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A Novel Study on Uplink and Downlink Transceivers for LTE System: A Review

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Abstract: LTE is the latest cellular network technology to offer universal mobile and wireless access to smart-phones and tablets. The system provides a review on uplink and downlink strategy in LTE system. There are basically two modulation techniques that are used in LTE system mainly OFDMA and SC-OFDMA. OFDMA is used in downlink and SC-OFDMA is used in uplink. The major disadvantage of OFDMA is the high PAPR (peak to average power ratio) that causes more power consumption. That is why it cannot be used in uplink because UL is power limited link. The main objective of this paper is to design optimum physical layer architecture of a high data rate LTE uplink and downlink transceiver using SC–FDMA multiple access scheme to provide lesser PAPR value and avoiding packet loss by Interleaving. All simulations will be done in MATLAB tool.

Keywords: Interleaving, LTE System, SC–FDMA, PAPR, Bit Error Rate.

I. INTRODUCTION

LTE standard has been published by 3GPP as an extension of UMTS technologies. LTE is mainly designed for high speed data applications both in the uplink and downlink. LTE network offers about 300Mbps data rate in the downlink and about 75 Mbps in the uplink. There is possibility of supporting voice over LTE(VoLTE) in the future. There are various methods under progress to support VoLTE some of them includes VOIP, legacy fallback to previous existing wireless networks. LTE changes the current method of moving data to an internet protocol system. Rather than move small amounts of data, as both CDMA and GSM do, it will move large packets of data and streamline the service. LTE uses the OFDM (orthogonal frequency division modulation) technique for data transmission. OFDM has the advantages of high spectral efficiency and high transmission data rates.

OFDM is use for downlink radio transmission for long term evolution (LTE) and SC-OFDM is used for uplink radio transmission. In OFDM technique stream of data is divided into many sub streams and transmit in parallel on many sub carrier. The transmit signals in an OFDM have high peak value in the time domain due to many subcarriers components. The high PAPR (peak) peak to average power ratio in OFDM decreases the SQNR(signal to quantization noise) of ADC(analog to digital convertor) and DAC(digital to analog convertor). So it increases the power consumption and hence reduces the efficiency of the power amplifier.

Due to high PAPR value it cannot be used in uplink transmission because uplink is very power limited so SC-OFDM is used in uplink transmission. The Air interface between LTE network and UE supports high data rate owing to OFDM and Multiple antenna techniques employed.

OFDMA is used from network to UE air interface and SC-FDMA is used from UE to network air interface. As shown in the figure LTE SAE(System Architecture Evolution) consists UE, eNodeB and EPC(evolved packet core). Various interfaces are designed between these entities which include Uu between UE and eNodeB, X2 between two eNodeB, S1 between EPC and eNodeB. eNodeB has functionalities of both RNC and NodeB as per previous UMTS architecture.LTE is completely IP based network.

The basic architecture contains the following network elements.

1. LTE EUTRAN (Evolved Universal Terrestrial Radio)
2. LTE Evolved Packet Core.

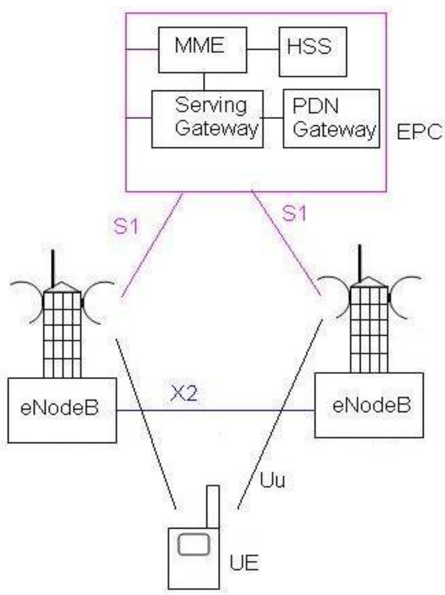

Figure 1:-Architecture of LTE system

LTE EUTRAN: It is a radio access network standard meant to be a replacement of the UMTS, HSDPA and HSUPA . Unlike HSPA, LTE's E-UTRA is an entirely new air interface system. It provides higher data rates, lower latency and is optimized for packet data. EUTRAN (Evolved Universal Terrestrial Radio) consists of eNB (Base station). EUTRAN is responsible for complete radio management in LTE. When UE powered is on, eNB is responsible for Radio Resource Management, i.e. it shall do the radio bearer control, radio admission control, allocation of uplink and downlink to UE etc. When a packet from UE arrives to eNB, eNB shall compress the IP header and encrypt the data stream. It is also responsible for adding a GTP-U header to the payload and sending it to the SGW. Before the data is actually transmitted the control plane has to be established. eNB is responsible for choosing a MME using MME selection function. The QoS is taken care by eNB as the eNB is only entity on radio. Other functionalities include scheduling and transmission of paging messages, broadcast messages, and bearer level rate enforcements also done by eNB.

eNodeB: LTE’s 4G Evolved Node B (eNodeB) base stations are software defined radios that house both digital baseband and Radio Frequency (RF) circuits in a compact, rugged, mountable enclosure to eliminate external interfaces and reduce installation errors and setup time. A range of eNodeB form factors are offered for different deployment scenarios and support standard 4G LTE band classes and frequency ranges from 400MHz to 6 GHz. The flexibility of the eNodeB provides users with high-speed network coverage to enable voice, video, data, text, and chat.

- **Affordable**: Highly scalable and cost effective.
- **Ruggedized**: Our eNodeB uses a hardened water and dust proof enclosure allowing for outdoor deployment to ensure communications regardless of the environment.
- **Compact Design**: The space saving design is pole and wall mountable, which reduces the time and cost associated with zoning and installation.
- **Remote Management**: The Element Management System is responsible for the eNodeB's configuration management, remote monitoring and alarm reporting.

Mobile technology was developed in the beginning for the sole purpose to provide voice service on mobility. Since the beginning voice was the killer application for many years until data became the lead. Today data traffic is the driving force behind most of the new developments in mobile technology.

- To provide better data throughput 3GPP offered LTE as the next generation mobile technology with only packet core. By creating a all IP network LTE completely removed the legacy circuit-switched part from it’s network architecture. But despite the fact data traffic is the major factors in today’s mobile network growth voice and other traditional circuit switched services like SMS still have a big role to play.
- The primary goal for operators is to provide telco-grade voice services over a data-only LTE network. **VoLTE** is ready for widespread commercial deployment, operators are faced with the challenge of providing call continuity between LTE and legacy circuit-switched networks.

LTE Evolved Packet Core (EPC): The LTE EPC consists of MME, SGW, PGW, HSS and PCRF.
Mobility Management Entity (MME): The MME is a control entity. It is responsible for all the control plane operations. All the NAS signaling originates at UE and terminates in MME. MME is also responsible for tracking area list management, selection of PGW/SGW and also selection of other MME during handovers. MME is also responsible for SGSN (Serving GPRS Support Node) selection during LTE to 2G/3G handovers. The UE is also authenticated by MME.MME is also responsible for bearer management functions including establishment of dedicated bearers for all signaling traffic flow.

Serving Gateway (SGW): Serving gateway terminates the interface towards EUTRAN. For each UE there is a single Serving GW associated with EPS at a given point of time. SGW acts as a local mobility entity for inter eNB handovers. It also acts a mobility anchor for inter 3GPP mobility. SGW is responsible for packet routing and forwarding, buffering the downlink packets. As eNB is responsible for uplink packet marking, SGW is responsible for downlink packet marking.

PDN Gateway (PGW): PGW terminates SGi interface towards the PDN. PGW is responsible for all the IP packet based operations such as deep packet inspection, UE IP address allocation, Transport level packet marking in uplink and downlink, accounting etc. PGW contacts PCRF to determine the QoS for bearers. It is also responsible for UL and DL rate enforcement.
Home Subscriber Server (HSS): The HSS is a central database that contains user-related and subscription-related information. The functions of the HSS include functionalities such as mobility management, call and session establishment support, user authentication and access authorization. It also holds information about the PDNs to which the user can connect. In addition the HSS holds dynamic information such as the identity of the MME to which the user is currently attached or registered. The HSS may also integrate the authentication center (AUC), which generates the vectors for authentication and security keys.
OFDMA is used in LTE technology for transmission of data at a very high speed and capacity. OFDM provides the spectrum flexibility and also a cost effective solution. In today’s environment users required very high data rate in wireless communication system. OFDMA provides high spectral efficiency, overcome the multipath fading, low intersymbol interference (ISI) and high power efficiency. High peak to average power ratio (PAPR) o the transmit

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signals in one of the major problem in OFDMA. If PAPR is controlled by using any method like by regulatory or application constraints hen he average power I also reduces so the range of multicarrier transmission also reduces. And also it is also required to operate the power amplifier I a inear region. This also effects the battery of mobile. This is the main disadvantage of the OFDMA technique. Just because of it OFDMA is used in downlink and SC-FDMA is used in uplink in lte transmission. There are many way to reduced the PAPR value in LTE transmission. Some of them are:-

Amplitude clipping, filtering, peak windowing, pea reduction carrier, envelope scaling, peak cancelation, selective mapping, tone injection clustered OFDM etc. clipping technique is the very simplest way to reduce the PAPR value. It consist of to clip the OFDM signal before amplification. It is a very nonlinear process in this clipping process in-band and out-band interference may occurs. this interfgerence destroy the orthogonality among the subcarrier. In these techniques a codeword Is selected to reduce the PAPR. One another technique is Partial Transmit Sequence(PTS) that required the transmission of side information. In these techniques there is no distortion and there is no out of band interference. Some other techniques like Selective Mapping(SM) and constellation extension or orthogonal pilot sequence(OPS) do not required the transmission of side information.

In this paper a PAPR reduction technique has been described. And the paper is organized as follows. Section II shows some works related to LTE OFDMA technique. Section III described the modulation techniques used in LTE technology system i.e. OFDMA and SC-FDMA. Section IV is the proposed work and finally section V is the conclusion.

II. RELATED WORK

Some authors proposed many solutions for controlling PAPR value in OFDM transmission technique used in downlink LTE system.(Author 1) P. jagatheeswari and M. Rajaram (2011) diagnosed that low dense parity check codes(LDPC) shall be used in higher order modulation like 64 QAM. LDPC will increase the spectral efficiency and reliability by approaching theoretical shannon limit while ensuring reduced complexity. With structured parity check matrices, it can reduce both the encoding and decoding complexity. Bit error rate(BER) performance of the LDPC code is better and is more power efficient.

Dhirendra Kumar Tripathi, S. Arulmozhi Nangai and R. Muthaiah(2011) have implemented scalable bandwidth single carrier frequency domain multiple access transceiver for the fourth generation wireless communication using FPGA. And the concluded that SC-OFDM is better than OFDM. But they did not compared SC-OFDM with OFDM, but they projected that QAM modulation can be used in place of QPSK for the high data rates.

Ashraf AwadElkarim Widaa Ahmed Ahmed Hamza Ibrahim Makki(2011) also worked on SC-FDMA and OFDMA multiple access technique for single and two hop system. By considering many subcarrier mapping scheme they measured the performance in terms of SER. A Hybrid multiple access technique has been proposed in as tradeoff between PAPR and the link performance requirements. This hybrid technique consisted of both 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. It proposed that the 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. By using this method a lower PAPR can be obtained as compared to OFDMA case.

Nagarajan Sathish Kumar and K.R.Shankar Kumar(2011) have analized Bit Error Rate performanceof Zero forcing maximum Likelihood(ML) and minimum mean square error rate performance of zero-forcing (ZF). Maximum likelihood and MMSE . They proposed that a more balanced linear equalizer is the MMSE Equalizer, which does not eliminate ISI but instead minimizes the total power of the noise and ISI

Muhammad Mokhlesur Rahman and Shalima Binta Manir (2012) also analyzed the performance of SC-FDMA and OFDMA in LTE. And they concluded that SC-FDMA is less sensitive to frequency offset than OFDMA and also less PAPR value so that it is more efficient than OFDMA.

Kussum Bhagat, Dr. Jyoteesh Malhotra(2015) have introduced various PAPR reduction techniques. . The PTS and SC-FDMA techniques was proposed that gives the improved result of PAPR. The survey on various reduction techniques conclude that IFDMA performs better and lowers the PAPR value up to high extent. To reduce the PAPR the simulation results for 16QAM/OFDM system with PTS and subcarrier mapping schemes of SC-FDMA technique has been analyzed. And they shows that as the number of sub blocks increases the PAPR value decreases. They concluded that TFDMA perform better than LFDMA.

Cheng-Chung Lin, Kumbesan Sandrasegaran, Xinning Zhu, and Zhuliang Xu are proposed the COMP Handover algorithm in LTE-A, and compared with open literature handover algorithm, due to COMP algorithm radio resource can be used in an efficient manner in the system in both channel capacity and channel quantity domain.

Abhishek Arun Dash and Mr. Vishal Gagrai introduces he OFDM techniqhe and proposed a solution for reducing PAPR value by comparing many techniques. They compared three techniques- Amplitude clipping and filtering, Selective mapping(SLM), Partial transmit sequence(PTS). And they found that PTS is more effective than others to reduce the PAPR value.

Arun Gangwar Manushree Bhardawraj also studied the OFDMA technique and also introduces the problems in

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OFDMA technique that is PAPR value. They hey described many aspect related to PAPR and names of several methods to reduce the PAPR value. All these techniques can be used in system to reduce the PAPR value at the cost of loss of data rate, BER performance degradation and so on.
Dr. G. Indumati and D. Allin Joe proposed and designed the optimum physical layer architecture for a high data rate LTE uplink transceiver. They used interleaving to improve the reliability of the system and used the LDPC codes to reduce the PAPR value so that the high data rates can be achieved by doing this and hence they proposed that for a high data rate uplink transceiver LDPC and SC-FDMA are used to reduce the PAPR. The system will be more efficient because of low PAPR value.

III: MODULATION TECHNIQUES USED IN LTE SYSTEM

Two types of modulation techniques are used in LTE systems that are OFDMA and SC-FDMA. OFDMA is used in downlink and SC-FDMA is used in uplink.

OFDMA:
OFDM is a form of multicarrier modulation. An OFDM signal consists of a number of closely spaced modulated carriers. When modulation of any form - voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. As a result when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. This is not the case with OFDM. Although the sidebands from each carrier overlap, they can still be received without the interference that might be expected because they are orthogonal to each another. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period.

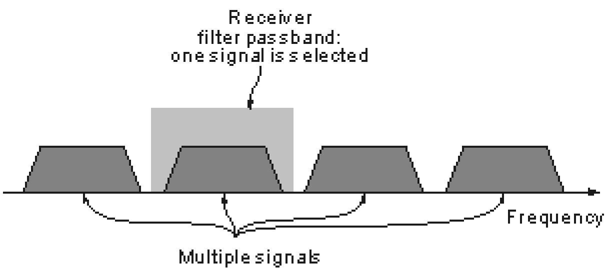

Figure 2: Traditional view of receiving signals carrying modulation

To see how OFDM works, it is necessary to look at the receiver. This acts as a bank of demodulators, translating each carrier down to DC. The resulting signal is integrated over the symbol period to regenerate the data from that carrier. The same demodulator also demodulates the other carriers. As the carrier spacing equal to the reciprocal of the symbol period means that they will have a whole number of cycles in the symbol period and their contribution will sum to zero - in other words there is no interference contribution.

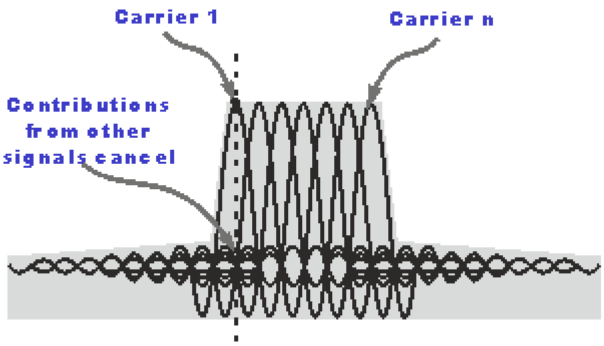

Figure 3: OFDM Spectrum

OFDM Spectrum: One requirement of the OFDM transmitting and receiving systems is that they must be linear. Any non-linearity will cause interference between the carriers as a result of inter-modulation distortion. This will introduce unwanted signals that would cause interference and impair the orthogonality of the transmission.
In terms of the equipment to be used the high peak to average ratio of multi-carrier systems such as OFDM requires the RF final amplifier on the output of the transmitter to be able to handle the peaks whilst the average power is much lower and this leads to inefficiency. In some systems the peaks are limited. Although this introduces distortion that results in a higher level of data errors, the system can rely on the error correction to remove them.

LTE OFDMA in the downlink:
The OFDM signal used in LTE comprises a maximum of 2048 different sub-carriers having a spacing of 15 kHz. Although it is mandatory for the mobiles to have capability to be able to receive all 2048 sub-carriers, not all need to be transmitted by the base station which only needs to be able to support the transmission of 72 sub-carriers. In this way all mobiles will be able to talk to any base station. Within the OFDM signal it is possible to choose between three types of modulation for the LTE signal:

1. QPSK (= 4QAM) 2 bits per symbol
2. 16QAM 4 bits per symbol
3. 64QAM 6 bits per symbol

LTE SC-FDMA in the uplink:
For the LTE uplink, a different concept is used for the access technique. Although still using a form of OFDMA technology, the implementation is called Single Carrier Frequency Division Multiple Access (SC-FDMA). One of the key parameters that affect all mobiles is that of battery life. Even though battery performance is improving all the time, it is still necessary to ensure that the mobiles use as

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little battery power as possible. With the RF power amplifier that transmits the radio frequency signal via the antenna to the base station being the highest power item within the mobile, it is necessary that it operates in as efficient mode as possible. This can be significantly affected by the form of radio frequency modulation and signal format. Signals that have a high peak to average ratio and require linear amplification do not lend themselves to the use of efficient RF power amplifiers.
As a result it is necessary to employ a mode of transmission that has as near a constant power level when operating. Unfortunately OFDM has a high peak to average ratio. While this is not a problem for the base station where power is not a particular problem, it is unacceptable for the mobile. As a result, LTE uses a modulation scheme known as SC-FDMA - Single Carrier Frequency Division Multiplex which is a hybrid format. This combines the low peak to average ratio offered by single-carrier systems with the multipath interference resilience and flexible subcarrier frequency allocation that OFDM provides.

PAPR Overview: The transmit signals in an orthogonal frequency-division multiplexing (OFDM) system can have high peak values in the time domain since many subcarrier components are added via an inverse fast Fourier transformation (IFFT) operation. As a result, OFDM systems are known to have a high peak-to-average power ratio (PAPR) when compared to single-carrier systems. In fact, the high PAPR is one of the most detrimental aspects in an OFDM system as it decreases the signal-to-quantization noise ratio (SQNR) of the analog-digital convertor (ADC) and digital-analog convertor (DAC) while degrading the efficiency of the power amplifier in the transmitter. As a side note, the PAPR problem is more of a concern in the uplink since the efficiency of the power amplifier is critical due to the limited battery power in a mobile terminal.

Let's start by showing why PAPR problems are an important problem to take care of in an OFDM system. The PAPR of a signal is expressed by the following formula:

$$PAPR_{dB} = 10\log\left(\frac{max[x(t)x^*(t)]}{E[x(t)x^*(t)]}\right)$$

Where ()* corresponds to the conjugate operator. Since an OFDM symbol can be express as a sum of complex tones equally spaced in frequency, let's start by calculating the PAPR of a single complex tone. Consider a complex tone signal:

$$x(t) = e^{2\pi ft}$$

with a period T. The peak value of the signal is:

$$max[x(t)x^*(t)] = max\left[e^{2\pi ft}e^{-2\pi ft}\right] = max\left[e^{0}\right] = 1$$

The mean square value of the signal is:

$$E[x(t)x^*(t)] = E\left[e^{2\pi ft}e^{-2\pi ft}\right] = 1$$

This gives us a PAPR of 0 dB. Consider that an OFDM time signal is made of K complex tones (usually called subcarriers). Our signal can be represented by the following formula:

$$x(t) = \sum_{0}^{K-1} a_k\, e^{\frac{j2\pi kt}{T}}$$

For simplicity, let's assume a_k=1 for any k. In this scenario, the peak value of the signal is:

$$max[x(t)x^*(t)] = max\left[\sum_{0}^{K-1} a_k e^{\frac{j2\pi kt}{T}} \sum_{0}^{K-1} a_k^* e^{\frac{-j2\pi kt}{T}}\right] = max\left[a_k a_k^* \sum_{0}^{K-1}\sum_{0}^{K-1} e^{\frac{j2\pi kt}{T}} e^{\frac{-j2\pi kt}{T}}\right]$$
$$= K^2$$

The mean square value of the signal is:

$$E[x(t)x^*(t)] = E\left[\sum_{0}^{K-1} a_k e^{\frac{j2\pi kt}{T}} \sum_{0}^{K-1} a_k^* e^{\frac{-j2\pi kt}{T}}\right] = E\left[a_k a_k^* \sum_{0}^{K-1}\sum_{0}^{K-1} e^{\frac{j2\pi kt}{T}} e^{\frac{-j2\pi kt}{T}}\right] = K$$

Given this, the PAPR of an OFDM symbol with K subcarriers, with each subcarrier having the same modulation, is simply K.

IV. PROPOSED WORK

The LTE is based on Orthogonal Frequency-Division Multiple Access (OFDMA) in the Downlink, and Single-carrier FDMA in the Uplink. It studied the performance of LTE-A systems with CA for LTE and LTE-A users under two bandwidth allocation strategies. The concept of effective bandwidth has been introduced to map the user throughput requirement into the bandwidth requirement considering the wireless channel statistics. Some provided a simulation for finding the optimum pair for the high data rate LTE uplink transceiver. Interleaving is done to improve the reliability of the system and LDPC codes are used which is more suitable for higher data rates. But in this, PAPR value is high which costs energy efficiency. The problem of high PAPR value in the System decreases energy efficiency of system. And the problem of high traffic creates high energy usage in the network which decreases the channel capacity of system. The secondary transmission capacity gets worse with the increase of throughput improvement ratio and it becomes zero when throughput improvement ratio is larger than a critical point. In downlink, the transmission capacity gets poorer with the increase of throughput improvement ratio and it becomes zero when throughput improvement ratio is larger than a critical point. Due to this, it will design a high data rate LTE system for improving PAPR Value under Rayleigh fading channel by Analytical filtering method.

V. CONCLUSION

In this work, it reviews the performance of LTE system with for users under bandwidth allocation strategy. It provides a review on optimal structure in LTE downlink system. It also provides a review on finding optimal result for high data rate LTE downlink receiver. For high data rate, high modulation format will be used.

The main objective is to reduce high PAPR value by suitable filtering approach under downlink system. For this, it will use analytical concept for reducing PAPR value. Also it will prefer the optimal method for capacity of system. If system has less PAPR value then its energy efficiency is better. In future scope, it will work on LTE-A system for improving capacity and also for bandwidth efficiency of system.

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