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Exhaustive Appraisal of Adaptive Hybrid LTE-A Downlink Scheduling Algorithm

Shrishti Bhatia, Ashwini Kunte

Abstract:*Long Term Evolution- Advanced (LTE-A) networks have been introduced in Third Generation Partnership Project (3GPP) release – 10 specifications, with an objective of obtaining a high data rate for the cell edge users, higher spectral efficiency and high Quality of service for multimedia services at the cell edge/Indoor areas. A Heterogeneous network (HetNet) in a LTE-A is a network consisting of high power macro-nodes and low power micro-nodes of different cell coverage capabilities. Due to this, non-desired signals acting as interference exist between the micro and macro nodes and their users. Interference is broadly classified as cross-tier and co-tier interference. The cross tier interference can be reduced by controlling the base station transmit power while the co-tier interference can be reduced by proper resource allocation among the users. Scheduling is the process of optimal allocation of resources to the users. For proper resource allocation, scheduling is done at the Main Base station (enodeB). Some LTE-A downlink scheduling algorithms are based on transmission channel quality feedback given by user equipment in uplink transmission. Various scheduling algorithms are being developed and evaluated using a network simulator. This paper presents the performance evaluation of the Adaptive Hybrid LTE-A Downlink scheduling algorithm. The evaluation is done in terms of parameters like user's throughput (Peak, Average, and Edge), Average User's spectral efficiency and Fairness Index. The evaluated results of the proposed algorithm is compared with the existing downlink scheduling algorithms such as Round Robin, Proportional Fair, Best Channel Quality Indicator (CQI) using a network simulator. The comparison results show the effectiveness of the proposed adaptive Hybrid Algorithm in improving the cell Edge user's throughput as well the Fairness Index.*

Keywords: ***Long Term Evolution (LTE), Long Term Evolution- Advanced (LTE-A), Scheduling algorithms, Channel Quality Indicator (CQI), Throughput, Fairness Index.***

I. INTRODUCTION

The growth in data traffic usage has increased by 109% in the year 2018. The average data usage grew 69% in 2018 with a 10GB data traffic usage per user per month in December 2018 as studied by the Nokia's annual Mobile Broadband India Traffic (MbiT) index [1]. This study also discusses the increase in the number of people using broadband on mobile which is led by the growing popularity of video streaming and video content in local languages on the various over the top (OTT) applications, online gaming on gaming apps, media apps educationrelated apps etc. This surge in data traffic usage creates challenges for the network operators.

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The network operators now have to cope with the increasing demands of data usage in outdoor as well indoor environments. The increasing data traffic also creates a burden on the macro-cellular network. Wireless communications have evolved from the first generation(1G) analog communications followed by the introduction of digital cellular technology in second generation(2G) and through the deployment of third generation (3G) systems providing high speed data, thereby improving coverage by using heterogeneous networks in the fourth generation (4G) networks being deployed today . The evolution of LTE to LTE-A –LTE Release 10 was mainly to provide higher bitrates in a cost efficient way and to fulfil the requirements set by ITU for IMT Advanced and its subsequent Long Term Evolution (LTE-A) [2]. For indoor coverage with higher capacity along with high quality of service, advanced wireless heterogeneous networks support deployment of medium and low power nodes viz. small cells and femto cells. A Femtocell is a low power base station which can be installed indoors to cover an indoor area not covered by the Macro Base Station (MBS) network [3], [4]. The Femtocellalso offloads heavy data traffic from the macro cellular network to the femto cellular network. Thus, the quality of service as well the capacity of the user in terms of user throughput can be improved. The deployment of a femtocell in the macro cell has its own drawback. The undesired signal from the MBS to the Femto user and from Femto base station to the nearest macro user is called interfering signal. This leads to Interference which is broadly classified into two categories viz.: cross-tier and co-tier interference. Cross tier interference is caused by the high power undesired signal of different frequency received by Femtouser from the MBS or vice versa. This paper explores the performances of LTE-A network for different scheduling algorithms such as Round Robin, Best CQI, and Proportional Fair [5] with Adaptive Hybrid Scheduling algorithm which was proposed in our previous paper [6] using simulations in Vienna LTE simulator. Adaptive Hybrid Scheduling algorithm is tested and evaluated by varying number of users in the cell, change in bandwidth such as 20MHz and 100MHz, for various frequencies such as 2.4GHz, 5.2 GHz and 10 GHz and finally with and without Fractional Frequency Reuse in the cell. Wireless network parameters such as throughput, Fairness Index and spectral efficiency are used to evaluate the performance of the Adaptive hybrid scheduling algorithm. The simulation results are compared with the existing LTE-A downlink Scheduling algorithm.The remainder of this paper is structured as follows: section II presents an overview of LTE-A system, various LTE-A downlink Scheduling algorithms followed by simulation parameters set up for the simulation in Section III, Section IV presents the simulation results and comparative study of the adaptive hybrid scheduling algorithm with the Round Robin, Best CQI and Proportional Fair scheduling algorithms, also comparative study of these algorithms with and without FFR and finally Section V concludes this paper. Different algorithms are being developed with research work. The classic LTE-A downlink scheduling algorithms are Round Robin algorithm, Best Channel Quality Indicator (CQI) and Proportional Fair Algorithm. A lot of research work is done in packet scheduling and resource allocation in wireless systems. Atta-ur-Rahman, Qureshi I and Malik A., proposed an adaptive resource allocation in Orthogonal FrequencyDivision Multiplex (OFDM) using Genetic Algorithm and FuzzyRule Base system," [6]. Genetic Algorithm was used to maximize the sum capacity of OFDM system in [7]. Adaptive hybrid scheduling algorithm was proposed in the paper [8] for improving the trade-off between the cell edge user's throughput and fairness among the users. The author in that paper proposes an adaptive hybrid downlink scheduling algorithm which considers the transmission channel quality as well the buffer traffic of the activated users for scheduling. The users are activated when the buffer traffic is greater than the threshold integer value. Popular existing Round Robin downlink scheduling algorithm gives the highest fairness among the users but the spectral efficiency is poor. The proportional fair algorithm tries to achieve some balance in fairness and throughput of the user. But, the adaptive hybrid scheduling algorithm improves the trade-offbetween the fairness and the throughput of the Edge users.

II. LITERATURE

In this section, some concepts of LTE physical layer and basic Scheduling Algorithms are presented. LTE-A uses Orthogonal Frequency Division MultipleAccess (OFDM) for downlink transmission while using the Single Carrier Frequency Division Multiple access (SC-FDMA) for uplink transmission. A single frame is of 10 ms, with half -frame period of 5 ms, sub-frame of 1 ms.This sub frame is further divided into two slots, with each slot of 0.5 ms. Each slot consists of seven OFDM symbols for a normal cyclic prefix or six OFDM symbols for an extended cyclic prefix. One OFDM symbol with one subcarrier together constitutes one Resource Element (RE). RE is the smallest unit of the Resource Block (RB). This resource block is 180 kHz wide in frequency with twelve subcarriers and 0.5 ms wide in time slot. Thus, for one resource block with normal cyclic prefix, there are 12 x 7 = 84 resource elements while those with extended cyclic prefix consist of 72 REs.Fig. 1 below shows the LTE-physical structure and resource block element [9].

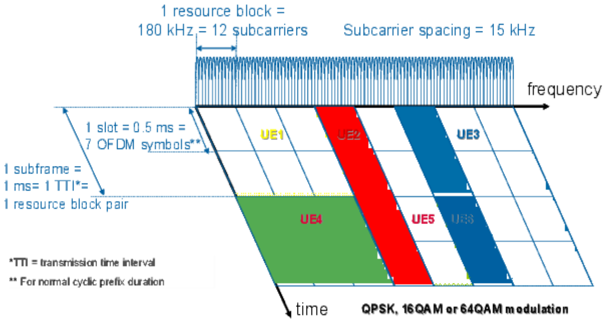

Fig.1 LTE-A OFDMA representing resource blocks [9]

Multiple input multiple output (MIMO) techniques are used to increase the capacity while spatial Multiplexing is used to increase the robustness of the communication system against fading channels and to increase the Signal to Noise Ratio (SNR) at the receiver. A 10 MHz downlink signal consists of 50 Resource Blocks while a 20 MHz downlink signal consists of 100 Resource Blocks. The process of allocation of Resource Blocks to different users is called scheduling and the entity body is called Scheduler i.e. the eNodeB. The allocation of Resource Blocks to different users is done in the MAC sub layer by the eNodeB. The eNodeB is responsible for the Radio Resource Management functions such as transmission power management, mobility management and radio resource scheduling [2], [9]. Various scheduling algorithms are proposed for proper allocation of the resources to the users to increase the user's throughput and spectral efficiency.

Channel Quality Indicator (CQI) defines the channel quality based on the feedback provided by the user to the eNodeB over the uplink transmission channel. The Higher value of CQI the better is the channel quality. Based on the CQI value provided by the user in uplink, the modulation scheme and channel coding for the channel link can be changed, which is known as Link Adaptation. Some scheduling algorithms use CQI values to decide which user is to be scheduled and how many resources are to be allocated. The performance of the heterogeneous network can be enhanced by proper resource allocation among the users with a selection of proper scheduling algorithms along with Adaptive Modulation and Coding. Metrics are calculated per Resource Block and their values are capered and used for the transmission priority of each user on a specific Resource Block and for resource allocation to each User Ew2quipment (UE).

A. LTE-A Scheduling Algorithm [6],[9], [10], [11], [19].

LTE-A Downlink Scheduling algorithms such Round Robin, Best CQI, Proportional Fair and Adaptive hybrid are described below.

i. Round Robin Scheduling

It is one of the simplest LTE-A Downlink Scheduling Algorithms which does not take into account the quality of the channel while allocating resource blocks to the users. Depending on the number of users, this method uses the fixed number of Resource Blocks for scheduled allocation in rotation based on time sharing with no priority between the users. The advantage of the Round Robin (RR) algorithm is that even the edge users with poor channel quality gets a fair chance of usage of Resource Blocks. Hence, higher Fairness is possible among the users. Further, the Resource Blocks are not used efficiently thereby reducing the spectral efficiency. Since the Resource Blocks are not used efficiently, the data rate to UEs also reduces. The RR algorithm can be expressed in the mathematical equation as given below.

$$M_{n,k} = T_K - t \qquad (1)$$

Where M is the metric for the kth user on the nth resource block, t is the instantaneous time and T_k is the previous time the user k was scheduled.

ii. Best Channel Quality Indicator Scheduling

This is an algorithm of downlink scheduling in which the channel quality of the user, as reported by the user, is considered as the feedback to eNodeB before allocating the resources to the users. A reference signal (pilot signal) is sent by the base station eNodeB to the users in the downlink. The user uses this reference signal to estimate the channel quality and sends the CQI to the eNodeB. Users with a good CQI are scheduled and allocated resources whereas the users with poor channel quality are not allotted Resource Blocks. By doing so, the peak throughput of the users is maximized as well the spectral efficiency achieved is high but the fairness among the users is reduced. The Best CQI scheduling algorithm provides higher capacity of the cell. Edge users with poor channel quality do not get fair resource allocation.

$$M = arg\ max\, R_i \qquad (2)$$

iii. Proportional Fair Scheduling

Proportional Fair Scheduling was proposed to improve the fairness among the users. This scheduling algorithm balances the overall cell throughput and fairness. It is especially suitable for non-real time traffic .This algorithm schedules resources to a user when its instantaneous CQI is high relative to its own average channel condition over time. Proportional Fair Scheduling algorithm assigns more resources to users who have relatively the best channel conditions [19]. Resources are assigned to a User K according to the following equation

$$M = arg\, max \quad \frac{R_I}{R\prime_i}(3)$$

Where R_i is the current transmission rate for user i, and $R'_i$is the average data transmission rate for user i.

iv. Adaptive Hybrid Scheduling

Adaptive Hybrid Scheduling is a Downlink Scheduling algorithm as proposed in the previous paper [6] was mainly aimed to enhance the Edge user's throughput along with Fairness Index. As discussed in the paper, the algorithm divides the time slot into two slots. In the first time slot, the scheduler allocates the resources based on the CQI feedback given by the user to the eNodeB. The user with the good CQI is allocated the Resource Block which gives the maximum average throughput being tracked by the eNodeB. In the second time slot, activated users are scheduled. Activated users are the users with buffer traffic greater than threshold value while the users with no buffer traffic or less than the threshold value of traffic are deactivated. So, the total number of active users to be allocated Resource Blocks is reduced. The average user throughput, Edge user throughput and the Fairness Index is improved. Edge users with more traffic also get a fair chance of scheduling along with more Resource Blocks in comparison with the best CQI scheduling algorithm. The algorithm can be expressed as given below:

$$\mathrm{M} = \mathrm{argmax}\ \mathrm{R_i} \quad \text{for } 0 < t < \mathrm{t_1}$$

$$\mathrm{M} = \textstyle\sum_0^i \beta \qquad \text{for} \quad \beta > \beta_T \ \text{and}\ \ t_1 < t < t2 \ \ (4)$$

Where β is the user with buffer traffic greater than β_T ,β_T is user with buffer traffic greater threshold 'T'.
Flow of the algorithm is depicted in Fig.2.

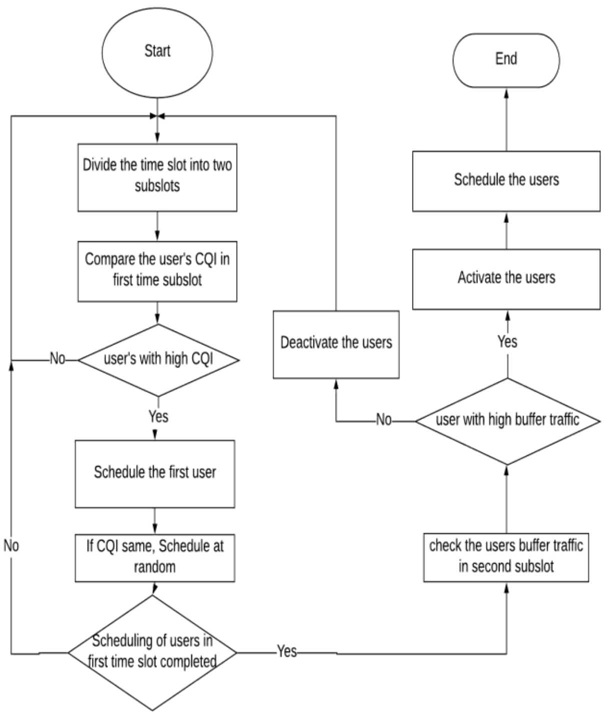

Fig. 2 Adaptive Hybrid Downlink scheduling algorithm

III. SIMULATION PARAMETERS

Table 1 given below presents the Simulation Parameters[11-13] used to perform analysis of the Adaptive Hybrid Downlink Scheduling Algorithm.

Table 1: Simulation Setup Parameters

Simulation Parameters	Value
Bandwidth	20MHz, 100MHz
Operating frequency	2.14GHz,5.2GHz, 10GHz
Transmission Mode	2X2, 4X2,4X4 Closed Loop spatial Multiplexing
Path loss model	Urban
Minimum Coupling Loss	70dB
Distance between eNodeB	500 metres
Macro-Base Station Transmit power	46dBm

Femto Base Station Transmit power	20dBm
Downlink-Scheduling Algorithms	Round Robin, Best CQI, Proportional Fair and Adaptive Hybrid.

IV. SIMULATION RESULTS AND DISCUSSIONS

Performance Evaluation of the proposed Adaptive Hybrid Downlink Scheduling Algorithm is done in terms of parameters like throughput (Peak, Average and Edge User's throughput), Average Spectral Efficiency and Fairness Index for varying number of users, change in operating frequencies such as 2.14GHz, 5.2GHz and 10GHz. Also evaluation is done while changing the bandwidth from 20MHz to 100 MHz.Performance of Adaptive Hybrid Scheduling algorithm is also evaluated in a cell without Fractional Frequency Reuse (FFR) and with FFR for the same parameters.

A: Increase in the number of Users and Bandwidth of 20MHz

Throughput: The throughput of user is classified as Peak, Average and Edge User throughput [12]-[14].

a) Peak user throughput: The Peak User throughput is defined as the maximum achievable throughput per user. Figure 3 shows the performance of Adaptive Hybrid Scheduling algorithm in comparison with other existing LTE-A downlink scheduling algorithms for increasing number of users. The graph is peak users throughput versus number of users for various downlink scheduling algorithms.

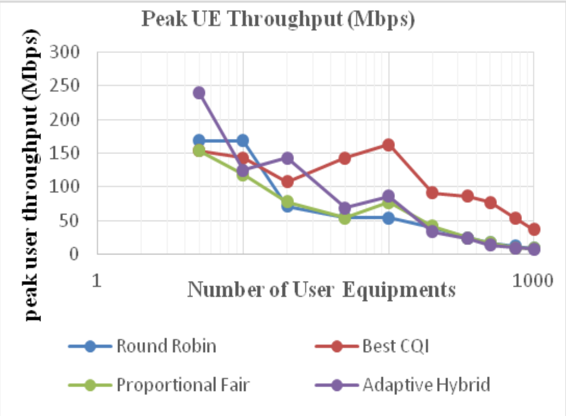

Fig. 3 Peak UE Throughput (Mbps) versus number of users.

The above Fig.3 shows that the Best CQI gives better peak user throughput in comparison to other scheduling algorithms. This is due to the consideration of the transmission channel condition while allocating resources. The peak user throughput using Best CQI algorithm increases due to allocation of more number of Resource Blocks to users with a good channel condition. The user gives feedback to the eNodeB which estimates the CQI as an integer value. The higher the CQI value, the better is the quality of the transmision channel.

b) Average user throughput: Average user throughput is defined as the amount of data sent successfully for a user during the Transmission Time Interval (TTI). Figure 4 below shows the comparison of Adaptive hybrid downlink scheduling with other scheduling algorithms in terms of average user throughput for increasing number of users.

The average user throughput of the proposed adaptive hybrid scheduling algorithm, with increasing number of users, decreases in the same manner as Best CQI and both have better average user throughput as compared to other LTE-A downlink scheduling algorithms.

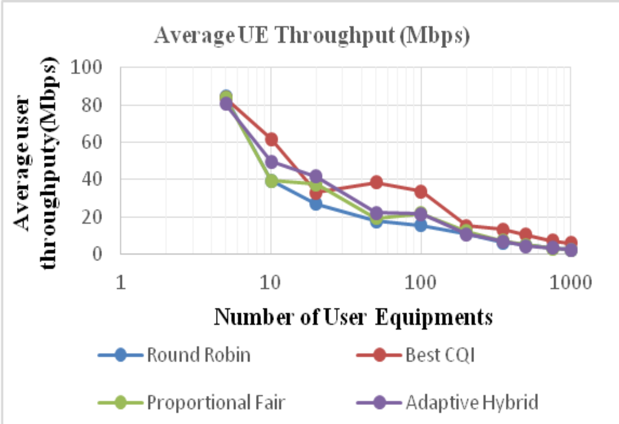

Fig. 4Average user throughput (Mbps) Versus Number of UEs

c) Edge user throughput:

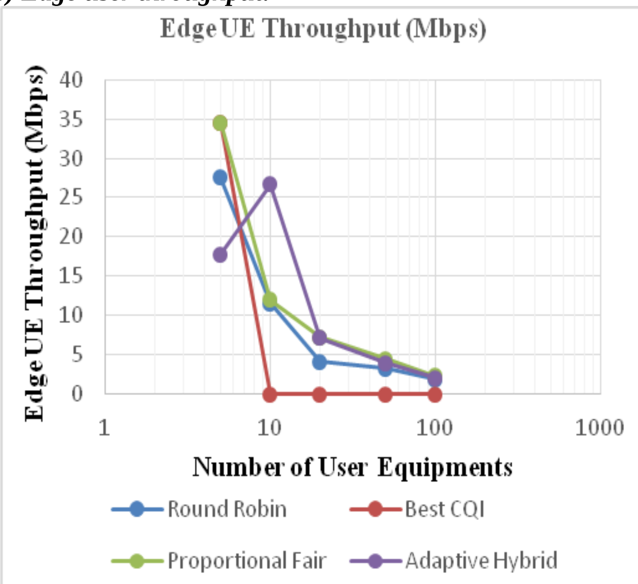

Fig. 5 Edge user throughput versus Number of UEs

Figure 5 shows the improvement in the Edge user throughput with the proposed Adaptive Hybrid algorithm compared to other LTE-A downlink scheduling algorithms. The Adaptive Hybrid algorithm calculates the metric based on channel quality condition, efficiency of the Resource Block, average throughput and buffer traffic. Hence, the Edge user throughput gives better results than Best CQI but similar to the Round Robin LTE-A downlink scheduling algorithm.

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Fairness Index: The Fairness index is defined as per the Jain's Fairness Index as a metric which is the ratio of the square of the summation of the user's throughput to the product of the number of users and the sum of the squares of the throughput of the users[14,15]. As seen from Figure 6, the Fairness index achieved with the proposed LTE-A downlink scheduling algorithm is highest and improved even with the increase in the number of users. It is worst for the Best CQI LTE-A downlink Scheduling Algorithm as the resource allocation is done to the users with the good channel condition and users with poor channel quality are not scheduled.

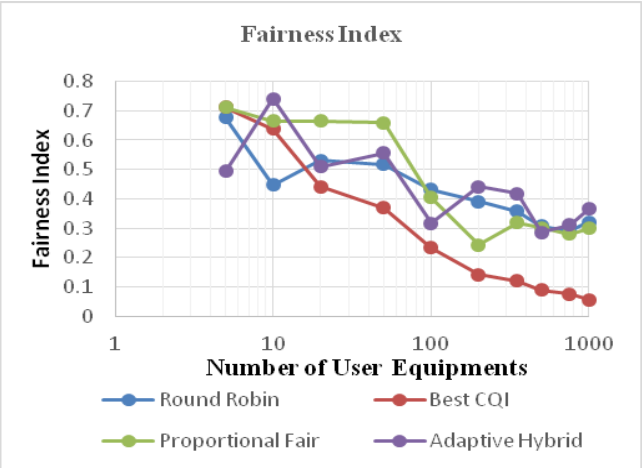

Fig.6.Effect of number of users on Fairness Index for various scheduling algorithms

B: Increase in number of users and Bandwidth of 100MHz

The performance comparison of Adaptive Hybrid scheduling algorithm with RR, PF and Best CQI in terms of parameters such as peak user throughput, edge user throughput, fairness index and average user spectral efficiency is shown in Figures 7, 8, 9 and 10 below for a femtocell with ten users and the bandwidth increased from 20 MHz to 100MHz. The trade-off between peak user throughput and edge user throughput is better in Adaptive Hybrid LTE-A downlink scheduling as compared to RR, PF andBest CQI scheduling algorithms.

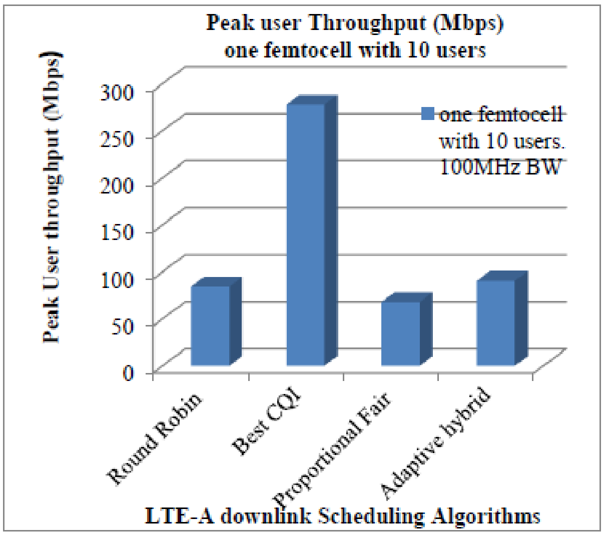

Fig.7Peak User Throughput(Mbps) versus LTE-A Downlink scheduling algorithms in a femtocell with 10 users

.Fig. 8below shows the effectiveness of the adaptive hybrid LTE-A downlink scheduling algorithm in improving the edge user's throughput in comparison with RR, PF and Best CQI.

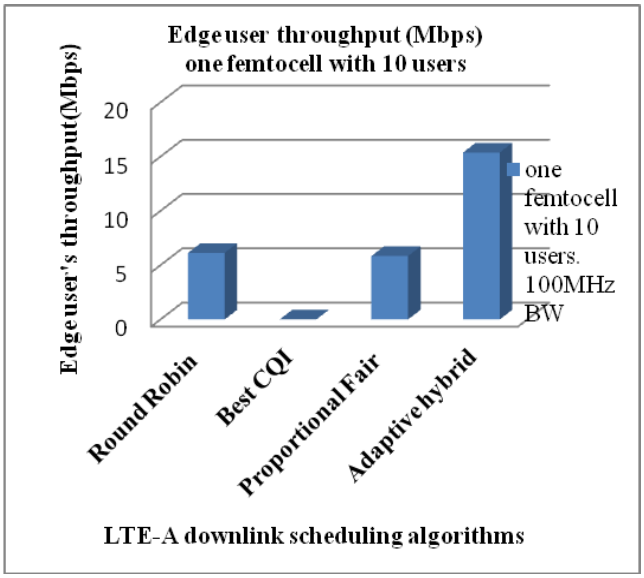

Fig.8.Edge User Throughput(Mbps) versus LTE-A downlink scheduling algorithms in a femtocell with 10 users

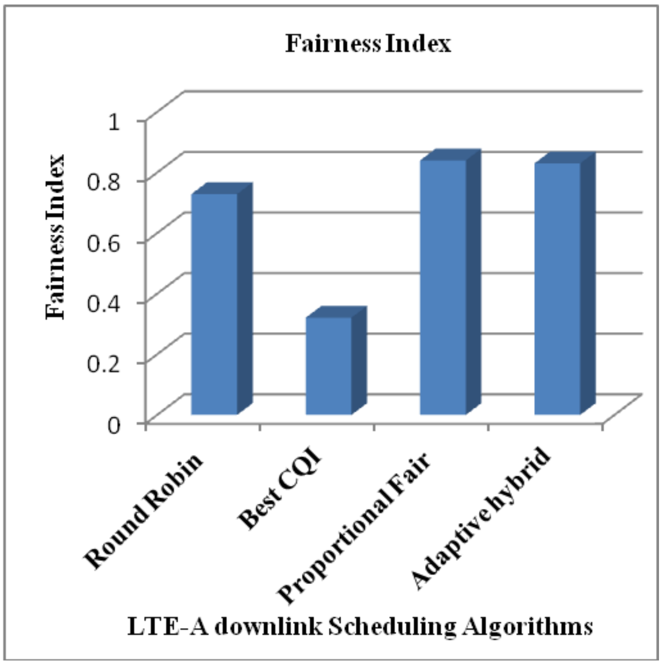

Fig. 9Comparison of Fairness Indexachieved in a femtocell by various LTE-A downlink scheduling algorithms

Fig. 9. Shows that the adaptive hybrid algorithm achieves better fairness index as compared to RR, Best CQI, and PFdownlink scheduling algorithms.

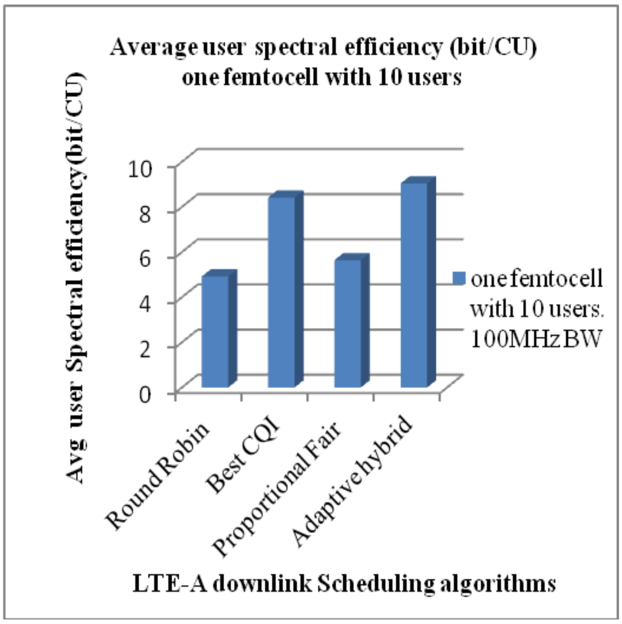

Fig 10AverageUser spectral efficiency (bits/ CU) versus LTE-A downlink scheduling algorithms in a femtocell with 10 users.

*Average User Spectral efficiency:*The average user spectral efficiency is obtained by dividing the net data rate in bits per second by the bandwidth (Hz). The unit of the same is bits per sec per Hz (bit/sec/Hz) or can also be expressed as bits per channel usage (bits / CU). Figure 10 above shows that the proposed Adaptive Hybrid Downlink Scheduling Algorithm has higher Spectral efficiency in comparison with other LTE-A RR, PF and Best CQI scheduling algorithms.

C. Performance Evaluation of Adaptive hybrid scheduling algorithm at various frequencies such as 2.4 GHz, 5.2GHz and 10 GHz:

The Adaptive Hybrid LTE-A downlink scheduling algorithm is evaluated for frequencies such as 2.14 GHz, 5.2 GHz and 10 GHz as shown in Fig 11 and Fig 12.

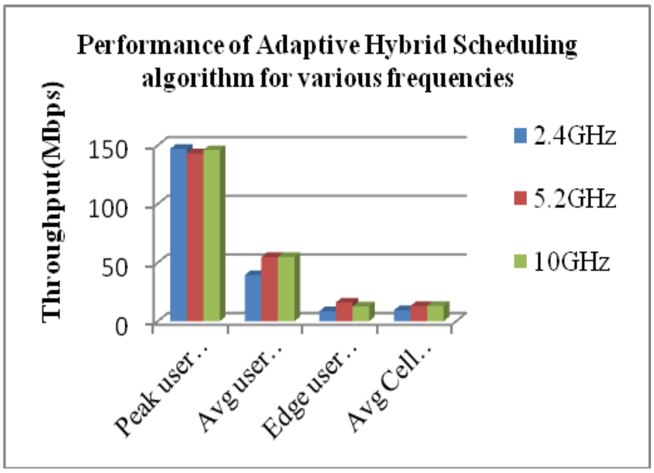

Fig. 11Uaer's Throughput (Peak, average, edge) using Adaptive hybrid scheduling at different frequencies

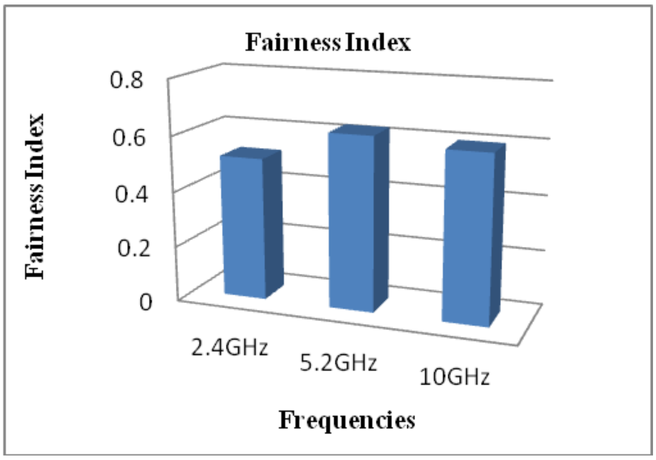

Fig. 12: Fairness Index of usersversus different frequencies

The performance of Adaptive hybrid LTE-A scheduling algorithm is less affected by the variation in operating frequency. Secondly, this algorithm is also evaluated for individual femto user's throughput in a femto cell to show the distribution of throughput achieved by users. The throughput values of all Femto users are nearly similar in Adaptive Hybrid downlink scheduling as compared to the Best CQI algorithm showing large differences in throughput values among the Femto users.

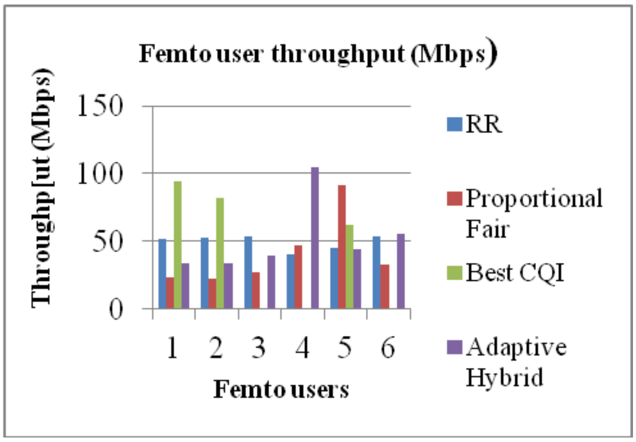

Fig.13. Comparison of Femto User throughput with Adaptive Hybrid scheduling with other scheduling algorithms

D. Fractional Frequency Reuse Method

A Fractional Frequency Reuse (FFR) scheduler along with adaptive Hybrid Downlink Scheduling algorithm shows further improvement in the Edge user throughput [16-18].Fractional Frequency Scheduler divides the cell into two parts:

- Full Reuse (FR), the central part of the cell;
- Partial Reuse (PR), edge part of the cell.

The whole spectrum is divided into two parts:

The first part of the spectrum is used in the central region (FFR-1) and a high factor, $1/3^{rd}$ of the remaining spectrum, is used in the edge region of the cell .(FFR-3). The aim of this type of Frequency Reuse is to reduce the interference and increase the cell capacity, Bandwidth ratio and SINR value.

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SINR value defines the FR and PR border. β_{FR} = 0.01 and SINR = 15dB. The bandwidth used is 20MHz with 100 Resource Blocks. 33 Resource Blocks are allocated to every PR part and one Resource Block is allocated to the FR part. The Adaptive Hybrid Scheduling algorithm is simulated along with FFR main scheduler and compared with other LTE-A downlink Scheduling Algorithms for the edge user throughput.

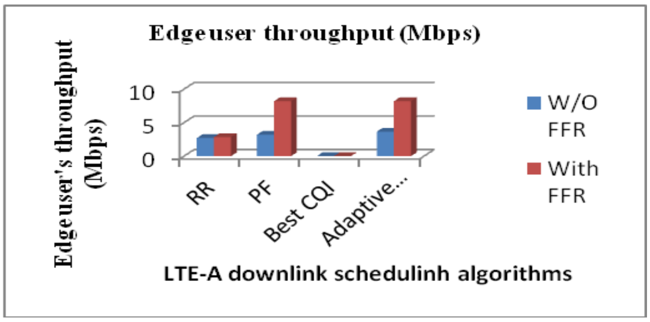

Fig.14: Edge User throughput with and without FFR for various scheduling algorithms

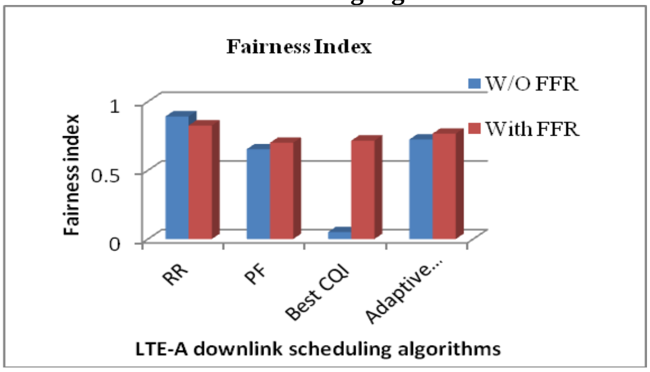

Fig.15 Fairness Index with and without FFR for various Scheduling Algorithms.

Simulation results shows that thetrade-off between the Fairness Index and Edge user throughput with adaptive hybrid scheduling algorithm is improved in comparison with other LTE-A Scheduling algorithms. The Fairness Index with FFR and adaptive hybrid scheduling is higher than Proportional Fair and Best CQI but less than Round Robin scheduling algorithm.

V. CONCLUSION

In this paper, we have presented the performance evaluation of the Adaptive Hybrid LTE-A downlink scheduling algorithm in comparison with the other existing downlink scheduling algorithms. The performance evaluation is done on the basis of wireless metrics such as throughput (Peak, Average and edge user throughput), Fairness index and average Spectral Efficiency. Adaptive hybrid scheduling algorithm is evaluated for increasing number of users, Change in bandwidth, various operating frequencies and with Fractional Frequency reuse applied in a macrocell. The simulation results justify the effectiveness of this scheduling algorithm in improving the edge user's throughput, fairness index and average user's spectral efficiency. Indoorarea coverage with high data rate can be fulfilled by deploying femtocellsin macro-cell and using Adaptive hybrid scheduling algorithm for proper resource allocation. Fairness index and edge user throughput are greatly enhanced with the application of Adaptive hybrid scheduling algorithm. The Edge User Throughput and Fairness Index are fairly improved with the FFR with Adaptive Hybrid LTE-A downlink Scheduling as cross tier and cotier interference are greatly reduced.

REFERENCES

1. Nokia_MBiT_2019_FINAL.pdf. Nokia MBiT Index is a report on mobile broadband performance in India.
2. 3GPP: Technical Specification Group Radio Access Networks; Deployment aspects (Release8) 2008. http://www.3gpp.org/ftp/specs/html-info/25943htm.
3. Ana Gago ,NunoCota, "Performance Evaluation of Femtocells Usage on LTE," presented in Conference on, "Electronics, Telecommunications and Computers -CETC-13, published by Elsevier Ltd
4. Mohammad Reza, Amini, MostafaRezaei, MortezaBayat, "A Survey on Scheduling algorithms in LTE," published in Journal of Telecommunications, Vol. 13, Issue 2, April 2012.
5. BechirNsiri, MalloukiNasreddine, Mahmoud Ammar , WalidHakimi, MhatliSofien, "Modeling and Performance Evaluation of Scheduling Algorithms for Downlink LTE cellular Network," published in International conference on Wireless and Mobile Communications," 2014
6. Atta-ur-Rahman, Qureshi I. and Malik A., "Adaptive Resource Allocation in OFDM systems using Genetic Algorithm and Fuzzy Rule Base System," World Applied Sciences Journal, vol.18, no.6, pp.836-844, 2012.
7. Liu B., Jiang M., and Yuan D., "Adaptive Resource Allocation in Multiuser OFDM system Based on Genetic Algorithm," in Proceedings of International Conference on Communication and Mobile Computing, Jinan, China, pp.270-273, 2009.
8. Shrishti Bhatia, Dr.AshwiniKunte, "Performance Enhancement of two tier Wireless Network using an Adaptive Hybrid Scheduling Algorithm," in UGC and ISSN approved journal, "International Journal of Emerging Technologies and Innovative Research," published in vol. 6, Issue 2, February-2019, pp 187-193.
9. Available [online]: http://morse Colorado.edu/~ tlen5510/ text /class web ch8 html.
10. Schwarz S, Mehlfuhrer C, Rupp M, "Throughput maximizing multiuser Scheduling with adjustable fairness," Proc.IEEE International conference on Communications (ICC 2011), Kyotyo, Japan 2011.
11. S.F.Sulthana, R. Nakkeeran, " Performance Analysis of service based scheduler in LTE OFDMA system," Wireless Personal Communication, 2015, 83(2); pp.841-854
12. Mchlfiihrch C h, Ikuno J.C, Simko M, Schwarz S, Wrulich M, Rupp M The Vienna LTE Simulators, "Enabling reproducibility in wireless communications research." EURASIP Journal on Advances in Signal Processing, 2011, str1-14.
13. Ikuno J C, Wrulich, M. Rupp System level simulation of LTE networks, Proc.2010 IEEE 71st Vehicular Technology Conference (VTC2010 –Spring), "Taipei, Taiwan, 2010.
14. Sun Z., Yin C., Yue G., "Reduced Complexity Proportional Fair Scheduling for OFDMA system," IEEE International Conference on Communications, Circuits and systems vol 2, Guilin China, June 2006, str 1221-1225.
15. Caban S., Mehlfuhrer Ch., Rupp M., Wrulich M., "Evaluation of HSDPA and LTE From Test bed Measurements to System Level Performance," The Atrium Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom, John Wiley & Sons Ltd, 2012.
16. Josep Colom Ikuno, Martin Taranetz, Markus Rupp, "A Fairness based performance Evaluation of Fractional Frequency Reuse in LTE," Vienna University of Technology, Austria.
17. Rupp M., Mehlfuhrer C., Cabab S., "On achieving the Shannon bound in cellular systems," Proc 20th International Conference Radio Electronika 2010, Brno, Czech Republic, 2010.
18. Ikuno J C, Taranetz, M. Rupp,, "A Fairness – based Performance Evaluation of Fractional Frequency Reuse(FFR) in LTE," presented in 17th International ITG Workshop on Smart Antennas (WSA), Stuttgart, Germany March 2013, str.1-6.
19. Davinder Singh, Dr.Preeti ,"Performance Analysis of QoS-aware Resource Scheduling Strategies in LTE Femtocell Networks," published in International Journal of Engineering Trends and Technology (IJETT), Vol.4,Issue7, July 2013.

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