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Performance Evaluation and Packet Scheduling in HeNB Deployments

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A study on system capacity for HeNBs with different schedulers

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***Abstract*—This work provide a detailed study of HeNBs also know as femtocells on the average Signal-to-Interference-plus-Noise-Ratio (SINR) and simulation for a building with a 5x5 apartments. The simulation results present a comparison for variations on the apartments sides and transmitter powers of the HeNBs. Also the impact of considering PF, FLS or EXPRule schedulers was taken in account. Results for the average SINR and for simulations shows that is more advantageous to considered smaller areas to deploy HeNBs. It is possible to extract from results the need of a rigorous selection of the schedulers, since in the considered scenario the FLS scheduler and EXPRule schedulers are a more secure options than the PF scheduler.**

***Index Terms*—HeNB, Femtocell, Enterprise HeNB, LTE-Sim, Scheduler, SINR, Performance Evolution, Proportional Fair scheduler, Frame Level Scheduler, Exponential Rule scheduler**

I. Introduction

Since 80 percent of the traffic occurs indoor and most of the cellular networks is composed by macro base stations (eNBs), in-building coverage becomes a critical problem to solve. Also applications used by user's are requiring more and more higher data throughputs.

To achieve high data throughputs the system need to operate with higher codifications like 64QAM. And these orders of modulation does not go well through walls. Adopt lower frequencies will not allow to transport high data throughputs, and adopt higher frequencies will lead to same problem of higher codifications, higher frequencies does not go well through walls too, specially with metallized windows.

One way to solve the lack of indoor coverage is to resort to a smaller coverage cell areas [1]. Home base stations (HeNBs) also known as femtocells appear to deal with these issues, mainly to deal with the indoor coverage in areas where the traditional cellular network struggle or they are unable to provide coverage.

The deployment of HeNBs in the cellular network is being done through some assumptions appointed by 3GPP [2]. These assumptions are also being accomplished by research and specilly with simulations [1], [3], [4], [5] and [6]. One of the constraits in [2] is the number of users that could be served by a HeNB. Like it is appointed by [7] and studied in [1] the number of users served by a HeNB could be eight. In [1] authors consider only four HeNBs to cover 25 apartments, and the eight users are distributed in area corresponding to a quarter of the total area of building. The building is a geometry of 5x5 apartments.

In this work a variation from two users up to eight users inside each apartment is presented. The main contribution of this paper is to present a study in deployments with a variation of the number of users beyond the recommendations of 3GPP and even the variation of the transmitter power of the HeNBS and the apartment dimensions. The impact of different schedulers is also analysed as well.

II. Theoretical Average SINR

Authors in [6] present a study on the Signal-to-Interference-plus-Noise-Ratio (SINR) for HeNB deployments. The SINR is expressed for a user in a position served by a cell with a transmitter power P_{Tx}, ans is given by

$$\text{SINR}(P_{Tx}, x, y) = \frac{P_{ow}(P_{Tx}, x, y)}{P_{nh}(P_{Tx}, x, y) + P_{noise}}. \quad (1)$$

The received power from the own cell is defined by P_{ow}, P_{noise}, in dBW, is the thermal noise power. P_{nh} is the total amount of interference power coming from neighbour cells. Fig. 1 presents results for the average SINR for values of transmitter power varying from -20 dBm up to 35 dBm and apartment sides from 5 m up to 35 m. The variation of the transmitter power of the HeNB does not affect the average SINR results. Even considering such a high variation of the transmitter power and apartment sides, the average SINR only considerably varies with the apartment sides.

III. Perfomance Evaluation

The deployment scenario follows most of the assumptions from [6]. However new simulations details are given in Tab I.

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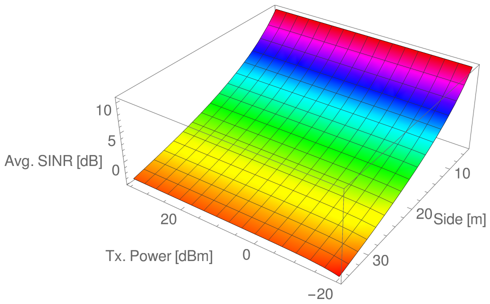


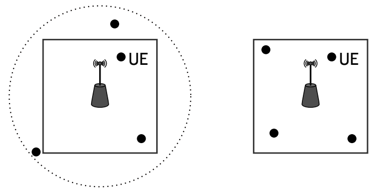
Fig. 1: Average SINR as a function of the transmitter power and apartment side.

TABLE I: Simulation Parameters

Parameters	
Simulation duration	30 [s]
Flow duration	20 [s]
Frame structure	FDD
CQI	Periodic
Number of eNB	1
eNB cell Radius	1 [km]
Cluster	1
eNB Bandwidth	20 [MHz]
Number of HeNBs	25
HeNB cluster	2
HeNB Bandwidth	10 MHz + 10 MHz
Access policy	Open
Power of HeNB	[0, 10, 20] [dBm]
Number of users per HeNB	[2, 4, 6, 8]
User speed	0 [km/h]
User position	Random
Application type	Video and Best Effort
Video bit rates	440 [kB/s]
Maximum delay	0.1 [s]
Number of buildings	1
Number of floors	1
Geometry of buildings	5x5
Apartment side	[5, 10, 15, 20] [m]
Building position	Random
Path loss model	WINNER II
Number of simulations	50

The video application, is a video trace that is compressed using the H.264 standard compression at the average coding rate of 440 kb/s, which is available in [8]. The Best Effort (BE) application models an ideal greedy source that always has packets to send. The BE application only transmit packets when there are enough resources to send it. A maximum of 100 ms for the maximum delay is considered. The maximum delay is the maximum tolerable time interval within each the packet must be received. When this maximum delay is suppressed the package is dropped. The considered Channel Quality Indicator (CQI) feedback is considered periodic. Within the CQI reporting feature, the UE estimates the channel quality and converts it into a set of CQI feedbacks reported periodically to the eNB.

The LTE-Sim as been used to analyse the overall



(a) Original version (b) Updated version

Fig. 2: Users distribution in a HeNB

performance of HeNBs, [1], [3], [4], [5], and [6]. Since LTE-Sim is an open source framework, in [6] we have proposed a correction to the simulator, that enable to use a distribution of the users near a truly uniform random distribution.

Since its first version until the last version, the LTE-Sim considers the generation of users taking into account the influence area of the HeNB. This coverage influence area of the HeNB is a circle, as shown in fig. 2a. In this work users are considered to be inside the apartment and apartments are delimited by a square. The generation of users was upgraded to accommodate this consideration, as shown in fig. 2b.

The full functional code is provided in List. 1. As introduced in [6], with this code the simulator need to be compiled with a ISO/IEC 9899:2011 [9].

Listing 1: User distribution in a apartment

```
unsigned seed = std::chrono::system_clock::now().
      time_since_epoch().count();
std::mt19937 rng_mt(seed);
std::uniform_real_distribution<double> distx_double
      (0.0,1);
std::uniform_real_distribution<double> disty_double
      (0.0,1);

double xa=distx_double(rng_mt);
double ya=disty_double(rng_mt);

double x = 2*sidehome*xa-(sidehome/2);
double y = 2*sidehome*ya-(sidehome/2);

CartesianCoordinates *newCoordinates = new
      CartesianCoordinates ();
newCoordinates->SetCoordinates(x,y);
newCoordinates->SetCoordinateX (cellCoordinates->
      GetCoordinateX () + newCoordinates->
      GetCoordinateX ());
newCoordinates->SetCoordinateY (cellCoordinates->
      GetCoordinateY () + newCoordinates->
      GetCoordinateY ());

vectorOfCoordinates->push_back(newCoordinates);
```

IV. Packet Schedulers

In this work, we analyse the overall performance of three of the schedulers that are included in LTE-Sim simulator [10], as follows. The Proportional Fair (PF), Frame Level Scheduler (FLS) and Exponential Rule (EXPRule) have been considered in this study. According to [11] and [12], these schedulers are channel sensitive, i.e., the UEs intermittently forwarded a CQI report to the eNB. This CQI report presents the channel quality experienced by each UE, and estimated by the scheduler.

1) Proportional Fair: PF schedules a user when its instantaneous channel quality is high relative to its own average channel condition over time [13]. PF scheduler is used as a typical way to find a trade-off between requirements on fairness and spectral efficiency [14]. It is effective in reducing variations in user bit rates with little average bit rate degradation, as long as user average values of SINR are fairly uniform [15]. The limitation of the PF is a low spectral efficiency [11].

2) Frame Level Scheduler: In the authors approach [12], the time is seen as an endless sequence of frames, which are further split in time intervals. At the highest level, an innovative low complexity resource allocation algorithm was designed using discrete time linear control theory, which is referred as a FLS. At the beginning of each frame, FLS computes the amount of data that each real-time source should transmit within the frame, to satisfy its delay constraint. Then, to ensure a good level of fairness among multimedia flows, the lowest level scheduler assigns radio resources according to the PF algorithm [16] subject to the constraint imposed by FLS.

3) Exponential Rule: In [17], the EXPRule was studied as a scheduling algorithm which explicitly uses information on the state of the channel and queues. Authors mention as main result that the EXPRule throughput is optimal, i.e., it renders queues stable in any system for which stability is feasible at all, with any other rule. Altgouh the complexity of this schedulers is high [11], the EXPRule and LOGRule have been presented as the most promising approaches for DL scheduling in LTE systems with delay-sensitive applications, [18].

V. Simulation Results

Results are presented for apartment sides of five meters and twenty meters. The figs. present results for the three schedulers, the PF, FLS and ExPRule.

A. Simulation results for a side of 5 m

Fig. 3 presents results for the goodput of the video application for the three schedulers (PF, FLS and EXPRule) and transmitter power of 0, 10 and 20 dBm. The average goodput for video is identical for all the schedulers. By combining the results of the average goodput and the average PLR for the video flows, fig. 4, it is possible to extract lessons from the analysis. Since results for the average goodput are identical between the schedulers and values for the average PLR are almost negligible one can conclude that is possible to serve eight users per HeNB for an apartment side of five meters. These eight

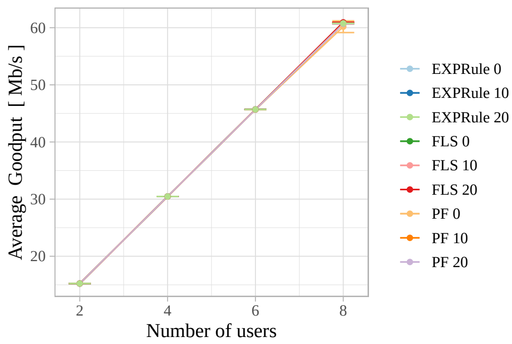


Fig. 3: Video average goodput for an apartment side of 5 m.

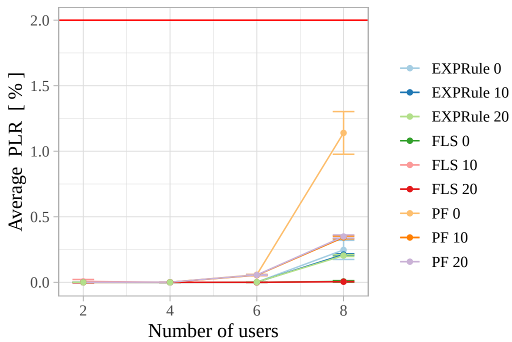


Fig. 4: Video average PLR for an apartment side of 5 m.

users per apartment represent a total of 200 users in the building. The highest value for the PLR was obtained for the PF scheduler and it is around 1.13%, which is almost half of the maximum value for the 3GPP for the video flows.

Despite of the number of considered users in the building the average goodput for the BE application (fig. 5) presents the lowest average goodput circa 430 Mb/s for all the three schedulers considering eight users per HeNB. When the number of users increases the average goodput for video also increases while the average gooput for the BE application decreases.

B. Simulation results for side 20 m

Considering the results obtained in fig. 1, simulation results are presented for an apartment side of twenty meters. With the increase of the apartment side from five meters to twenty meters the average SINR decrease is expected to cause some decay in the system performance. The first parameter that needs to be analysed confirm the previous statement is the average goodput for the video flows, as shown in fig. 6. Results for the average goodput for video flows considering apartment sides of twenty meters only present a slight difference when the

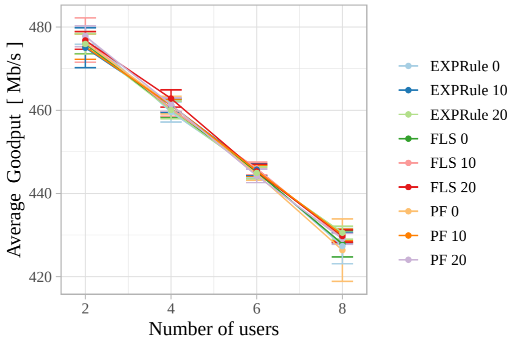


Fig. 5: BE average goodput for an apartment side of 5 m.

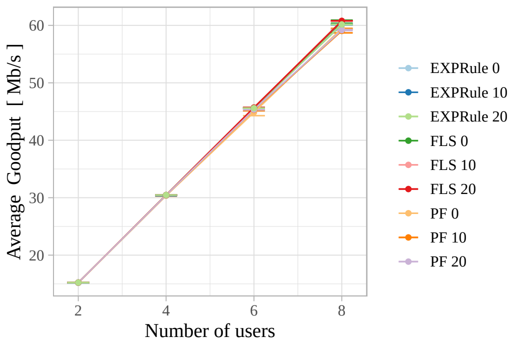


Fig. 6: Video average goodput for an apartment side of 20 m.

number of users is eight, comparing to the previous case when the apartment side is five meters. To really analyse for this behaviour it is mandatory to analyse results for the average PLR, as shown in fig. 7. With this increase

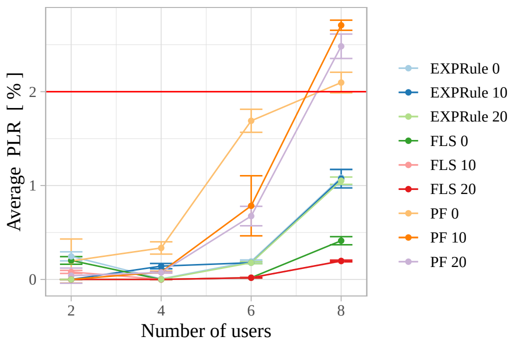


Fig. 7: BE average PLR for an apartment side of 20 m.

of the apartment side all the schedulers tend to present an higher average PLR for video. This is more evident for the PF scheduler. For this scheduler when the number of users is six and the transmitter power is 0 dBm the average PLR is near 2%. The maximum value of 2% is surpassed considering the PF scheduler for all considered values for the transmitter power and when eight users are considered for each HeNB. Other schedulers still present average PLR values near 1% (worst case).

The average goodput for the BE application fig 8 decrease around 80 Mb/s for all the number of the served users. As excepted the lowest average goodput for the

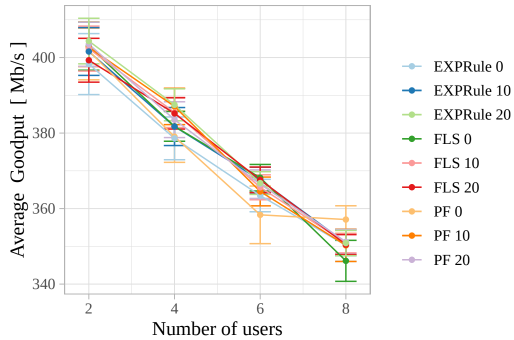


Fig. 8: BE average goodput for an apartment side of 20 m.

BE was obtained when eight users are considered.

VI. Conclusions

The study on the theoretical average SINR leads to the main conclusion that the average SINR only occurs when the variation of the apartment sides is considered. Results from simulations correlate the conclusions of the study of the average SINR, that is more advantageous to coverage smaller areas. When five meters for apartment side is considered it is observed that is possible to serve even eight users per HeNB for any scheduler. When twenty meters of apartment sides are considered the PF scheduler surpassed the maximum desirable of 2% for the packet loss ratio for the video flows. The maximum results for the FLS and the EXPRule is 1% of packet loss ratio, which indicate that is possible to accommodate more users per HeNBs. Simulations show that is preferable to considered the FLS or the EXPRule over the PF scheduler.

References

[1] R. R. Paulo, F. J. Velez, and G. Piro, "Design of Coordinated HeNB Deployments," in *2018 IEEE 87th Vehicular Technology Conference (VTC Spring)*, June 2018, pp. 1–6.

[2] G. TSG-RAN4#51, Alcatel-Lucent, picoChip Designs, and Vodafone, "R4-092042, Simulation assumptions and parameters for FDD HENB RF requirements," May 2009.

[3] S. Xing, P. Ghosal, K. Sandrasegaran, and A. Daeinabi, "System level simulation for femtocellular networks," in *2014 Australasian Telecommunication Networks and Applications Conference (ATNAC)*, Nov 2014, pp. 164–169.

[4] M. Çakir and A. Kalaycioglu, "Power adjustment based interference management in dense heterogeneous femtocell networks," in *2017 2nd International Conference on Computer and Communication Systems (ICCCS)*, July 2017, pp. 133–137.

[5] F. Capozzi, G. Piro, L. Grieco, G. Boggia, and P. Camarda, "On accurate simulations of LTE femtocells using an open source simulator," *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, no. 1, p. 328, 2012. [Online]. Available: http://jwcn.eurasipjournals.com/content/2012/1/328

[6] R. R. Paulo, F. J. Velez, and G. Piro, "Performance Evaluation and Packet Scheduling in HeNB Deployments," in *2018 IEEE 88th Vehicular Technology Conference (VTC-Fall)*, Aug 2018, pp. 1–6.

[7] I. Ashraf, H. Claussen, and L. T. W. Ho, "Distributed Radio Coverage Optimization in Enterprise Femtocell Networks," in *2010 IEEE International Conference on Communications*, May 2010, pp. 1–6.

[8] V. T. Library. (20199) http://trace.eas.asu.edu/tracemain.html. [Online]. Available: http://trace.eas.asu.edu/tracemain.html

[9] International Standards Organization and International Electrotechnical Commission, *ISO/IEC 9899:2011, Programming Languages – C*, 1st ed. 11 West 42nd Street, New York, New York 1O036: American National Standards Institute (ANSI), Dec. 2011. [Online]. Available: http://www.open-std.org/jtc1/sc22/wg14/

[10] G. Piro, L. Grieco, G. Boggia, F. Capozzi, and P. Camarda, "Simulating LTE Cellular Systems: An Open-Source Framework," *Vehicular Technology, IEEE Transactions on*, vol. 60, no. 2, pp. 498–513, Feb 2011.

[11] H. S. A. Ben Abdelmula, M. N. B. Mohd Warip, B. Ong, and N. Yaakob, "Technical review of RRM for carrier aggregation in LTE-Advanced," vol. 91, pp. 397–410, 09 2016.

[12] G. Piro, L. Grieco, G. Boggia, R. Fortuna, and P. Camarda, "Two-Level Downlink Scheduling for Real-Time Multimedia Services in LTE Networks," *Multimedia, IEEE Transactions on*, vol. 13, no. 5, pp. 1052–1065, Oct 2011.

[13] S. Sesia, I. Toufik, and M. Baker, *LTE, The UMTS Long Term Evolution: From Theory to Practice, 2nd Edition*. Wiley Publishing, 2011.

[14] R. Basukala, H. Mohd Ramli, and K. Sandrasegaran, "Performance analysis of EXP/PF and M-LWDF in downlink 3GPP LTE system," in *Internet, 2009. AH-ICI 2009. First Asian Himalayas International Conference on*, Nov 2009, pp. 1–5.

[15] R. Kwan, C. Leung, and J. Zhang, "Proportional Fair Multiuser Scheduling in LTE," *Signal Processing Letters, IEEE*, vol. 16, no. 6, pp. 461–464, June 2009.

[16] E. Dahlman, S. Parkvall, J. Skold, and P. Beming, *3G Evolution, Second Edition: HSPA and LTE for Mobile Broadband*, 2nd ed. Academic Press, 2008.

[17] S. Shakkottai and A. L. Stolyar, *Scheduling for multiple flows sharing a time-varying channel: The exponential rule*, 11 2002, pp. 185–201.

[18] B. Sadiq, S. J. Baek, and G. de Veciana, "Delay-Optimal Opportunistic Scheduling and Approximations: The Log Rule," *Networking, IEEE/ACM Transactions on*, vol. 19, no. 2, pp. 405–418, April 2011.