

A Review of Heterogeneous Resource Allocation in LTE-A based Femto cell Networks with CQI Feedback

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Abstract

Background/Objectives: The Long-Term Evolution- Advanced (LTE-A) based heterogeneous networks focus on the Femto based cell deployment. These Femto cells will benefit the customers and service providers in term of network coverage and spectral efficiency. In such networks, optimal means of resource allocations is the major concern. **Methods/Statistical Analysis:** This paper reviews a detail study of resource allocation in Femto cell based LTE-A networks. In addition, a resource allocation strategy is suggested by means of Heterogeneous Channel Quality Index (CQI) based Scheduling Techniques (HCBST). It makes use of an indexed adaptive modulation and coding technique by referring the various CQI parameters. **Findings:** The HCBST algorithm is implemented by analyzing various scheduling technique at Femto and Macro base stations. The proposed resource allocation strategy is implemented by means of two scenarios, namely, Femto without node mobility and Femto with node mobility. **Application/Improvements:** The proposed HCBST system with modified largest weight delay first with CQI at Macro cell and Exponential with CQI at Femto cell (ML-EXP-CQI) based scheduling display 1.1879% and 2.85% better in term of throughput and spectral efficiency, respectively, as compared to existing scheduling algorithm..

Keywords: Femto Cell Networks, HCBST, Long-Term Evolution- Advanced, ML-EXP-CQI, Scheduling

1. Introduction

The development of Long Term Evolution- Advanced (LTE-A) technology added a golden part in the development of wireless communications domain. To improve the performance of LTE-A based network relay and Pico-cell came into picture. Relays a wireless radio extension of Base Station (BS) and it provides limited intelligence to network operators. On the other hand, Pico based deployment provides intelligent BS, which is owned, planned and placed by operator. If we observe both the deployments, customers do not come into picture. In order to give more

priority to customer's, the LTE-A wireless networks suggest Femto cell based network architecture. Femto Cell provides intelligent BS, which is mostly owned and placed by consumer and no initial planning is required for Femto cell deployment. Challenging issues in Femto cell is the proper resource allocations and interference.

Various scheduling algorithms are already available for resource allocation. However, the challenge is to use proper scheduling technique for appropriate applications. Comparison of different scheduling technique in Femto based deployment is explained¹. It compares the scheduling techniques, namely, Round Robin, Best CQI

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scheduler, Kwan Max Throughput Scheduler, Proportional Fair Scheduler, Max-Min scheduler and Resource Fair Scheduler. Among these schedulers, the Best Channel Quality Index (CQI) scheduler performs better than other schedulers do in term of throughput. Alternatively, the Round Robin and Fair Proportion schedulers are does not perform well under mobility conditions. The choice of optimal admission control and resource allocation for uplink traffic is discussed by Joint Admission Control and Resource Allocations algorithm². It focused on the transport layer resource allocations of Femto equipment along with interference aware resource allocation.

Further advancement of resource allocation is based on cooperative power scheme that reduce the power setting with Carrier Aggregation based Femtocell³. Femto cell cooperatively adjust the power in order to optimize the power but this scheme applicable only in dense Femto cell condition. Later, distributed algorithm came in picture, which combined the power control and Scheduling for Femto cell network for downlink condition⁴. It discusses a distributed algorithm, which considers the channel quality and iterative power. This is applied to cell edge users and cell centre user but it is applied in interference-limited bandwidth. A novel spectrum method is proposed in literature⁴⁻⁶, which discrete the network completely, where Macro base station divide the frequency spectrum in to two parts: 1. Particular frequency spectrum allocated to the Femto Cell and 2. Another Frequency spectrum allocated to the Macro-Cell. Such scheduling scheme maintains the interference pool table. This mostly focused on the resources allocated for link monitoring, handling and managing the radio resources and channel state information with feedback.

A Q-Based learning scheduling is analysed where the first approach towards heterogeneous network. It is advance version of the Round Robin algorithm. It weeds out the RBs which has high interference at Macro Evolved Node B (ENB) and make use of round robin to maintain fair resource allocation. The dynamic system level behaviour of multi users of Femto cell placed in Microcell has been discussed in literature⁷⁻⁹. It investigate multiuser and multi cell in Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO) configuration of

antenna. Later, self-optimization of Femto cell is considered by cooperative spectrum sharing, power allocations and scheduling technique. It uses a dynamic approach for sharing spectrum and power allocation and showed that effective channel usage ratio can reach 75% of its average spectrum utilization.

The impact of coordination delay during resource allocation with distributed algorithm is explained¹⁰, where prior to scheduling among multi user, it checks the channel traffic and prioritize the traffic. Here, prime focus is on signalling of transmission power over pilots so that neighbouring cell knows the Signal to Noise Interference Ratio (SNIR) of corresponding node. Based on the SNIR value, it deploys adaptive coding and modulation technique. Here, the round robin method is utilized and resource scheduling is carried out as channel independent. A resource allocation scheme¹¹ is focused on the dense Femto cell interference with Macro cell in uplink or interference with Femto cell in downlink.

The importance of channel quality index consideration during resource allocation is discussed in literature¹², where it uses dynamic sub-carrier allocations. It explained in detail about the limitation of full CQI in real time scenario. It shows that how a partial CQI technique is much better in case of mobility. Such kind of CQI technique is further attached with fair proportional to improve the performance of the network¹³. A decentralized user centric scheduling is suggested for small cell^{14,15}. Here, each Macro cell is divided into a small cell and one node acts a centric node, which will take care of channel quality and provide feedback to eNB¹⁶⁻²¹. As found in the literature, a redundant bits or additional physical device is required to achieve the scheduling technique in Femto based networks. In this paper, without increasing the complexity of the network, a heterogeneous scheduling technique is proposed for Macro-Femto scenario with seamless service in mobile condition.

The rest of the paper is organised as follows: In Section 2, the design of the proposed system is presented. Section 3 describes the simulation results for Femto immobile nodes and Femto nodes with mobility. Finally, Section 4 concludes the major findings and future research directions.

2. System Model

The system model consider in this section consists of two scenarios, namely, Femto nodes without mobility as shown in Figure 1. Femto nodes with mobility are shown in Figure 2. In Figure 1, the system consists of a cell of hexagonal shape with a radius of 10 km. The eNB of Marco cell are placed at the centre of the hexagonal cell and it is named as Macro BS. The User Equipment's (UE) associated with eNB are placed randomly in the cell and they are mobile in nature. In every iteration location of MS keeps on changing. In first scenario, Femto cells are placed inside a building without mobility. Assumption made here is building is of 5*5 grid. Each grid consists of the 25 apartments. Femto cells are placed in this apartment randomly. One Femto BS can carry load of 30 home Femto User Equipment's (FUE). Distance between Femto BS and FUE is 35m and between FUE is 10-20 m.

To evaluate the performance of the system, VOIP, Video and Voice are the target services considered for evaluation. Video is considered as the Real Time (RT)

service, whereas the Voice Over Internet protocol (VoIP) and Best Effort (BE) are the Non-Real Time (NRT) services. All the resource allocations happened in down link of LTE-A based Femto cell network. In proposed scenario, scheduling technique used for Femto and Marco scenario is heterogeneous. The term heterogeneous means the usage of Fair Proportional (FP) scheduling in Marco scenario and a scheduling other than FP in Femto Cell. This paper considers three scheduling schemes, namely, FP, Modified Largest Weight Delay First (MLWDF) and exponential scheduling. FP always focuses in maximizing the throughput of the channel and to provide minimal service (fairness) to all the users. In other words it provides a trade-off between overall system gain and data rate fairness among the users. The drawback of the FP algorithm is that it requires independent identical distributed among the users and not much efficient under mobility condition.

On the other hand, the other two algorithms, MLWDF and Exponential scheduling are more focused on real time applications like video services. MLWDF is the

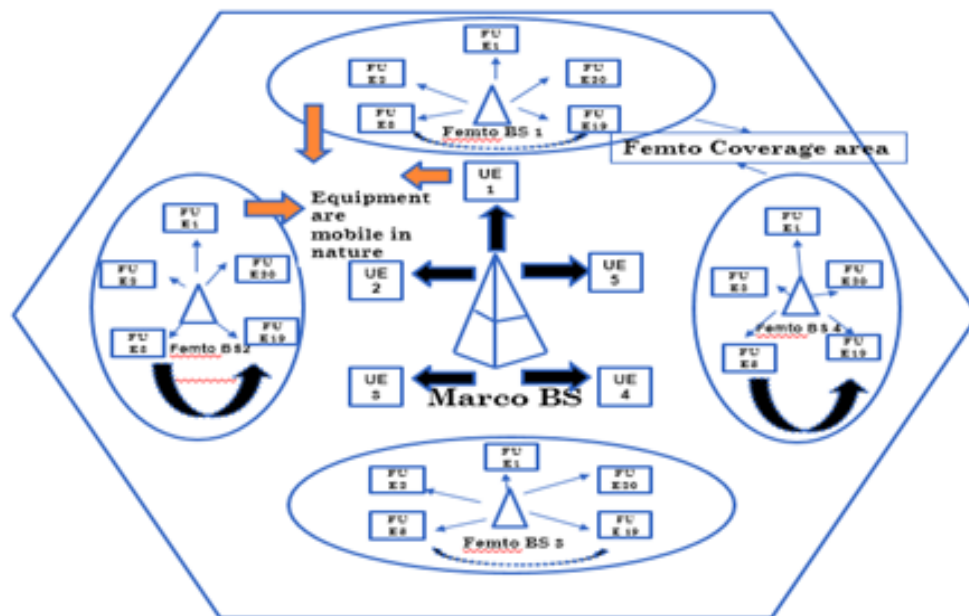


Figure 1. Marco-femto scenario without mobility.

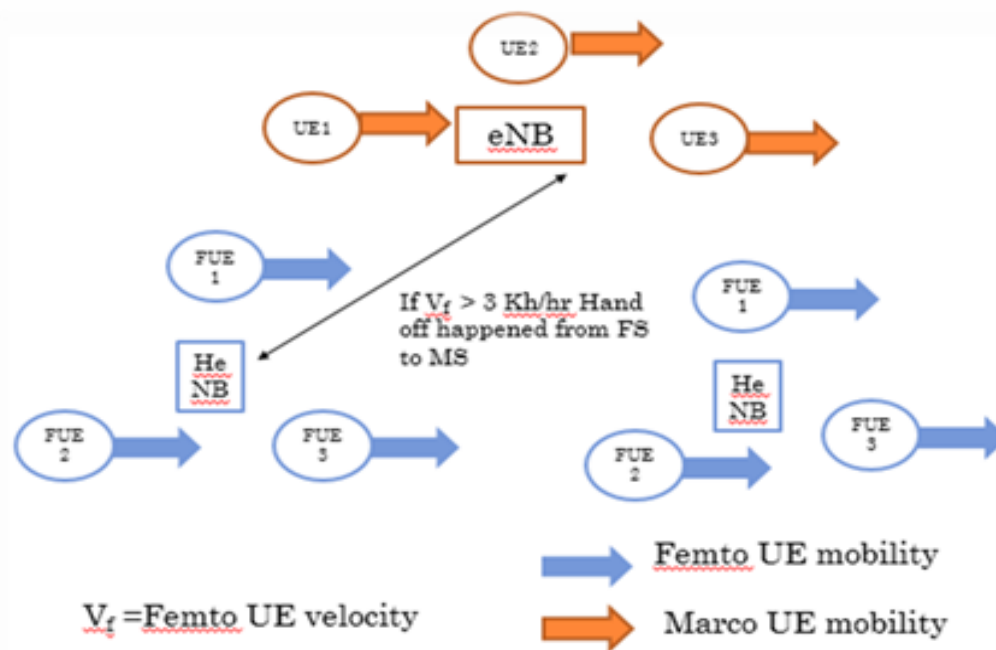


Figure 2. Hand-off between marco and femto.

advance version of Largest Weighted Delay First (LWDF) and the basic idea behind this algorithm is that packet with same Quality of Service (QoS) is gathered in a single queue and packets in that queue get equal scheduling opportunity. It generally ensures that delay packet probability doesn't exceed the minimum allowable packet loss. Alternatively, the exponential algorithm is an advance version of FP scheduling and it is applicable for both real time and non-real time applications. Only difference in exponential algorithm is that it gives more priority to the real time services than non-real time services. The second scenario considered in this paper with the mobility with FUE inside a Femto cell. This scenario is almost similar to first scenario except the Femto equipment is in mobile nature inside building premises.

With mobility consideration in FUE, a handoff often occurs between HENB and ENB and hence a handoff aware resource allocation is considered along with these three resource allocation algorithms. In order to elaborate the handoff aware resource allocation in detail, consider a sample illustration of Marco-Femto scenario is shown

in the Figure 2. Also, this paper considers one ENB and two HENB. UE and FUE all are associated to it respective ENB and HENB. FUE are in the mobile state. As per the literature and simulation, we found that high velocity of Femto equipment causes an unnecessary interrupt to the service. To overcome such hurdle, proposed paper found that if velocity of the Femto cell is more 3km/hr, respective HENB is not suitable for handling to it. In that case handoff is requiring from HENB to ENB as ENB can handle high velocity equipment. Black arrow in the Figure 1 shows the handoff from HENB to ENB.

Once done with system architecture, we have simulated the above network with scheduling technique with Femto node (UE) immobility as well as in Femto node mobility. Under no mobility scenario, exponential scheduling at Marco ENB and fair proportional scheduling at FENB combination shows better performance than other possible combinations. However, in mobility condition, MLWDF at Marco ENB and exponential scheduling at FENB shows the better combination. To improve the system performance, we consider a channel quality awareness

Table 1. LTE-A CQI with ACM

CQI	Modulation	SNR(dB)	Code rate
0	Out Of Range	Out Of Range	Out Of Range
1	QPSK	-7.27	1/12
2	QPSK	-4.96	1/9
3	QPSK	-2.06	1/6
4	QPSK	0.61	1/3
5	QPSK	2.81	1/2
6	16 QAM	4.69	3/5
7	16 QAM	6.29	1/3
8	16 QAM	8.69	1/2
9	16 QAM	11.37	3/5
10	16 QAM	13.11	1/2
11	64 QAM	16.44	1/2
12	64 QAM	19.62	3/5
13	64 QAM	23.01	3/4
14	64 QAM	26.19	5/6
15	64 QAM	28.66	11/12

based feedback technique along with best possible combinations of scheduling under immobility and mobility scenario. Such consideration is named as Heterogeneous CQI based Scheduling Techniques (HCBST). Channel quality awareness is identified by means of channel quality index that generally has 4 bits and numbered from 1-15. Based on the choice of the number, respective adaptive coding and modulation is carried out as shown in Table 1. Further, to reduce the number of feedbacks, an M-Feedback CQI technique is considered in HCBST. In M-Feedback CQI, each subcarrier is divided into many sub channels S and each user compute the SNR on this sub channels and send the indices. Based on the sub channels indices base station choose the highest index.

The range of signal to noise ratio (SNR) and its respective indices is shown in Table 1.

2.1 Path Loss (PL) Model

The Path Loss model considered for simulating the Femto LTE scenario follows urban model and the following describes the Path Loss (PL) for UE and FUE is as follows:

- $PL = 15.3 \text{ dB} + 37.6 \log_{10} (R_{UE}/m_{ENB})$ for outdoor UE
Where R_{UE} is the distance between UE and ENB and m_{ENB} is the Macro cell coverage.
- $PL = 15.3 \text{ dB} + 37.6 \log_{10} (R_{FUE}/m_{HENB}) + \text{Low}$ for indoor FUE.

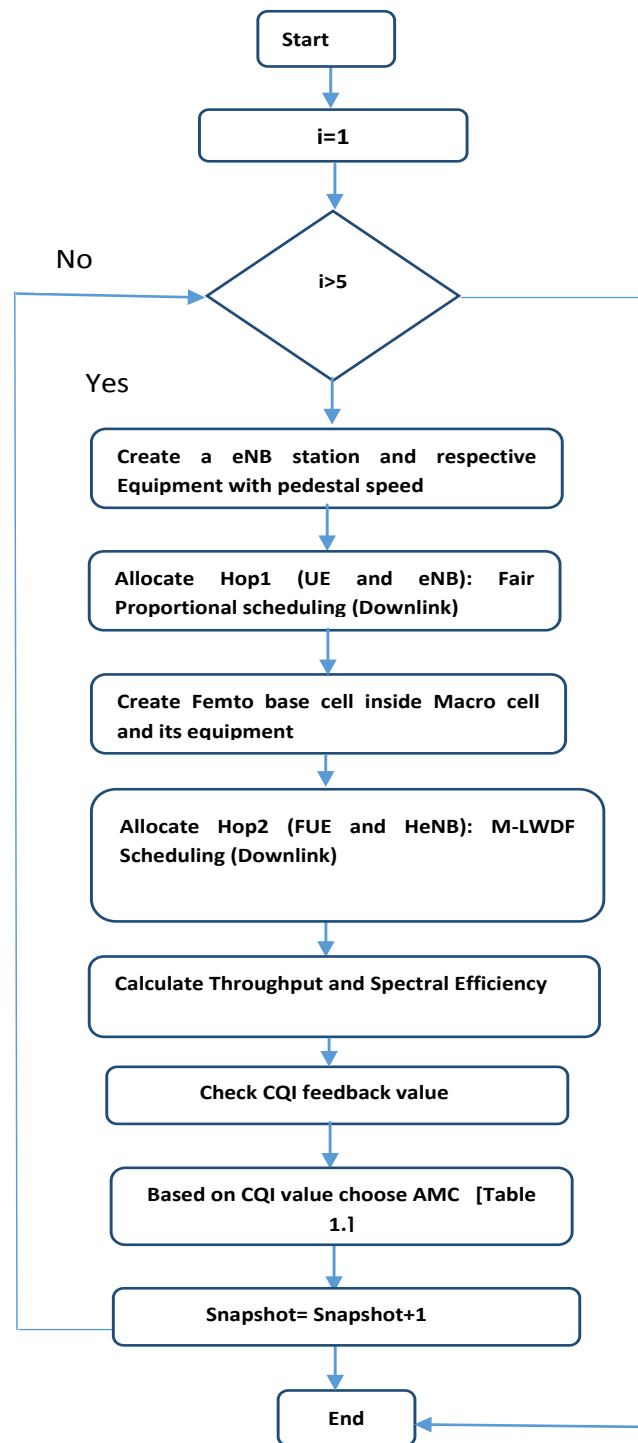


Figure 3. Flow chart of femto-marco with EXP-FP-CQI and without mobility scenario.

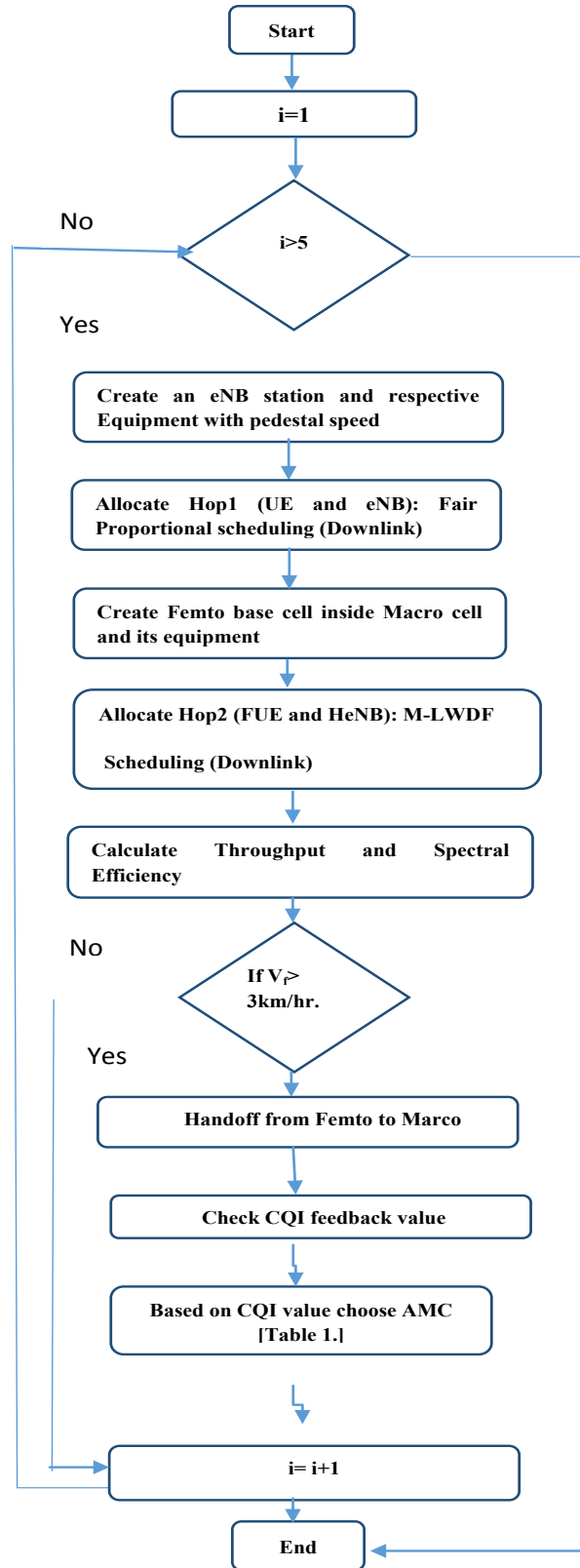


Figure 4. Flow chart of femto-marco with ML-EXP-CQI under mobility scenario.

Where R_{FUE} is the distance between FUE and HENB and m is the Femto cell coverage

Figure 3 and Figure 4 display the flow chart of HCBST algorithm. It consists of five iterations. In each iteration user equipment changes its position. The algorithm has taken five iterations. Initially set $I = 1$. Create a scenario of Marco first along with its equipment. After that deploy Femto cell inside it while deployment of Marco and Femto assigned the respective scheduling technique. Once done with that check the CQI for next channel and assigned the ACM for it. Once $i > 5$ it will be come out of the loop.

3. Results and Discussion

3.1 Heterogeneous Scheduling in Macro-Femto Scenario under Immobile FUE

The simulation parameters used for evaluating the performance of the network and the various scheduling mechanisms is shown in Table 2 and Table 3, respectively. The curves in Figure 5 show the throughput of heterogeneous scheduling in Macro-Femto scenario under immobile node with INF-BUF application. EXP-FP

show better performance in case of immobile node. For the considered scenario an average throughput of 25.633 Mbps, which is 2.145% better compared to the second best ML-EXP based resource allocation. The resource allocation by ML-FP exhibits a throughput of 23.195 Mbps due to inappropriate combination of scheduling at Macro ENB and Femto HENB. Through the curves, it could be inferred that the throughput of FP-EXP changes drastically with increase in the number of users.

The curves in Figure 6 display the spectral efficiency of heterogeneous scheduling in Macro-Femto scenario under immobile nodes. Among the schedulers, the EXP-FP shows the best spectral efficiency of 2.085185b/s/Hz. Conversely, the ML-EXP show least spectral efficiency of 1.8831b/s/Hz. Among these schedulers, the EXP-FP shows an improvement of 10.7315% than ML-EXP. If we observe the immobile node scenario, exponential scheduling is used in Marco, where nodes are in mobile condition. In addition, FP shows best performance in Femto immobile condition. It tries to maintain the maximum throughput along with minimal service to the users. Further, exponential scheduling is better for high mobile conditions.

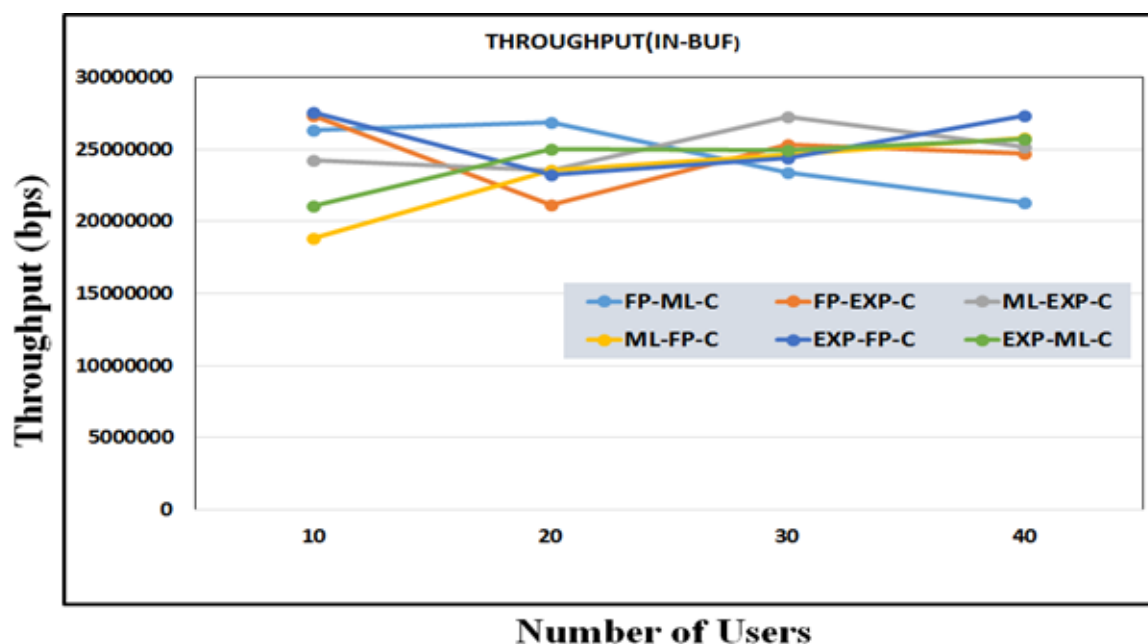


Figure 5. Throughput of the heterogeneous network with IN-BUF application without node mobility.

Table 2. Simulation parameter

PARAMETERS	VALUES
Cellular Layout	Hexagonal grid
Inter-site distance	500 m
Carrier Frequency	2000 MHz
Shadowing standard deviation	8 dB
Shadowing correlation	Between cells: 0.5 fixed Between sites: 1.0 fixed
Macro/Femto UE noise figure	9 dB
Maximum FUE velocity 3 km/h	3 Km/hr.
Number of Tx, Rx antennas for Macro and Femto	2x2
Total macro eNB TX power	46 dBm
Total femto HeNB TX power	20 dBm
Minimum distance between eNB and macro eNB	35 m
Minimum distance between eNB and Femto HeNB	20 m

Table 3. Abbreviations used in simulations

Parameters	Scheduling used in Marco	Scheduling used in Femto
FP-ML	Fair Proportional	MLWDF
FP-EXP	Fair Proportional	Exponential
ML-EXP	MLWDF	Exponential
ML-FP	MLWDF	Fair Proportional

Table 3 Continued

EXP-FP	Exponential	Fair Proportional
EXP-ML	Exponential	MLWDF
EXP-FP-CQI	Exponential With CQI	Fair Proportional With CQI
ML-EXP-CQI	MLWDF With CQI	Exponential With CQI

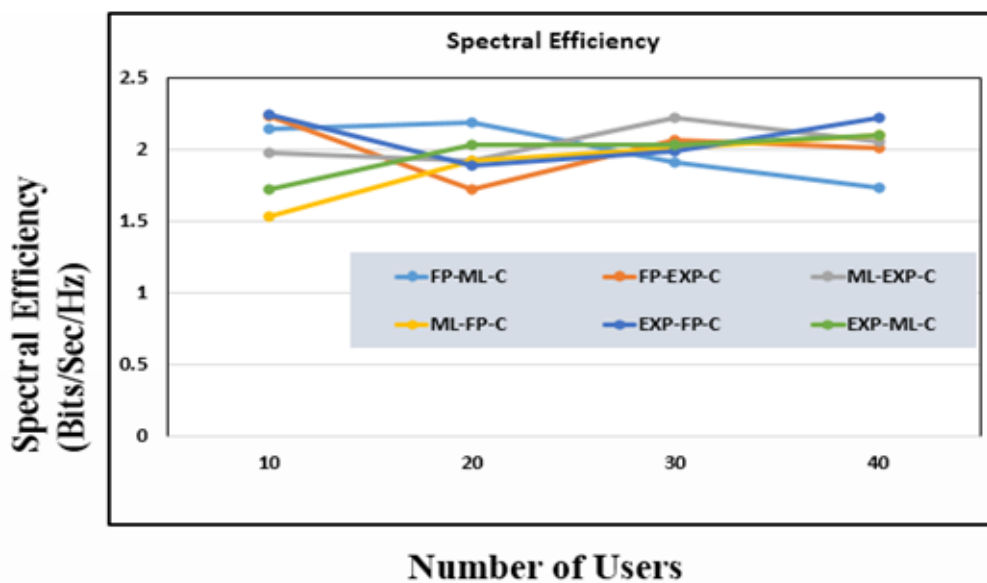


Figure 6. Spectral efficiency of users in heterogeneous resource allocations with immobile node.

3.2 Heterogeneous Scheduling in Macro-Femto Scenario under Mobile FUE

The curves in Figure 7 display the throughput of heterogeneous scheduling in Macro-Femto scenario under mobility conditions. The scheduling with ML-EXP shows the best possible combination under mobile condition. It gives throughput of 24.833 Mbps. Alternatively, the ML-FP shows minimum throughput of 23.54 Mbps. Further, it results in 5.49277% less as compared to ML-EXP based resource allocation.

The curves in Figure 8 display the spectral efficiency of heterogeneous scheduling in Macro-Femto scenario under mobility. The ML-EXP scheduling shows the best spectral efficiency of 2.0123 and ML-FP show least performance, which correspond to a spectral efficiency value of 1.97365. The ML-EXP scheduler performs 1.9315% perfect better than ML-FP scheduler. Hence, ML-EXP is considered as the best combination under mobility condition. Here, ML-EXP resource allocation considers Macro ENB with MLWDF scheduling and Femto HENB using exponential scheduling. In this scenario, we can observe

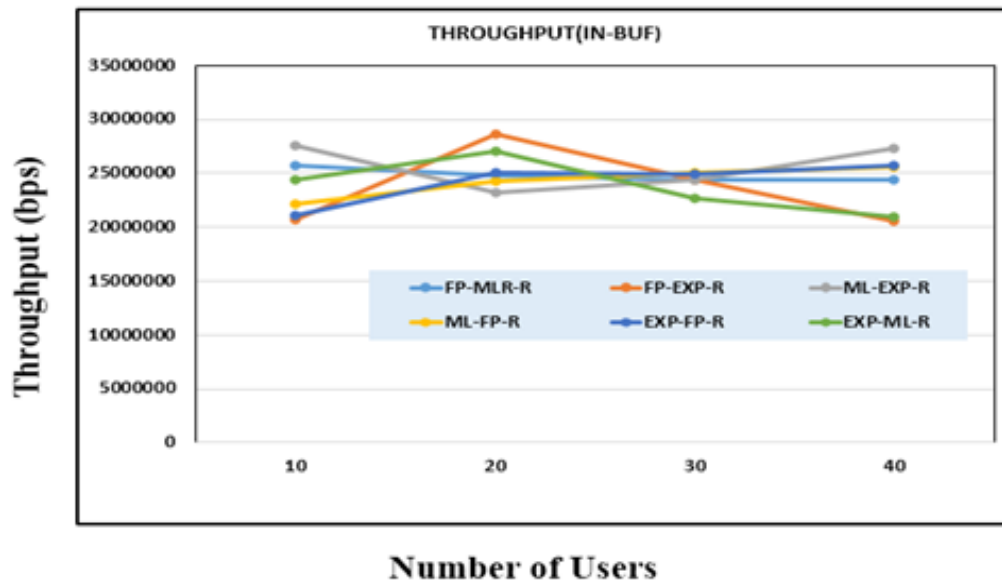


Figure 7. Throughput of the heterogeneous network with IN-BUF application with node mobility.

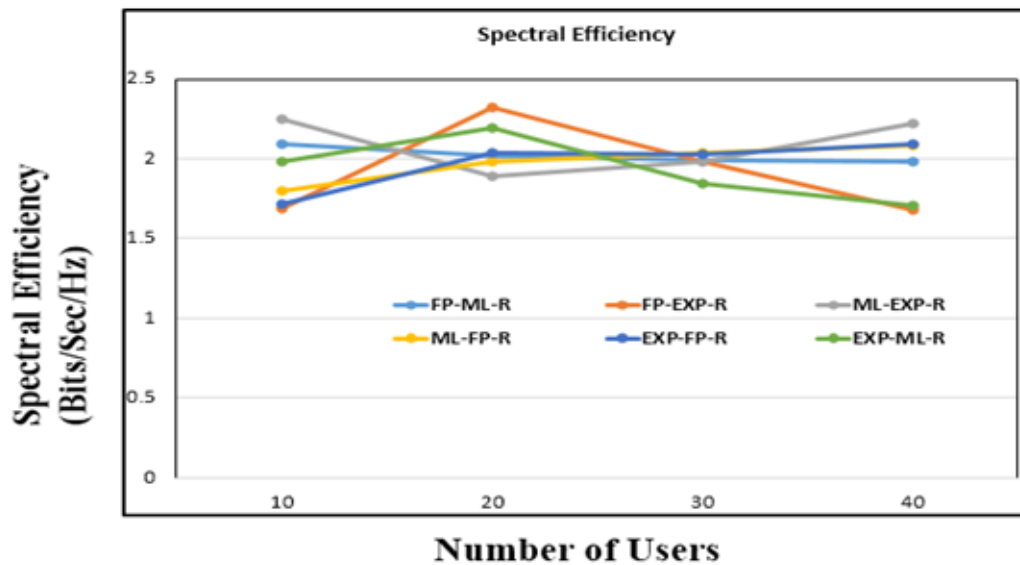


Figure 8. Spectral efficiency of users in heterogeneous resource allocations with mobility.

that FP scheduling has not been chosen for scheduling. The reason behind is FP is not suitable candidate in mobile condition. MLDWF is suitable for high mobile

condition because it generally ensure that delay packet probability doesn't exceed the minimum allowable packet

loss. Exponential scheduling is more suitable for multi-media service and can stand well in mobile condition.

3.3 EXP-FP and EXP-FP-CQI in Femto Node Immobile Scenario

The graph in Figure 9 and Figure 10 display the throughput

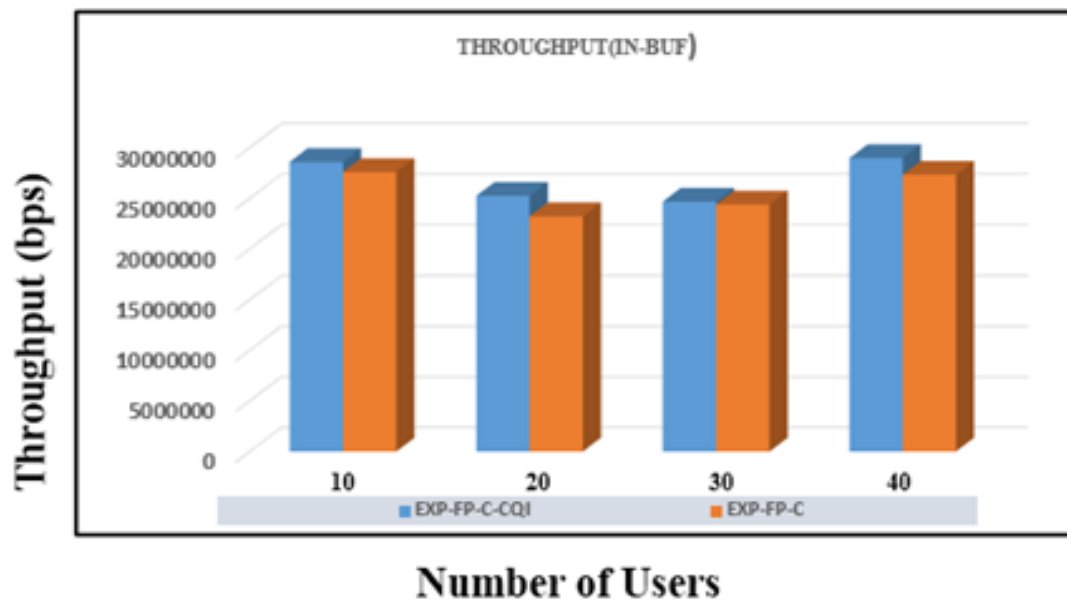


Figure 9. Throughput comparison of EXP-FP-C-CQI with EXP-FP-C.

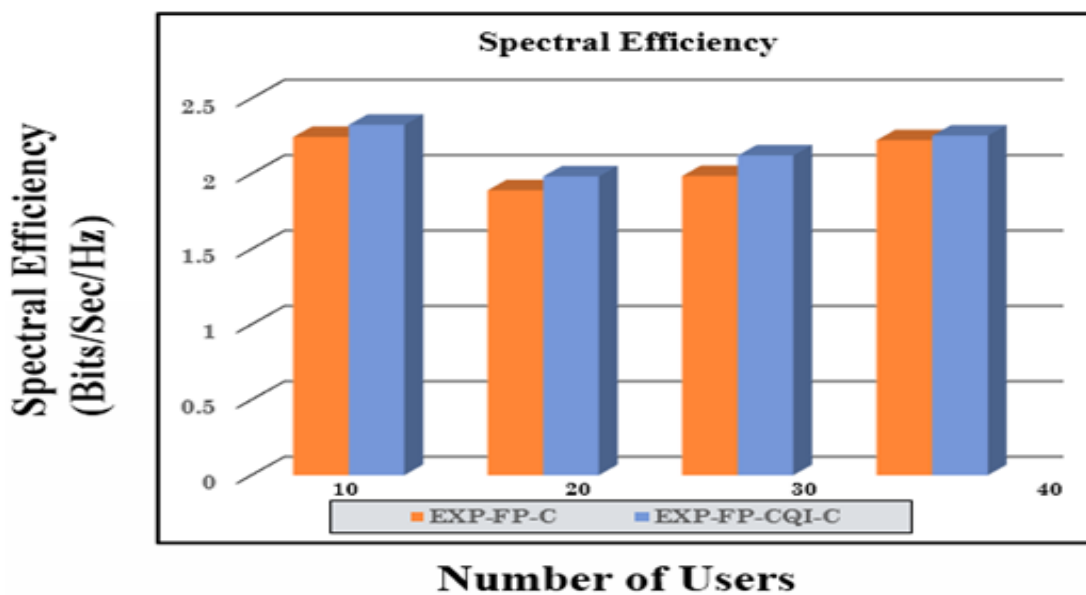


Figure 10. Spectral efficiency comparison of EXP-FP-C-CQI with EXP-FP-C.

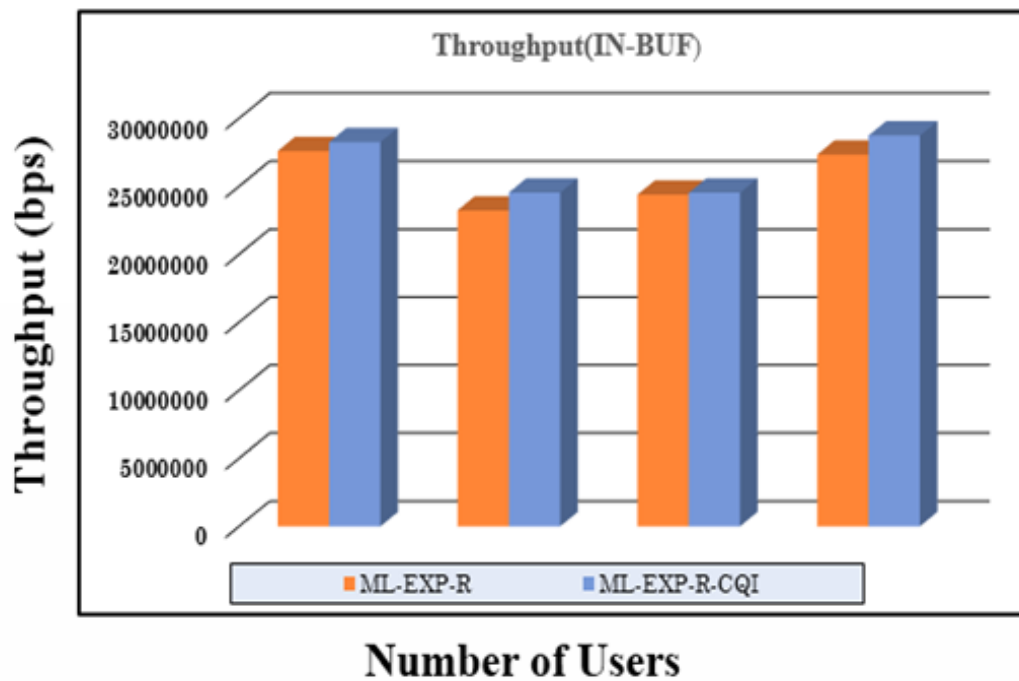


Figure 11. Throughput comparison of ML-EXP-R-CQI with ML-EXP-R.

Table 4. Mean comparison of the scheduling mechanisms with femto immobile nodes

Scheduling Type	Throughput (Mbps)	Spectral Efficiency (b/s/Hz)	Delay (μsec)
Existing [5]	13.26	1.54	113.12
FP-ML [8,21]	24.47	1.9927375	62.11
FP-EXP [8,21]	24.62	2.003925	61.73
ML-EXP [8,21]	25.05	2.001575	60.67
ML-FP [8,21]	23.195	1.8880975	65.53
EXP-FP [8,21]	25.633	2.01234	59.29
EXP-ML [8,21]	24.19	1.96886	62.38
EXP-FP-CQI	26.128	2.1231	57.8689

Table 5. Mean comparison of the scheduling mechanisms with femto node mobility

Scheduling Type	Throughput (Mbps)	Spectral Efficiency (b/s/Hz)	Delay (μ sec)
Existing [5]	13.26	1.54	113.12
FP-ML [8,21]	24.64	2.021945	60.90
FP-EXP [8,21]	23.54	1.9166475	64.27
ML-EXP [8,21]	24.833	2.085185	60.886
ML-FP [8,21]	24.622	1.97365	61.44
EXP-FP [8,21]	24.19	1.96886	62.54
EXP-ML [8,21]	23.79	1.9329075	63.55
ML-EXP-CQI	25.128	2.1342	60.17

and spectral efficiency comparison between EXP-FP-CQI and EXP-FP-C scheduling under Femto node immobility conditions. From the graph it can be observed that EXP-FP-CQI show better performance compared to EXP-FP scheduling. In particular, the EXP-FE-CQI scheduling provide a throughput 26.128 Mbps and spectral efficiency 2.1231 b/s/Hz. It is 1.8945% and 5.504% better in term of throughput and spectral efficiency as compared to EXP-FP-C scheduling.

3.4 EXP-FP and EXP-FP-CQI in Femto Node Mobility

Figure 11 and Figure12 display the throughput and spectral efficiency comparison between ML-EXP-R-CQI and

ML-EXP-R scheduling under Femto node immobility conditions. Here, ML-EXP-R-CQI based scheduling shows better performance compared to ML-EXP-R based scheduling. In particular, ML-EXP-R-CQI gives a peak throughput of 25.128Mbps and spectral efficiency of 2.1324 b/s/Hz. Further, it is 1.1879% and 2.85% better in term of throughput and spectral efficiency as compared to ML-EXP-R based scheduling. The mean comparison of the various scheduling schemes for Femto cell based LTE-A networks for immobile user and mobile users is shown in Table 4 and Table 5, respectively. It could be inferred that the ML-EXP-CQI based scheduling perform better than the existing and other scheduling algorithms that are discussed for LTE-A networks.

4. Conclusion

This paper details the resource allocation in scenarios with Femto immobile nodes and with Femto node mobility. In Femto immobile nodes, exponential scheduling at Marco ENB and fair proportional at Femto ENB shows the better performance. However, with M-Based CQI consideration, the performance of the combined scheduler is increased by 1.8945% and 5.504% better in term of throughput and spectral efficiency than the heterogeneous scheduler without considering CQI. Similarly, in case of Femto node mobility, MLDWF scheduler at Marco ENB and exponential at Femto ENB showed the best possible combinations. In addition, with combining M-Based CQI with the aforementioned heterogeneous scheduler, the system performance is increased by 1.1879% and 2.85% better in term of throughput and spectral efficiency than without considering CQI.

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