International Journal of Advanced Research in
Engineering and Applied Sciences ISSN: 2278-6252

PERFORMANCE PEAK-TO-AVERAGE POWER CODE-ALLOCATION RATIO BASED REDUCTION TECHNIQUE FOR MC-CDMA SYSTEMS

Jimish Desai*

Poornima Raikwar*

Mohd.Ahmed*

Abstract: *In this paper market research finds that mobile MC-CDMA Diversity commerce for 4G wireless systems will be dominated by basic human communication such as messaging, voice, and video communication. Because of its typically large bandwidth requirements, broadband communication is expected to emerge as the dominant type of traffic in 4G wireless systems. In this paper a new TCP based Multi carrier access technique named MC-CDMA for mitigating 4Grequirements is proposed. This paper also presents analytical information regarding the transfer of data flows on paths towards interconnected wireless systems, with emphasis on 4G cellular networks. The focus is on protocol modifications in face of problems arising from terminal mobility and wireless transmission. We advocate the use of the transport layer protocol for high speed data in a Multi-Carrier CDMA (MC-CDMA) system for 4G wireless communications.*

Keywords: *4G, MC-CDMA, large bandwidth traffic for multi-carrier modification*

*Department of Electronics & Communication OIST, RGPV, Bhopal, M.P.

INTRODUCTION

Orthogonal Frequency Division Multiplex (OFDM) is a promising radio access technique for mobile communication systems due to its high spectrum efficiency and strong immunity against multi path fading with only simple equalization. As a hybrid scheme of OFDM and Code Division Multiple access (CDMA). Multicarrier Code Division Multiple Access (MCCDMA or OFDM-CDMA) intends to exploit the advantages of both OFDM and CDMA. In the downlink of MC-CDMA systems, CDMA coding is applied to provide multiple access ability as well as to spread each user's data across the entire available frequency band which can greatly reduce the impact of frequency selective fading. And then the spreading code's chips are modulated on orthogonal sub carriers and spread across the time domain via the OFDM modulation. Therefore MC-CDMA can achieve high data rate transmission with protection against both frequency selective fading and time dispersion while at the same time offer a spectrum efficient multiple access strategy [1][2]. However MC-CDMA systems suffer from one of the major drawbacks of all multicarrier transmission schemes, a high peak to average power ratio (PAPR). A high dynamic range is required in the linear Power Amplifiers (PA) at the transmitter in order to transmit a signal with large PAPR. The power efficiency performance of such amplifiers decreases as the PAPR increases. And if the dynamic range of PA is insufficient, the signal is distorted from the nonlinearity thus degrade the signal quality. These shortcomings are especially unaffordable for battery powered portable wireless terminals. Various PAPR reduction schemes have been proposed in literature, such as the most extensively studied scrambling techniques like partial transmit sequence (PTS) and Selected Mapping (SLM) [3]. PTS partitions sequence into sub blocks and each sub block is multiplied by a phase weighting factor to produce alternative sequences with low PAPR. SLM pseudo randomly modifies the phases of the original information symbols in each OFDM block several times and selects the phase-modified OFDM block with the best PAPR performance for transmission. But they all require independent multiple IFFT computation process for PAPR reduction for every symbol with which the non-negligible side information must be transmitted along. Although these OFDM based schemes are applicable to the MC-CDMA systems [4][5], more efficient MC-CDMA specific algorithm can be developed by exploiting the characteristics of the OFDM–CDMA that distinguish it from the conventional OFDM [6].Interference cancellation(PPIC) operations proposed by Divsalar et al. for multi carrier code division multiple access (MC-CDMA) systems. Based on this approach, K multiplications of the original scheme are replaced with K additions for each interference cancellation (IC) stage and two equivalent PPIC-based multi-user detectors of lower complexity are presented. Also, a new bit estimator is derived for PPIC-based multi-user detectors to reduce the variances of the final signal estimates. The bit estimator linearly combines soft information of each IC stage using weighting factors derived from those for PPIC. Computer a PPIC-based multi-user detector with the bit estimator has performance gain over the original one. Multi carrier code division multiple access (MC-CDMA) is one of the promising techniques for fourth-generation wireless mobile communication systems. MC-CDMA has several advantages, such as efficient spectrum utilization and immunities to multipath impairments. One major drawback associated with MC-CDMA is that multiuser detection is often necessary to overcome the multiple access interference (MAI)problem in uplink systems [1]-[3].In this paper, we propose a new low-complexity approach to realizing the main PPIC operations that firstly cancels the MAI estimates completely from the received signal at each IC stage and then adds a compensated term to the resulting signal, where K multiplications of the original scheme are replaced with K additions for each IC stage. Based on this approach, two equivalent simplified receiver structures of the conventional PPIC and TPPIC detectors are presented, and a new bit estimator is derived for PPIC-based receivers. The new bit estimator linearly combines the soft tentative decisions of each IC stage according to their fidelity demonstrate that it can enhance performance of various PPIC-based receivers. The rest of this paper is organized as follows. In section we describe the system model and introduce the combining schemes. A brief review is given on the multistage PIC approach and its improved techniques. Also, a new method is presented for realizing the main PPIC operations. In section IV, we derive a new bit estimator for PPIC-based receivers to further improve the system performance. In section V, we show performance of various PPIC-based receivers with/without the proposed bit estimator. some conclusions are made.we describe the system model used in our derivations and introduce the combining schemes for dispreading. The MC-CDMA modulator and demodulator

MC-CDMA SYSTEMS

Consider a quasi-synchronous MC-CDMA uplink system with *K* physical users, where for simplicity the number of sub carriers *N* is assumed to equal the spreading factor *G* for each user. No pulse shaping is considered. The MC-CDMA modulator performs the IDFT operation to generate the time domain transmitted signal for user *k* as follows.

$$u_n^k = \frac{1}{N}\sum_{i=0}^{N-1}(a^k c_i^k s^k)e^{j\frac{2\pi}{N}ni}, \qquad n = 0,1,\ldots,N-1$$

where ak is the amplitude, cik is the ith chip of normalised spreading code ck, and sk is the data signal for user k. After a sufficient cyclic prefix is inserted between modulated symbols to compensate for the symbol asynchronism and the multipath delay spread, the complete signal is transmitted through a radio channel, where the impulse response vector of the discrete-time multipath channel for user k is given by

$$\mathbf{h}^k = [\alpha_0^k, \alpha_1^k, \ldots, \alpha_{L-1}^k]^T$$

with α_l^k being the complex fading gain of the lth path.

At the base station, the time-domain received data vector without the cyclic prefix is the sum of the distorted transmitted signal for each user and the additive white Gaussian noise(AWGN) vector n, i.e.,

$$\mathbf{x} = \sum_{k=1}^{K} u_n^k \otimes \alpha_n^k + \mathbf{n}$$

where the operation $\otimes$ means the circular convolution. The MC-CDMA demodulator performs the DFT operation of (3) to obtain the frequency-domain received data vector, i.e.

$$\mathbf{X} = \mathbf{HAs} + \mathbf{w}, \qquad \mathbf{X} : N \times 1$$

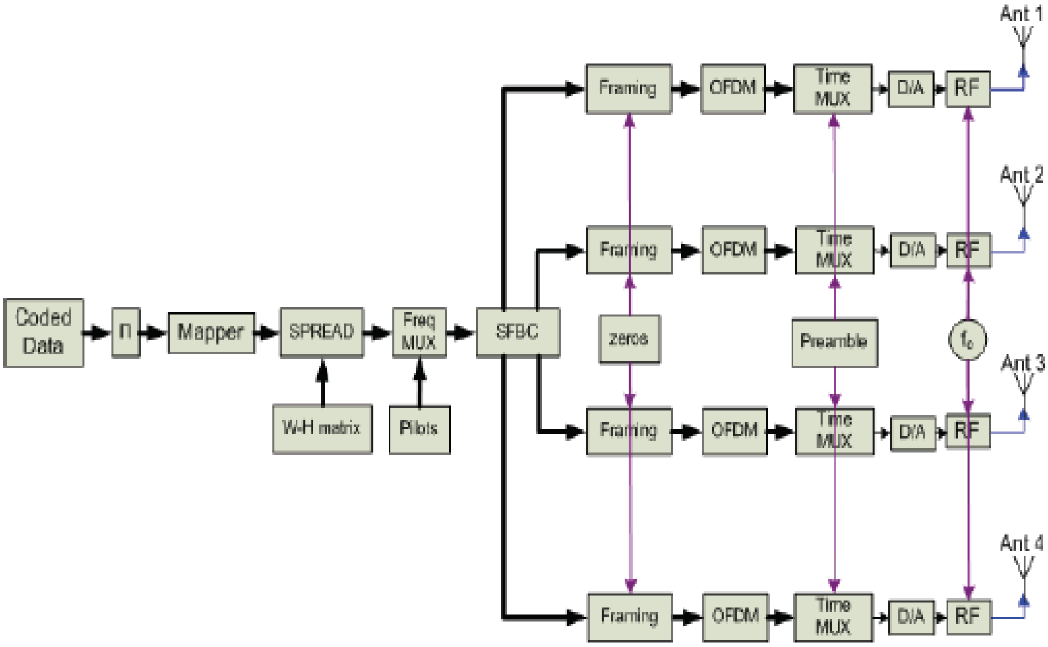
In this contribution, a MIMO MC-CDMA system is designed with MT=4 and MR=1,2,3 where two coding operations have been incorporated, one through the use of orthogonal Walsh-Hadamard (WH) coding, and one in quasiorthogonal SFBC domain (on a per sub carrier basis). The designed system has R=1 at the expense of orthogonality [2], and with the incorporation of an iterative scheme with low number of iterations a noticeable performance gain is achieved with respect to classical 2xMR scheme. Based on the theoretical outcomes of [2] and [3], where the specific quasi-orthogonal scheme has been originally presented, in this work its performance is evaluated in SFBC MIMO MC-CDMA systems with the enhancement of an iterative process and furthermore taking into account the shortcomings inserted by the channel estimation stage, as well as that one of the RF stages. The whole system has been evaluated in real life scenarios based on channel models of 3GPP.25.996 definition. Such an evaluation highlights the system level performance (BER), as well as the importance of the channel estimator efficiency to the overall system operation under self-interference conditions. A binary data block b[k] of K bits is scrambled, encoded by a concatenated Reed-Solomon and convolutional encoder, followed by a puncturer and an interleaver. The resultant bit stream is mapped using a set of predefined constellation diagrams and forward error correction schemes giving a symbol stream d[m] of M symbols. The output symbols are interleaved and spread in frequency domain by a unique(user-specific) spreading vector Ci (WH) of length SF=16(Spreading Factor) enabling 3 spread symbols to be transmitted-CDMA without requiring complex equalizers. By combining the spatial transmission diversity with the space-time block codes for MC CDMA systems, it shows high performance improvement. A code division multiple access system allocates the entire bandwidth to each user. Although the users are separated from each other by a distinctive spreading code in the code domain, different sub channels will be affected by different fading coefficients, and orthogonally between users will be destroyed at the receiver, and as a result, Multi User Interference (MUI) occurs. As the number of users in multiple access environment increases, MUI is increased and performance of the system will be decreased subsequently. In such conditions, proper multi-user detection schemes will be worth. Different single-multi user detection techniques have been investigated so far [4-7]. Especially related to this study, in [6], an EM-based approach has been investigated for a type of spread spectrum DS-CDMA systems which transmits the users' symbols by spreading them directly in the time domain. In this paper, we are going to develop a multi-user detection technique for space-time block coded MC-CDMA systems based on the expectation maximization (EM) algorithm as an efficient computational alternative solution for maximum likelihood (ML) estimate of the and compare the performance of different I with the proposed one. Our algorithm received signal into its components and esteem information independently from the others. This paper has the following structure: introduction, transceiver structure, contain space-time per OFDM symbol of Nd=192 data sub carriers over 4 Tx antennas. The spread symbols are given as follows

$$\begin{bmatrix} s_1 \\ s_2 \\ \cdots \\ s_{16} \end{bmatrix} = \begin{bmatrix} c_{1,1} & c_{1,2} & \ldots & c_{1,16} \\ c_{2,1} & c_{2,2} & \ldots & c_{2,16} \\ . & . & . & . \\ c_{16,1} & c_{16,2} & \ldots & c_{16,16} \end{bmatrix} \cdot \begin{bmatrix} d_1 \\ d_2 \\ \cdots \\ d_{16} \end{bmatrix} \Leftrightarrow \boldsymbol{S} = \mathbf{C} \cdot \boldsymbol{d}$$

This format allows U=SF users to be active simultaneously in the same frequency bandwidth or U parallel data streams(virtual users) of the same physical user enabling maximized data rate in link level. The data symbol stream is multiplexed in frequency domain with the pilot symbols and subsequently-coded according to eq. above mentioned for a block of 4 spread symbols. The operator (.)* corresponds to complex conjugate operation and the subscript dm indicates the operation in diversity mode. Hence, Nd=192 sub carriers are used for data and Np=16 for channel estimation resulting in Nc=208 active sub carriers.

$$\mathbf{S}_{dm} = \begin{bmatrix} \mathbf{S}_A & \mathbf{S}_B \\ \mathbf{S}_B^* & -\mathbf{S}_A^* \end{bmatrix} = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ s_2^* & -s_1^* & s_4^* & -s_3^* \\ s_3^* & s_4^* & -s_1^* & -s_2^* \\ s_4 & -s_3 & -s_2 & s_1 \end{bmatrix}$$

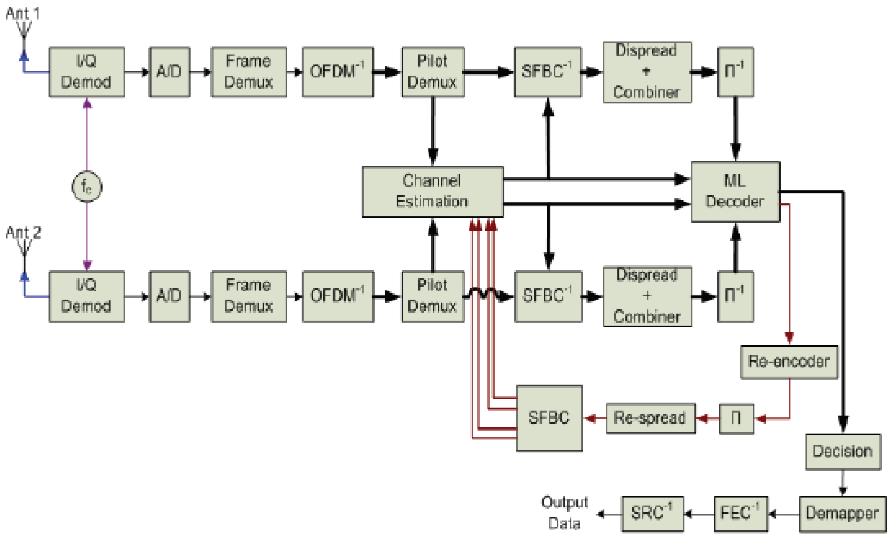
Finally, the SFB-coded symbols are grouped in packets of Nc symbols and zero padded in order to form the OFDM symbols that are inserted in a 256-IFFT modulator. A predefined group of OFDM symbols are time multiplexed with preamble OFDM symbols, designed for synchronization issues, in order to form the OFDM frame. The produced signals are converted in analogue ones and up-converted to the carrier frequency through RF stages with a common oscillator.



Transmitter block diagram of the 4xMR MC-CDMA architecture

$$\begin{bmatrix} R_1^{(1)} \\ R_2^{(1)} \\ R_3^{(1)} \\ R_4^{(1)} \end{bmatrix} = \mathbf{S}_{dm} \cdot \begin{bmatrix} H^{(11)} \\ H^{(12)} \\ H^{(13)} \\ H^{(14)} \end{bmatrix} + \begin{bmatrix} N_1^{(1)} \\ N_2^{(1)} \\ N_3^{(1)} \\ N_4^{(1)} \end{bmatrix} \Leftrightarrow \mathbf{R}^{(1)} = \mathbf{S}_{dm} \cdot \mathbf{H}^{(1)} + \mathbf{N}^{(1)}$$

H(mR,mT) indicates the channel from mT-th transmit antenna to mR-th receive antenna assuming that the channel coherence bandwidth is greater than a frequency span of 4 neighbour sub carriers. Also, (mR)i R and (mR)i N correspond to the received signal and the AWG noise respectively at mR-th receive antenna and at i-th sub carrier.



Receiver block diagram of the iterative MC-CDMA system

CHANNEL ESTIMATION SCHEME

The channel estimation (CE) process has been realized using a scattered pilot based approach with the pilot symbols following the same coding structure as the data one. Based on the MMSE processing, at the pilot blocks, the estimated channel consists of the actual channel effects and an error that is caused by the non orthogonal design Hdm dm X = S _S (residual factor), as well as the AWGN, as in eq. The operator (.) corresponds to hermitian matrix transformation. Note that the matrix X is perfectly known at the pilot blocks and it is always invertible as a full rank structure, which in addition can be splitted in two independent 2x2 matrices [3]reducing further the amount of required processing power. The channel distortion at the data positions is estimated using Wiener filtering [5] and the required noise variance is acquired by monitoring the middle sub carrier that is zero padded at transmission phase for DC offset reasons. The MIMO MC-CDMA system under consideration is simulated in a link level [11].For the case of full load scenario(U=SF) the proposed scheme achieves maximum data rates of 13.29Mbps at BPSK-1/2 (rate 0), of 26.58Mbps at QPSK-1/2(rate 1), of 38.4Mbps at QPSK-3/4 (rate 2), of 49.37Mbps at16QAM-1/2 (rate 3), of 69.11Mbps at 16QAM-3/4 (rate 4), of 86.39Mbps at 64QAM-2/3 (rate 5), and of 115.19Mbps at 64QAM-3/4 (rate 6). Note that the ratios 1/2, 2/3, and 3/4 referto the overall coding overhead. OFDM stages are based on a 256-point FFT/IFFT with cyclic prefix of CP=1/4. Each frame conveys constant number of uncoded information (2400 bits)resulting in a variable frame duration (41.67_sec - 361.14_sec)depending on the modulation order and the FEC code used.The evaluation is performed on the basis of achieving bit error rate (BER) estimation relative variance of 10-4 with an upper limit of 1000 frames [12]. We are using 4G wireless technology in the car based on new services and business models. This is enabled by ultra-high bandwidth technology, always-on network connectivity, cloud computing, cloud storage, and value added network assets such as content management. Furthermore, we apply location services, presence, identity, security, billing and innovative in-vehicle hardware and software systems. This service package provides always-on access to the internet, along with entertainment and real-time navigation systems. 4th generation, 4G wireless technology in cars, public transport and emergency services. The article describes the standards for Mobile WiMAX (standard IEEE 802.16e-2005) and the 3rdGeneration Partnership Project, the 3GPP Long Term Evolution

(LTE). In a vehicle which applies the 4Gwireless technology car solution concept, consumers would be able to access network- and cloud-based applications, putting on-demand entertainment, infotainment, diagnostics, and navigation. We discuss the advantages of introducing the solution concept «4G connected car» and the use of this technology in Russia. We have carried out experimental investigations. Our results show that the system operates up to the speed of the car of 140 km/h. The interactive system to send and receive signals works with data rates of 10 Mbps. accounts for an added compensated term. The factor α(m) is equal to (1− β (m)) , and it decreases for each successive IC stage due to the fact that β (m) increases for each successive IC stage. The new realization form of the main PPIC equations means that more reliable signal estimates can be obtained at a later stage, and less amount compensated term is required for a given stage than that needed for the previous stage. Since only a factor α (m) is used for interference cancellation, it is easy to see that the new realization form replaces K multiplications of the original one with K additions for each IC stage and thus reduces the computational complexity.

MC CDMA 4G MOBILE AND WIRELESS COMMUNICATION SYSTEM

Communication system, 4G Mobile and wireless communication systems should support following functions:

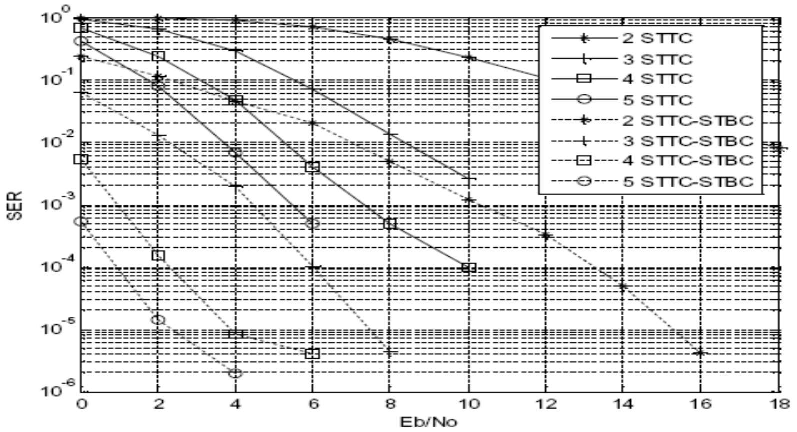
1. Higher transmission rate up to 100Mbps
2. Flexible to advanced Internet, QoS control
3. Enhanced security
4. Seamless operation across networks
5. Multiple broadband access options in combined public and private networks including wireless LAN, wireless home link and ad-hoc network.

1G and 2G systems were voice communications, and digitized voice communications with some data communications, respectively, where a major difference was roaming between regions. 3G systems provide multimedia and wireless Internet at relatively high data rates, by utilizing packet switched services. However, significant paradigm shift should be taken into account for 4G systems, since wireless LAN, wireless MAN (WiMAX), wireless ad-hoc and sensor networks are becoming popular, evolution of networking and paradigm shift. Up to 2001, web-based service by using dial-up or always-on IP connection has become popular. In this paper, we describe the vision of the 4Gsystems focusing on major key technology such as MCCDMA system. The remainder of this paper is organized as follows. provides a brief background on aspects of 4G cellular environment and MC-CDMA system pertinent to the subject of the provides related research in this field. Section 5 illustrates been dominant. Now, mobile Internet is very popular and the driving force is mobile. The flexible and secure broadband seamless networking is the key to establish Ubiquitous network which is characterized by distributed computing, broadband and wireless, and peer-to peer for everything, and driving force is service. In our view, 4G systems are regarded as a "shopping mall type", whereas 3G systems department store type". Key issues for seamless operation are: Service discovery and fast seamless connections services in the IP based multi-modal access Mobility management IP multimedia services platform independent of radio access technology and underlying IP transport technology Enhancement to support Human (H) to H, H to Machine (M) and M to M communications Flexible introduction of new technologies into a system and service view of the IP-based 4G mobile and wireless network architecture. IP-based backbone transport network supports multi-modal access among various wireless networks. As a lower middleware, the basic network management layer treats many functions related to multiple interface management, mobility management using mobile anchor point with buffer, security, QoS etc. As an upper layer of the services middleware, service support layer handles location, billing, media conversion, distribution etc. Application can be operated by using such common service middleware. 4G systems are also characterized by the bandwidth to be allocated. In 2-5GHz band, propagation loss is higher resulting in smaller cell size. Also, due to higher Doppler shift, more complex and robust synchronization and channel estimation techniques are needed. Key technologies being researched

in physical layer are OFDM, multi-carrier CDMA(MCCDMA),multi-hop systems, MIMO and AAA, Time Division Duplex (TDD) CDMA, and downlink queuing and scheduling algorithm, routing protocol and distributed public key management for mobile ad-hoc networks in higher layers.

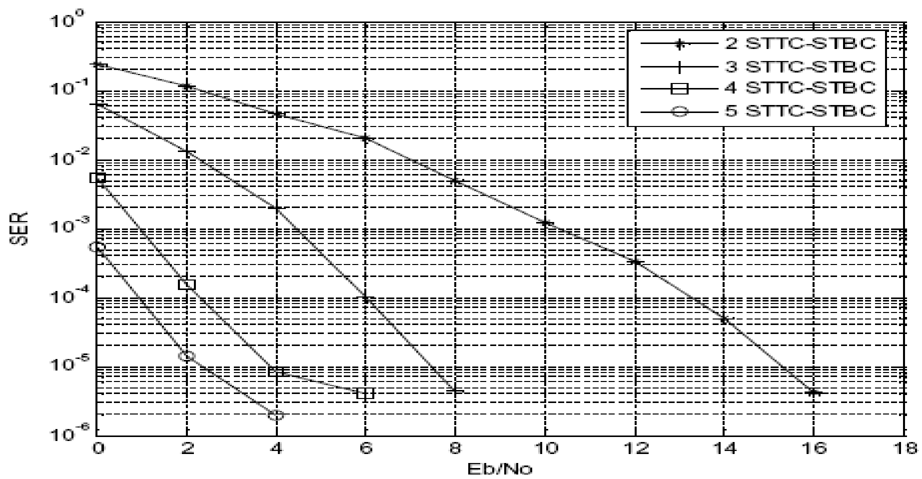
MC-CDMA TECHNIQUES FOR 4G SYSTEMS

The evolution of mobile communications systems. In discussions about 2G systems in the 1980s,two candidates for the radio access technique existed, time division multiple access (TDMA) and CDMA schemes. Finally, the TDMA scheme was adopted as the standard. On the other hand, in the discussions about 3G systems in the 1990s, there were also two candidates, the CDMA scheme, which was adopted in the one generation older systems, and the OFDM-based multiple access scheme called band division multiple access (BDMA) [2]. CDMA was finally adopted as the standard. If history is repeated, namely, if the radio access technique that was once not adopted can become a standard in new generation systems, then the OFDM-based technique looks promising as a 4G standard. It is well known that the CDMA scheme is robust frequency selective fading. Likewise, the OFDM schemes a1so inherently robust to frequency selective fading. Thus the combination of OFDM and CDMA schemes may give batter performance. In 1993, Multi-carrier CDMA (MC-CDMA) system which is indeed a combination of OFDM and CDMA schemes was independently proposed by three different groups [4-6] almost simultaneously. Currently, an updated DS-CDMA technique is being used for the 4G mobile communication systems [7]. However the MC-CDMA looks more promising for the 4G standard. In DS-CDMA, Rake receivers are used, which have complexity in design and provide low performance. Thus, DS-CDMA is no longer the best choice available for the4G standard. On the other hand, MC-CDMA system directly applies coding in the frequency domain to separate each user and thereby making it possible to support multiple users. This system is more effective in eliminating the frequency selective problem faced in the DS-CDMA system by not dividing the user bits into chip to uniquely encode them [7]. Instead, the user's codes are employed in different frequency and thus offer longer bit duration and make the signal to experience only flat fading. This is how it mitigates the problem of inter-chip interference [8]. Moreover, MC-CDMA system has lot of flexibility inherent in terms of system design that allows better spectrum utilization [9]. It also has the benefit of relatively simple receiver structure. The main idea of the proposed modifications covers the combination of orthogonal frequency division multiplex (OFDM) with direct sequence spread spectrum (DSSS). This approach is similar to multi carrier code division multipleaccess (MC-CDMA) [2, 3] where orthogonal spreadingsequences are assigned to different users in order to distinguish them at the receiver. Systems applying MC CDMA are generally designed to increase the throughput in multi access scenarios. In contrast to that, our proposed modifications use the combination of OFDM and DSSS by gaining high transmission robustness at the cost of reduced data rate in IEEE 802.11 systems. A novelty of the proposed modifications is the aspect that receivers of very low complexity can be realized without an equalizer, allowing for low gate count in terms of hardware implementation costs. In addition, more complex receivers reusing common IEEE 802.11 hardware might be employed to gain additional performance in very low SNR environments.



Performance comparison of the system with STTC

The physical layer in MC-CDMA uses convolutional and Turbo coding between the base station and mobile (in both directions) to achieve high coding gain. This helps in achieving a lower value of the packet error rate, this leads to a reduction in the burst errors, which is highly desirable. The FEC process is followed by the interleaving process, which provides time diversity as a further safeguard against burst errors. The basic function of the interleaver is to distribute one long burst of errors into many smaller bursts of correlated errors, spread across many different physical layer frames. This prevents the concentration of errors in any particular TCP window, which allows TCP fast retransmit mechanisms to offer better throughput, as shown in the simulations in [21].MC-CDMA, owing to its wide-band signal, is able to discriminate between the various multi path arrivals [24].The use of rake receivers (essentially a set of correlators) at both the base station and the mobile allows the combination of multi paths to form a strong signal. Thus, MC-CDMA uses multi path arrivals to its advantage in contrast to other wireless technologies, and hence suffers significantly lesser burst errors caused by multi path fading. The 4G MC-CDMA systems [25] will be able to provide data rates of up to 2 Mbps per user, which is inappreciable improvement over the current day CDMA systems that can only provide up to 9.6kbps per user. An out come of the increased data rates is that the transmission delays at BS are lowered which reduces the probability of interference between the TCP level and link level retransmissions significantly and thus makes the link layer mechanisms more viable. We feel that there is a strong need to further explore the link layer retransmission techniques in light of high data rates that will become available in the next generation (4G) MC-CDMA systems present a seminal analysis of the impact of handoffs resulting from the host movement on the throughput and delay of the reliable transport layer protocols. In their expert it analyses the performance of Tahoe TCP in a 2 Mbps wireless LAN environment with the host motion. This setup allows for the simulation of both the possible cellular scenarios i.e. overlapping cells and non overlapping cells with different beacon periods. The instants at which handoffs can be initiated are also precisely controlled using this host simulation software. The handoff process when the mobile host (MH) moves across non-overlapping cells is illustrated We will use base station (BS) in our description, which is the equivalent of Mobility Support Stations (MSS) mentioned in [6]. The BS defines each cell and also acts the gateway for routing the packets to and from the mobile hosts (MH) in the cell.



Performance of the STBC site diversity for various antennas

CONCLUSION

We have proposed various techniques for MC-CDMA that provides mechanisms at different layers, which help in improving the performance of in MC-CDMA cellular wireless networks. We feel that the physical and link layer techniques are absolutely necessary to deal with the harsh mobile radio environment. In addition, one or more transport layer techniques (may not be limited to the ones mentioned in the paper) may be combined judiciously with them to further improve the performance. Improved Interference Cancellation for 4G wireless MC-CDMA Large Communication Bandwidth & Higher Transmission Rate Systems in MC-CDMA environment has vast research potential, especially because the next generation cellular networks (4G) have chosen MC-CDMA as the air interface.

REFERENCES

[1] Young Kyun, Kim; Prasad, Ramjee. 4G Roadmap and Emerging Communication Technologies. Artech House, pp 12-13. ISBN 1-58053-931-9.

[2] Chuang, J., and N. Slenderer, ''Beyond 3G: Wideband Wireless Data Access Based on OFDM and Dynamic Packet Assignment,'' IEEE Commun. Mag., Vol. 38, No. 7, pp. 78–87,July 2000.

[3] Y. W Cao, C. C. Ko. And T. T. Tjhung, " A new multi-code multi carrier DS-CDMA system," IEEE Global Telecommunication Conference, vol. 1 pp. 543-546, November 2001.

[4] Yee, N., J. P. Linnartz, and G. Fettweis, Multicarrier CDMA in Indoor Wireless Radio Networks,'' Proc. of IEEE PIMRC'93,Yokohama, Japan, pp. 109–113, September 1993.

[5] Fazel, K., and L. Papke, ''On the Performance of Convolutionally-Coded CDMA/ OFDM for Mobile Communication System, ''Proc. of IEEE PIMRC'93, Yokohama, Japan, pp. 468–472, September 1993.

[6] Chouly, A., A. Brajal, and S. Jourdan, ''Orthogonal Multicarrier Techniques Applied to Direct Sequence Spread Spectrum CDMA Systems,'' Proc. of IEEE GLOBECOM'93, Houston, TX, pp.1723–1728, November 1993.

[7] Rodger E. Ziemer and Roger L. Peterson, "Introduction to Digital Communication, Second Edition," Prentice Hall, New Jersey,2001.

[8] S. A. Zekavat and Carl R. Nassar, "Spectral sharing in multisystem environments via multi-carrier CDMA, " Accepted in IEEE International Conferen Communications, ICC'03,Alaska, May 11-15, 2003.

[9] N. Nakagami, "The m-distribution, a general formula for intensity distribution of rapid fading," In Statistical Method in Radio Wave Propagation, W. G. Hoffman, Ed. Oxford, U.K.:Pergamon, 1960.

[10] C. Casetti, M. Gerla, S. Mascolo, M. Y. Sanadidi, and R. Wang.TCP Westwood: end-to-end congestion control for wired/wireless networks. Wireless Networks, 8(5):467–479, 2002

[11] T. Goff, J. Moronski, D. S. Phatak, and V. Gupta. Freeze-TCP: Atrue end-to-end TCP enhancement mechanism for mobile environments. In Proc. IEEE INFOCOM, 2000.

[12] R. Ludwig and R. H. Katz. The Eifel algorithm: Making TCProbust against spurious retransmissions. ACM SIGCOMM Comput. Commun. Rev., 30(1):30–36, 2000.

[13] M. C. Chan and R. Ramjee. TCP/IP performance over 3G wireless links with rate and delay variation. In Proc. ACM MOBICOM, Atlanta, USA, Sep. 2002.

[14] M. C. Chan and R. Ramjee. Improving TCP/IP performance over third generation wireless networks. In Proc. IEEE INFOCOM, Hong Kong, Mar. 2004.

[15] C. Barakat, E. Altman, and W. Dabbous. On TCP performance in an heterogeneous network: A survey. IEEE Communications Magazine, pages 40–46, Jan. 2000.

[16] H. Elaarag. Improving TCP performance over mobile networks. ACM Comput. Surv., 34(3):357–374, 2002.

[17] T. Shono, T. Yamada, K. Kobayashi, K. Araki, I. Sasase, "Intercode interference and optimum spreading sequence in frequency selective Rayleigh fading channels on uplink MC-CDMA", Trans. of IEICE on Communications, Vol.E87-A, No.8, pp.1981-1993,Aug. 2004.

[18] T. Shono, T. Yamada, K. Kobayashi, K. Araki, and I. Sasase, "Spreading code assignment for multicarrier CDMA system over frequency-selective fading channels", Trans. On IEICE on Communications, Vol.E87-B, No.12, pp3734-3746, Dec. 2004.

[19] G. Bao. Performance evaluation of TCP/RLP protocol stack over CDMA wireless link. Wireless Networks, pages 229-237, 1996.

[20] M. Zorzi and R. R. Rao. The effect of correlated errors on the performance of TCP. IEEE Communications Letters,1(September):127-129, 1997.

[21] A. Chockalingam, M. Zorzi and R. R. Rao, "Performance of TCP on wireless fading links with memory," Proc. IEEE, ICC'98, 595-600, 1998.

[22] A. Chan, Danny H.K. Tsang, and S. Gupta, "Impacts of Handoff on TCP Performance in Mobile Wireless Computing", Proceedings of IEEE International Conference on Personal Wireless Communications (ICPWC'97), India, December 1997.

[23] G. Xylomenos and G. C. Polyzos. "Internet protocol performance over networks with wireless links". IEEE Network, 13(4):55-63,1999.

[24] William C. Y. Lee, "Overview of cellular CDMA," IEEE Transactions on Vehicular Technology, Vol.40, No.2, May 1991.

[25] 3GPP home page: http://www.3GPP.org.[26] R. Caceres and L. Iftode, "Improving the performance of reliable transport protocols in mobile computing environments," IEEE.