Simulation Model of Multi-RAT in Wireless Network

Md Abdullah Al Mamun and Abdulhadi Jaralla AlQahtani

College of Engineering
Qatar University

***Abstract*—As the network is becoming more dense and complex, also there are lacking of coordination between all network technologies where all the resources in the wireless network cannot be used in additional to unsatisfied user experience. Thus, 5G technology is expected to support new challenging use-cases by operating the network in a wide frequency ranges. Multi-RATs (Radio Access Technologies): LTE and Wi-Fi will together establish 5G in order to meet its own technology vision which is 1 Gbps cell edge data rate with less than 1 ms latency. In this paper, implementing LTE and Wi-Fi using MATLAB and conducting simulations experiments to measure the throughput to select the right radio access technology based on BER are the key goals. The empirical results meet this claims.**

I. Introduction

Forthcoming fifth generation (5G) wireless communication will satisfy the rising need of broadband multimedia applications, for example, machine-type networking, video and mobile gaming, HDTV, 3D TV, and VoIP. According to the architecture of 5G, there will be heterogeneous Radio Access Technologies (RATs) use (i.e., GSM, HSPA, LTE, LTE-A, Wi-Fi, and so on), multiple base stations (BS) with multi-tier radio coverages (e.g., macrocell, microcell, picocell, femtocell, relay links, Wi-Fi hotspot, and various level of transmitted power [1].

In another word, in order to offer ultra-reliable connection access to a broad range of purposes with low latency and high throughput desires, developing 5G communication will only feature pick data rates, but also combine a different Radio Access Technologies (RATs). However, network operators are facing a continuous challenge to flawlessly incorporate the heterogeneous RATs, efficiently utilize the radio resources, successfully functioning them as a single node, and delivering obvious service to the clients.

Also, multiple RAT connectivity support can be considered as a network function of mobile network operators which is located on the core network. Thus, the industry realized the need of multi-RAT for providing the seamless user connectivity whether RAT is fix or user mobility. It can be concluded that improved multi-RAT synchronization can fulfill the requirement [2]. To make it real, some smart methods to receive better performance is required where not only the co-existence of multiple RATs but also the variation in the level of signal coverage. More specifically, equipment of one network can be used in another network to facilitate a smooth transition from one technology to another. Another advantage of multi-RATs, the co-existence of 5G and legacy technologies must increase the communication reliability because legacy technology such as LTE can act as a backup radio. The co-existence is shown in Fig 1.

We should keep in mind that placement of 5G non-standalone model considered as single RATs in 5G. Radio Access Network (RAN) can be split into distributed and centralized units where centralized unit keeps a connection with higher layers and distributed unit, on the other hand, maintain the communication with lower layers. In addition, the distributed unit can be located on the same or separate datacenters based on the requirement.

A multi-RAT facility is always good to offer supplementary coverage in the area where interference is high and received signals are very weak. In this case, the network densification may reduce the distance between BSs and users thus increasing the data flow capacity and spectral efficiency [3]. Though low power base station offers large data volume capacity and fast communication, more than one RAT availability can encourage the user to change one RAT to another so frequently. As a result, the happening of unnecessary handover may increase signal overhead and degradation of performance.

Therefore, efficient RAT selection algorithms have to be investigated in the 5G Multi-RAT. In today's network, cell usually sends data using a single radio access technology which can be either LTE or Wi-Fi, but in 5G, there will be multiple RATs. The challenge is to select the best RAT for a single cell to transmit and receive data over the 5G network. The main objectives of this research are to select the best RAT based on Bit Error Rate (BER) by varying the SNR. To achieve our main goal, the characteristics of wireless links such as LTE, and Wi-Fi has been studied. Improve the resources utilization efficiency by selecting the best technology

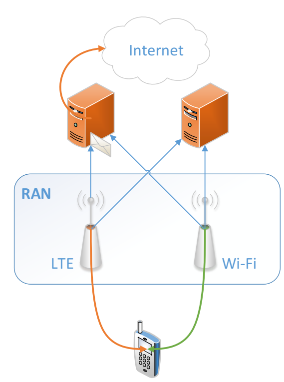

Fig. 1. Co-existence of Multi-RATs (LTE and Wi-Fi) in 5G

based on performance. Study and evaluate the data rate and latency on different scenarios. Also, this paper explains the key requirements and capabilities of 5G, along with its technology components and spectrum needs.

II. Related Works

5G is a technology that still needs a lot of research to be mature. Many research has been done on 5G but few of them discussed multi-RAT, optimized network/cell selection. Some technical report and research were working on tight inter-networking i.e., instead of coexistence only between New Radio (NR) and LTE, equipments of one network may communicate with apparatus of another which is called 5G multi-RAT scenario. This is because of the operation expectation from 5G means it will have a varied range of frequencies including extremely high mmWave [4]. In high spectral frequency, the conditions of propagation are far more challenging for example higher path loss and lower diffraction. However, massive MIMO and beamforming are two concepts that solve this issues [5]. Some researchers also addressed the problems of high directivity with respect to the channel variation and user mobility [6].

A comprehensive study on what will 5G be is discussed approximately all the technical, social and economic aspects of 5G in [7]. The one of the critical issue in the scenario of multiple RATs is to determine the optimal links that can operate at various frequencies using various protocols. this problem is still an unfolding issue that needs much attention. Conversely, a thought-provoking game theory is applied to select RAT, where convergence to Nash equilibria and the Pareto-efficiency of the equilibria are investigated [8]. A collaboration of cellular operator and Wi-Fi network owner is explored in the special issue as a relevant research outcome [9].

Similar to our research, a tight integration of LTE and WLAN with 5G multi RATs have been studied to get the benefit of efficient radio resource management, faster mobility and various multi-connectivity characteristics [10]. The same idea is implemented in many research where a loose or tight integration among more than one radio access technologies has been proposed for example LTE and Wi-Fi or LTE and 5G air interface to meet the 5G requirement [11], [12]. This approach has several significant goals which are to provide better connection continuity, quick mobility, and efficient resource management. The author recommends that the RRC and PDCP layers should be common in such integration for LTE and new air interface that supports by 5G [11]. Some concept has been applied to propose the dedicated DU for each IoT, D2D, and under a Multi-RAT environment such as LTE-5G and LTE-Wi-Fi [13].

In some articles, the best-rate path selection methods have been proposed for multiple radio access technologies with a different range of data flows [14]. From the abstract view, optimal path selection problem is considered as load balancing problem. We found a good number of research articles has been conducted in this direction as well. In addition, the problem of aggregating utility maximization, proportional Fairness rate allocation in WI-Fi settings where the cell has an access of either single access point or multiple have been studied [15], [16], [17], [18], [19], [20], [21]. Nevertheless, most of the articles have the method those are computationally complex which is NP-hard. Although the optimal path selection problem is relevant to this problem, necessarily different from multi-path TCP (MPTCP) optimization [22], [23], [24], [25]. Google Fi project is another example of best path selection and places any time slot for a certain cell.

Apart from above, considering the improvements suggested in the previous sections, the performance of Dual Connectivity (DC) and FS were compared to decide that there is no perfect solution that can be fitter well for all cases [26]. While FS can achieve better gain than DC for high load, DC accomplish better than FS for low loads. This intuition can be used to merge both DC and FS to select DC in low and FS in high load [26]. Though many research has been done on wireless radio access technology, few of them addressed the multi-RATs issue in 5G. Thus, selecting the optimum network/link in 5G network has yet a gap to be addressed. This paper attempts to propose a solution where BER is the selection criteria to be chosen a path.

III. Simulation Model

To make a good user experience by providing high-performance throughput and reliable connection, it is prerequisite to having multiple radio access technology where the cell can select the best link based on some criteria. In this simulation model, the criteria is Bit Error Rate (BER) to select the access point among a legacy 4G communication standard LTE or IEEE 802.11ac Wi-Fi. One of these radio access technologies will be selected that has lowest BER. The performance of this model will be evaluated on the value of throughput because when a link will be selected with lowest BER that will provide the highest throughput which has been discussed in the result section. However, interchange of link selection is occurred by varying SNR value. Since SNR is the difference between the level of signal and noise power, it has

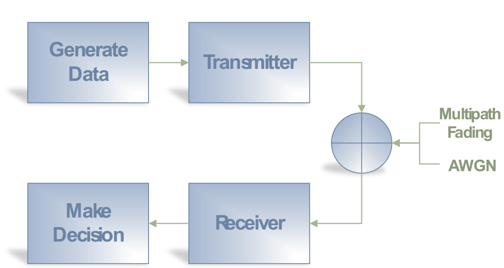

Fig. 2. Theoretical model

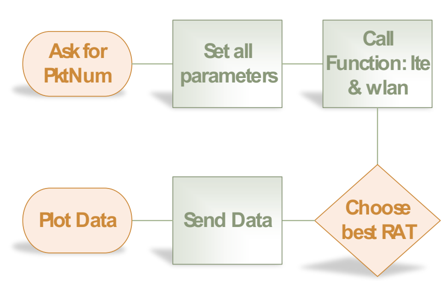

Fig. 3. Simulation model

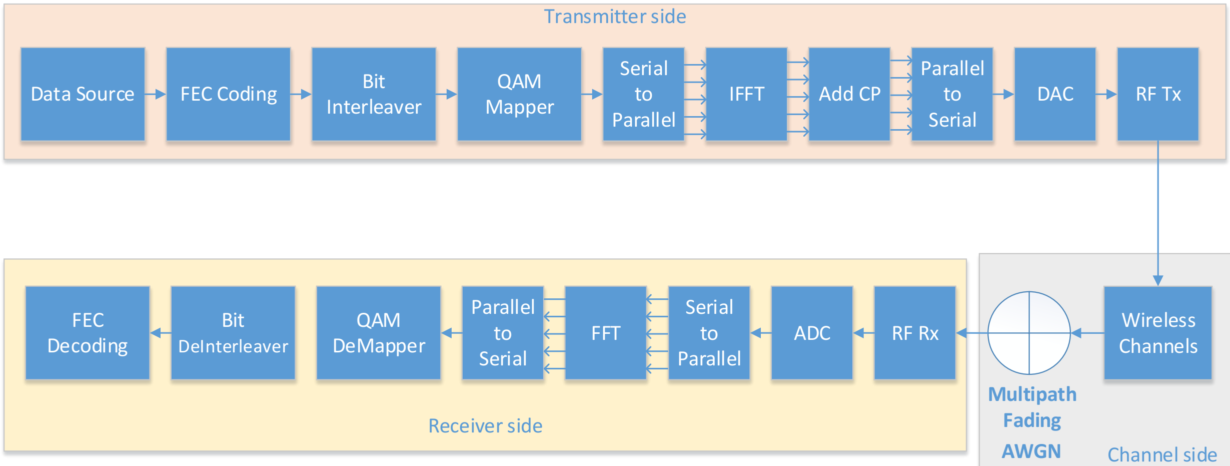

Fig. 4. Overall simulation model

a significant impact on changing the value of BER. As this difference became larger, the signal will be considered as a good or strong signal. In this section, the simulated scenario and necessary configuration will be detailed.

A. Simulated Scenario

If two users want to communicate with them, user-1 will generate the data to send by following the data transmission procedures. In the transmission link, multipath fading has been used to make the channel fading and a basic noise model Additive white Gaussian noise (AWGN) is used to make the signal noisy. The theoretical model is shown in the Fig. 2. After mixing the noise, the signal has been transmitted to the user-2 where data will be extracted. After that make the comparison between original and received signal to calculate the BER and throughput. Finally, a link will be selected that has lowest BER value. Later, when data needs to send again, the last value of BER will be considered to select new link and this process will be repeated.

In the end simulation model, Fig 3 is showing the simulation steps need to be done to get the results. Firstly, the model will ask the number of data the user wants to send. Secondly, all the parameters are required to initialize and configure. Two user-defined functions have been developed for WLAN and LTE respectively those return the value of the BER and Throughput. Chose RAT based on the BER value and send the data. This process kept running until all data packets are sent. Since the simulation is identical to the practical real-life implementation, all the ideal data transmission steps are implanted to make the model more acceptable and accurate. Although the transmitting and receiving procedures are already well known, some components are worth mentioning, for example, 16 QAM mapper has been used in this simulation. The receiver side is exactly the reverse of transmitter side.

B. Setup and Configuration

In this research, the experiment was done in MATLAB. The test environment and scenario configuration of LTE small cell and Wi-Fi are shown in Table III-B. HUAWEI LTE small cell vs Wi-Fi user experience white paper has been taken as

TABLE I. TEST ENVIRONMENT AND SCENARIO CONFIGURATION OF LTE SMALL CELL AND WI-FI

	LTE	IEEE 802.11ac
Scenario	Single Cell	Single Cell
Frequency (GHz)	2.6	2.4
Tx Power (dBm)	23	24
NodeB/AP Type	TD-LTE eNodeB	AP: (TL-WR1041N)
Bandwidth (MHz)	20	20
Antenna	DL: 2x2, UL: 1x2	DL: 2x2, UL: 1x2

a configuration guide in this experiment [27]. The number of cells is only one in both LTE and WLAN. The carrier frequency of the LTE and WLAN are 2.6 and 2.4 respectively. MiMO 2×2 antenna technology for both downlink and uplink is used in both cases. Same bandwidth is used for data transmission. Practical SNR has considered between an acceptable range of 8 to 20dB as per some mobile operator. Each time the SNR is selected randomly from the mentioned range that is calculated based on real-life experience.

IV. RESULTS AND EVALUATION

In this experiment, BER and throughput are calculated to measure the performance. The responses of LTE and WLAN are shown in Fig. 5 and Fig. 6 respectively. In both graphs, the x-axis indicates the number of data to be sent and y-axis means the SNR, BER, and throughput respectively. As the SNR becomes decrease, BER increase, thus throughput is increased. This behavior is observed in both LTE and WLAN. For example, in Fig, the lowest SNR has been recorded at the at the point of 7 whereas BER is highest and throughput is also lowest. Since the SNR is the difference between signal power and noise power, the signal becomes very noisy when the difference gets very small, consequently, throughput becomes lower.

The relation between BER and SNR is depicted in Fig. 7 How BER change with respect to the SNR is the main observation of this graph. As the SNR becomes larger, the value of BER of WLAN is keeping upper than the LTE. Inversely, when SNR value was lower in the initial stage, the

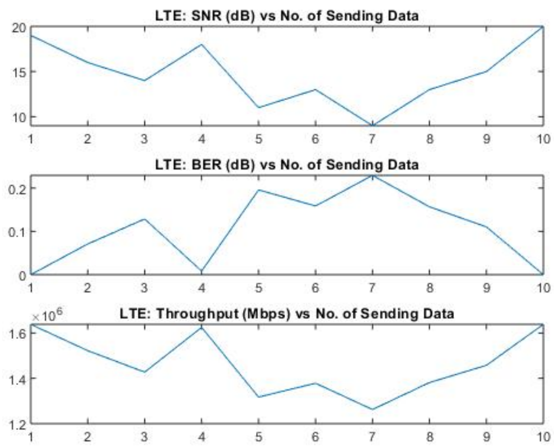

Fig. 5. LTE responses

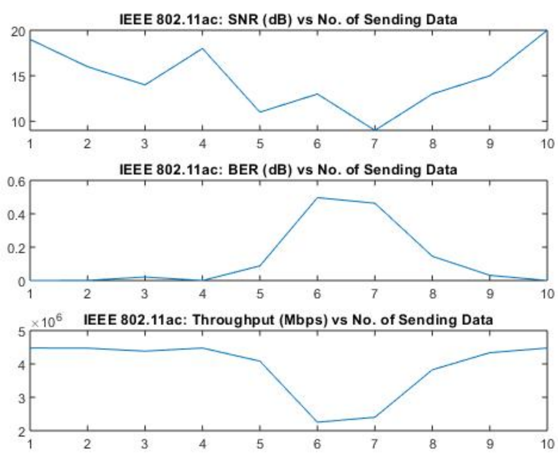

Fig. 6. WLAN responses

BER value of LTE was higher that goes down by the end. Since SNR change the value of BER, the selection of right RAT is indirectly depends on SNR as well. In this experiment, the cell sends data 5 times, in the first attempt, LTE is selected because the value of SNR is 10 and at this point, the value of BER of WLAN is lower than the BER of LTE. Also, LTE is still selected for the following packets but when the third

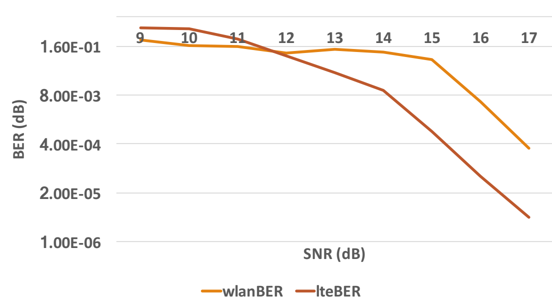

Fig. 7. Relationship between BER and SNR

packet comes, WLAN is selected because the value of SNR is 15 now. In this stage, Wi-Fi is performing well. Why is this happening? Because it depends on two things, transmitted power and carrying frequency.

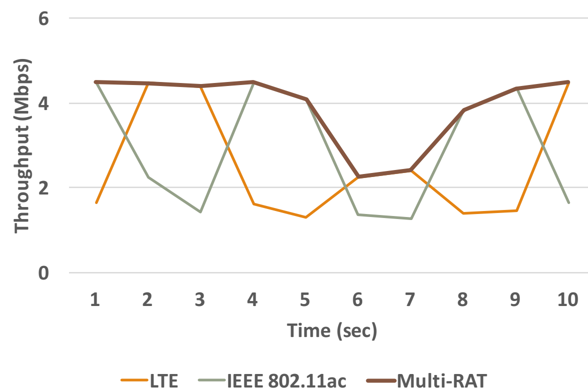

Fig. 8. Instant Throughput with/without Multi-RAT

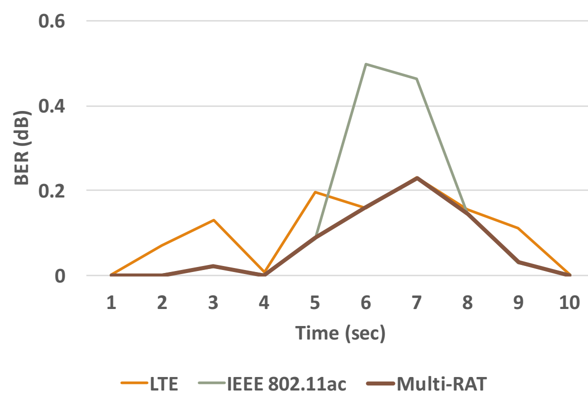

Fig. 9. Instant BER with/without Multi-RAT

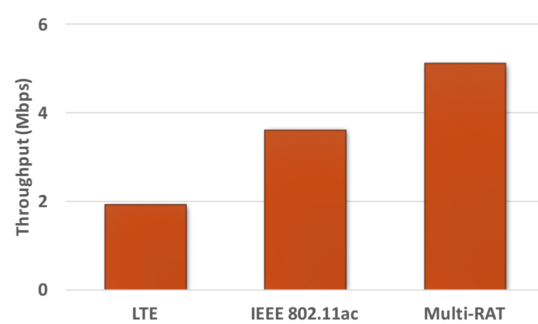

Fig. 10. Average Throughput with/without Multi-RAT

The Fig. 8 shows the instant throughput of single and multi-RAT scenario. It is called instant because when a cell sends the data, it will not send whole data in one shot, it will send the data packet by packet. This graph shows the throughput measures when it sends the data by selecting the link using manual selection either WLAN or LTE. Also, it shows the changing of throughput value when a link from multi-rat is selected based on the given criteria. It is clearly observed

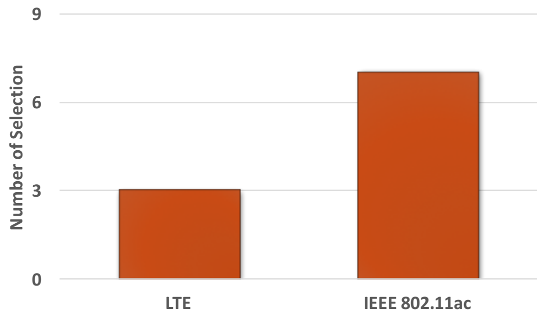

Fig. 11. Number of Selection for Each Technology

that the maximum throughput is recorded when it selects the link using the multi-RAT method. Similarly, BER with/without multi-RAT is shown in the Fig.9 where the lowest BER is recorded all along with the multi-RAT scenario as like as an envelope on both LTE and WLAN.

The bar charts illustrates the average throughput of the data in Fig. 10. As we can see the multi-RAT gives the highest throughput based on random selection of SNR. Also, the number of selection of each technology is given in Fig. 11. Per our experimental setup, top selected link is WLAN.

V. Conclusion

This research confers the way of multi-connectivity using multiple radio access technology for example tight integration of LTE and Wi-Fi with 5G, to manage the central radio resource efficiently. The ultimate benefit of this scheme is to get high throughput and reliable backup link. This 5G architectural solution meets the wide range of 5G requirements including high broadband on BER investigation with SNR. The principle goal is to develop a flexible, scalable and cost-effective RAN architecture for 5G. This aim is met by tightly coupling with multiple RATs such as LTE and WI-Fi.

References

[1] Ericsson, "5g radio access," Ericsson, Tech. Rep., 2016. [Online]. Available: https://www.ericsson.com/assets/local/publications/white-papers/wp-5g.pdf

[2] N. Alliance, "5g white paper," *Next generation mobile networks, white paper*, 2015.

[3] M. Fallgren, B. Timus *et al.*, "Scenarios, requirements and kpis for 5g mobile and wireless system," *METIS deliverable D*, vol. 1, p. 1, 2013.

[4] A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, O. Queseth, M. Schellmann, H. Schotten, H. Taoka *et al.*, "Scenarios for 5g mobile and wireless communications: the vision of the metis project," *IEEE Communications Magazine*, vol. 52, no. 5, pp. 26–35, 2014.

[5] Z. Marzi, D. Ramasamy, and U. Madhow, "Compressive channel estimation and tracking for large arrays in mm-wave picocells," *IEEE Journal of Selected Topics in Signal Processing*, vol. 10, no. 3, pp. 514–527, 2016.

[6] H. A. Abdullah Al Mamun, Sultan Anwar, "4g and 5g mobile communication networks: Features analysis, comparison and proposed architecture," *International Journal of Computer Science and Technology*, vol. 7, no. 2, pp. 155–160, 2016.

[7] J. G. Andrews, S. Buzzi, W. Choi, S. V. Hanly, A. Lozano, A. C. Soong, and J. C. Zhang, "What will 5g be?" *IEEE Journal on selected areas in communications*, vol. 32, no. 6, pp. 1065–1082, 2014.

[8] E. Aryafar, A. Keshavarz-Haddad, M. Wang, and M. Chiang, "Rat selection games in hetnets," in *INFOCOM, 2013 Proceedings IEEE*. IEEE, 2013, pp. 998–1006.

[9] L. Gao, G. Iosifidis, J. Huang, L. Tassiulas, and D. Li, "Bargaining-based mobile data offloading," *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 6, pp. 1114–1125, 2014.

[10] S. Chandrashekar, A. Maeder, C. Sartori, T. Höhne, B. Vejlgaard, and D. Chandramouli, "5g multi-rat multi-connectivity architecture," in *Communications Workshops (ICC), 2016 IEEE International Conference on*. IEEE, 2016, pp. 180–186.

[11] I. Da Silva, G. Mildh, J. Rune, P. Wallentin, J. Vikberg, P. Schliwa-Bertling, and R. Fan, "Tight integration of new 5g air interface and lte to fulfill 5g requirements," in *Vehicular Technology Conference (VTC Spring), 2015 IEEE 81st*. IEEE, 2015, pp. 1–5.

[12] U. Doetsch, H. Droste, A. Roos, T. Rosowski, G. Zimmermann, P. Agyapong, N. Fonseca, I. D. S. Lindqvist, H. Eriksson, H. Tullberg *et al.*, "Deliverable d6. 4 final report on architecture."

[13] A. Nanjundappa, S. Singh, and G. Jain, "Enhanced multi-rat support for 5g," in *Consumer Communications & Networking Conference (CCNC), 2018 15th IEEE Annual*. IEEE, 2018, pp. 1–2.

[14] S. Borst, A. Ö. Kaya, D. Calin, and H. Viswanathan, "Dynamic path selection in 5g multi-rat wireless networks," in *INFOCOM 2017-IEEE Conference on Computer Communications, IEEE*. IEEE, 2017, pp. 1–9.

[15] T. B. L. E. L. R. Ramjee, "Generalized proportional fair scheduling in third generation wireless data networks," in *Proc. IEEE Infocom 2006*, 2006.

[16] R. Chai, H. Zhang, X. Dong, Q. Chen, and T. Svensson, "Optimal joint utility based load balancing algorithm for heterogeneous wireless networks," *Wireless networks*, vol. 20, no. 6, pp. 1557–1571, 2014.

[17] W. Li, Y. Cui, S. Wang, and X. Cheng, "Approximate optimization for proportional fair ap association in multi-rate wlans," in *International Conference on Wireless Algorithms, Systems, and Applications*. Springer, 2010, pp. 36–46.

[18] L. Li, M. Pal, and Y. R. Yang, "Proportional fairness in multi-rate wireless lans," in *INFOCOM 2008. The 27th Conference on Computer Communications. IEEE*. IEEE, 2008, pp. 1004–1012.

[19] Q. Ye, B. Rong, Y. Chen, M. Al-Shalash, C. Caramanis, and J. G. Andrews, "User association for load balancing in heterogeneous cellular networks," *IEEE Transactions on Wireless Communications*, vol. 12, no. 6, pp. 2706–2716, 2013.

[20] H. Zhou, P. Fan, and J. Li, "Global proportional fair scheduling for networks with multiple base stations," *IEEE Transactions on Vehicular Technology*, vol. 60, no. 4, pp. 1867–1879, 2011.

[21] A. Al Mamun, T. R. Sheltami, H. Ali, and S. Anwar, "Performance evaluation of routing protocols for video conference over mpls vpn network," *Journal of Ubiquitous Systems & Pervasive Networks*, vol. 7, no. 1, pp. 01–06, 2016.

[22] H. Han, S. Shakkottai, C. V. Hollot, R. Srikant, and D. Towsley, "Multi-path tcp: a joint congestion control and routing scheme to exploit path diversity in the internet," *IEEE/ACM Transactions on networking*, vol. 14, no. 6, pp. 1260–1271, 2006.

[23] P. Key, L. Massoulié, and D. Towsley, "Path selection and multipath congestion control," in *INFOCOM 2007. 26th IEEE International Conference on Computer Communications. IEEE*. IEEE, 2007, pp. 143–151.

[24] Q. Peng, A. Walid, J. Hwang, and S. H. Low, "Multipath tcp: Analysis, design, and implementation," *IEEE/ACM Transactions on Networking*, vol. 24, no. 1, pp. 596–609, 2016.

[25] M. A. Al Mamun, M. Begum, and M. Rubel, "An experimental improvement analysis of loss tolerant tcp (lt-tcp) for wireless network," *IJACSA Editorial*, 2011.

[26] V. F. Monteiro, M. Ericson, and F. R. P. Cavalcanti, "Fast-rat scheduling in a 5g multi-rat scenario," *IEEE Communications Magazine*, vol. 55, no. 6, pp. 79–85, 2017.

[27] HUAWEI, "Lte small cell v.s. wifi user experience," HUAWEI, Tech. Rep., 2013. [Online]. Available: http://www.huawei.com/mediafiles/CBG/PDF/Files/hw_323974.pdf