Asian Journal of Information Technology 13 (8): 395-400, 2014
ISSN: 1682-3915

Techniques Performance Analysis and Linking to OFDM and MIMO

P. Karthik and G. Kumaran
SKP Engineering College, Tiruvannamalai, India

Abstract: The next generation wireless broadband communication services has been developed in last several years. In last few years, wireless communications have gained enormous popularity in all over the world. Orthogonal Frequency Division Multiple Access (OFDMA) offers an attractive option for many personal as well as organizational communication requirements due to various parameters including cost, effectiveness and mobility. Fifth generation is being develop to accommodate the QoS (Quality of Service), low latency and required data rate such as wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV and virtual environment communication services. This study focuses on various multiple access techniques which are being proposed in 5G communication systems. Among all the Multiple Access (MA) techniques, it is attempted to exiting the OFDMA and MIMO (Multiple Input and Multiple Output) technology can efficiently mitigate the interference among users and support high data rate without compromising the required quality of service.

Key words: OFDMA, MIMO, multiple access, input, output

INTRODUCTION

The cellular network increases the users count and introduce the new features which include web browsing and smart technologies. In past few years, the request for bandwidth has started to surpass the network availability in wireless networks. The different techniques have been studied to improve the bandwidth, efficiency and increase the number of users count that can be accommodated within each cell (Jayanthiladevi *et al*., 2012; Park *et al*., 2012). The International Telecommunication Union (ITU) also defined the recommendations of mobile communication system for fifth generation (5G). In these recommendations data rates up to 100 Mbp for high mobility and up to 1 Gbp for low mobility or local wireless are predicted (Fan, 2006). Systems fulfilling these requirements are usually considered in fourth generation (4G). But 3G systems delivered the data rate from 3.6-7.2 Mbp. This (Haykin, 2001; Carlson *et al*., 2002; Shanmugam, 2000; Lathi, 1998; Sarkar, 2004; Sofer and Segal, 2005) existing multiple access techniques are used in 1G/2G/3G systems (such as FDMA/TDMA/CDMA, respectively) are basically suitable for voice communication and unsuitable for high data rate transmission and burst data traffic which possible the dominant portion for traffic load in 4G System (Jayanthiladevi *et al*., 2012). In modern communication system, Code-Division-Multiple-Access (CDMA) and OFDM have made its impact of wireless communication (McCormick and Al-Susa, 2002; Yu *et al*., 2011; Necker, 2008; Mao *et al*., 2008). It offers well known features such as dynamic hannel sharing, soft capacity, reuse factor of one, low dropout rate and large coverage (due to soft handover), easiness for cellular forecasting, 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 (Rrasad and Ojanpera, 1998) System is limited by Multiple Access Interference (MAI) as well as Inter Symbol Interference (ISI) (Suzuki and Tanaka, 2002). Also, the complexity of CDMA multiuser detection has been always a serious concern for large number of users. A 4G System is expected to provide the comprehensive and secure all possible facilities such as IP telephony, ultra broadband internet access services and streamed multimedia may be provide to users. There are various numbers of multiple access techniques which proposed for 4G System named as LTE (Astely *et al*., 2009), OFDMA (Park *et al*., 2012) (Orthogonal FDMA), MIMO (Torlak and Duman, 2012), etc.

MULTIPLE ACCESS SCHEMES

FDMA: In Frequency Division Multiple Access (FDMA), the total system bandwidth is divided into frequency channels which are allocated to the users. FDMA is distinct from Frequency Division Duplexing (FDD). FDMA allows multiple users at simultaneous access to a transmission system, FDD denotes, how the radio channel is shared between the uplink and downlink (for instance, the traffic going back and forward among a mobile-phone

Corresponding Author: P. Karthik, SKP Engineering College, Tiruvannamalai, India

and a mobile phone base station). Frequency-Division Multiplexing (FDM) is distinct from FDMA. FDM is a physical layer method that combines and transmits low-bandwidth channels through a high-bandwidth channel. On the other hand FDMA is an access technique in the data link layer. FDMA is also supports demand assignment in addition to static assignment. Demand assignment allows all users, actually continuous access for radio spectrum by assigning the carrier frequencies on a temporary basis using a statistical assignment process. Crosstalk may cause interference among frequencies and disrupt the transmission. Number of channels in a FDMA system equation is given as:

$$N = \frac{B_t - B_{guard}}{B_c}$$

Where:

N = Number of channels
B_t = Total spectrum allocation
B_{guard} = Guard band
B_c = Channel bandwidth

TDMA: In Time Division Multiple Access (TDMA), each frequency channel is divided into time slots and allocated the time slot into each user. There are three OSI layers involved in GSM: the physical layer, the data link layer and signaling protocol layer. The physical layer is applied to TDMA, modulation scheme and data rate, channel bandwidth shown in Table 1 (Jayanthiladevi *et al*., 2012). In TDMA, the signal is divided into time using the fundamental unit of a burst period. This burst period lasts around 15/26 msec and is grouped together by 8 bursts in a frame. A single traffic channel is well-defined by grouping the 26 frames and giving a total time frame 120 msec of these traffic channels are used to transmission speech and data. Number of channels in a TDMA system is given as:

$$N = \frac{m \times (B_{tot} - 2 \times B_{guard})}{B_c}$$

Where:

N = Number of channels
m = Number of TDMA users per radio channel
B_{tot} = Total spectrum allocation
B_{guard} = Guard Band
B_c = Channel bandwidth

CDMA: In CDMA (Prasad and Ojanpera, 1998), each user can assigned a unique code sequence which used to encode its information-bearing signal. The receiver has been known the code series of the user decodes a received signal after reception and recovers the original data. Since, the cross connections between the desired user code and the codes of the other users are lesser is possible. Choosing the code signal bandwidth is should be larger than the bandwidth of the information-bearing signal, the encoding process enlarges (spreads) the spectrum signal. Therefore, it is known as spread spectrum. 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 named as multipath FDMA and TDMA which are narrow band systems can not separate between the multipath arrivals and choice of equalization to moderate the negative effects of multipath. But mainly, the performance of CDMA System is limited for Multiple Access Interference (MAI) and Inter Symbol Interference (ISI) also it does not provide high data rate for transmission (user purpose). So, all these problems lead to the Fourth Generation (4G) System. CDMA has a several transmitters to send information simultaneously over a single communication channel. It allows more than one users to share a band of frequencies. In order to achieve high data rate without undue interference between the users, CDMA employs spread-spectrum technology and special coding scheme (in each transmitter researchers have to assigned a code).

In Spread-Spectrum Communication System, the transmitted signal is spread over a wide frequency band typically much wider than the smallest bandwidth required transmitting the data. The distribution uses a waveform which appears random to anyone except the intended receiver of the transmitted signal. If the waveform is essentially pseudo-random in the sense then it can be generated by precise rules yet it has been the statistical properties when truly random sequence. Spreading consists of the multiplying the input data by a Pseudo-random or Pseudo-Noise (PN) arrangement, the bit rate of which is much higher than the data bit rate. This increases the data rate while totaling redundancy to the system. The ratio of the arrangement bit rate to the data bit rate is known as the spreading factor. When the signal is acknowledged, the spreading is removed from the desired signal by multiplying it to the same PN sequence that is exactly synchronized to the transmitted PN signal. This is achieved in CDMA Systems by assigning each user/transmitter distinct codes that have low cross-correlation possessions such as the ideal orthogonal codes or any one of the PN, Gold or Kasami code.

TDMA/CDMA: The IS-95, 2G technologies implemented using CDMA (Code Division Multiple Access) and TDMA (Time Ivision Multiple Access), respectively.

Approximately, 80% of the mobile communication industry uses GSM technology with IS-95 following at around 10-15%. As the market shifts of 3G technologies, GSM is moving towards the execution of Wideband CDMA (W-CDMA) while the successor of IS-95 is CDMA 2000. The succeeding document gives a technical overview of all these technologies. Channel has a bandwidth of 1.25 MHz also IS-95A has the same bandwidth size (IS-95) and IS-2000 (1×RTT). On the other hand, the channel arrangement is very different in addition to that the back-end network is completely packet-based so it is does not constrained by the limitations typically while it present on a circuit switched network.

OFDMA: OFDMA (Park *et al*., 2012; Fan, 2006; Necker, 2008) is formed by dividing the available sub-carriers in OFDM into non-overlapping subsets then assigning the each user as unique subset and each sub-carrier is occupied by utmost one user (Fig. 1). Orthogonality among the sub-carriers can be maintained in multi-path channels provided that the cyclic prefix length is longer than the channel length. Clearly, this also guarantees to orthogonality among users. In practice, DFT and IDFT can be implemented using the Fast Fourier Transform (FFT) and its inverse FFT cost will be low. Each coded bit is modulated onto a sub-carrier 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 separated by 128, 512, 1024 or 2048 sub-carriers. The 20 MHz bandwidth with 2048 sub-carriers has the value is 9.8 MHz spacing between sub-carriers. But it has some problems in OFDMA which are the large amplitude variation. If it increases in-band noise then increases the BER when the signal is go through the amplifier non-linearity and there is tight synchronization between the users are required for FFT in receiver. That 's why this technique is required for some improvement such as time synchronization, frequency synchronization and effective digital signal processing implementation of OFDMA, etc. for the efficient processing of fourth generation (4G) (Fig. 2).

Out of 1024 frequency carriers (also called sub-carriers), 720 sub-carriers can be used to carry the user data (the rest are reserved for pilots and guards). In order to properly allocate the data carriers to different MS, the standard organizes are divided the 720 sub-carriers into 30 sub-channels (each sub-channel contains 24 sub-carriers). A sub-channel is the smallest unit that can be allocated to an MS (Fig. 3).

The standard allows frequency resources (in sub-channels) be dynamically allocated to MS. This means while the model is running, BS can dynamically change the sub-channel allocation to MS1 and MS2. For example, in one burst, sub-channels 0~5 are allocated to MS1 and sub-channels 6~25 are allocated to MS2. In another burst, the allocation may become 2~10 and 15~25, respectively. When more sub-channels are allocated to one MS, more data can be transmitted to this MS in one burst. This dynamic change introduces variable-size signaling.

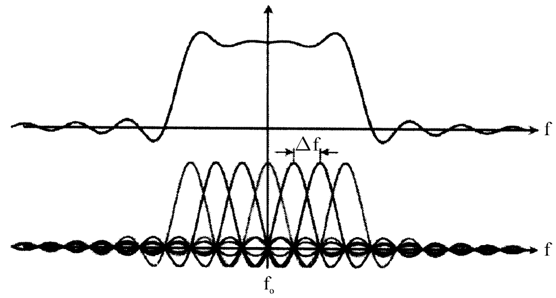

Fig. 1: General OFDM sub-carrier allocation

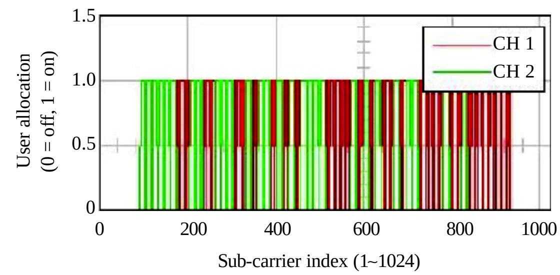

Fig. 2: OFDM symbol packing sub-carrier allocation (1-1024)

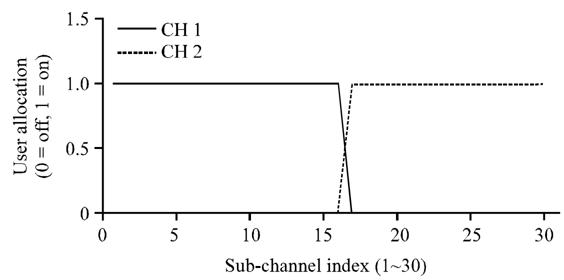

Fig. 3: OFDM symbol packing sub-carrier allocation (1-30)

SC FDMA: Single-Carrier FDMA (SC-FDMA) (Mao *et al*., 2008; Ng and Lam, 2013) is a frequency-division multiple access scheme. Like other multiple access schemes (TDMA, FDMA, CDMA, OFDMA), it deals with the assignment of multiple users to a shared communication resource. SC-FDMA can be inferred as a linearly precoded OFDMA scheme in the sense that it has an further DFT processing preceding the conventional OFDMA processing.

SC-FDMA has drawn a great attention as an attractive different to OFDMA, especially the uplink communications where lower Peak to Average Power Ratio (PAPR) have great benefit to mobile terminal in terms of transmit power efficiency and reduced cost of the power amplifier. It has been implemented as the uplink multiple access scheme in 3GPP Long Term Evolution (LTE) or Evolved UTRA (E-UTRA). The performance of SC-FDMA, in relative to OFDMA has been the subject of various studies. Although, the performance gap is not much high, SC-FDMA's further advantage of low PAPR makes it as favorite transmission, especially for uplink wireless transmission in future mobile communication systems where transmitter power efficiency is of paramount importance.

MIMO: In radio, multiple-input and multiple-output (Torlak and Duman, 2012; Kusume *et al*., 2010) is the use to multiple antennas of both transmitter and receiver to improve communication performance. It is one of more than few forms of smart antenna technology. Note that the relations input and output refer to the radio channel carrying the signal not to the devices having antennas. Multi user-MIMO (Kusume *et al*., 2010) technology has attracted attention in wireless communications because it offers data throughput increments and link range without additional bandwidth or increased transmit power are important. It reaches the goal by spreading the same total transmits power over the antennas to achieve an array gain that improves the spectral efficiency and/or to achieve a diversity gain which improves the link reliability (reduced fading). Because of these things, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi) (Mao *et al*., 2008) 4G, 3GPP Long Term Evolution (LTE), LTE-Advanced, WiMAX (Etemad, 2008) and HSPA+. Using the flat-fading Rayleigh channel, it demonstrates the concept of orthogonal space-time block coding which is employable after multiple transmitter antennas are used. It is assumed here that the channel suffers independent fading between the multiple transmit-receive antenna pairs. For chosen system also it offers a measure of the performance degradation when the channel is imperfectly estimated at the receiver, linked to the case of perfect channel knowledge at the receiver.

Transmit diversity vs. receive diversity: Using diversity reception is a well-known technique to mitigate the effects of fading over a communications link. However, mostly it has been relegate to the receiver end. In a transmit diversity scheme offers similar diversity gains by using multiple antennas at the transmitter (Fig. 4).

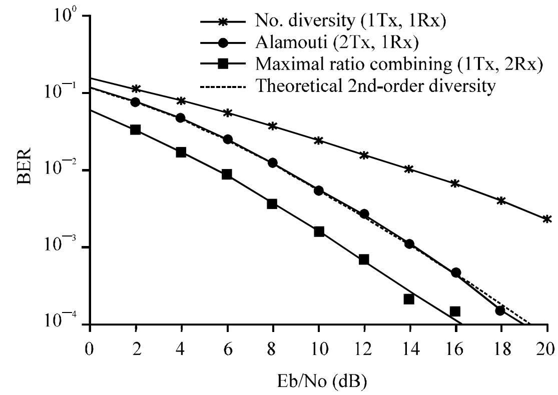

Fig. 4: Transmit diversity vs. receive diversity

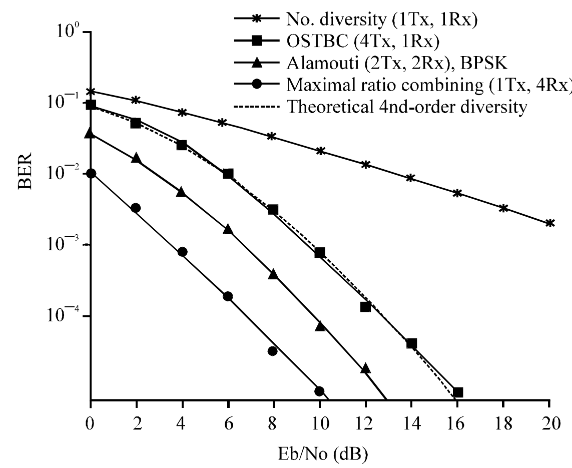

Fig. 5: Orthogonal space-time block coding

This was conceived to be more practical as for example, it would only need multiple antennas at the base station in comparison to multiple antennas for every mobile in a cellular communications system. Transmit diversity, researchers use two transmit antennas and one receive antenna (2×1 notationally) for receive diversity researchers employ one transmit antenna and two receive antennas (1×2 notationally) (Fig. 5).

The simulation covers an end to end system showing the encoded and/or transmitted signal, channel model and response and demodulation of the received signal. It also provide the no-diversity link (single transmit-receive antenna case) and theoretical performance of second-order diversity link comparison. It is expected here that the channel is known perfectly at the receiver for all systems. Researchers run the simulation finished a range of Eb/No points to generate BER results that allow us to compare the different systems. Since, these results take some time to produce, researchers load the results from a prior simulation.

Table 1: Performance analysis of various multiplexing techniques

Parameters	FDMA	TDMA	CDMA	OFDMA	MIMO
Modulation scheme	FSK	QPSK, GFSK	Spread spectrum	QAM	Spatial modulation
Parameter which distinguish the users in single channel scenario	Frequency	Time slot	Signature sequence	Orthogonal frequency	Orthogonal frequency
ISI elimination	Cyclic prefix	Equalization	Rake receiver	Cyclic prefix	Guard interval
Solutions to high single user rate	High order modulation	High order modulation	Multi code CDMA	High order modulation	High order modulation
Intra-cell interference cancellation	Not necessary	Not necessary	MUD	Not necessary	Not necessary
Inter-cell interference	Sensitive	Sensitive	Mitigated	Sensitive	Mitigated
Synchronization required	Yes	Yes	No	Yes	Yes
Bandwidth (Hz)	30 k	200 k	20 M	100 M	1 Gb
Data rate	28-56 kbp	50-250 kbp	200 kbp to sevaral Mbp	Up to 1 Gbp	Up to 1 Gbp

As expected, the similar slopes of the BER curves for the 4×1, 2×2 and 1×4 systems indicate an equal diversity order for each system. Also, observe the 3 dB penalty for the 4×1 system that can be attributed to the same total transmitted power assumption made for each of the three systems. If researchers adjust the transmitted power such that the received power for each of these systems is the same then the systems would make identically. Again, the theoretical performance matches the simulation performance of the 4×1 system as the total power is normalized across the diversity branches.

COMPARATIVE ANALYSIS

Important features of all named multiple access are compared (Table 1) with the existing MA, high data rates can be achieved by reducing the spreading factor but the former leads to reduced spreading gain against fading and interference and the latter needs to overcome the interference among spreading arrangements. In contrast, high data rate transmission can be achieved in MIMO Systems by assigning the uplink and downlink. So, OFDMA 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.

CONCLUSION

In this study, comparisons between different MA techniques have been made on the basis of parameters like user separation, inter and intra-cell interference cancellation, bandwidth, data rates, etc. Among all the comparisons discussed so far, the features of MIMO shows its suitability for the applications to support multimedia services in broadband wireless networks like Wi-Max and fifth generation communication. Also, all other MA techniques is given to show the performance gain over MIMO. Hence, it can be the representative for future communication services. Although, the performance of MIMO technique is well suited for next generation wireless networks but still it have some challenging issues such as interleaver design, coding scheme, channel behavior, optimum signaling scheme, resource allocation, interference cancellation, etc. in which research is going on in all over the world.

REFERENCES

Astely, D., E. Dahlman, A. Furuskar, Y. Jading, M. Lindstrom and S. Parkvall, 2009. LTE: The evolution of mobile broadband. IEEE Commun. Mag., 47: 44-51.

Carlson, A.B., P.B. Crilly and J.C. Rutledge, 2002. Communication Systems. 4th Edn., McGraw-Hill, Singapore.

Etemad, K., 2008. Overview of mobile WiMAX technology and evolution. IEEE Commun. Magaz., 46: 31-40.

Fan, P.Z., 2006. Multiple access technologies for next generation mobile communications. Proceedings, of the 6th International Conference on ITS Telecommunications, June, 2006, Chengdu, pp: P10-P11.

Haykin, S., 2001. Digital Communication. Replika Press Pvt. Ltd., N. Delhi, India.

Jayanthiladevi, A., H.M. Premlatha and G.M.K. Nawaz, 2012. Analysis study of seamless integration and intelligent solution in any situation by the future advanced mobile universal systems 4G-(FAMOUS4G). Proceedings of the International Conference on Emerging Trends in VLSI, Embedded System, Nano Electronics and Telecommunication System, January 7-9, 2013, Tiruvannamalai, pp: 1-5.

Kusume, K., G. Dietl, T. Abe, H. Taoka and S. Nagata, 2010. System level performance of downlink MU-MIMO transmission for 3GPP LTE-advanced. Proceedings of the IEEE 71st Vehicular Technology Conference (VTC2010-Spring), May 16-19, 2010, Taipei, pp: 1-5.

Lathi, B.P., 1998. Modern Digital and Analog Communication Systems. 3rd Edn., Oxford University Press, New Delhi, India.

Mao, X., A. Maaref and K.H. Teo, 2008. Adaptive soft frequency reuse for intercell interference coordination in SC-FDMA based 3GPP LTE uplinks. Proceedings of the IEEE Global Telecommunications Conference, November 30-December 4, 2008, New Orleans, LO., pp: 1-6.

McCormick, A.C. and E.A. Al-Susa, 2002. Multicarrier for future generation mobile communication. Electron. Commun. Engin. J., 14: 52-60.

Necker, M.C., 2008. Interference coordination in cellular OFDMA networks. IEEE Network, 22: 12-19.

Ng, B.K. and C.T. Lam, 2013. On maximizing the performance of SC-FDMA systems with rotated constellation. Proceedings of the 9th International on Wireless Communications and Mobile Computing Conference, July 1-5, 2013, Sardinia, pp: 1699-1704.

Park, J., P. Pawelczak, P. Gronsund and D. Cabric, 2012. Analysis framework for opportunistic spectrum OFDMA and its application to the IEEE 802.22 standard. IEEE Trans. Vehicular Technol., 61: 2271-2293.

Prasad, R. and T. Ojanpera, 1998. A survey on CDMA: A evolution towards wideband CDMA. Proceedings of the IEEE 5th International Symposium on Spread Spectrum Techniques and Applications, Volume 1, September 2-4, 1998, Sun City, pp: 323-331.

Sarkar, N., 2004. Elements of Digital Communication Systems. 1st Edn., Oxford University Press, New Delhi, India.

Shanmugam, K.S., 2000. Digital and Analog Communication. Replika Press Pvt. Ltd., New Delhi, India.

Sofer, E. and Y. Segal, 2005. Tutorial on multi access OFDM (OFDMA) technology. IEEE January, 2005. The Institute of Electrical and Electronics Engineers, New York, USA.

Suzuki, T. and T. Tanaka, 2002. Study on canceling inter symbol interference of inverse-GPS. Proc. 6th Int. Conf. Signal Process., 2: 1637-1640.

Torlak, M. and T.M. Duman, 2012. MIMO communication theory, algorithms and prototyping. Proceedings of the 20th Signal Processing and Communications Applications Conference, April 18-20, 2012, Mugla, pp: 1-2.

Yu, Y., E. Dutkiewicz, X. Huang and M. Mueck, 2011. Load distribution aware soft frequency reuse for inter-cell interference mitigation and throughput maximization in LTE networks. Proceedings of the 2011 IEEE International Conference on Communications, June 5-9, 2011, Kyoto, pp: 1-6.