDMA system with controlled processing gain (limited spread bandwidth) is bounded by MAI, and in order to exploit all multipath miscellany it is essential to apply a matched filter estimated by a rake receiver with adequate number of arms. This leads to added receiver complexity with adaptive receiver filters and a significant signalling overhead.

2.3 MC-CDMA

In DS spread spectrum broadcast, the user data signal is proliferated by a code sequence. Mostly, binary sequences are used. Chip time is the extent of an element in the code. The ratio between the user symbol time and the chip time is known as the spread factor. DS-CDMA with a spread factor N can house N concurrent users only if highly intricate interference withdrawal techniques are used. Practically it is difficult to implement. MC-CDMA can handle N concurrent users with good BER (bit error rate) using customary

receiver techniques. This is the key benefit of MC-CDMA over DS-CDMA [5]. Multi-Carrier CDMA (MC-CDMA) is a multiple access scheme which is used in OFDM based telecom system, allowing the systems to provision numerous users simultaneously. It spreads each symbol in the frequency sphere. That is, each user symbol is passed over multiple analogous subcarriers, but phase shifting is performed according to a code value. The code values vary per subcarrier and per user. The receiver chains all subcarrier signals, by weighing these to reimburse varying signal strengths and rectify the code shift. The receiver has the capability to isolate signals of different users, because these have different code values. However, MC-CDMA systems suffer from high complexity in receivers and transmitters and the extreme requisite for changing the scattering codes at high rates which make the system unrealistic at high traffic.

2.4 OFDMA

OFDMA is directly derived from OFDM methodology, which is formed by distributing the accessible subcarriers in OFDM into non-overlying subsets and allocating each user a unique subset. Some properties of OFDMA are stated below. Each subcarrier is occupied by at most one user at a particular time [6]. Orthogonality among subcarriers can be preserved in multi-path channels given that the cyclic prefix length is longer than the channel length. Clearly, this also promises the orthogonality among numerous users. Practically DFT and IDFT may be employed using the fast Fourier transform (FFT) and its inverse IFFT with a significant amount of reduced costs. All the modulated subcarriers are transmitted in parallel. OFDMA also has some features such as- Bandwidth options 1.25, 5, 10 or 20 MHz. Entire bandwidth is divided into sub carriers ranging between 128 1024, 2048 or 512 20 MHz bandwidth with 2048 subcarriers having 9.8 MHz spacing between subcarriers [6] [7]. Key advantages of OFDMA are- broadband signal experience frequency selective fading, BER performances are better only in diminishing environment, it permits different users to communicate over tough portions of the broadcast spectrum. But there are also some glitches in OFDMA, which are- the outsized amplitude variation leads to an increase in in-band noise and also amplifies the BER while the signal has to go through amplifier non-linearity's and tight harmonization between users required for. So, this technique also required some enhancement such as timing and frequency synchronization, optimum digital signal processing of OFDMA etc. for the competent processing of fourth generation (4G) [6].

2.5 IDMA

To support multiservice transmissions over the shared wireless link number of MA technologies have been proposed for broadband networks. MA technologies such as time-division multiple-access, frequency division multiple-access (FDMA), orthogonal-FDMA and lastly code-division multiple-access (CDMA) [1] have been studied extensively. Although, various challenging issues arise when the MA technologies are used, as the demand for high data rate services grows in wireless networks. For orthogonal MA technologies such as TDMA, FDMA and OFDMA, the major issue includes their sensitivity to inter-cell interference and frame synchronization essential for providing orthogonality. For non-orthogonal technology such as random waveform CDMA, however it mitigates inter cell interference and sustains asynchronous transmission, the question is to counter intra-cell interference. The solution seems to be a new technique known as IDMA (Interleave Division Multiple Access) [8].

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

Cell specific interleaving can bring more robust performance as compared to the other. The pros of interleaving over scrambling seem very obvious for cell edge subscriber station to receive broadcast services such as common signalling broadcasting as some advanced transmitting techniques for unicasting cannot be applied for broadcasting [9]. The diagram for IDMA is shown in figure 1 for K users. It also illustrates the rule of iterative multi-user detection (MUD) which is an efficient technique for multiple access problems (MAI). The turbo processor requires elementary signal estimator block (ESEB) and a bank of K decoders (SDECs). Without considering FEC coding the ESEB partially resolves MAI. The results of the ESEB are then input to the SDECs for additional refinement with the help of FEC coding constraint through de-interleaving block. The SDECs results are given back to the ESEB to improve its estimates in the next iteration along with proper user specific interleaving. For a pre-set number of times this iterative procedure is repeated (or terminated if a certain stopping criterion is fulfilled). Post the final iteration, the SDECs creates hard decisions on the information bits [1]. $O(K^2)$ complexity involved per user by

the iterative minimum mean square error (MMSE) technique in CDMA, while it is independent of user in IDMA, this can be a major advantage when K is large.

3. COMPARATIVE ANALYSIS

IDMA have been compared with the existing MA technologies along with essential features [Table 1]. High data rates can be achieved with the existing CDMA by reducing spreading factor or accepting multi-code CDMA, but the former leads to condensed spreading gain against fading and interference, and the latter requires to surpass the interference among spread sequence. In contrast, high data rate transmission can be achieved in IDMA systems by allocating the FEC codes with high coding rates.

Disregarding intra-cell interference at nominal computational cost the MAI is a major concern for not only CDMA but also IDMA cellular networks. The existing CDMA alleviates the MAI by multi-user detection (MUD). However, the large cost of computation involved in MUD which limits the large number of user- application in practical systems.

In contradiction to CDMA, IDMA uses the iterative chip-by-chip (CBC) detection algorithm to counter intra-cell interference. The per-user computational complexity of the CBC is not dependent of the number of various users involved. It achieves multi-user gain in the situation of each user with a rate constraint. This implies that given equal sum-rate, the more users in a system, the less mean transmitted sum-power is required. The properties of IDMA differentiated from other MA techniques must be taken into account in MAC design for IDMA based networks. IDMA provides dynamic control of power to improve link capacity and guarantee Quality of service for users [Table 2].

So, IDMA can comparatively perform better for good number of users. It sustains asynchronous transmission. The orthogonal MA technologies, such as TDMA, FDMA and O-FDMA need frame synchronization. In IDMA networks, there is no sophisticated harmonization necessity on data transmission [Table 1].

4. CONCLUSION

In this paper, on the grounds of various parameters such as user separation, inter and intra-cell interference cancellation, MAC protocols etc. differences between various MA techniques have been shown. IDMA shows its suitability for the applications to sustain multimedia services in wireless network among all the comparisons discussed so far.

Parameters	TDMA	FDMA	OFDMA	CDMA	IDMA
Parameters 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 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	Mitigated	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 MDPRMABB	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: Comparison between MAC Protocols of IDMA and CDMA [9].

5. REFERENCES

- [1] Pingzhi Fan, "Multiple Access Technologies for Next Generation Mobile Communications", 6th International Conference on ITS Telecommunications Proceedings, 2006
- [2] Ahmed Mahdy and Jitender S. Deogun, "Wireless Optical Communications: A Survey", IEEE, 2004
- [3] Ramjee Prasad and Tero O. Janepera, "A Survey on CDMA: A Evolution towards Wideband CDMA" in proc. of IEEE, 1998
- [4] Shimon Moshavi, "Multi User Detection for DS-CDMA Communications", IEEE, 1996
- [5] Ali Pezeshk and Seyed Aliraza Zekavat, "DS-CDMA vs MC-CDMA", IEEE, 2003
- [6] A.C. Mc Cormick and E.A. Al-Susa, "Multicarrier for future generation Mobile Communication", IEEE, April 2002
- [7] Eli Sofer, Yossi Segal "Tutorial on multi access OFDM (OFDMA) technology", IEEE Jan, 2005
- [8] Li Ping, Lihai Liu, K. Y. Wu, and W. K. Leung "Interleave Division Multiple-Access (IDMA) Communications" IEEE April 2006.
- [9] Qian Huang, King-Tim-Ko, Peng Wang, "Interleave Division Multiple Access Based Broadband Wireless Networks", IEEE Jun, 2006
- [10] Qian Huang, Sammy Chan, Li Ping, "A QoS Architecture for IDMA based Multi-service Wireless Networks", IEEE, 2007
- [11] Kai Li and Ping Li, "Analysis and Optimization of IDMA Communication Systems", 2005.

