Multicarrier modulation with OFDM for 4G networks

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Abstract- This paper presents a new approach based on multicarrier modulation (MCM) with OFDM, to accomplish the goals of 4G. MCM [1] is a form of multicarrier system and a derivative of frequency-division multiplexing. MCM is a baseband process that uses parallel equal bandwidth sub channels to transmit information. Normally implemented with Fast Fourier transform (FFT) techniques, MCM's advantages include better performance in the inter symbol interference (ISI) environment, and avoidance of single-frequency interferers.

Index Terms- MCM, OFDM, transceiver, ISI.

I. Introduction

A third-generation (3G) cellular service provides to different access technologies. The voice, video, multimedia, and broadband data services are becoming integrated into the same network. It is apparent that 3G systems, while maintaining the possible 2-Mbps data rate in the standard, will realistically achieve 384-kbps rates. To achieve the goals of true broadband cellular service, the systems have to make use of fourth-generation (4G) network.4G is intended to provide high speed, high capacity, low cost per bit, IP based services.

A. Multicarrier modulation

The basic idea of multi carrier modulation [2] is to divide the transmitted bit stream into many different sub streams and send these over many different sub channels. Typically the sub channels are orthogonal under ideal propagation conditions. The data rate on each of the sub channels is much less than the total data rate, and the corresponding sub channel bandwidth is much less than the total system bandwidth. The number of sub streams is chosen to ensure that each sub channel has a bandwidth less than the coherence bandwidth of the channel, so the sub channels experience relatively flat fading. Thus, the inter symbol interference on each sub channel is small. The sub channels in multicarrier modulation need not be contiguous, so a large continuous block of spectrum is not needed for high rate multicarrier communications. Moreover, multicarrier modulation is efficiently implemented digitally.

B. OFDM

In this discrete implementation, called orthogonal frequency division multiplexing (OFDM) the ISI can be completely eliminated through the use of a cyclic prefix. The simplest form of multicarrier modulation divides the data stream into multiple sub streams to be transmitted over different orthogonal sub channels centered at different subcarrier frequencies. The number of sub streams is chosen to make the symbol time on each Sub stream much greater than the delay spread of the channel or, equivalently, to make the sub stream bandwidth less than the channel coherence bandwidth. This ensures that the sub streams will not experience significant ISI.

The rest of the paper is organized as follows section 2 describes the implementation of 4G using MCM, chapter. Section 3 explains information processing in 4G. Section 4, section 5 explains MCM/OFDM transmitter and receiver. Section 6 concludes the paper.

II. Implementation of MCM for 4G

Two different types of MCM are useful for 4G. These include multicarrier code division multiple access (MC-CDMA) and orthogonal frequency division multiplexing (OFDM) using time division multiple access (TDMA). Note: MC-CDMA is actually OFDM with a CDMA overlay.

Similar to single-carrier CDMA systems, the users are multiplexed with orthogonal codes to distinguish users in MC-CDMA [3]. However, in MC-CDMA, each user can be allocated several codes, where the data is spread in time or frequency. Either way, multiple users access the system simultaneously.

In OFDM with TDMA, the users are allocated time intervals to transmit and receive data. As with 3G systems, 4G systems have to deal with issues of multiple access interference and timing. Differences between OFDM with TDMA and MC-CDMA can also be seen in the types of modulation used in each subcarrier. Typically, MC-CDMA uses quadrature phase-shift keying (QPSK), while OFDM with TDMA could use more high-level modulations (HLM), such as, multilevel quadrature amplitude modulation (M-QAM) (where M = 4 to 256). However, to optimize overall system performance, adaptive modulation can be used; where the level of QAM for all subcarriers is chosen based on measured parameters.

III. Processing 4G Information

As 4G is based on a multicarrier technique, key baseband components for the transmitter and receiver are the FFT and its inverse (IFFT). In the transmit path the data is generated, coded, modulated, transformed, cyclically extended, and then passed to the RF/IF section. In the receive path the cyclic extension is removed, the data is transformed, detected, and decoded. If the data is voice, it goes to a vocoder. The baseband subsystem will be implemented with a number of ICs, including digital signal processors (DSPs), microcontrollers, and ASICs. Software, an important part of the transceiver, implements the different algorithms, coding, and overall state machine of the transceiver. The base station could have numerous DSPs. For example, if smart antennas are used, each user needs access to a DSP to perform the needed adjustments to the antenna beam.

A. 4G Transceiver structure

The structure of a 4G transceiver is similar to any other wideband wireless transceiver. Variances from a typical transceiver are mainly in the baseband processing. Base stations and mobiles are distinguished in that base stations transmit and receive/ decode more than one mobile, while a mobile is for a single user. A mobile may be a cell phone, a computer, or other personal communication device.

The line between RF and baseband will be closer for a 4G system. Data will be converted from analog to digital or vice versa at high data rates to increase the flexibility of the system. Also, typical RF components such as power amplifiers and antennas will require sophisticated signal processing techniques to create the capabilities needed for broadband high data rate signals.

In the transmit path in phase and quadrature (I&Q) signals are up converted to an IF, and then converted to RF and amplified for transmission. In the receive path the data is taken from the antenna at RF, filtered, amplified, and down converted for baseband processing. The transceiver provides power control, timing and synchronization, and frequency information. When multicarrier modulation is used, frequency information is crucial. If the data is not synchronized properly the transceiver will not be able to decode it.

IV. TRANSMITTING SECTION

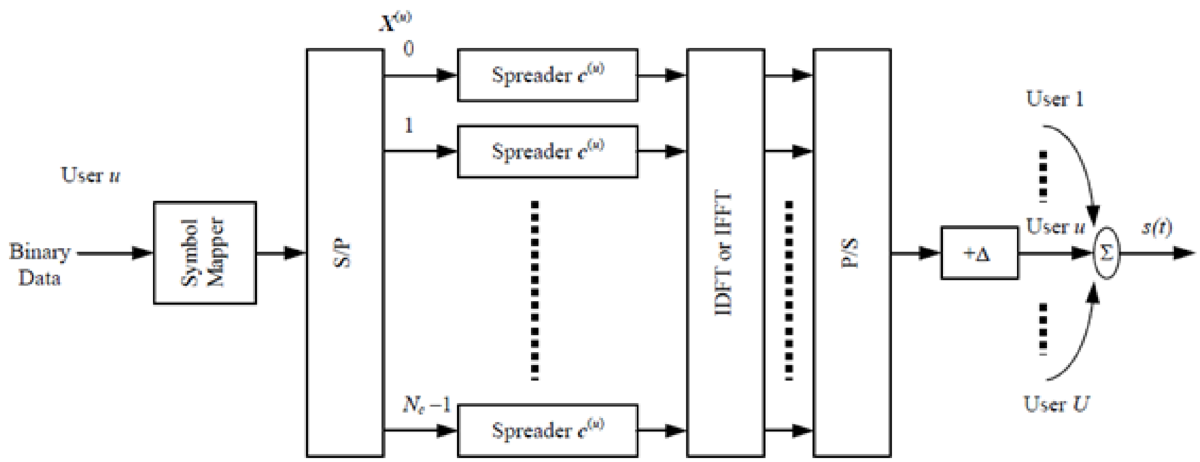

Fig. 1 MC/DS-CDMA Transmitter Model

Fig 1 gives the transmitter section of MCM/CDMA [4].The purpose of the transmitter is to generate and send information. As the data rate for 4G increases, the need for a clean signal also increases. One way to increase capacity is to increase frequency reuse. As the cell size gets smaller to accommodate more frequency reuse, smaller base stations are required. Smaller cell sizes need less transmit power to reach the edge of the cell, though better system engineering is required to reduce intra-cell interference.

One critical issue to consider is spurious noise. The regulatory agencies have stringent requirements on the amount of unwanted noise that can be sent out of the range of the spectrum allocated. In addition, excess noise in the system can seriously diminish the system's capacity.

With the wider bandwidth system associated with 4G, it will be difficult to achieve good performance without help of linearity techniques. To effectively accomplish this task, feedback between the RF and baseband is required. The algorithm to perform the feedback is done in the DSP, which is part of the baseband data processing.

V. RECEIVER SECTION

Fig 2 shows the receiver model of MCM/CDMA. For 3G, using the 2-Mbps data rate in a 5-MHz bandwidth, the SNR is only 1.2 dB. In 4G, approximately 12-dB SNR is required for a 20-Mbps data rate in a 5-MHz bandwidth[5]. This shows that for the increased data rates of 4G, the transceiver system must perform significantly better than 3G. With any receiver, the main issues for efficiency and sensitivity are noise figure, gain, group delay, bandwidth, sensitivity, spurious rejection, and power consumption. For a 4G receiver using a 5-MHz RF bandwidth, 16 QAM modulation, the receiver sensitivity is -87 dBm. For 3G, the receiver sensitivity needs to be -122 dBm; the difference is due to the modulation.

The other configuration has one down conversion, as in a homodyne (zero IF or ZIF) receiver, where the data is converted directly to baseband. The challenge in the receiver design is to achieve the required sensitivity, inter modulation, and spurious rejection, while operating at low power.

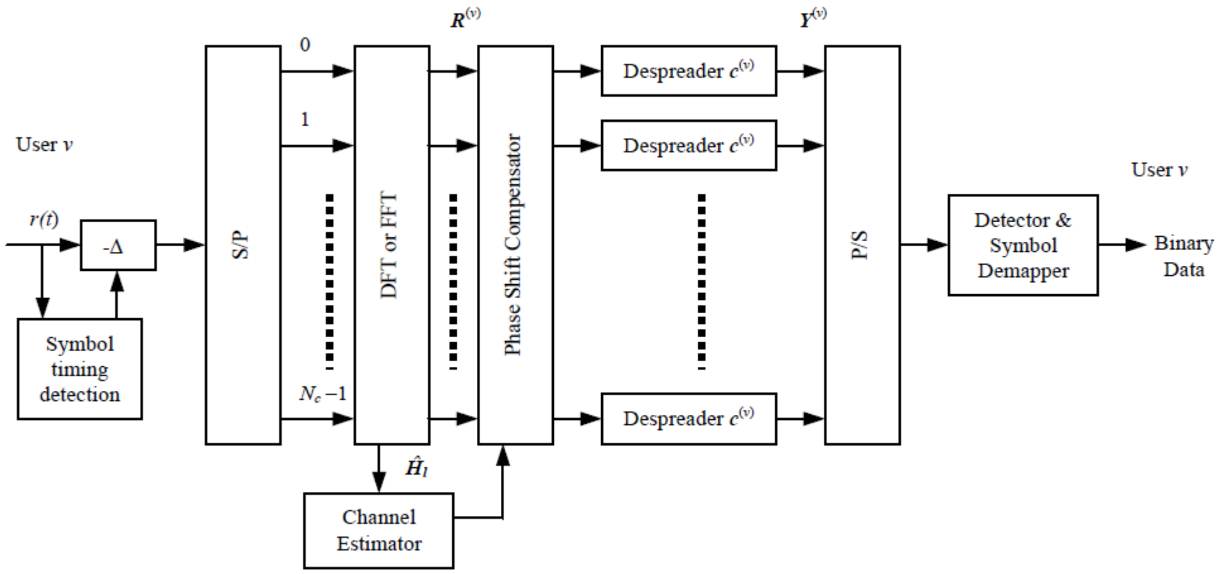

Fig. 2 MC/DS-CDMA Receiver Model

The down converter section of the receiver will have to achieve good linearity and noise figure while consuming minimal power.

The error correction coding of 4G has not yet been proposed, however, it is known that 4G will provide different levels of QoS, including data rates and bit error rates. It is likely that a form of concatenated coding will also be used, and this could be a turbo code as used in 3G, or a combination of a block code and a convolution code. This increases the complexity of the baseband processing in the receive section.4G baseband signal-processing components will include ASICs, DSPs, microcontrollers, and FPGAs. The receiver will take the data from the ADC, and then use it to detect the proper signals. Baseband processing techniques such as smart antennas and multi-user detection will be required to reduce interference.

The goal is to improve the signal by adjusting the beam pattern of the antennas. The number of DSPs needed to implement an smart antenna depends on the type of algorithm used. The two basic types of smart antenna are switched-beam antennas and adaptive arrays. The former selects a beam pattern from a set of predetermined patterns, while the latter dynamically steers narrow beams toward multiple users. Generally speaking, SA is more likely be used in a base station than a mobile, due to size and power restrictions.

B. Multi-user detection (MUD)

Multi-user detection (MUD) is used to eliminate the multiple access interference (MAI) present in CDMA systems. Based on the known spreading waveform for each user, MUD determines the signal from other users and can eliminate this from the desired signal. Mobile devices do not normally contain the spreading codes of the other users in the cell, so MUD will likely be implemented only in base stations, where it can improve the capacity of the reverse (mobile-to-base) link.

C. Power control

Power control will also be important in 4G to help achieve the desired performance; this helps in controlling high PAVR - different services need different levels of power due to the different rates and QoS [7]levels required. Therefore, power control needs to be a very tight, closed loop. Baseband processing is just as critical whether dealing with the receiver or transmitter sections. As we've seed, RF and baseband work in tandem to produce 4G signals. The baseband processing of a 4G transmitter will obviously be more complicated than in a 3G design. The digital-to-analog converter (DAC) is an important piece of the transmit chain. It requires a high slew rate to minimize distortion, especially with the high PAVR of the MCM signals. Generally, data is oversampled 2.5 to 4 times; by increasing the oversampling ratio of the DAC, the step size between samples decreases. This minimizes distortion.

D. Increasing the capacity

In the baseband processing section of the transmit chain, the signal is encoded, modulated, transformed using an IFFT, and then a cyclic extension is added. Dynamic packet assignment or dynamic frequency selection are techniques which can increase the capacity of the system. Feedback from the mobile is needed to accomplish these techniques. The baseband processing will have to be fast to support the high data rates.

VI. Conclusion

The proposed MCM and OFDM-based technologies will provide large amounts of bandwidth for broadcast and broadband applications. With Higher bandwidth MCM/ OFDM technologies also offer economic benefits additional features and wider coverage. In most instances MCM/CDMA will remain the leading and most economical platform for the delivery of mobile broadband services. Mass adoption of these wide-bandwidth OFDM-based solutions will surely cater the needs of 4G networks.

References

[1] R. Ziemer, W. Tranter, "Principles of Communications: Systems, Modulation and Noise" (5th Edition, John Wiley & Sons, 2002)

[2] A. Bahai, B. R. Saltzberg, "Multi-Carrier Digital Communications – Theory & Applications of OFDM" (Klumer Academic / Plenum Publishers, 1999)

[3] H. Matsutani, M. Nakagawa, "Multi-Carrier DS-CDMA Using Frequency Spread Coding", IEICE Trans. Fundamentals, vol.E82-A, no.12, pp.2634-2642, Dec 1999.

[4] C. Y. Li, S. Roy, "Performance of Frequency-Time MMSE Equalizer for MC-CDMA over Multi-path Fading Channel", Dept. of Elec. Eng., Uni. Of Washington, USA, April 2002.

[5] S. Abeta, H. Atarashi, M. Sawahashi, F. Adachi, "Performance of Coherent Multi-Carrier/DS-CDMA and MC-CDMA for Broadband Packet Wireless Access", ICICE Trans. Comm., vol.E84-B, no.3, pp.406-414, March 2002.

[6] S. Hara, R. Prasad, "Design and Performance of Multi-carrier CDMA System in Frequency Selective Rayleigh Fading Channels", IEEE Trans on Vehicular Tech., vol.48, no.5, pp1584-1595, Sep 2002.

[7] A. Harada, S. Abeta, M. Sawahashi, "Adaptive Radio Parameter Control Considering QoS for Forward Link OFCDM Wireless Access", IEEE VTC 2002, pp.1175-1179.

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