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LTE Advanced Techniques and Its Applications: A Literature Review

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ABSTRACT

Mobile technology plays a vital role that is developing extremely fast in present time. With the increase in higher demand for higher date rate and large user experience. Larger peak rates, larger coverage and throughputs, and lower time for transmission and reception, which results with the better user experience is being supported by LTE-Advanced (is also familiar as LTE Release-10) remarkably improves the existing LTE Release-8. After studying various papers a discussion and comparison of existing LTE-Advanced technology is done. Comparison in technique, measuring parameters, advantages and limitation are presented. The review concludes with best method for LTE-Advanced.

Keywords:- MMSE, high rank MIMO, LTE-A, BER, SER.

I. INTRODUCTION

As the technology is evolving there is need to increase in higher demand for larger data rate and rich user experience, the focus is on High Rank MIMO in the LTE –Advanced Pro system, Multi-point SU-MIMO transmission scheme and on OFDM UMTS Based LTE System. Mobile technology which is the collaborative term which is used to explore different cellular communication technology. The high demand for increased data rates nowadays for mobile wireless communication systems for supporting the broad span of multimedia, internet services has gained a significant attraction throughout the world from mobile researchers and industries, especially with the entry of Jio which is a big competitor for other service provider also to increases their quality. Next generation communication system is beyond the current 4G/IMT-Advanced standards. LTE advanced aims larger capacity in comparison with current 4G with larger quantity of mobile broadband customers in one unit area. With this higher number of customers which users uses for high definition media even without Wi-Fi. Increased support of research and development for machine to machine communication, noted as the Internet of things, aiming at lesser cost, lesser battery consumption and lesser time consumption than 4G devices. 300Mbps large peak data rates and 75 Mbps on the downlink side and uplink side is being provided by the 20 MHz bandwidth, Universal Mobile Telecommunications System (UMTS) Long Term Evolution (LTE) Release 8 [6]. Research are going on to modify the recent LTE Release-8 allowing it to overreach International Mobile Telecommunications Advanced (IMT-A) requirements. These improvements are taken as part of LTE-Advanced (LTE-A, named as LTE Release 10), which comprises of carrier aggregation, progressive uplink (UL) and downlink spatial multiplexing, downlink coordinated multipoint (CoMP) transmission, and inharmonious networks which emphasis significantly on different types of relays [6].

Single-user Multiple-Input Multiple-Output (SU-MIMO) schemes are used to improve the spectral efficiency and reliability of signal transmissions by using multiple transmit and multiple receive antennas. Downlink SU-MIMO operation has been defined since the early stage of LTE development to support a maximum of four MIMO layers. In Rel-10, the support of SU-MIMO was further enhanced by extending MIMO configuration with maximum of eight layers and by adding support of UE-specific demodulation reference signals (UE-RS). Up to now, SU-MIMO is considered as main transmission schemes in LTE-A. It is good to transmit MIMO layers by Spatial multiplexing SU-MIMO transmission schemes with per-point precoding separately with the neighboring point(s) in addition to the MIMO layer(s) transmitted by the serving point. In the given multi-point SU-MIMO transmission scheme, a genuine proportional fair scheduling algorithm is invented to get load balancing over the cooperating transmission points [1]. Layer mapping and sorted SINR is discussed which is used for better spectral efficiency [2]. Approach of comparison in different technique, measuring parameters and their values, advantages and limitation is viewed and the conclusion for best method.

This paper is ordered as: section II covers the existing algorithm and technique of LTE-A, section III deals with performance observation, section IV deals the comparison table of the current LTE Advanced technology, finally section V concludes the review.

II. EXISTING ALGORITHM AND TECHNIQUE OF LTE-A

As the technology is evolving for higher speed here the focus is on High Rank MIMO in the LTE –A Pro system, Multi-point SU-MIMO transmission scheme and also on OFDM UMTS Based LTE System. It is appropriate to classify the existing algorithm as follows.

A. *Multi-Point Single-User MIMO Transmission Scheme for communication Systems beyond LTE-Advanced [1]*

If the propagation time plus delay spread for the signals transmitted by the serving and neighboring points falls within cyclic prefix interval of the OFDM symbol, the k[th] sub carrier and l[th] OFDM symbol is to be represented by the generalized received signal model as [1]:

$$\mathbf{y}(k,l)=\sum_{m=1}^{M}\mathbf{H}^{(m)}(k,l)\mathbf{W}^{(m)}\mathbf{x}(k,l)+\mathbf{n}(k,l)\,, \quad (1)$$

where y(k,l) is the $N_r \times 1$ received signal vector at the user equipment with N_r receive antennas, $H^{(m)}(k,l)$ with dimensions $N_r \times N_t$ (m) is the channel matrix between the user device and the m_{th} transmission point with N_t (m) transmitting antennas, W(m) is the joint precoding matrix of dimensions N_t (m) × N_L, x(k,l) is the $N_L \times 1$ vector of signals transmitted on each MIMO layer, where N_L is the total number of scheduled MIMO layers, and n(k,l) is additive interference plus noise vector and Covariance matrix R_n. The received signal model more simplified to [1]

$$\mathbf{y}(k,l)=\sum_{m=1}^{M}\mathbf{H}_{eff}^{(m)}(k,l)\begin{bmatrix} x_{s_1}(k,l) \\ x_{s_2}(k,l) \\ \vdots \\ x_{s_{N_L^{(m)}}}(k,l) \end{bmatrix}+\mathbf{n}(k,l)\,, \quad (2)$$

Where H_{eff}= H(m)(k,l)V(m)is the effective channel after precoding on the m-th transmission point and X_s is the group of indices corresponding to the MIMO layers transmitted by the m_{th} transmission point.

The post-processing signal to noise plus interference ratio (SINR) for the MIMO layer transmitted by the m_{th} transmission point after linear Minimum Mean-Squared Error Interference Rejection Combining (MMSE-IRC) processing is given as [1]:

$$\gamma_k^{(m)}=\frac{1}{\left[\left(\mathbf{H}_{eff}^{(m)}\mathbf{R}^{(m)^{-1}}\mathbf{H}_{eff}^{(m)}\right)^{-1}\right]_{k,k}}-1,\quad k=1,\ldots,N_L^{(m)} \quad (3)$$

Where R(m) is the interference plus noise covariance matrix that includes interference from non-merge transmission points (Rn). It is seen that the post-processing SINR is a function of the interference plus noise covariance matrix R(m), corresponding to the MIMO layers transmitted by other cooperating points. The precoding vectors V(m) and the optimal number of layers N_L (m) for all transmission points can be selected by maximizing the capacity function as follows[1]:

$$\arg\max_{N_L^{(m)},\mathbf{V}^{(m)}}\sum_{m=1}^{M}\sum_{k=1}^{N_L^{(m)}}\log\left(1+\gamma_k^{(m)}\right) \quad (4)$$

For the proposed multi-point SU-MIMO transmission scheme, a greedy proportional fair user algorithm was considered, which is defined for the set “S” of already scheduled user as follows [1]:

$$\mathrm{PF}\{\mathrm{S}\}=\sum_{s\in S}\frac{\tau(s)}{T(s)}\,, \quad (5)$$

Where τ(s) is the instantaneous throughput of user‘s’ for the given sub frame derived from the reported effective SINR value and *T* (s) is the average throughput of user‘s’.

B. *High-Rank MIMO Precoding For Future LTE Advanced Pro[2]*

In signal model the received signal is given by:

$$\mathbf{y} = \mathrm{HWs} + \mathrm{n} \quad (6)$$

MMSE receiver is employed to detect as given by $\hat{\mathbf{S}}$ [2].

$$\hat{\mathbf{s}}=\mathbf{G}^H(\mathbf{G}\mathbf{G}^H+\sigma^2\mathbf{I})^{-1}\mathbf{y} \quad (7)$$

Where G = HW is the equivalent channel matrix.

In this paper the model on the mechanism of layer mapping is studied. The layer mapping is one-to-one or many-to-one mapping, the example of layer mapping when the transmission rank is 3 and 7 are depicted. When the signal of each layer is received, the receiver employs MMSE algorithm to detect the signal. Hence the SINR for each layer can be calculated. However, in LTE-A systems, for all the layers mapped from a codeword, only one CQI is obtained to evaluate the channel quality. An equivalent SINR for each codeword has to be obtained with the SINR in different layers. After calculating the equivalent SINR, the receiver feeds back the CQI for each codeword, and the transmitter changes the MCS adaptively based on the CQI feedback. The LTE-A systems employ codebook-based precoding to constrain the feedback overhead [2].

C. *OFDM UMTS based LTE System [3]*

Orthogonal frequency division multiplexing (OFDM) technique shown as multicarrier modulation technique noting with rather simple implementation performed using FFT/IFFT algorithms, and resilient against frequency-selective fading channels that can be obtained by transferring the channel into flat fading sub channels. In this each of the subcarrier is given fixed number of cycles which are in time interval T, and the value of cycles in which each neighbor subcarrier differs is definitely by one. The spectrum of four orthogonal signals with minimum frequency separation is provided. LTE is an orthogonal frequency division multiplexing (OFDM)-based radio access technology, with conventional OFDM on the downlink and discrete Fourier transform spread OFDM (DFTS-OFDM) on the uplink. One of the key elements of any OFDM system is the existence of the Fast Fourier transform (FFT). In different subcarriers those generated streams from the OFDM modulation are carried out. Hence, the transmitter complexity is reduced by the use of the inverse Fast Fourier Transform (IFFT). In the same way low complexity Fast Fourier Transform (FFT) operation to demodulate the OFDM signals is designed at the receiver side.

D. Performance Evaluation Of A Low Complexity OFDM UMTS-LTE System[4]

The design structure of transmitter is discussed here, OFDM UMTS-LTE transmitter structure design shown in block diagram of Fig.1 [4]. The transmitter is placed on conventional Orthogonal Frequency Division Multiplexing (OFDM) system structure.

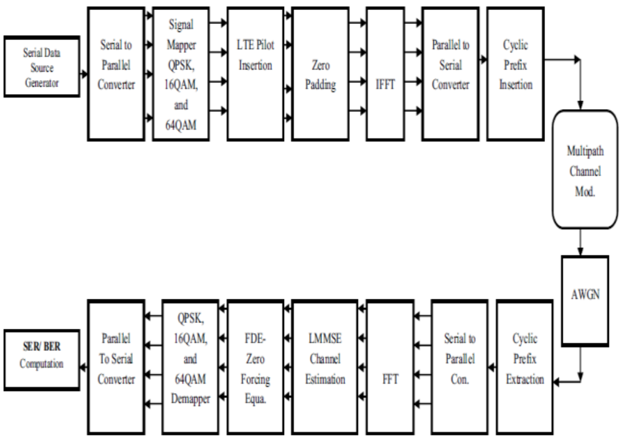

Fig.1 Block diagram of the OFDM UMTS LTE system [4].

Computation of LMMSE of channel estimate has [4]:

$$\hat{h}' = R_{h' y_r} R^{-1}_{y_r y_r} y_r \qquad (8)$$

Where R is covariance matrices and Y is the received signal. LMMSE Equalization with per-subcarrier frequency-domain equalizer (FDE) is designed in the form of a linear MMSE equalizer. The simplicity of the implemented frequency domain equalizer leads to cheap hardware implementation because it is a low-complexity design. Then the equalized signal is applied to the M-QAM demodulator block to retrieve the binary information [4]. The LMMSE estimate of $x_d(i)$ as [4]:

$$\hat{x}_d(i) = \frac{c_d(i)^*}{\|c_d(i)\|^2 + \sigma_n^2} y_d(i) \qquad (9)$$

E. Next Generation Wireless Communication: A Critical Review [5]

Multiple access technologies used in digital wireless systems. Generation, comparison of 1G-4G technology with respect to data bandwidths, standard, technology etc. Various similarity and dissimilarity of GSM, CDMA, CDMA2000, WiMAX and Long Term Evolution is discussed in paper [5]

III. PERFORMANCE OBSERVATION

Full buffer and non-full buffer traffic models were considered for the evaluation. Fig. 2 [1] shows the system RU for different values of the packet arrival rate λ for the baseline single-point SU-MIMO system. It can be seen from the figure that low (RU < 20%), medium (20% ≤ RU < 50%) and high (RU ≥ 50%) traffic loading factors are provide for packet arrival rates λ = 5, 10, 15, 20 s^{-1}, λ = 25, 30, 35 s^{-1} and λ = 40, 45 s^{-1}, respectively.

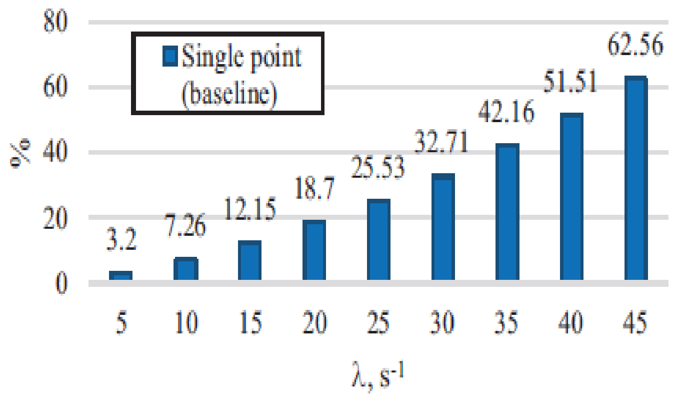

Fig.2 System resource utilization for different packet arrival rate value [1].

In busy traffic loading factors (i.e., RU ≥ 50%), noticeable performance improvement is provided for high-throughput UEs, while the performance improvement for other UEs reduces. It can be also seen from Table I that the highest gain of 33% in the 5%-tile UE throughput (i.e., cell-edge UE throughput) is achieved for the high loading factor corresponding to packet arrival rate of λ = 45 s^{-1}. The highest performance gain of 19% in the average UE throughput is achieved for medium resource utilization factor corresponding to packet arrival rate of λ = 30 s^{-1}.

The throughput analysis for High Rank Precoding is provided and BLER of the j^{th} codeword is given by [2]:

$$BLER_j = 1 - (1 - f_j(Q(k_j\sqrt{\mathrm{SINR}^{(j)}})))^B \qquad (10)$$

Table I. Relative Gain Due To the Use of the Proposed Scheme [1]

	5%-tile UE throughput	50%-tile UE throughput	95%-tile UE throughput	Average UE throughput
$\lambda = 5\ s^{-1}$	14%	0%	0%	3%
$\lambda = 10\ s^{-1}$	16%	7%	0%	6%
$\lambda = 15\ s^{-1}$	17%	20%	0%	10%
$\lambda = 20\ s^{-1}$	17%	20%	0%	14%
$\lambda = 25\ s^{-1}$	17%	17%	0%	17%
$\lambda = 30\ s^{-1}$	12%	16%	23%	19%
$\lambda = 35\ s^{-1}$	16%	15%	30%	18%
$\lambda = 40\ s^{-1}$	21%	10%	26%	15%
$\lambda = 45\ s^{-1}$	33%	5%	11%	8%

Throughput of the j-th codeword is [2]:

$$T = \sum_{j=1}^{N} T_j = N_C \sum_{j=1}^{N} r_j (1 - f_j(Q(k_j \sqrt{\mathrm{SINR}^{(j)}})))^B \quad (11)$$

The sub-space optimization model to maximize the system throughput can be expressed as [2]:

$$\max_{\mathbf{U}\in\Xi} \sum_{j=1}^{N} r_j (1 - f_j(Q(k_j \sqrt{\mathrm{SINR}^{(j)}})))^B \quad (12)$$

The MIMO channel capacity is given by [2]:

$$C = \log(\det(\mathbf{I} + \frac{1}{L\sigma^2} \mathbf{HWW}^H \mathbf{H}^H)) \quad (13)$$

The sorted SINR approach has the best performance with almost 1db gain over the type-2 column order [2].

In reference paper [3] minimum BER at iteration 11 and system performance better in BPSK and 16QAM modulators. The proposed model is experimented for minimum bit error rate (BER) with different energy by bit divides noise power spectral density ratio (E_b/N_0). The performance of the proposed model is compared with other modulators like BPSK, QPSK, 16QAM, 64QAM and also compared with wavelet based OFDMIDMA system for next generation wireless communication system. The experimental results show better performance for BPSK and 16QAM [3].

The measure for performance observation in [4] is the achieved bit and symbol error rates (BER and SER) for the various given QAM modulation formats. The transceiver performance is based on bit error rate (BER) and symbol error rate (SER) versus signal-to-noise ratio (SNR). As the number of transmitted QAM symbols increases, higher data rates are achieved. This, of course, is achieved at the expense of higher energy resources needed for adequate operation [4].

Generation comparison table of 1G-3G technology is shown in Table I [5].The Table 1 shows that the technology have evolved from analog cellular to digital cellular to broadband with CDMA, IP technology which shows how services have upgraded from larger capacity packetized data to integrated large quality audio, video and data transfer. Table II [5] shows comparison in GSM and CDMA. Estimate of the similarities or dissimilarities of CDMA systems is shown in Table III [5]. The table shows that as CDMA system evolved from 2G to 3G there is variation in their channel bandwidth, chip rate and max capacity. In downlink the LTE requirement can be fulfilled by OFDMA. While in uplink OFDMA properties are less suitable. It is because of less peak-to-average power ratio (PAPR) effects of an OFDMA signal, which results in worst uplink coverage [5]. Thus, the LTE uplink transmission layout is form of SC-FDMA with cyclic prefix. With SC-FDMA selected as LTE uplink access scheme because SC-FDMA signals have better PAPR properties in comparison with OFDMA signal [5]. The peak-to-average power ratio features are valuable for lower cost design of UE power amplifiers and also it has some similarities with OFDMA signal processing, so parameterization of downlink and uplink is balanced. There are various ways be finding where an SC-FDMA signal be generated [5]. DFT spread-OFDM (DFT-s-OFDM) is chosen for E-UTRA. The concept is given in Fig. 2 [5].

The downlink behavior through a different workload (bursty traffic model) is explained [6]. For proper working of network load and the user geometry the bursty traffic model is important to dependency of the user data rate.

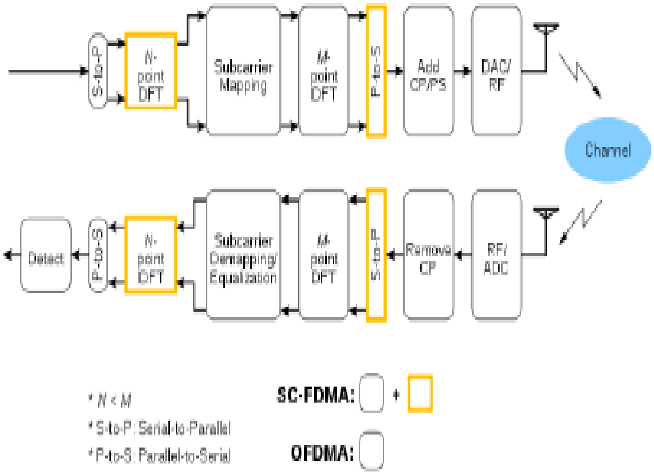

Fig: 2 Diagram of LTE system [5].

The characteristics is that the model uses users only for the duration of the file transfer, users are made arbitrary and begins file transfers in the simulated network with a certain rate in accordance with the Poisson process, data transfer equipment are viewed for the duration of the file transfer and then dropped from the simulation once the file data volume is transferred, during the interval of application file transfer it is assumed to download as quickly as the network allows [6]. The behavior of UL for the bursty traffic scheme is summarized. It may be noted that the mean user data rate at 50 percent resource utilization is approximately 10 Mb/s, while the 5 percent edge throughput is approximately 1.5 Mb/s [6].

IV. COMPARISON OF EXISTING LTE ADVANCED TECHNOLOGY

Approach of comparison in different technique, measuring parameters and their values, advantages and limitation is presented in Table III. Greedy proportional fair user algorithms with MMSE-IRC, Full buffer and non-Full buffer traffic model have advantage of higher throughput. Layer Mapping, Sorted SINR technique uses MMSE, SINR and CQI as measuring parameter for better spectrum efficiency. OFDM technique is robust and cyclic prefix reduces ISI. OFDM UMTS LTE technique uses BER, SER and LMMSE equalization as measuring parameter which are cheaper and have low hardware complexity.

TABLE II Comparison of existing LTE-ADVANCED TECHNOLOGY

SR. NO.	Reference Paper	Name of Technique	Measurement Parameters	Advantage	Limitation
1.	[1]	Greedy proportional fair user algorithm	MMSE-IRC, Full buffer and non-Full buffer traffic Model, 33% in 5% tile UE Throughput at λ=45/sec, 19% in average UE Throughput at λ=30/sec	Reduce Complexity, Beneficial for higher λ, Improves throughput	Performance Degradation for Higher Throughput (for 95%)
2.	[2]	Layer Mapping, Sorted Signal to Interference Noise Ratio (SINR)	MMSE, SINR and CQI, $\text{BER} = f_j(Q(k_j\sqrt{\text{SINR}^{(j)}}))$ Channel Capacity $C = \log(\det(\mathbf{I} + \frac{1}{L\sigma^2}\mathbf{HWW}^H\mathbf{H}^H))$ Throughput; T= $N_c\sum_{j=1}^{N} r_j(1 - f_j(Q(k_j\sqrt{\text{SINR}^{(j)}})))^B$	Better Spectrum Efficiency, Sorted SINR has more than 1db gain and close to 3bit feedback	Practical Receiver such As MMSE can't achieve channel Capacity.
3.	[3]	OFDM	PAPR BER Evaluation (BER 0.00000021 BPSK @ 22 E_b/N_o) (0.0003 16QAM @ 16 E_b/N_o).	Robust, CP reduces ISI BER is low for BPSK and 16 QAM, BER reduces with iterations (11).	Not guarantee Linear behavior of system.
4.	[4]	OFDM UMTS LTE	BER, SER, MMSE Channel Estimator, LMMSE equalization	Robustness and flexibility in multipath channel, Cyclic prefix reduces ISI, Transmitter complexity Reduced by IFFT, Cheaper and low hardware Complexity	Performance Degradation as Terminal speed Increases
5.	[5]	GSM CDMA LTE	GSM - Capacity $\eta = n/f_r$ [channels/MHz/site] CDMA - Capacity $\eta = n.k/c$ [channels/MHz/site] LTE - OFDMA (DL @ 100 Mbps) SCFDMA(UL @ 50 Mbps)	More stable, Robust, Less signal deterioration, Better performance, Full mobility, Handover and roaming Support, Better PAPR	Fixed max. cell site range of 35 km.
6.	[6]	LTE (Release 8) LTE-A (Release 10) Carrier aggregation DL spatial multiplexing using up to eight-layer MIMO DL intracell CoMP transmission and reception UL Spatial Multiplexing using four-layer MIMO	LTE (release8) – DL-OFDM @ 300 Mbps UL-SC-FDMA @ 75 Mbps (BW=20MHz) LTE A (Release 10) - Layer shifting mechanism for spatial multiplexing Bursty Traffic Model Frequency selective scheduling found on the Proportional Fair Metric Mean user data rate at 50 percent resource utilization is around 10 Mbps, where as the edge throughput of 5 percent is approximately 1.5 Mb/s.	Micro-sleep, Low power consumption, Reduce cubic meter DL Speed=1Gbps UL=500Mbps Crosstalk suppression, Power saving in layer shifting Interference over thermal noise ratio (IOT) is constrained in 9-11db range.	Carrier aggregation has limited UE Transmitted Power

V. CONCLUSION

This review focused mainly on the literature survey and analysis of existing LTE-A technology based application with its algorithm for communication system. A comparison of existing LTE Advanced technology is done which discusses LTE advanced techniques, measuring parameters, advantage and limitation. For the machine to machine communication research is going on for lower cost, lower battery drainage and lower time in comparison with 4G equipment. LTE-Advanced with Multi-Point Single-User MIMO is the next technology for further LTE-advanced. A new approach of supporting SU-MIMO CoMP transmission where additional MIMO layers with per-point precoding are independently transmitted from the neighboring point(s) with the existing MIMO layer(s) that are going to the serving point. Use of MMSE-IRC, Full buffer and Non-Full buffer traffic model as parameters for future advancement of LTE-A can improves performance and throughput. With the focus on multi-point SU-MIMO transmission scheme which can improve the system performance with greedy proportional fair user selection algorithm, therefore it may be regarded as a candidate improvement for the next generation cellular systems beyond LTE-Advanced.

REFERENCES

[1] Alexei Davydov and Gregory Morozov, "Multi-Point Single-User MIMO Transmissin Scheme for Communication Systems beyond LTE-Advanced", 83rd Vehicular Technology Conference (VTC Spring), IEEE 2016, ISBN 978-1-5090-1698-3.

[2] Hao Wu, Jianxing Cai, Huahua Xiao, Yijian Chen, Yu-Ngok Ruyue Li, Zhaohua Lu, " High-Rank MIMO Precoding for Future LTEAdvanced Pro", 83rd Vehicular Technology Conference (VTC Spring), IEEE 2016, ISBN 978-1-5090-1701-0.

[3] Shadma Pragi, Agya Mishra, "OFDM UMTS Based LTE System" International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013.

[4] Amman Osman and Abbas Mohammed," Performance Evaluation of a Low-Complexity OFDM UMTS-LTE System", Vehicular Technology Conference, 2008, VTC Spring, IEEE 2008, ISBN 978-1-4244-1645-5, ISSN 1550-2252.

[5] Shadma Pragi, Agya Mishra, "Next Generation Wireless Communication: A Critical Review" GJCAT, Vol 3 (3), 2013, 1267-1272, ISSN 2249-1945.

[6] Amitava Ghosh, Rapeepat Ratasuk, Bishwarup Mondal, Nitin Mangalvedhe, And Tim Thomas, Motorola Inc," LTE ADVANCED", IEEE Wireless Communications (Volume: 17, Issue: 3, June 2010), ISSN 1536-1284.