Performace Comparison of Network Layouts with Mobile Users under Different Resource Scheduling Techniques in Downlink LTE

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***Abstract*—LTE-A addresses the challenges of coverage block holes and increase in user density with new features, such as small cell and femto cell. Small cell can be an inexpensive substitute to macro cell in coverage depleted areas. In contrast, heterogeneous network using femto cells with its ubiquitous coverage, can deliver high-speed data. Resource scheduling algorithm has an important role in determining the overall system performance. Several schedulers are available whose performance ranges from maximizing UE throughput to achieving the best fairness. UE mobility significantly affects the performance of different network topologies and various scheduling algorithms. In this paper, we have evaluated and compared various LTE downlink performance parameters between small cell network and heterogeneous network to conclude which type of network deployment is best suited for mobile users and dense urban environment under different scheduling schemes.**

***Keywords*—UE mobility; Small cell; Heterogeneous network; Resource scheduling.**

I. Introduction

LTE is a 3rd Generation Partnership Project (3GPP) standard designed to improve system coverage, increase capacity, efficient spectrum utilization, lower latency and high data speed. For downlink transmission Orthogonal Frequency Division Multiple Access (OFDMA) scheme is implemented to improve throughput and spectral efficiency [1]. LTE offers several Multiple-Input and Multiple-Output (MIMO) modes to acquire high-data rate and better spectral efficiency. A maximum data rate of 326.4Mbps and 86.4Mbps can be achieved in the downlink and uplink respectively for a 20MHz channel [2]. Conventional macro cell network experiences several problems for seamless coverage especially in urban environments. Moreover with ever-escalating user density, capacity exhaustion of macro cells is inevitable. To overcome these obstacles for better User Equipment (UE) performance LTE introduced multiple features [3]. The potential aspects in the latest 3GPP releases are femto cell and small cell to meet high traffic demand and better network coverage. Femto cell is used in conjunction with macro cell forming a Heterogeneous Network (HetNet) which is flexible and provides a uniform broadband experience. Femto cells act as low power base stations (BSs) extending network coverage for the UEs. This provides substantial gain in UE data rate and improves the spectral efficiency. Therefore by inserting femto cells into the existing macro cell network in an unplanned manner, significantly enhances the capacity of wireless networks. Small cell is based on macro structure with smaller cell radius and comparative low transmission power. This establishes a network with a high concentration of BSs in the given area. Its network architecture is flexible thus can be used to form seamless network coverage between high rise buildings.

One of the key system parameters is resource scheduling which distribute system resources among active UEs. It is done in the medium access control (MAC) layer of the BS. The scheduling method affects the UE and cell throughput therefore the type of scheduling technique has a significant impact on the system efficiency. Several resource scheduling algorithms are available each with their own merits and demerits. Among them the most popular are proportional fair (PF) and Round Robin (RR).

A significant contributor that limits the system efficiency is UE velocity. Many re-searches have been conducted on the performance of various scheduling schemes [4-7]. The potential use of small cells in outdoor environments and indoor environments are being investigated [8-9]. Small cell outdoor deployment for optimized UEs throughput is discussed in [10]. Femto cell deployment architectures and its benefit are discussed in [11].

In this paper, we have compared several downlink performance parameters (Average UE throughput, Cell edge throughput and Spectral efficiency) between Small cell Network (ScNet) and HetNet under different scheduling schemes to assess which network type provides better UE performance for a wide range of UE velocity. Also we have calculated the Area throughput under both ScNet and HetNet to determine which network type is suitable to provide better network performance in terms of the geometrical area covered by the networks. This is necessary to find which network topology is suitable for a densely populated region. Furthermore, we have analyzed and compared the effect of UE density on the network and UE performances under low, medium and high UE velocities.

The remainder of the paper is organized as follows. In section II the ScNet and HetNet layouts, different scheduling schemes and various performance metrics are presented. Simulation setup and analysis of the performance metrics are discussed in section III. Finally the conclusions are drawn in section IV.

II. System Model

A. Network Models

To compare the performance of ScNet and HetNet distinct strategies were employed. Fig. 1(a) illustrates the ScNet deployment strategy with UE positions. In our simulation we have designed a ScNet comprising of 19 BSs, forming a hexagonal geometry, with an inter BS separation of 150m. Each small cell has a BS with tri-sectored antennas. Fig. 1b demonstrates the HetNet deployment plan with UE positions. Here we have a macro cell with 19 BSs and 20 femto cells. The inter BS distances in the macro cell is 500m and have tri-sector antennas whereas femto cells have single antennas respectively.

B. Resource Scheduling

PF and RR algorithm are employed to schedule data transfer among the users. PF technique maximizes total data rate while at the same time allows a minimal level of service to all the users, hence achieving a high throughput with a desirable fairness index. The scheduling procedure is based upon user prioritization where each user is set a priority coefficient according to the priority function:

$$P = \frac{T^{\alpha}}{R^{\beta}} \quad (1)$$

where T is the achievable throughput for a UE in a particular time slot and R is the average data rate of the UE. The parameters α and β are used to tune the fairness of the scheduler. For PF scheduling algorithm $\alpha \approx 1$ and $\beta \approx 1$ [12].

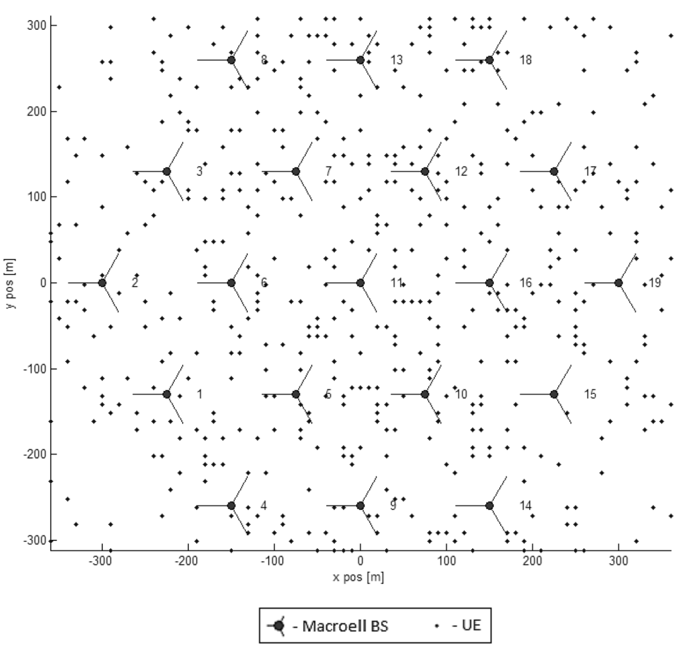

Fig. 1(a): Small cell network (ScNet) deployment.

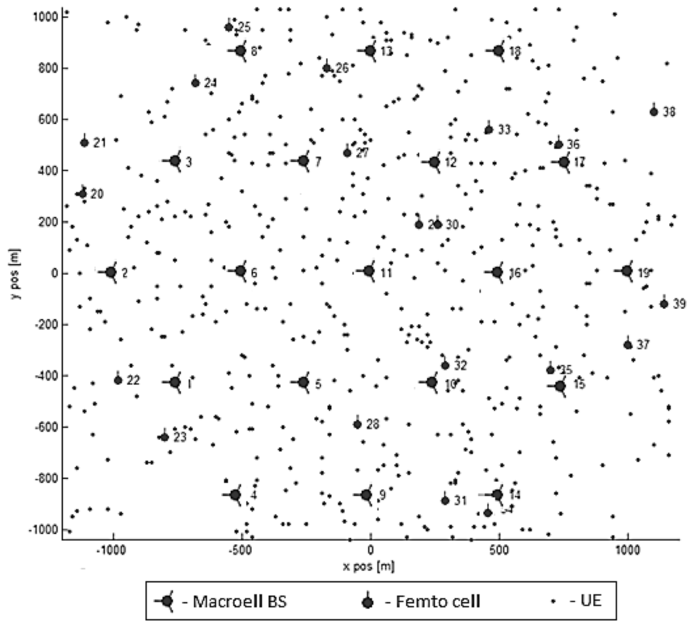

Fig. 1(b): Heterogeneous network (HetNet) deployment.

RR algorithm does not prioritize among the UEs and allows all the UEs to share the channel in a cyclic order. As channel conditions are not taken into account this technique provides the best fairness but a lower UE throughput. For RR scheduling algorithm $\alpha = 0$ and $\beta = 1$.

C. Key Performance Indicators

1) Average UE throughput: In a cellular network UEs are located randomly relative to the base station. UEs in the vicinity of a base station have the highest SINR and this decrease with an increase in distance away from the base station. Thus UEs under a single base station have a wide range of SINR. As UE data rate depends on its channel quality which is determined by the SINR received by the UE, therefore a wide SINR range received by the UEs results in a high UE throughput diversity. Therefore for a better understanding on the impact of network topologies on user throughput performance average UE throughput (T_{avg}) is considered and is defined as:

$$T_{avg} = \frac{\sum_{k=1}^{n} T_k}{n} \quad (2)$$

where T_k is the total throughput for k^{th} user and n is the total number of users.

2) Cell edge throughput: The strength of the transmitter signal is weakest at the edge of a cell. This region also receives a fair amount of signal from its neighboring cell introducing inter-cell interference that further degrades network performance limiting the user throughput. Therefore to achieve ubiquitous network coverage for mobile users and to avoid call drop during cell handover it is imperative to maintain a minimum throughput. Cell edge throughput is defined as the 5th percentile of the UE throughput empirical cumulative distribution function (ECDF).

3) Area throughput: Average UE throughput reflects on the UE performances only. A new parameter, area throughput (T_{area}), is introduced to gain an insight on the performance of different radio planning strategies under various user densities. Area throughput is calculated as:

$$T_{area} = \frac{\sum_{k=1}^{n} T_k}{Geometrical\ area} \quad (3)$$

4) Spectral efficiency: Spectral utilization depends on wireless technologies and requires a specific spectrum based parameter for comparison. An effective way is to measure the spectral efficiency which indicates the rate at which data is transferred over a given bandwidth and is defined as:

$$S = \frac{\sum_{k=1}^{n} T_k}{W} \quad (4)$$

where T_k is the throughput for k^{th} user and W is the system bandwidth.

III. Simulation Results and Discussion

A. Simulation Setup

LTE system level simulator was used to simulate ScNet and HetNet [13]. Simulation was carried out using a total number of 570 UEs randomly placed within the simulation geometries for a velocity range of 0-125 kmph. For UE mobility we have considered the random walk model. Multiple MIMO techniques are available e.g. transmit diversity (TxD), closed loop spatial multiplexing (CSLM) to improve the overall UE throughput. In this paper we have considered the TxD mode for a 2x2 MIMO system, to compare the various throughputs between ScNet and HetNet, because of its robustness under different fading scenarios. Link quality prediction in response to UE SINRs was performed using the mutual information based effective SINR mapping (MIESM) procedure as it is more accurate than some other well-known methods such as exponential effective SINR mapping (EESM) [14-15]. Resource scheduling procedure for the UEs has to address the tradeoff between throughput and fairness. RR provides best fairness at the expense of a lower throughput. In contrast PF provides a higher throughput with an acceptable fairness index therefore PF was used for UE resource scheduling [16]. In HetNet, homogeneous spatial distribution of femto cells is considered.

Macroscopic pathloss model of urban environment considered for both femto cells and macrocell BSs are given below [17]:

$$L = 40(1 - 4 \times 10^{-3} h_{BS}) \log_{10}(R) - 18 \log_{10}(h_{BS}) + 21 \log_{10}(f) + 80dB \quad (6)$$

where R is the BS-UE separation in kilometers, f is the carrier frequency in MHz and h_{BS} is the height of BS in meters. Additional simulation parameters implemented are tabulated in table-I.

Table I – Simulation Paramters for Small Cell Network and Heterogeneous Network

Simulation parameters	
Channel model	WINNER+
Frequency	900MHz
Bandwidth	10MHz
No. of transmitter	2
No. of receiver	2
Transmission mode	Transmit diversity (TxD)
BS height	20m
BS power	45dB
Receiver height	1.5m
Adaptive RI	2
Antenna azimuth offset	30°
Antenna Gain	15dBi
BS Transmitter power	45dBm
Femto cell transmission power	10 (Watts)
Simulation time	10 TTI

B. Results Analysis

The simulation results suggest that average UE throughput, depicted in Fig. 2(a), for HetNet is higher than ScNet. This may be due to the additional low power BSs in HetNet that improves the rate at which data is transmitted to the UEs. Moreover, the result of the ScNet indicates its independency to the type of scheduler used to allocate resource to users. Also the result of the HetNet implies that RR scheduler is more robust to UE mobility and provides better throughput for

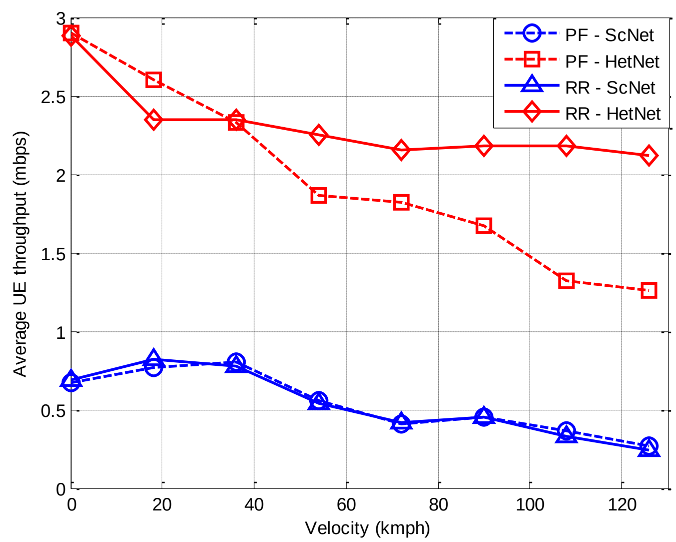

Fig. 2(a): Average UE throughput in ScNet and HetNet for mobile users.

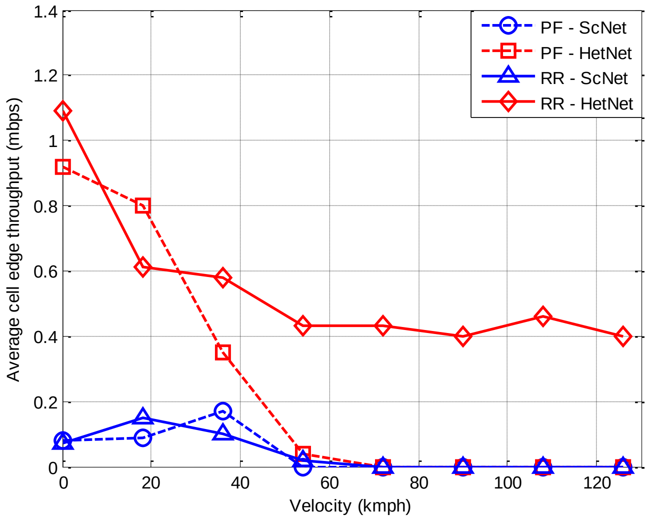

Fig. 2(b): Average cell edge throughput in ScNet and HetNet for mobile users.

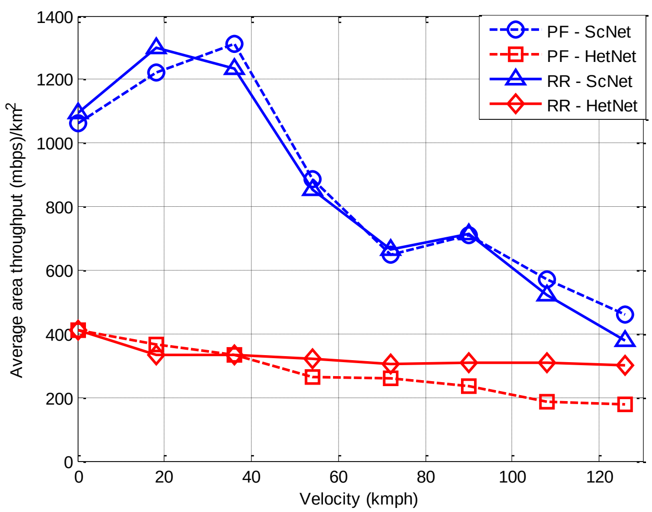

Fig. 2(c): Average area throughput in ScNet and HetNet for mobile users.

high velocity users because it does not consider the UE channel quality. The results of the average cell edge throughput shown in Fig. 2(b) for ScNet demonstrates similarities for both types of scheduler. In contrast to ScNet, where the edge throughput reduces to zero for high velocity users, HetNet under RR scheduling technique is able to provide a fair amount of data rate to its cell edge users under a diverse range of velocities. This is significant to obtain a seamless network that can avoid call drop due to the lack of data rate during cell handovers. Area throughputs for different network layouts under multiple scheduling schemes are shown in Fig. 2(c). It is evident that ScNet provides higher throughput per unit coverage area but this is sensitive to UE mobility and the area throughput decreases with an increasing UE velocity. On the other hand HetNet delivers almost similar area throughput for a wide range of velocities and is not significantly affected by UE mobility. Moreover the results show that area throughput is not affected by the type of scheduling algorithm. Fig. 2(d) stipulates that bandwidth is

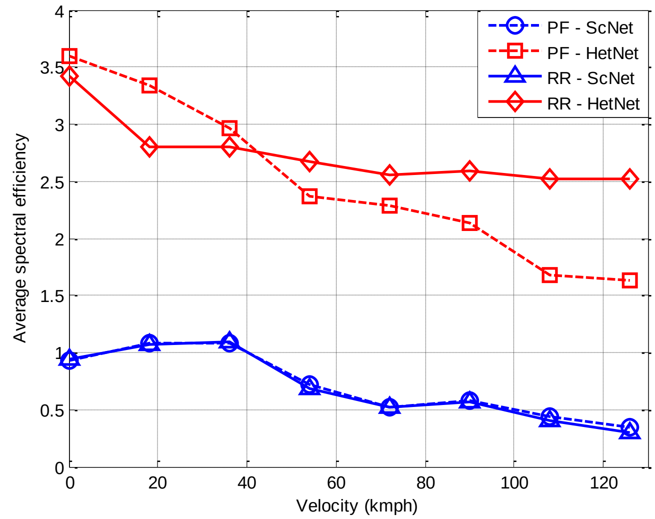

Fig. 2(d): Average spectral efficiency in ScNet and HetNet for mobile users.

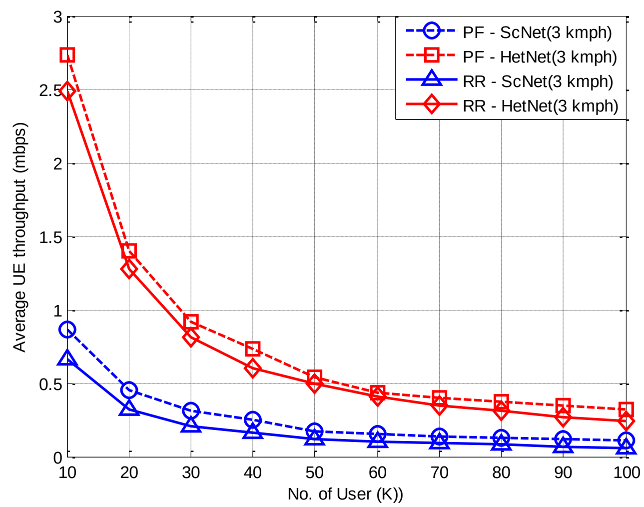

Fig. 3(a): Average UE throughput vs. UE density with low UE velocity for ScNet and HetNet under PF and RR scheduler algorithm.

more efficiently utilized in HetNet for data transfer, since it supports more BSs for this purpose. The spectral efficiencies attained for different scheduler types are similar in ScNet. On the contrary, in HetNet PF provides higher efficiency for low velocity users but for high velocity case RR dominates. Fig. 3(a) shows that for pedestrians the average UE throughput decreases with increase in UE densities. For either scheduler HetNet achieves a better performance than ScNet, due to the presence of more BSs. In terms of scheduler performance PF provides higher UE throughput in both the networks even for high UE densities. For medium UE velocity the average UE throughput declines comparatively faster with an increase of UE densities as illustrated in Fig. 3(b). In this scenario also HetNet dominates ScNet and RR scheduler achieves better UE performance in either networks. Both networks reach saturation in terms of UE throughput for higher UE densities in which case PF and RR provides similar data rate to the UEs. HetNet for high UE velocity also provides a higher throughput than ScNet and experiences a declining pattern

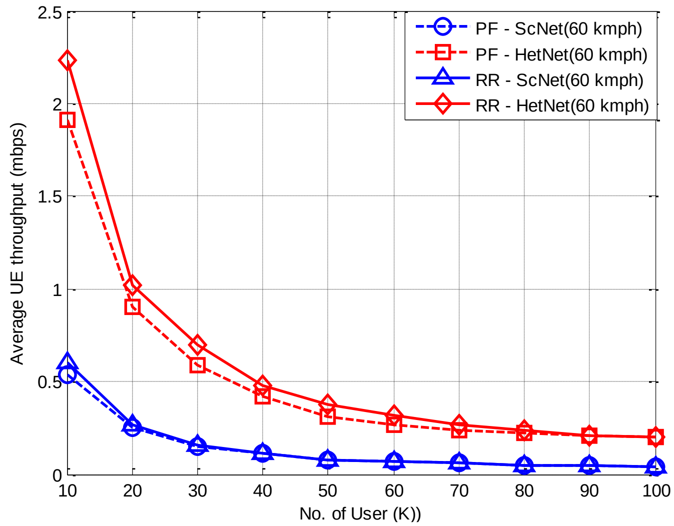

Fig.3(b): Average UE throughput vs. UE density with medium UE velocity for ScNet and HetNet under PF and RR scheduler algorithm.

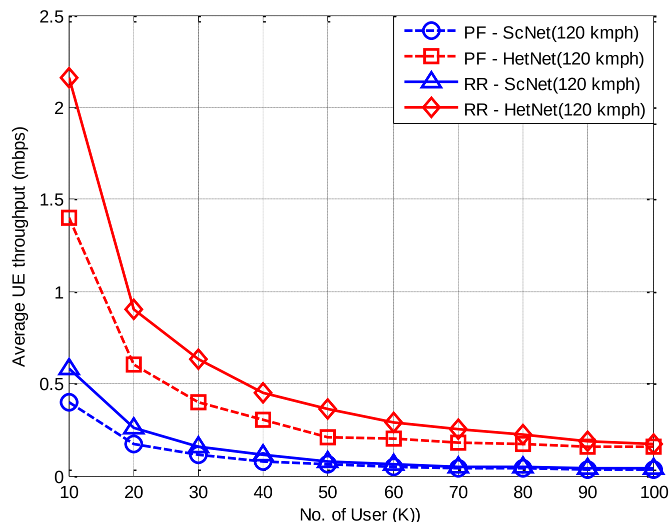

Fig. 3(c): Average UE throughput vs. UE density with high UE velocity for ScNet and HetNet under PF and RR scheduler algorithm.

similar to low and medium velocities, depicted in Fig. 3c, with increase in UE densities.. But in case it is apparent that RR technique outperforms PF for low UE densities in both types of network layouts. Again for high UE densities the UE throughput saturates and produces similar throughput performances for both PF and RR scheduling scheme. The effect of UE densities on mean cell edge throughput are illustrated in Fig. 3(d)-(f). It can be seen that the data rate at cell edge decreases with the increase in UE densities and HetNet provides better cell edge throughputs from low to high UE densities at all velocities. Moreover for pedestrians only PF performs better than RR in either network. For medium to high UE velocities RR significantly dominates PF and the latter produces null throughput in both the network layouts. HetNet under RR achieves a very low cell edge throughput even for high UE densities. In contrast ScNet works better for low UE densities and the cell edge throughput decrease at high UE densities.

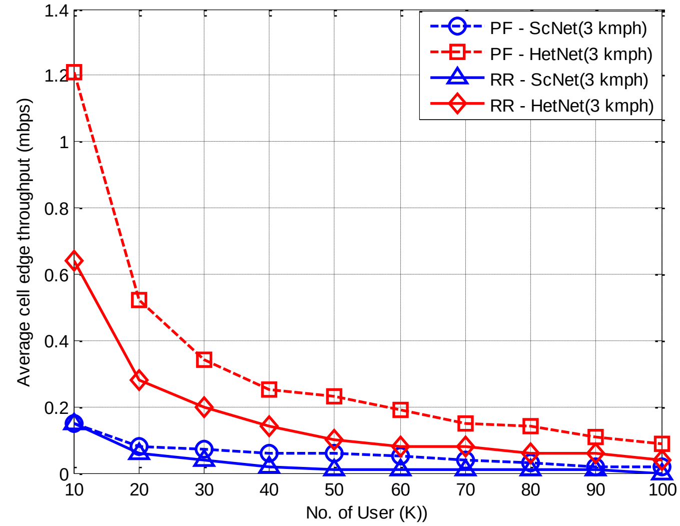

Fig. 3(d): Average cell edge throughput vs. UE density with low UE velocity for ScNet and HetNet under PF and RR scheduler algorithm.

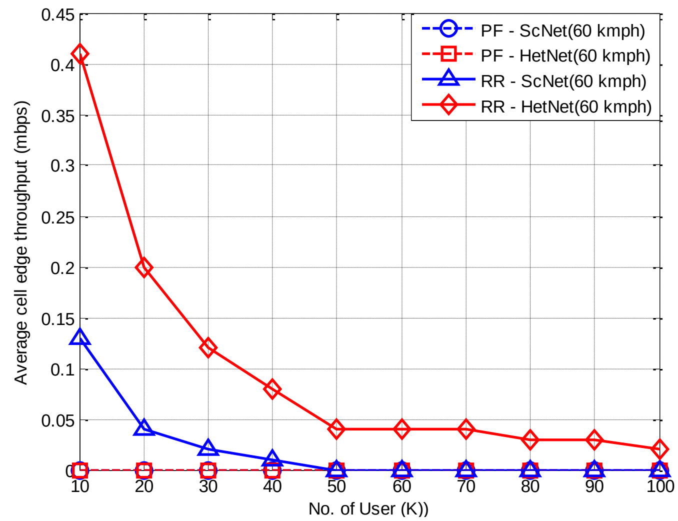

Fig. 3(e): Average cell edge throughput vs. UE density with medium UE velocity for ScNet and HetNet under PF and RR scheduler algorithm.

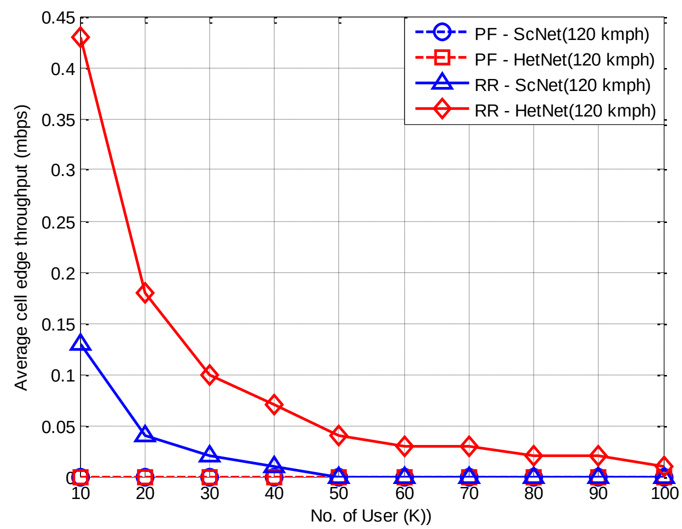

Fig. 3(f): Average cell edge throughput vs. UE density with high UE velocity for ScNet and HetNet under PF and RR scheduler algorithm.

IV. CONCLUSION

In this work, we have developed the simulation environment for HetNet using femto cell and ScNet where we simulate for two different resource scheduling algorithms under UE mobility. Simulation results revealed that average UE throughput under HetNet is higher than ScNet. Moreover RR achieves better UE performance for high velocities and in HetNet provides an acceptable throughput at cell edges over a larger range of UE velocities which PF in HetNet and ScNet under both scheduling algorithm fails to achieve. On the other hand if throughput density is considered then ScNet outperforms HetNet even considering for mobile UEs. Therefore ScNet can be considered in densely populated areas, where network exhaustion is more of a concern than UE performance, using either PF or RR. In contrast if better UE performance is required at high velocities than HetNet can be used under RR scheduling to avoid call drops at cell edges and to achieve high UE throughput. In addition HetNet performs better for higher user densities and under RR provides higher UE performance than PF at high velocities. In terms of average UE throughput at high velocity and for high UE density both schedulers have similar performances. HetNet also provides better cell edge throughput than ScNet for high UE densities and RR performs best in case of cell edge throughput for densely populated high velocity UEs.

REFERENCES

[1] T. Ali-Yahiya, "Understanding LTE and its Performance," *Springer* 2011.

[2] M. Tolstrup, Indoor Radio Planning: "A Practical Guide for 2G, 3G and 4G," *3rd edition Wiley* 2015.

[3] 4G Americas, "Mobile Broadband Evolution Towards 5G: Rel-12 & Rel-13 and Beyond," June 2015.

[4] Y. Barayan and I. Kostanic, "Performance Evaluation of Proportional Fairness Scheduling in LTE," *World Congress on Engineering and Computer Science (WCECS)*, Vol. 2, pp. 712-717, 23-25 October, 2013.

[5] M. H. Habaebi, J. Chebil, A. G. Al-Sakkaf and T. H. Dahawi, "Comparison between Scheduling Techniques in Long Term Evolution," *IIUM Engineering Journal*, Vol. 14, No. 1, pp. 66-75, 2013.

[6] S. A. AlQahtani and M. Alhassany, "Performance Modeling and Evaluation of Novel Scheduling Algorithm for LTE Networks," *Journal of Selected Areas in Telecommunications (JSAT*), Volume 4, Issue 1, January Edition, pp. 1-8, 2014.

[7] M. T. Kawser, H. M. A. B. Farid, A. R. Hasin, A. M. J. Sadik, and I. K. Razu, "Performance Comparison between Round Robin and Proportional Fair Scheduling Methods for LTE," *International Journal of Information and Electronics Engineering*, Vol. 2, No. 5, pp. 1-4, September 2012.

[8] J. Andrews, "Seven Ways that HetNets are a Cellular Paradigm Shift," *IEEE Commun. Magazine*, vol. 51, no. 3, pp. 136–144, 2013.

[9] J. G. Andrews, H. Claussen, M. Dohler, S. Rangan, and M. C. Reed, "Femtocells: Past, present, and future," *IEEE Journal on Selected Areas in Communication*, vol. 30, no. 3, pp. 497 –508, April 2012.

[10] X. Li, X. Tang, C. Wang, X. Lin, "Gibbs-Sampling-Based Optimization for The Deployment of Small cells in 3G Heterogeneous Networks," in *Proc. Int. Symposium on Modeling Optimization in Mobile, Ad Hoc Wireless Networks (WiOpt)*, pp. 444–451 ,May 2013,.

[11] D.Calin, H.Claussen, and H.Uzunalioglu, "On Femto Deployment Achitectures and Macrocell Offloading Benefits in Joint Macro-Femto Deployments," *IEEE Communication Magazine*, vol. 48, no. 1, pp. 26 – 32, Jan. 2010.

[12] Y. Ji, Z. Yifan, W. Ying, Z. Ping, "Average Rate Updating Mechanism in Proportional Fair Scheduler for HDR," *IEEE Global Telecommunications Conference*, pp. 3464–3466, 2004.

[13] LTE System Level Simulator v1.6r885 by Institute Of communicationand Radio Frequency Engineering,Vienna University of Technology,Vienna.

[14] J. Olmos, S. Ruiz, M. Garcia-Lozano, D. Martin-Sacristan, "Link Abstraction Models Based on Mutual Information for LTE Downlink," COST 2100 TD(10)11052, Aalborg, Denmark, June 2-4, 2010.

[15] L. Wan,S. Tsai,and M. Almgren, "A Fading-Insensitive Performance metric for a United Link Quality Model," Proceedings of *Wireless Communication and Networking Conference (WCNC)* , pp. 2110-2114, 3-6 April, 2006.

[16] S. Sesia, I. Toufik and M. Baker, "LTE - The UMTS Long Term Evolution - from theory to practice," *Wiley*, 2009.

[17] Technical Specification Group RAN, "E-UTRA; LTE RF system scenarios," 3rd Generation Partnership Project (3GPP), Tech. Rep. TR 36.942 version 10.2.0 Release 10, 2011.