PERFORMANCE ENHANCEMENT OF TWO TIER WIRELESS NETWORK USING AN ADAPTIVE HYBRID SCHEDULING ALGORITHM

[1]S.Bhatia, [2] Dr. Ashwini S. Kunte ,

[1] Department of Electronics and Telecommunication,
Thadomal Shahani college of Engineering,
Bandra(west) , Mumbai -400 050

Abstract – Long Term Evolution-Advanced (LTE-A) aims to provide high data rate, high spectral efficiency, improved throughput and Fairness to users in the cell as well in the indoor area in different traffic conditions. A low power base station, Femto-cell can be installed in indoor areas for indoor coverage in LTE-A networks. By using Base station Transmit Power control, the network performance is improved as Cross channel Interference reduces. This improves the user's throughput. Further, proper Packet Scheduling by the Radio Resource Management (RRM) will enhance the performances of the wireless heterogeneous LTE-A network by reducing the co-channel interference. Presently, Downlink scheduling algorithms viz : Round Robin, Best-CQI and Proportional Fair are used in LTE/LTE-A. A new hybrid scheduling algorithm is proposed in this paper. The proposed hybrid algorithm is simulated using Vienna LTE-A simulator. The performance of the proposed algorithm is compared with the Round Robin, Best-CQI and Proportional Fair downlink scheduling algorithms in LTE-A. In this proposed scheme, one sub-frame time slot is divided into two sub time slots. In the first time sub slot, the User equipment (UE) Channel Quality Indicator (CQI) feedback report is considered and the resource blocks are assigned to the UE with best CQI. In the next time slot, resource blocks will be assigned to all the users which are connected only if traffic exists to achieve proper fairness. Simulation results proves that the proposed scheme improves the tradeoff between Average user throughput and Fairness Index in comparison with existing Round Robin, Best-CQI and Proportional Fair downlink Scheduling algorithms.

Index Terms—Long term Evolution- Advanced, Downlink Packet Scheduling, Radio Resource Management throughput, Spectral Efficiency, Fairness.

I.INTRODUCTION

Long Term Evolution–Advanced (LTE-A) is a mobile communication standard and a major enhancement of the Long Term Evolution. LTE-A was standardized by the 3rd Generation Partnership Project (3GPP) as 3GPP Release 10 in March-2011. LTE-A was formally submitted as a potential candidate 4G to International Telecommunication Union-T in late 2009 as meeting the requirements of the International Mobile Telecommunication–Advanced standard. LTE-A boosts the signal quality, can provide very high data rate, high spectral efficiency, high user equipment throughput as it can support transmission bandwidths up to 100 Mhz. Due to this, the capacity of the user equipment increases during transmission and reception process[1][2]. It uses OFDMA in downlink and SC-FDMA in Uplink transmission.

Radio Transmission Characteristics management of the wireless communication such as cellular communication, wireless sensor network etc, allocation of scarce radio Resources and co-channel interference management is done by a system level management called Radio Resource Management[3]. The main function of the RRM is to efficiently utilize the radio network infrastructure and radio frequency spectrum. RRM considers multi-user and multi-cell network capacity instead of point-to–point channel capacity [4].

The process in which eNodeB decides which UEs should be given Resource Blocks (RBs) and how much Resource Blocks should be given to send or receive data, is called Packet Scheduling. The main objectives of Packet scheduling are to maximize the cell capacity, satisfy the minimum Quality of Service required for connection and fairness to all the users. The smallest unit of radio resource that can be allocated to a user is called Physical Resource Blocks (PRBS). The entity is called scheduler. In LTE-A, one frame of ten milliseconds is divided into ten sub-frames of one millisecond each. Scheduling is done in every subframe. The main functions of the Scheduler are as follows [5]:

1. Link Adaptation: With good channel condition using Channel Quality Indicator (CQI), the scheduler has to adopt higher modulation and coding scheme such as 64 Quadrature Amplitude Modulation (QAM) and Transmit mode such as 4 x 4-Closed loop Spatial Multiplexing (CLSM)

2. Packet Scheduling and Resource allocation: Various scheduling algorithms are used to allow RRC connected Active users to access the air interface and radio resources per sub frame basis.
3. Power Control: Control of eNodeB transmit power to reduce cross channel interference and maintain the desired SINR
4. Hybrid Automatic Repeat request and Forward Error Correction: Hybrid automatic repeat request (HARQ) is a combination of high rate forward error correcting coding and ARQ error control. Scheduler has to take care of retransmission of data packets lost due to error in transmission and reception.

In LTE, three types of standard scheduling algorithms are used. Round Robin, best channel quality (CQI) and Proportional Fair. In this paper, a new modified Fair algorithm is proposed to optimize the average user throughput along with high fairness to users in the cell. Matlab Based Vienna LTE-System level Simulator is used [6]. All the three schemes are simulated along with the proposed one. Finally, a comparison is done based on the wireless network performance metrics such as Fairness, Peak throughput , average and edge user throughput mean Resource Block occupancy and spectral efficiency. Empirical Cumulative Distribution Function (ECDF) is used to evaluate the network performance in terms of average user's throughput and users wideband signal-to-Interference and Noise Ratio.

II.LITERATURE REVIEW

4G LTE/LTE-A access network uses Orthogonal Frequency Division Multiple Access (OFDMA) in downlink and Single carrier Frequency Division Multiple Access SC-FDMA in uplink [7-10]. 4G LTE operates in both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) modes. Adaptive Modulation Coding schemes along with advanced antennas such as Multiple Input Multiple Output (MIMO) enable operators to transfer more amount of data per MHz of spectrum at lower cost per bit. Presently, Frequencies 850MHz, 1800MHz and 2300 MHz are used to provide bandwidth of 5MHz, 10MHz and 20MHz respectively. In time domain, the downlink channels in air interface are divided into Frames of 10ms each. Each frame is further subdivided into ten sub-frames of 1ms interval each. The sub frame time interval is called Transmission Time Interval (TTI). Each sub frame is divided into two time slots of 0.5ms each. In Frequency domain the total bandwidth is divided into sub channels of 180 kHz. Each sub-channel consists of 12 subcarriers of 15 kHz each. A Resource Block consists of 180 kHz sub-channel of 12 Subcarriers with each subcarrier composed of 6 to 7 OFDM symbols with cyclic prefix in the frequency domain and 0.5ms of time slot in time domain. Number of Resource blocks in the available bandwidth is called Resource grid. 4G LTE operates in the bandwidth of 1.4MHz up to 20MHz with number of Resource Blocks ranging from 6 to 100 for bandwidths 1.4MHz to 20 MHz respectively [7-10]. These radio resource blocks are to be distributed among the active user with some scheduling algorithms ensuring desired Quality of service (QoS) for the users. This scheduling is done in the Media Access Control (MAC) layer of eNodeB. The different scheduling algorithm effects the throughput of each user and the throughput of the entire cell area. There are three main scheduling algorithms used in 4G-LTE viz: Round Robin, Best CQI and Proportional Fair [11-13].

a.**) Round Robin Scheduling:** Round Robin Scheduling is a channel independent scheduling algorithm. The algorithm provides the physical Resource Blocks cyclically based on time sharing to the users thus ensuring highest fairness to all the users. Even the cell edge users with poor channel quality gets a fair chance of resource blocks usage. It does not consider the instantaneous channel quality, so it experiences poor performances in terms average cell throughput. But the users are equally scheduled. The modulation scheme also is not adjusted adaptively with the channel quality thus reducing the spectral efficiency. The resource blocks are not efficiently utilized by the users with poor channel quality.

$$RRn,k = t - tk \qquad (1)$$

Where t refers to the current time and t_k refers to the previous time when the user was serviced.

b) Best Channel Quality (Best CQI): The scheduler considers the channel quality feedback given by the user. The user with the good channel condition is allocated the resource blocks. The Base station transmits the reference signal (downlink pilot) in the downlink to the User Equipment (UE). UE uses this reference signal by the eNodeB to estimate the channel quality as it calculates CQI and sends that as a feedback to eNodeB. Higher value of CQI represents good channel condition. This algorithm is spectrally efficient but not fair enough for the users at the edge of the cell with poor channel quality condition. But the total cell throughput is greatly improved.

$$Mk,n = rk,n(t) \qquad (2)$$

Where $r_{k,n}(t)$ refers to the instant data rate for the k^{th} user in the time t on the nth RB. In this scheduling the user with higher data rate will be served prior to the user with lower data rate. This scheduling is not fair for the users at the edge of the hexagonal cell due to poor channel quality condition.

c) Proportional Fair Scheduling (PF): This scheduling provides balance between the overall cell throughput and fairness. This scheduler allocates the resource blocks to the user with good channel quality in the first time slot and in the second time slot allocates the resource blocks to the users in order such that fairness is achieved. In the first time slot t the scheduler obtains the feedback of the instantaneous channel quality (CQI) for each UE. For each resource block allocated, it checks for the average throughput achieved by the user in the past window of length T. Scheduling gives priority is given to the user with good channel condition by allocating the resource block which gave the maximum throughput [16].

$$K = \arg\max\,[R_k(t)/T_k\,(t)]\ on\ nth\ RBs \text{ -- } (3)$$

The Proportional Fair Scheduling algorithm provides fairness to the users while maintaining the high average cell throughput. This scheduling is not fully optimized. So, a new modified scheduling algorithm is proposed in this paper.

d) Proposed Hybrid Scheduling : Hybrid Scheduling algorithm divides the time slot of 1ms into two time slots of 0.5ms each. In the first time slot it uses the Best CQI methodology to allocate users with efficient resource Blocks (i.e.Resource blocks which gave maximum throughput for a particular good quality channel) later the eNodeB will keep track of the average throughput for each user equipment on the assign Resource Block RBs and in the second successive time slot the scheduler will deactivate the users with less than the threshold or no traffic in buffer and will schedule only the activated users (i.e. users with high buffer traffic) with fairness. In this manner, the scheduling algorithm is dynamically activating or deactivating the user depending on the buffer traffic in the time slot. This hybrid scheme improves the spectral efficiency by using the Best CQI scheduling in the first time slot and Fairness by using modified Proportional Fair scheduling in the second time slot. Thus, it improves the UE capacity and cell performance. The eNodeb MAC scheduler provides fairness as all active users will be scheduled although in different time slots. This scheme shows improvement in throughput of cell edge users compared to others.

Algorithm of Hybrid Scheduling is as follows:
1. The time slot of 1ms is divided into sub-slot period of 0.5ms.
2. In the first time slot, as per the channel quality feedback received by eNodeB from users , Users are scheduled with best channel quality in order, If more than one users are having good quality channel , then scheduler will select randomly from them.
3. The user's traffic buffer will be checked in the second time slot. The users with almost no or very less traffic will be deactivated. Only the users with traffic in buffer will be scheduled to improve fairness among the users.

III. SIMULATION SET UP

In this section, the simulation parameters are shown in tabular form as given below in Table-1. The simulation is done using Matlab based Vienna LTE-A system level Downlink Simulator.

Table 1 Simulation set-up

Simulation Parameters	Value
Bandwidth	20 MHz
Operating Frequency	2GHz
Transmission mode	4x2Closed Loop Spatial Multiplexing (CLSM)
Path loss model	Urban
Minimum Coupling Loss	70dB
Transmit Mode	CLSM
Transmission Time Interval(TTI) -ms	50 ms
No of Macro-users / Femto-Users	5,10.20/ 2,5,10
Distance between eNodeB	500metres
eNodeB ring	0,1
Base station transmit power	46dBm
Femto Base station Transmit power	20dBm
Channel type	TU
User speed	5/3.6 km/h
Scheduling Algorithm	Round Robin, Proportional Fair, Best CQI and proposed Hybrid

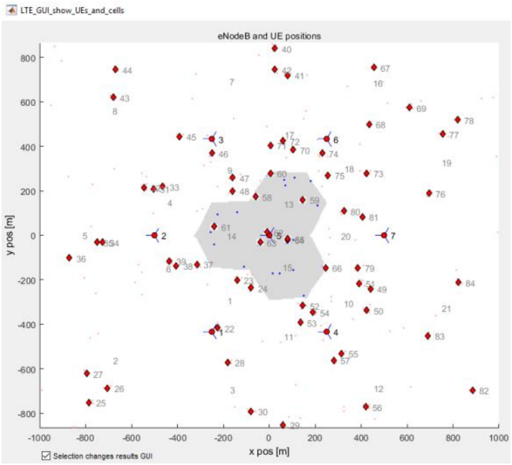

Fig 1. Heterogeneous network with macro-users and Femto-cells

In this paper, we consider the effects of different scheduling algorithms and the proposed hybrid on the throughput of the user in a heterogeneous network along with the fairness .

IV. RESULTS AND DISCUSSION

This section presents simulation results of the performance of different scheduling algorithms along with the proposed hybrid Scheduling scheme. Three Macro-cells with four femto-cells each with 4x2 CLSM transmit mode are considered in the simulation set-up. The transmission scheme of 4x2 MIMO CLSM is chosen as it shows better average user throughput. The comparison evaluation is done on wireless metrics such as peak user throughput, average user throughput, edge user throughput, and average cell throughput in Mbps and spectral efficiency in bits per channel use. In Wireless communication Statistics, an Empirical Cumulative Distribution Function (ECDF) is the distribution function associated with the empirical measure of Parameters such as average UE throughput (MBps) or average UE spectral efficiency in bit/ cu. Its value at any desired specified average UE throughput of the measured average UE throughput is the fraction of observations of the measured Throughput that are less than or equal to the desired specified value[14,15]. ECDF is an estimate of the CDF that gave the desired average UE throughput in average UE throughput measurement. It converges with probability 1 as per the Glivenko-Cantelli Theorem[15].

Spectral Efficiency is a wireless metric that gives the amount of information that can be transmitted in a given allotted bandwidth. A higher average UE throughput for a allocated bandwidth results in a higher average UE Spectral Efficiency.

Table 2: Comparison of different Scheduling Schemes

Parameters	Round Robin	Best CQI	Proportional Fair	Hybrid
Peak— throughput (Mbps)	11.07	82.68	76.0	84.18
Average user throughput (Mbps)	5.96	61.39	9.3	57.92
Edge user throughput (Mbps)	2.85	0.00	0.2	8.21
Average cell throughput (Mbps)	29.8	138.13	66.45	57.91
Spectral efficiency bit/cu	1.77	7.82	1.56	6.92
Fairness Index	0.82	0.716	0.68	0.767

ECDF of UE average Throughput and UE average Spectral Efficiency for Different Scheduling Algorithms are shown in figures given below.

A. Round Robin Scheduling (4X2 CLSM).

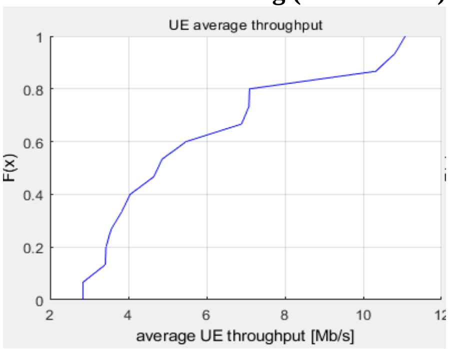

Fig 7 ECDF function of UE average throughput

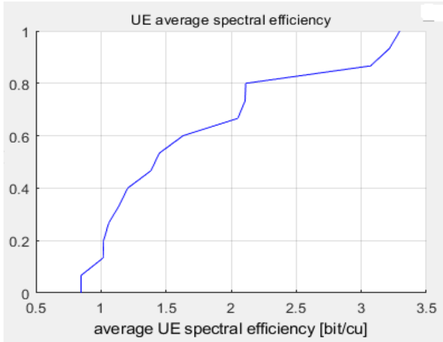

Fig 8. ECDF of UE average Spectral Efficiency

B. Best CQI Scheduling (4x2 CLSM)

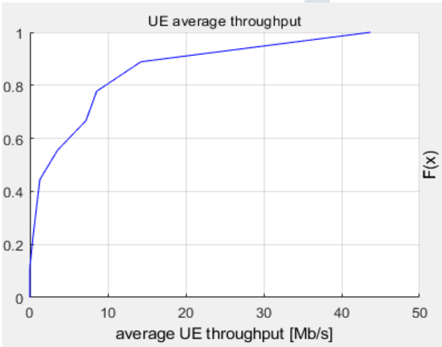

Fig 9. ECDF function of UE average Throughput

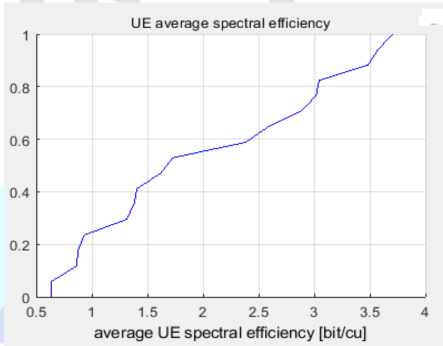

Fig 10. ECDF of UE average Spectral Efficiency

C. Prop Fair sun Scheduling (4x2 CLSM)

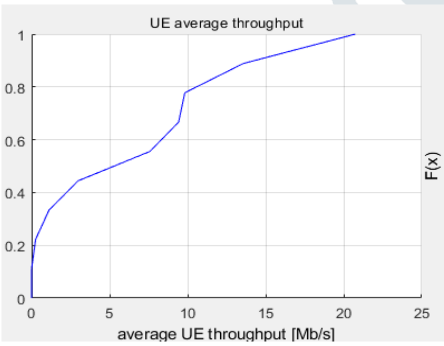

Fig 11. ECDF function of UE average Throughput

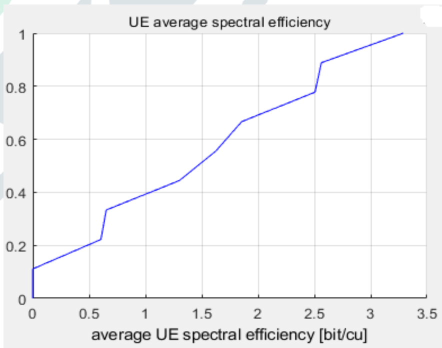

Fig 12. ECDF of Average UE Spectral Efficiency

D. Proposed new Hybrid Scheduling (4x2 CLSM)

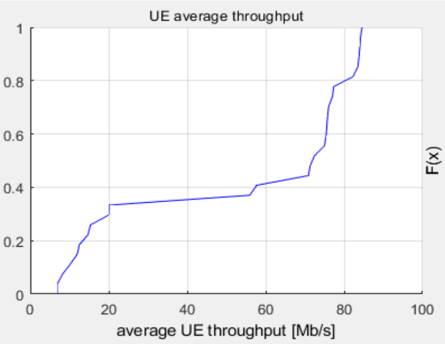

Fig 13. ECDF function of UE average throughput

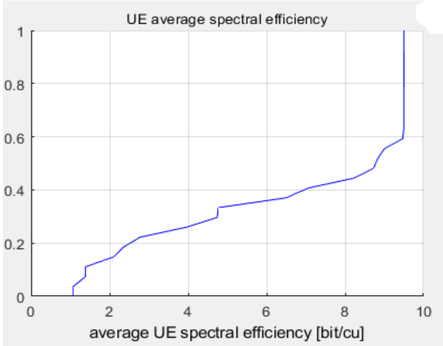

Fig 14. ECDF function of UE average Spectral efficiency

As observed from the comparison in Table 2, the proposed hybrid scheduling algorithm improves the cell edge user's throughput, along with fairness index. The Ecdf function of average UE throughput for new proposed Hybrid Scheduling algorithm as seen in Fig 13 shows that 35% to 40% users will experience not less than 50Mbps compared to very low average user throughput in RR, Best CQI, and Proportional Fair Scheduling algorithms. The average UE spectral efficiency as seen in Fig 14 for new proposed Hybrid Scheduling that 40% of the users will experience high spectral efficiency of 7 bit per cu(not less than 7 bit/cu) as compared to low spectral efficiency in RR and Proportional Fair. Thus, it improves the trade-off between the average cell user throughput and fairness index when compared to RR, PF and Best CQI. The transmission scheme of 4X2 MIMO CLSM has also improved the average user throughput.

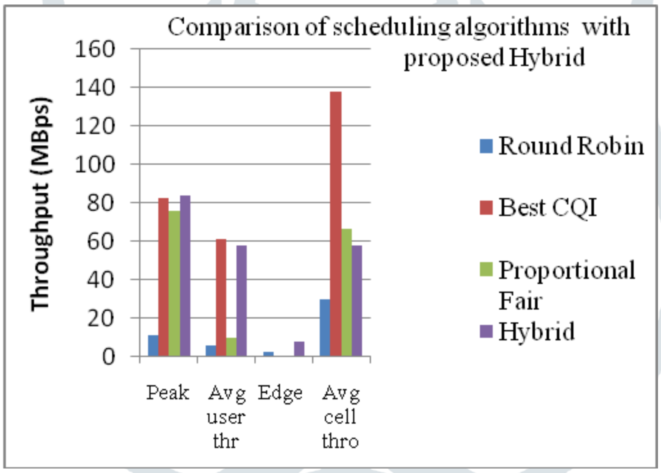

Fig 6. Comparison of Peak, Average, Edge user throughput for different Scheduling along with proposed Hybrid.

V. CONCLUSION

The hybrid scheduling algorithm showed an improvement in the throughput of the cell edge users as well fairness index as compared to the presently used Round Robin, Best CQI and Proportional Fair scheduling schemes used in LTE-A scheduling. Parameters such as Average cell throughput, average user throughput, spectral efficiency, peak and edge user throughput, along with Fairness index are used for comparison of the proposed algorithm with RR, Best CQI and Proportional fair scheduling algorithms.

VI. ACKNOWLEDGEMENT

The authors would like to acknowledge the Principal of Thadomal Shahani Engineering College, Dr. G. T. Thampi for his unconditional support for the research work.

REFERENCES

[1] 3GPP TR 22.816, published in the summer of 2017 in Release 14.

[2] 3GPP Recommendation ITU-R .M. 1079-2, "Performance and quality of service requirements for mobile telecommunications 2000(IMT2000) access networks",(1994-2000-2003).

[3] C. Cox, "An introduction to LTE, LTE-Advanced SAE and 4G mobile communications, 2013.

[4] Ayman Hajjawi, Mahamod Ismail, Nor F. Abdullah.et.al., "Investigation of the impact of different scheduling algorithm for Macro-Femto-cells over LTE-A networks," in IEEE 3rd International Symposium on Telecommunication Technologies (ISTT), 2016.

[5] M. N. Hindia, A. W. Reza, K. A. Noordin, and M.H.R. Chayon, " A Novel LTE scheduling Algorithm for Green Technology in Smart Grid," 2015.

[6] The Vienna LTE-A Simulators, V2[online] Available: http://www.nt.tuwein.ac.at/ltesimulator.

[7]H. A. M. Ramli, R. Basukala K. Sandrasegaran, R. Patacha-janand, "Performance of well known packet Scheduling algorithms in the downlink 3gpp LTE-system",2*009 IEEE 9th Malaysia International Conference on Communications (MICC)*, pp. 815-820, Dec 2009.

[8] Kwan Raymond, Cyril Leung, Zhang Jie, "Proportional fair multiuser scheduling in LTE," *IEEE signal Processing Letters*, no.6 pp.461-464, 2009.

[9] T. Nguyen, Y. Han, "A proportional fairness algorithm with QoS provision in downlink OFDMA systems," *IEEE communication letters*, Nov 2006, Vol.10, issue 11, pp.760-762.

[10] K. Petter, P. Jani, K. Niko, R. Tapani, H. Tero, M. Martti, "Dynamic Packet Scheduling performance in UTRA Long Term Evaluation Downlink ," *IEEE international symposium on wireless pervasive computing (ISWPC),2008, pp.308-313.*

[11] P. Parag, S. Bhashyam and R. Aravind, "A subcarrier allocation algorithm for OFDMA using buffer and channel state information", *IEEE vehicular technology conference, VTC- 2005- Fall*, 2005, pp. 622-625.

[12] Yaser Barayan and Ivica Kostanic, "Performance Evaluation of Proportional fairness scheduling in LTE," *Proceedings of the world congress on Engineering and Computer Science, WCECS*, 23-25 Oct, 2013, San Francisco, USA

[13] Ayman Hajjawi, Mahamod Ismail, Nor Fadzilah Abdullah et.al., "Investigation of the Impact of Different Scheduling algorithm for Macro-Femto-cells over LTE-A Networks," *IEEE* 3rd *International Symposium on Telecommunication Technologies(ISTT), Kuala Lumpur*, 28-*30 Nov,2016.*

[14] John O. Olaifa and Dogu Arifler, "Using System Level Simulation to Evaluate Downlink Throughput Performance in LTE-A Networks with clustered User Deployments," 2016 *1st International Workshop on Link- and System Level Simulations* (IWSLS).

[15] David Azriel and Armin Schwartzman, "The Empirical Distribution of a large Number of Correlated Normal Variables," 1st Sept,2015, J Am Stat Assoc, pp 1217-1228.

[16]. Kiyoharu Tagawa, Shun Miyanaga, et.al., "Weighted empirical distribution based approach to chance constrained Optimization Problems uding Differential Evolution," *IEEE Proceedings on Congress On Evolutionary Computation(CEC),*5-8 June,2017.