Performance Analysis of 4G Long Term Evolution Downlink Handover based on Multi-Cell MIMO

Mrs Latha M[1] Mrs Arpitha Shankar S I[2]
[1,2]Assistant Professor
[1,2]Department of Tele-Communication Engineering
[1,2]GSSSIETW, Mysuru

Abstract— With the substantial escalation of mobile applications and smart-phones, there is an increasing trend of technical adaptation of 3G (third generation). But with the exponential growing of massive traffic, it is seen that even 3G network is completely not capable of catering to the dynamic needs of the customers. This paper focuses on the handover of the 4G-LTE (fourth generation- long term evolution) network that not yet accomplished the soft handover. 4G LTE is designed on the principles of packet switching system on the backbone of IP protocol. We designed, simulated and compared variable step size 4G-LTE using the no. of antenna elements and array factor is verified using simulations on MATLAB.

Key words: 3GPP, 4G-LTE (Long Term Evolution), MIMO (Multiple Input Multiple Output), Handover

I. INTRODUCTION

The mobile users are accustomed to using high data rate services in LTE system and expect high data rate services even in handover region. Long Term Evolution (LTE) in Release 8 (2008), an entirely new air interface based orthogonal Frequency Division Multiplexing(OFDM) was implemented setting the basis for a 4G capable mobile communication technology, and first LTE capable went on-air in 2009/10[1].

The LTE standard was designed as a completely new standard, with new numbering and new documents—it does not build on the previous series of UMTS standards. Earlier elements were only brought in if there was a compelling reason for them to exist in the new standard. There is no requirement for backward compatibility or error interoperability, for example, because LTE will operate in different spectrum using a different physical layer and different coding.

The entire LTE system is specified by a large number of 3GPP working groups which oversee everything from the air interface to the protocol stack and the infrastructure network [2]. LTE is a departure from historical cellular and telecom operations, which were circuit switched. LTE is the first GSM/3GPP standard that is fully IP and packet-based. Much of the complexity of UMTS that deals with circuit switching is not carried into LTE; this has allowed some simplifications and optimizations of the architecture. LTE provides a packet switched model at the SAP, but retains a circuit switched model at the PHY. The physical layer itself maintains the continuous connection model, especially on the downlink, where there is continuous transmission.

Usually a 4G network is built from multiple wireless networks for supporting hand-off from one to other technologies. Wireless networks have their own advantages and limitations when such heterogeneous network is considered. Eventually LTE network is also associated with various issues [3]: e.g. i) network discovery, ii) access technologies, iii) network condition, iv) network architecture, v) charging and billing process, vi) security, vii) large number of operators, and viii) congestion control. In addition to such issues, there exist many more problems associated with the mobility management of 4G-LTE: e.g. i) inefficient QoS, ii) signaling overhead, iii) energy requirements, iv) less scalable and reliability in hand-off process.

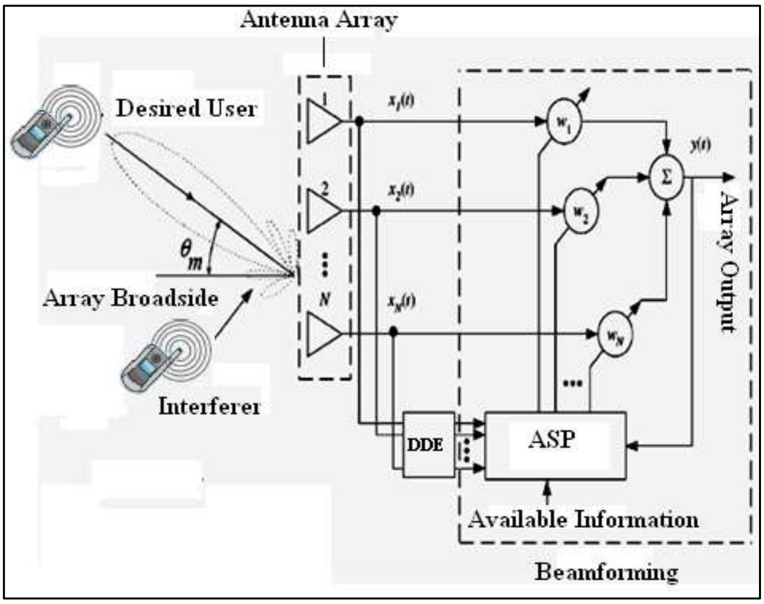

Fig. 1: Adaptive Antenna Block

Beam forming is a process of forming the beam in the desired direction and nulls in the direction of jammers. Figure 1 shows an Adaptive antenna structure with N antenna elements, DDE block, Adaptive Signal Processor where signal is processed by beam forming algorithms. The figure also shows main beam formed in the direction of desired signal and nulls in the direction of jammers

Interestingly, the study towards mobile networks is a decade old. Majority of the studies focus on individual wireless network, where the actual focus on problem is make. As the present users are more inclined towards adopting smart mobile communication technologies, e.g. 4G-LTE, it is essential that a researcher must have clarity of the effectiveness in the existing techniques based on which the researcher can perform further investigation. Modeling wireless communication system with the standards of 3GPP-LTE considering heterogeneity of the access network is one of the challenging problems for investigating the effectiveness of the techniques. Even for the purpose of benchmarking, it is important that we must know the best framework proposed till date in LTE network that has better mitigation techniques of critical problems.

This paper is organized as follows. Section 2 introduces the Background and related work. In Section 3 System Model is presented. In section 4 Emerging trend of research is discussed. Simulation results are presented in Section 5. Conclusions are drawn in Section 6.

II. BACKGROUND AND RELATED WORK

LTE (Long Term Evolution)—A 4G technology proposed and developed by 3GPP to improve the UMTS wireless standard [4]. LTE has been selected by more than 297 mobile technology mobile operators worldwide as their global technology for 4G services. . These global carriers, including industry leaders Vodafone, China Mobile and Verizon Wireless, along with AT&T, China Telecom, KDDI, MetroPCS, NTT DoCoMo, Sprint and T-Mobile—have all deployed or plan to deploy LTE at some point in the future.

Until recently, existing mobile service providers had to rely on services provided by 3G/UMTS networks. The 10years old technology didn't have the capacity to accommodate high bandwidth and high speed demands made by end users, which resulted in the adoption of 4G. What then is 4G? 4G also known as Fourth Generation (4G) is referred to as Mobile multimedia; Anytime/anywhere; Global mobility support; integrated wireless solution; and customized personal service which is an abbreviation for MAGIC [5].

1) Chen Xu [6], have discussed the radio resource allocation for Device to Device links based on interference avoidance approach and for system with multiple transmit antennas, beamforming technique is applied based on signal to leakage criterion to reduce the co-channel interference.
2) Hongyuan Zhang [7], proposed cooperative processing schemes, including joint transmission and BS selection, at multicell base stations, to address problems inherent on the downlink of cellular multiuser MIMO communications.
3) Andreas F. Molisch, Moe Z. Win, Yang-Seok Choi, and Jack H. Winters [8], investigated the behavior of MIMO systems that select a subset of available antennas at one link-end by deriving the upper bounds for the capacity of antenna selection. Although the authors discussed that their technique can considerably reduce congestion, there was no significant outcome to prove it.
4) José Bruno Iñiguez Chavarría [9], have quantitatively analyzed handover performance evaluation process of the LTE network by the statistical analysis. The authors have considered path-loss and SINR to evaluate the outcome accomplished from their study.
5) Cheng-Chung Lin, Kumbesan Sandrasegaran, Huda Adibah Mohd Ramli, and Riyaj Basukala.[10], proposes a new handover algorithm known as LTE Hard Handover Algorithm with Average Received Signal Reference Power (RSRP)

Constraint (LHHAARC) in order to minimize number of handovers and the system delay as well as maximize the system throughput.

6) Variable step size (VSS) methods are commonly sought after to provide steady state MSE performance. This method uses larger step size at the start of the iteration to speed up the convergence rate of the algorithm, and smaller step size when the algorithm is convergent [11].
7) Several VSS-LMS type Channel Estimation techniques have been proposed in the literature [12], [13], [14]. But these algorithms are not adaptive to track the optimum step size parameter in a non-stationary environment.

In 3G Networks the mobile user was detected by computing the power spectrum based on the value of Array correlation matrix and then finding the inverse of the array correlation matrix. As the number of antenna elements increases the magnitude of the array will become closer to zero and then the inverse of array correlation matrix will be infinity and also when the radiation is transmitted towards the mobile users the phase shifts will be applied to each of the individual elements. The phase shifts will depend upon the inverse of the array correlation matrix and the radiation will be spread across entire space due to which even interference users will get the radiation.

III. System Model

The 4G LTE FIXED algorithm is one of the most popular algorithms in adaptive signal processing, due to its simplicity and robustness. Many different modifications were proposed to improve performance of the 4G LTE FIXED and a large number of results on its steady state maladjustment and its tracking ability has been obtained. Unfortunately, its convergence rate is highly dependent on the conditioning of autocorrelation matrix. When inputs are highly correlated, convergence rate degrades radically. . Variable Step-Size 4G LTE (VSS 4G LTE) algorithms are used, with the intention of decreasing maladjustment and to maximize convergence rate. Step size is larger when the estimate is far from the optimum value and a smaller step-size as it approaches the optimum value. The performance of this method is promising especially in non stationary environment.
The autocorrelation matrix is given by

$$R = E[x(n)\,x(n)^H] \tag{3.1}$$

Where, $x(n)$ is the induced signal and $x(n)^H$ is the hermitian transpose of $x(n)$. The step size is calculated, during each iteration by using equation

$$\mu(n+1) = \alpha\,\mu(n) + \gamma\left|e(n)\right|^2 \tag{3.2}$$

Where, 'α' indicates the correlation of the present step size to the previous step size, α is in the range $0 < \alpha < 1$ and γ is used to control convergence characteristics of VSS-4G LTE algorithm, $\gamma = 0.5$ and e(n) is given by

$$e(n) = d(n) - y(n) \tag{3.3}$$

Where, $d(n)$ is the reference signal and $y(n)$ is the array output. The upper bound on the step size is given by

$$\mu_{upper} = \frac{2}{3tr(\mathrm{cov}(x))} \tag{3.4}$$

Where, $tr(\mathrm{cov}(x))$ is the trace of covariance matrix.

The weight update equation to put main beam in the desired direction and nulls in the jammer directions using VSS-4G LTE is given by

$$w(n+1) = w(n) + \mu(n+1)e(n)x(n) \tag{3.5}$$

The algorithm is bounded in step size with upper bound as defined in equation (3.6). During each iteration the step size is changed as

$$\begin{aligned}\mu(n+1) &= \mu_{upper} && \text{if } \mu(n+1) > \mu_{upper}\\ &= 0 && \text{if } \mu(n+1) < 0\\ &= \mu(n+1) && \text{otherwise}\end{aligned} \tag{3.6}$$

A. *Simulation Methodology of 4G LTE FIXED*

1) Compute the Lx1 steering vector for desired direction θ_0.
2) Compute the LxM array manifold vector corresponding to M interference source directions $\theta_1, \theta_2, \ldots\ldots\ldots, \theta_M$.
3) Obtain signal samples 'S' by sampling continuous time signal of baseband frequency. (For simulation sine wave samples is considered).
4) Compute the autocorrelation matrix R_{xx}.
5) Compute the step size by using equation (3.2)

6) Compute the following for all signal samples $0 \le n \le N_s$. Where, N_s is the total number of signal samples.

$$x(n) = a(\theta_0)s(n) + i(n)\sum_{i=1}^{M} a(\theta_i) + n_0(n) \qquad y(n) = w(n)^T x(n)$$

$$e(n) = s(n) - y(n)$$

$$w(n+1) = w(n) + \mu\, x(n)e^*(n) \quad (3.7)$$

7) The array factor is computed by using equation

$$AF = \sum_{i=1}^{L} w^H(i)\, e^{j2\pi d \sin(\theta)} \qquad -90^0 \le \theta + 0.001 \le +90^0 \quad (3.8)$$

8) Array factor versus angles are plotted.

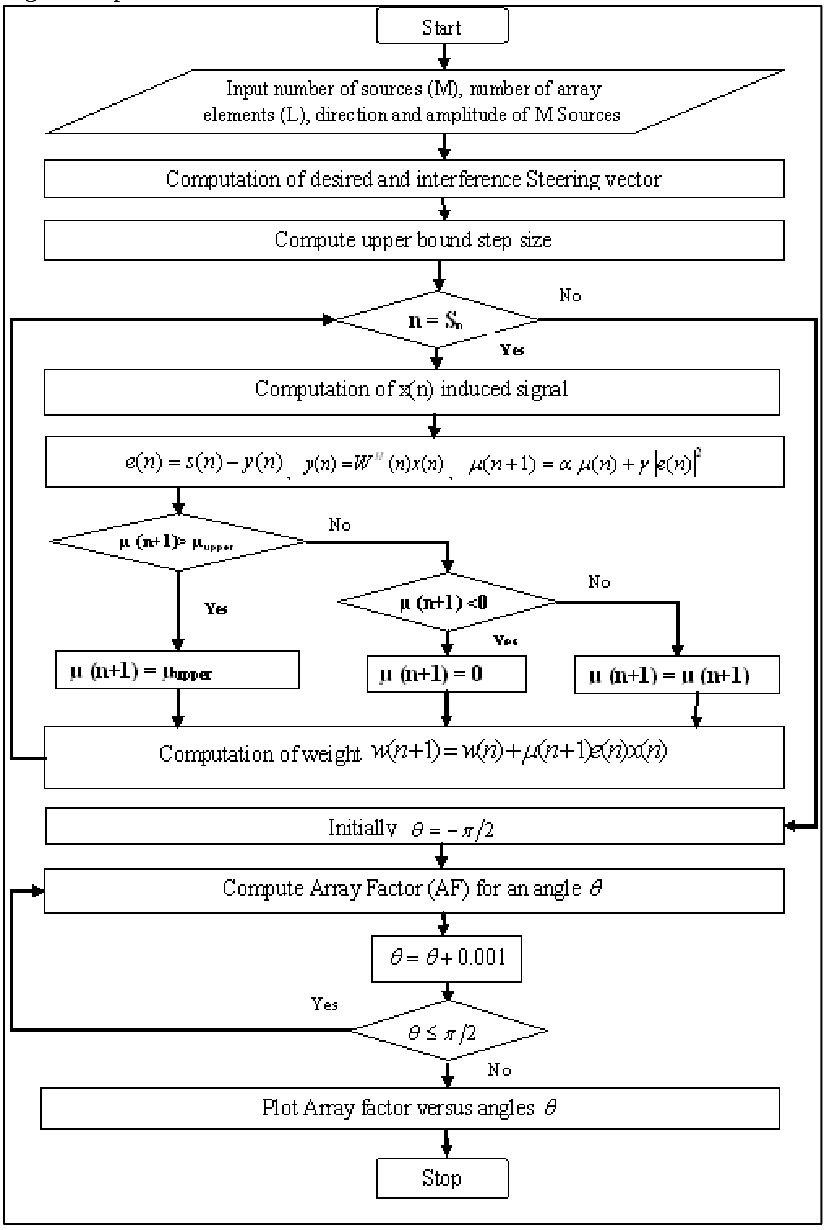

Fig. 2: 4G LTE variable Step Size based Antenna Radiation Formation.

IV. EMERGING TREND OF RESEARCH

The previous section has discussed about some recent potential studies with brief discussion of various techniques implemented. This section discusses about some of the evolving trends that have been witnessed by the research community. Hence, for this purpose, we choose to perform a close scrutiny of those concepts involved in existing standard publications that seemed to be slowly gaining pace among the researchers.

In the proposed work 4G network based mobile user detection is performed using subspace computation of the array correlation matrix When the radiation pattern is formed it forms the main beam towards the desired mobile users and nulls or reduced radiation towards the interference users. The beamforming is done in such a way that the Mean Square error is very less in case of 4G LTE network. Also in order to improve the convergence and capacity of 4G networks variable step size algorithms are used for beamforming.

A. MIMO Techniques

MIMO technologies overcome the deficiencies of these traditional methods through the use of spatial diversity [15, 16]. Data in a MIMO system is transmitted over T transmit antennas through what is referred to as a "MIMO channel" to R receive antennas supported by the receiver terminal. If the antennas within the transmit array and the antennas within the receive array are spaced sufficiently far apart, the signals traveling between the various transmit and receive antennas through the MIMO channel will fluctuate or fade in an independent manner. The transmitted data can therefore be encoded, using a so-called space-time code, to make use of this spatial diversity and allow processing at the receiver to extract the underlying data.

B. OFDMA

OFDMA (Orthogonal Frequency Division Multiple Access) is one of the most useful approaches in the mobile cellular system. As users in the same cell may have different signal-to-noise and interference ratios (SINRs), it would be more efficient to allow multiple users to select their own subset of subcarriers with better channel conditions, rather than selecting a single user that uses all the subcarriers at the same time. In other words, there may be one or more users with significantly better channel conditions, especially when the number of users increases. Improvement in the bandwidth efficiency, achieved by selecting multiple users with better channel conditions, is referred to as multi-user diversity gain. OFDMA [17] is a technique that can fully leverage the multi-user diversity gain inherent to the multi-carrier system. The amount of physical resources (i.e., time slots, subcarrier, and spreading codes, assigned to each user in these techniques) depends not only on the required data rate of each user, but also on the multi-user diversity gain among the users.

V. SIMULATION RESULT

Uniform linear array (ULAs) means that the array elements are same as each other and they are aligned along a straight line with equal element separations. Elements of ULA are isotropic antennas. The delay between the elements of ULA for a signal incident on the array is from -90 degree azimuth and zero degree elevation. The delays are computed w.r.t the phase center of the array.

Adaptive array beamforming is capable of performing the following function:

- Estimating the direction of arrival (DoA) of all incoming signals which also includes interference and multipath signals.
- Beam is steered only in the direction of the desired signal, which when the user moves from one direction to the other it keep tracking the user by placing the nulls at the interfering signal direction and also by updating the complex weights constantly.
- Desired signal is identified and undesired signals/ interfering signals are filtered from the incoming signal.

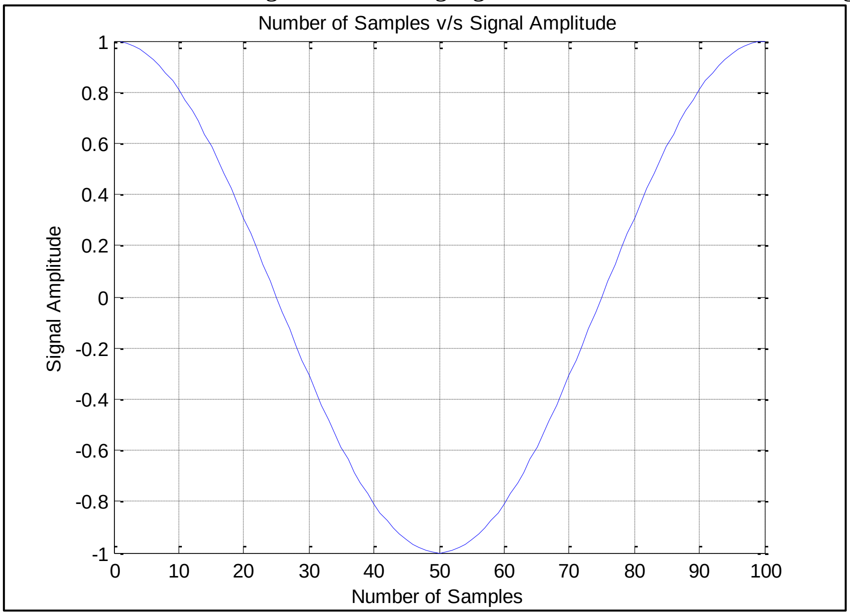

Fig. 3: Number of sample v/s Signal Amplitude

When the UE is powered up it needs a network to attach itself. The first towards it is Cell search. Cell Search is a procedure by which a terminal can find a potential cell to attach too. As a part of cell search procedure the terminal obtains the identity of cell and estimates the frame timing of the identified cell. LTE supports 510 different cell identifiers divided into 170-cell identity group of 3 identities each.

LTE provides two signals in downlink:

- Primary Synchronization Signal

– Secondary Synchronization Signal

In first step of cell search, UE uses primary sync signal to find the timing on 5 ms basis. This signal is transmitted twice in each frame (as LTE frame is of 10 ms). Terminal can use this signal to identify the frame timing with a 5 ms ambiguity. Here terminal locks it local oscillator frequency to the base station carrier frequency. The terminal also finds an identity within the cell. It also obtains partial knowledge about reference signal structure. In the next step terminal detects the cell identity group and determines the frame timing using secondary synchronization signal. In Fig 5.1, Synchronization signal is generated which is required during the hand-off .

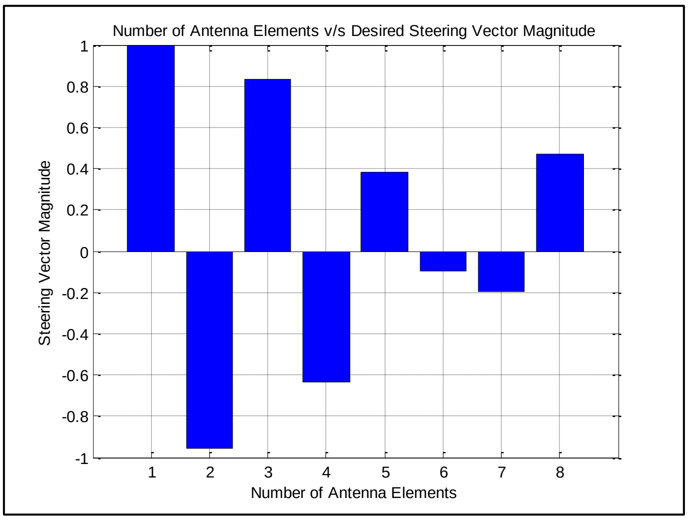

Fig. 4: Number of Antenna elements v/s Steering Vector Magnitude

Assuming number of Array Elements as 8 and the desired user is at the angle of 65 degrees. Let number of Jammers be3 and their angles are 25, 77 and 44 degrees respectively, for the values we have obtained the polar beam plot of the desired user which is obtained calculating the array factor as in fig 5.3. Steering Vector represents the relative phase shifts for the incident waveform across the array elements. By randomly generating the steering vector its magnitude is plotted w.r.t the no. of antenna elements (Fig5.2).

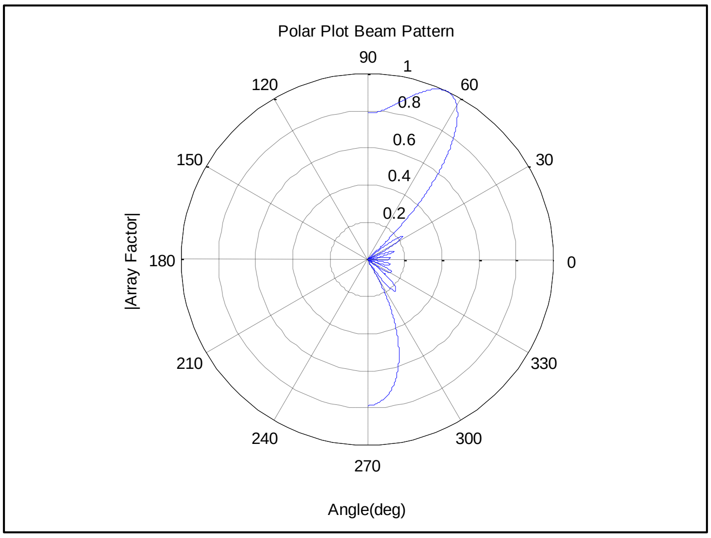

Fig. 5: Polar Plot Beam Pattern

As the User Equipment (UE) continuously searches for the cell MSE should converge very fastly which is shown in fig 5.4.

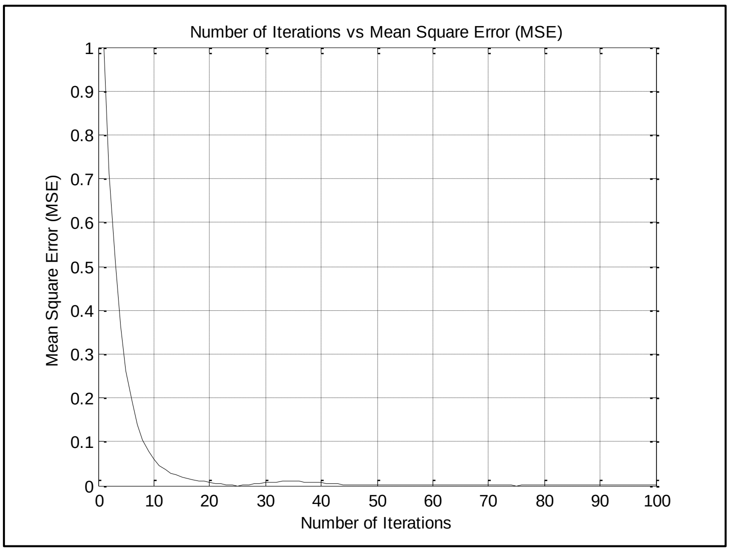

Fig. 6: No. of iterations v/s Mean Square Error (MSE)

Array weights are used because in the real time application the signal travelling from eNodeB to UE may get degraded due to fading or interference. And this array weight helps the lost signal to get recovered by adding appropriate weights. Where the array weights are randomly generated using the no.of array elements as shown in fig 5.5 and fig 5.6.

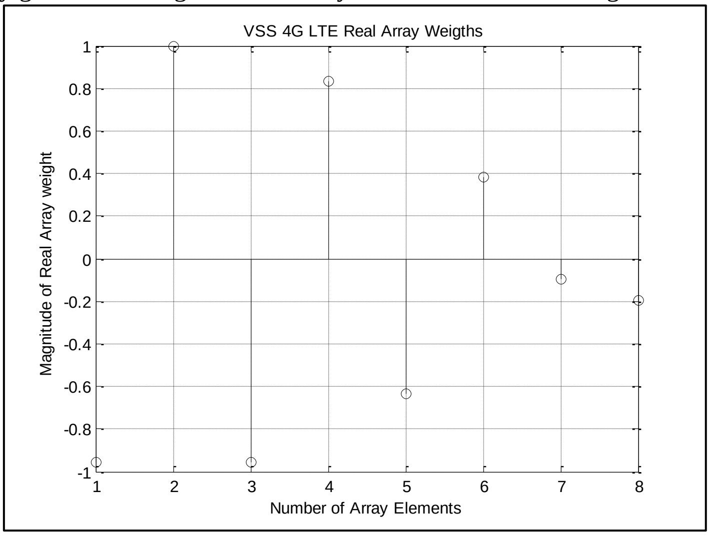

Fig. 6: VSS 4G-LTE Real array weights

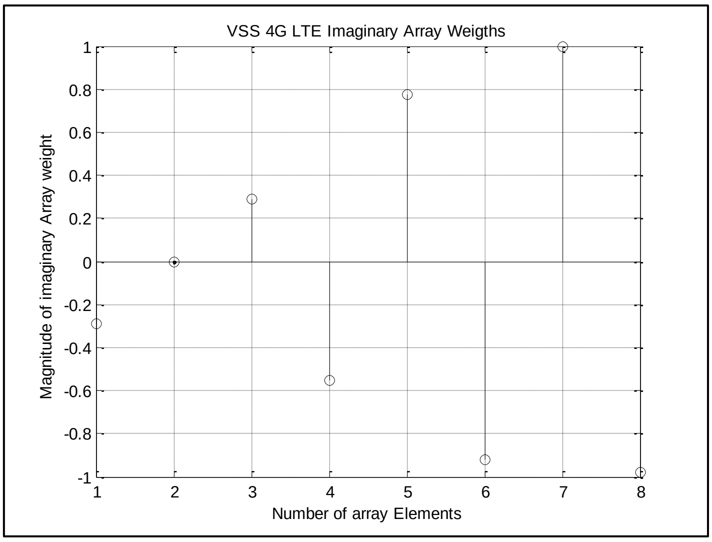

Fig. 7: VSS 4G-LTE Imaginary array weight

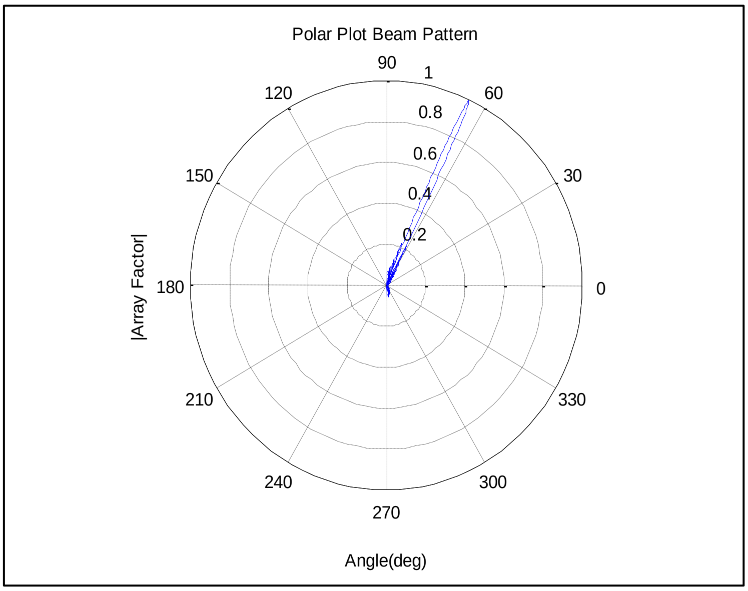

Fig. 8: Polar Plot Beam Pattern (for 100 antenna element)

VI. Conclusion

This paper has discussed various significant contribution of the past research attempts. The prime aim of the paper was to understand the effectiveness in the techniques for improving the LTE network. Our work towards future direction will be to design an efficient framework that can address the research gap highlighted in this paper. Our design principles consider OFDMA for downlink transmission and employ MIMO to further enhance the throughput under various dynamic traffic conditions. And the Using the capabilities of MATLAB we have successfully simulated VSS 4G-LTE. From the figure 5.3 we can see that beam pattern is generated only to the desired user by nullifying the interference signal even though the no. of antenna element increases to 100 (fig 5.7).

References

[1] LTE mobility enhancement handover QUALCOMM February 2010
[2] Long Term Evolution Protocol Overview, white paper
[3] Payaswini, P., Manjaiah, D.H.2013. Challenges and issues in 4G – Networks Mobility Management. International Journal of Computer Trends and Technology (IJCTT). Vol.4 Iss.5
[4] 4G LTE WHITE PAPER , “The Verizon Wireless 4G LTE Network”: Transforming the Business with next-generation Technology.
[5] 4G WIRELESS COMMUNICATION TECHNOLOGIES – Connecting People, Devices and Information. A Afolayan MSc Computer and Network security.
[6] Chen Xu, Lingyang Song, Zhu Han, Qun Zhao, Xiaoli Wang: Resource Allocation and Beamforming Algorithm Based on Interference Avoidance Approach for Device-to-Device Communication Underlaying LTE Cellular Network, Communications and Network, 2013, 5, 367-373
[7] Hongyuan Zhang, Huaiyu Dai, and Quan Zhou: Base Station Cooperation for Multiuser MIMO: Joint Transmission and BS Selection, Conference on Information Sciences and Systems, Princeton University, March 17-19, 2004
[8] Andreas F. Molisch, Moe Z. Win, Yang-Seok Choi, and Jack H. Winters: Capacity of MIMO Systems With Antenna Selection, IEEE transactions on wireless communications, vol. 4, no. 4, july 2005
[9] José Bruno Iñiguez Chavarría: LTE Handover Performance Evaluation Based on Power Budget Handover Algorithm, European Master of Research on Information and Communication Technologies.
[10] Cheng-Chung Lin, Kumbesan Sandrasegaran, Huda Adibah Mohd Ramli, and Riyaj Basukala: Optimized Performance Evaluation Of Lte Hard Handover Algorithm With Average Rsrp Constraint, International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. April 2011
[11] Costa, M. R. H., Bermudez, J. C. M. A noise resilient variable step size LMS algorithm. IEEE Trans. on Signal Processing, 2008, vol. 88, no. 3, pp.1-7
[12] Evans, J. B., Xue, P., Liu, B. Analysis and implementation of variable step size adaptive algorithms. IEEE Trans. on Signal Processing, 1993, vol. 41, pp. 2517–2535.
[13] Zhao, S., Man, Z., Khoo, S., WU, H. R. Variable step size LMS algorithm with a quotient form. IEEE Trans. on Signal Processing, 2009, vol. 89, no. 1, pp. 67 – 76.
[14] Mayyas, K., Aboulnasr, T. A robust variable step size LMS- type algorithm: analysis and simulations. In Proc. Acoustics, Speech, and Signal Processing. Detroit(MI, USA), 1995, vol. 2, pp. 1408 –1411.
[15] Veerendra, Md.Bakhar and Vani.R.M, “Robust Blind Beam formers for Smart Antenna System using Window Techniques”, Elsevier Procedia Computer Science, vol. 93, pp. 713 – 720, 2016.

[16] Veerendra, Md.Bakhar and Vani.R.M "Subspace Based Direction of Arrival Estimation using No Snapshot Criteria for Mobile Communications", The IUP Journal of Telecommunications, vol.7, no.3, pp.29-37, August 2015.