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A Survey of Uplink Multiple Access Techniques in LTE Mobile Communication System

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***Abstract*—The present paper gives an overview of multiple access techniques proposed for the uplink in future wireless communication systems. This paper provides the comparison between Orthogonal Frequency Division Multiple Access (OFDMA) and Single-carrier frequency division multiple access (SC-FDMA) techniques. A survey of Uplink Multiple Access Techniques in LTE Mobile Communication System, their basic features and various issues related to this have been introduced in this paper.**

Keywords- LTE, OFDMA, PAPR, SC-FDMA

I. INTRODUCTION

The demand for a radio system with high data rate and throughput has been increasing tremendously in recent years. The introduction of smart phones, almost constant access to wireless networks for laptops and an increase of mobile broadband for laptops have had a major impact on our habit of having constant access to the Internet. It is clear that the 3G mobile networks with peak speeds of a few Mbits/s will not be sufficient [1]. Updates such as High Speed Packet Access (HSPA) increase the speeds but reduce the overall performance. The 3rd Generation Partnership Program (3GPP) leads the specification of the next radio access technology that should take the telecom industry into the 2020s, known as Long-Term Evolution (LTE) [2]. Some of the requirements placed on LTE are that it should be more flexible in the utilization of the frequency spectrum and it should not only have higher data rates and lower latencies, but the data rates and latencies should also be high at the cell edges. To support these requirements the transmission schemes for the uplink (user equipment to base station) and the downlink (base station to user equipment) includes new solutions compared to the 3G networks.

LTE can provide a data rate of 100Mbps in downlink and 50Mbps in uplink when operating in a bandwidth of 20Mhz [3]. The high data rate of LTE not only demands a wider bandwidth but also a more advanced modulation technique. OFDM was considered as an optimum solution for downlink transmission requirement. But this modulation scheme has some major limitations like high PAPR which can increase complexity and power of transmitter (mobile) in uplink. So an uplink scheme should be considered with trade-off between low computation complexity and system performance [4]. A solution to this problem was to use SC-FDMA which is similar to OFDM but has an additional DFT pre-coding prior to OFDM modulation. LTE is based on Orthogonal Frequency Division Multiplexing (OFDM) with cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with cyclic prefix in the uplink. It supports both FDD and TDD duplex modes for transmission on paired and unpaired spectrum [5].

Single Carrier Frequency Division Multiple Access (SC-FDMA) is a promising technique for high data rate uplink communication. SC-FDMA is a modified form of OFDM with similar throughput performance and complexity. This is often viewed as DFT-coded OFDM where time-domain data symbols are transformed to frequency-domain by a discrete Fourier transform (DFT) before going through the standard OFDM modulation. Thus, SC-FDMA inherits all the advantages of OFDM over other well-known techniques such as TDMA and CDMA [6]. The major problem in extending GSM TDMA and wideband CDMA to broadband systems is the increase in complexity with the multipath signal reception. The main advantage of OFDM, as is for SC-FDMA, is its robustness against multipath signal propagation, which makes it suitable for broadband systems. SC-FDMA brings additional benefit of low peak-to-average power ratio (PAPR) compared to OFDM making it suitable for uplink transmission by user-terminals [7].

II. LITERATURE SURVEY

A. Luis Angel Maestro Ruiz de Temi no, Gilberto Berardinelli, Simone Frattasi and Preben Mogensen (2008)

In this paper, three new channel-aware scheduling algorithms (first maximum expansion (FME), the recursive maximum expansion (RME) and the minimum area-difference to the envelope (MAD^E)) for SC-FDMA with different level of complexity have been presented, and their performance have been evaluated in both local and wide area scenarios, considering LTE configuration parameters. Contiguous allocation of the RBs (resource blocks) for each user has been assumed as a constraint in order to preserve the low PAPR properties of the SC-FDM signal. By adopting a proportional fair metric all the proposed algorithms quickly reach a high level of data-rate fairness. At the same time, they definitely

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outperform the Round-Robin scheduling in terms of cell spectral efficiency with gains up to 68.8% in wide area environments [8].

B. Burcu Hanta (December 2009)

This paper covers the main points of SC-FDMA scheme and LTE uplink physical layer. The first one is pulse shaping operation that comes after the CP (cyclic prefix) extension might cause performance degradation if not carefully designed. The design parameter which should be taken into account is the roll off factor of the pulse shaping filter and second point is high power consumption at the mobile station is avoided by applying equalization at the base station. In other words, with complicated signal processing tools in the receiver (base station), it is possible to produce transmit symbols with low PAPR which helps the transmitter (mobile station) to reduce the power dissipated on the power amplifiers [9].

C. Hanguang Wu, Thomas Haustein and PeterAdam Hoeher (2009)

This paper presented a framework for an analytical comparison between the achievable information rate in SC-FDMA and that in OFDMA. Ideally, SC-FDMA can achieve the same information rate as in OFDMA since DFT and IDFT are information lossless; however, proper coding across the transmitted signal components and decoding across the received signal components have to be used. It further shows the achievable rate if independent capacity achieving AWGN codes is used and accordingly decoding is performed independently among the received components for SC-FDMA, assuming equal power allocation of the transmitted signal. A rate loss compared to OFDMA was analytically proven in the case of frequency selective channels, and the impact of the weak sub-carriers on the achievable rate was discussed [10].

D. Cristina Ciochina and Hikmet Sari (April 2010)

This paper proposed historical review of two popular multiple access techniques, which are OFDMA and SC-FDMA. The controversial SCT-FDE vs. OFDM issue, which started in the early 1990s at the time of the European DVB (Digital Video Broadcasting) project, continues today as an SC-FDMA vs. OFDMA debate in wireless communications. Whereas OFDMA was selected by the WiMAX Forum for mobile WiMAX systems for both downlink and uplink, the 3GPP project preferred to use OFDMA for the downlink only and favored SC-FDMA for the uplink [11].

E. Rafal Surgiewicz, Niklas Strom, Anser Ahmed, Yun Ai

This paper gives an overview of LTE and LTE uplink transmission. The advanced technology behind the uplink transmission: SC-FDMA is analyzed specifically. A comparison between the OFDMA and SC-FDMA is also done in this paper, which shows that SC-FDMA has a much lower PAPR than OFDMA and different sub carrier mapping schemes will also result in different PAPR value. IFDMA (Interleaved SC-FDMA) has a slightly better performance in terms of PAPR than LFDMA (localized SC-FDMA). This paper also proposed an Adaptive Hybrid Mapping scheme, which combines the advantages of both localized and distributed schemes [12].

F. Ashraf AwadElkarim Widaa Ahmed, Ahmed Hamza Ibrahim Makki (May 2010)

In this paper the SC-OFDMA and OFDMA multiple access technique have been studied for single and two hops scenarios. The performance is measured in term of the SER, considering the use of different sub carriers mapping schemes (the localized and interleaved). A Hybrid multiple access technique has been proposed in as tradeoff between PAPR and the link performance requirements. This hybrid technique combines the OFDMA and SC-FDMA techniques in the relay- assisted transmission scenario by adopting the SC-FDMA technique in the access link and OFDMA technique in the relay link. The obtained results show that the proposed hybrid technique achieves better end-to-end link performance as compared to the pure SC-FDMA technique and maintains the same PAPR value in access link. In this way, a lower PAPR is achieved compared to OFDMA case, which is an important merit in the uplink transmission due to the UE's power resources constraints (limited battery power) [13].

G. Omri, R. Bouallegue, R. Hamila and M. Hasna (August 2010)

In this paper a new neural-network-based channel estimation technique for LTE uplink system is presented. The proposed channel estimation method uses reference signals of SC-FDMA system to estimate the variations of the channel frequency response in time and in frequency. This method is based on two phases, in the first phase, the proposed method learns to adapt to the channel variations, and in the second phase it estimates the channel frequency response. First, the SC-FDMA transmission system and the multipath mobile radio propagation channel model are described in this paper. Then, three used channel estimation methods; Least Square (LS), minimize the mean-square error (MMSE) and estimation with decision feedback are presented, also the proposed neural network methods is described [14].

H. Muhammad Mokhlesur Rahman, Shalima Binta Manir (May 2012)

This paper, proposed the PAPR characteristics of LTE Frame Structure Type (LTE FDD & LTE TDD) of SC-FDMA and OFDMA. It concludes that, LTE FDD has better performance than LTE TDD. PAPR of SC-FDMA and OFDMA in LTE FDD achieve lower values on average. FDD has a continuous reduction of BER (Bit Error Rate) and it minimizes the BER up to a certain values of SNRs. Thus LTE FDD is the better option than in LTE TDD in uplink Transmission-SC-FDMA and downlink Transmission-OFDMA, because of its higher efficiency due to low PAPR [15].

I. Preethi S.J, K. Rajeswari (2012)

The purpose of this paper is to introduce different multiple access techniques for mobile communication. The paper explains a new concept in multiple access techniques for two-way mobile communications through single link called "Paired Carrier Multiple Access" (PCMA). PCMA is a novel method for frequency re-use which allows two mobile nodes to use the same frequency, time slots, and/or CDMA code at the same

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time. In PCMA, the uplink and downlink signals use same frequency band, time slot, CDMA code, but take advantage of the bent-pipe, loop-back nature of communications to separate uplink transmission from downlink transmission, there by it reduces the communication cost, but adds some additional processing of signal suppression in the receiver end [16].

J. Xue Jianbin, Li Songbai (2013)

This paper describes that each user in SC-FDMA system occupies only part band and sub-channel has time-frequency related properties, an SC-FDMA channel estimation based on pilot is proposed, from the theoretical analysis of this paper, channel estimation algorithm is feasible in LTE uplink system, because it not only improves channel estimation precision, but also reduces system BER. The only defect is that such algorithm becomes complex when making iterative computations, the actual hardware design feasibility and economy efficiency may not be obvious, so, how to improve estimation precision and reduce the algorithm complexity at the same time is still a problem that is worth studying [17].

K. Mayada Faris Ghanim, Mohammad Faiz Liew Abdullah and Aws Zuheer Yonis (May 2013)

This research describes that the performance of the system is different for various conditions. The transmitter and receiver system are implemented, which shows that the bit error rate has the minimum values for the system with FFT size=64 when using the BPSK and starts to increase with the increase of index modulation for different modulation technique. On the other hand when FFT size=128, BPSK and QPSK give the best results with least errors. It is noticed that the BER of the system with FFT size= 128 is less than in the system with FFT size=64. This indicates that the bit error rate is inversely proportional to the modulation index, despite the size of the FFT (in both cases). Finally, due to the low PAPR for SC-FDMA, SC-FDMA is used in the present and future as uplink of the forth and next generations [18].

L. Cristina Ciochina, David Mottier and Hikmet Sari

This paper gives a review and a performance comparison of multiple access techniques proposed for the uplink in future wireless communications systems. OFDMA is compared to SC/FDMA, which relies on single carrier like transmission with FDMA-type multiple access. The second technique can be implemented in the time domain (IFDMA) or in the frequency domain (DFT-S-OFDM). The distributed version of DFT-S-OFDM is completely equivalent to IFDMA. The single-carrier signal structure of DFT-S-OFDM provides lower PAPR and thus lower back-off requirements than its OFDMA system counterpart. For coded systems, the additional Eb/No loss caused by employing a lower back-off seems negligible at usual back-offs [19].

M. S. Tamil Selvi, K. Ramar

Multiple Access Interference (MAI) and Inter Symbol Interference (ISI) limit the capacity of the system. The conventional approaches for wireless communication may not be good in many ways. Thus in this paper , a proposal has been given to show that the problems in conventional approaches may be avoided, if the proposed Parallel Interference Cancellation (PIC) multi user detection with feedback (PICF MUD) is adopted in various multiple access schemes. In DS-CDMA system using PIC receiver with four stages, the Eb/No required to achieve a BER performance of 10^-3 is 8 dB, whereas the single stage PIC receiver with feedback approach requires only 2 dB to achieve the same BER. The proposed PICF MUD is extended in various multiple access systems to provide better BER performance [20].

N. Mohammed AL-Imari, Muhammad Ali Imran, Rahim Tafazolli, and Dageng Chen

In this paper, the performance of Multi carrier-Low Density Spreading Multiple Access (MCLDSMA) as a multiple access technique for mobile communication systems is evaluated. The MC-LDSMA technique is compared with current multiple access techniques, OFDMA and SC-FDMA. The performance is evaluated in terms of cubic metric, block error rate, spectral efficiency and fairness. The aim of this paper is to investigate the expected gains of using MC-LDSMA in the uplink for next generation cellular systems. MC-LDSMA can considerably reduce the required transmission power and increase the spectral efficiency and fairness among the users [21].

O. Mohamed Salah, Najah Abu Ali, Abd-Elhamid Taha and Hosam Hassanein

3GPP's Long Term Evolution is defined by the standardization body's Release 8 and 9, and provides more than a substrate for 3GPP's IMT-Advanced Candidate, namely LTE Advanced, which is due to be defined in Release 10. Both LTE and LTE-Advanced have SC-FDMA in their uplink, a multi-carrier access technique requiring contiguous sub carrier allocations for each UE. No scheduling algorithm, however, is dictated by the standard and several proposals have hence been presented to be implemented by vendors. A definite scheduling requirement is the support of QoS attributes of different types of uplink traffic. This paper evaluates the connection level performance of representative scheduling proposals, with focus on QoS aspects. Specifically, utilize a mixed type of traffic flows and evaluate the schedulers in terms of per-user throughput, packet loss and fairness [22].

III. OPEN ISSUE AND FUTURE SCOPE

- In future, SC-FDE techniques can be used in multi-band cognitive wireless systems. The interest in this topic is due to the fact that SC-FDE techniques are less sensitive to RF impairment than OFDM; for this reason they can applied to multi-band transmissions exploiting cognitive radio principles.
- The future work will be focused on the development of SC-FDMA channel-aware scheduling algorithms, taking care of different level of fairness among users as well as quality of service policies.
- From the general comparison of traditional OFDMA concept with SC-FDMA from the BER point of view. The application of SC-FDMA is not always straightforward and there exist certain scenarios, typically for high SNR, where OFDMA can perform better than SC-FDMA. This is a special relevance of

the upcoming next evolution of LTE, Advanced LTE, where OFDMA receives special interest even in the uplink of the cellular systems.

- Frequency Reuse (FR) and Power Control (PC) functionalities are strong tool for co-channel interference mitigation. This is still a critical issue in uplink multiple access technique.
- It would be beneficial to study and optimize MIMO performance for new deployment scenarios including higher mobility and non-uniform network deployments with low-power nodes, and the issues in practical multi-antenna UE implementation.

IV. CONCLUSION

SC-FDMA is the new multiple access technique adopted in the LTE uplink transmission scheme. Compared with the popular OFDMA, which is used in the LTE downlink transmission and WiMAX, SC-FDMA has a better performance in terms of PAPR and Frame Error Rate (FER) due to its coherent 'single-carrier' property and built-in frequency diversity. In this paper, we have given an overview of LTE uplink transmission. The advanced technology behind the uplink transmission: SC-FDMA is analyzed specifically. A comparison between the OFDMA and SC-FDMA is also done, which shows that SC-FDMA has a much lower PAPR than OFDMA. This paper also present some open issues and future scope of SC-FDMA in mobile communication system. It is hoped that paper will be of great use for researchers in the field of uplink multiple access technique in LTE mobile communication system.

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