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PERFORMANCE ANALYSIS OF DOWNLINK LTE USING SYSTEM LEVEL SIMULATOR

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Această lucrare analizează performanța traiectului descendent în LTE (Long Term Evolution) utilizând System Level Simulator din [1]. Rezultatele obținute vizează debitul de sector şi rata de eroare de bloc (BLER), debitul de utilizator şi informația de calitate a canalului (CQI) corespunzătoare pe toată perioada simulării. Scenariile considerate au avut în vedere două configurații de antene, două lățimi de bandă de transmisiune, trei strategii de planificare de pachete şi un număr variabil de utilizitori în celulă. De asemenea, este evaluat şi impactul pe care îl are viteza cu care se mişcă utilizatorii asupra performanței sistemului. Mediul radio este modelat în acest simulator, ceea ce înseamnă că rezultatele pot reprezenta un punct de plecare în dimensionarea unei rețele LTE comerciale.

This paper analyzes the performance of downlink LTE (Long Term Evolution) using System Level Simulator from [1]. The results obtained concern the sector throughput and BLER (Block Error Rate), the user throughput and the corresponding CQI (Channel Quality Indicator) during all simulation period. The scenarios used considered two antenna configurations, two system bandwidths, three packet scheduling strategies and different number of users in the cell. The impact of users speed on the system performance is also evaluated. The radio environment is modeled in this simulator meaning that the results may be considered as a start point in dimensioning an LTE comercial network.

Keywords: LTE, OFDMA, SISO, MIMO, scheduling, CQI, throughput

1. Introduction

In order to cope with the ever growing demand for packet-based mobile broadband systems and to meet the needs of future mobile communications, 3GPP (3rd Generation Partnership Project) has standardized a new technology – LTE (Long Term Evolution) – as the next step of the current 3G mobile networks. LTE is expected to provide an extended capacity and an improved performance compared to the current 3G/HSPA (High Speed Packet Access) networks.

The objective of LTE was to develop a framework for the evolution of the 3GPP radio-access technology towards a high-data-rate, low-latency and packet-

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optimized radio-access technology. The requirements specified in [2] envisage high speed data rates, low latency, increased spectral efficiency, scalable bandwidths, flat all-IP network architecture, optimized performance for mobile speed etc. In order to fulfill this extensive range of requirements several key technologies have been selected for LTE radio interface of which the most important are: multiple access through OFDMA (Orthogonal Frequency Division Multiple Access) in downlink and SC-FDMA (Single Carrier Frequency Division Multiple Access) in uplink and multi-antenna technology.

The LTE downlink has been previously analyzed in several papers like [3], [4] and [5]. The authors evaluated the system throughput and the fairness of the scheduling algorithms used in their simulations, but the work was restricted either to SISO (Single Input Single Output) antenna technology, static users, one system bandwidth and none of them were based on a simulator with the radio environment modeled. Moreover, the user throughput and BLER (Block Error Rate) and the CQI values for a particular UE (User Equipment) over the simulation period have not been treated.

The remainder of this paper is organized as follows: Section 2 presents an overview of LTE downlink, outlining several important aspects followed by the description of the System Level Simulator in Section 3. The selected simulation scenarios and the corresponding results are presented and analyzed in Section 4 and Section 5 concludes the paper.

2. LTE downlink overview

The LTE downlink is mainly characterized by OFDMA as multiple access scheme and MIMO (Multiple Input Multiple Output) technology. The benefit of deploying OFDMA technology on downlink LTE is the ability of allocating capacity on both time and frequency, allowing multiple users to be scheduled at a time. The minimum resource that can be assigned to a user consists of two Physical Resource Blocks (PRBs) and it is known as chunk or simply Resource Block (RB) [6],[7]. In downlink LTE one PRB is mapped on 12 subcarriers (180 kHz) and 7 OFDM symbols (0.5 ms) and this is true for non-MBSFN (Multimedia Broadcast multicast service Single Frequency Network) LTE systems and for normal CP (Cyclic Prefix). Scheduling decisions can be made each TTI (Time Transmission Interval) that in LTE is equal to 1 ms.

From all the multiple antenna techniques that can be used in downlink LTE the most performance improvements are reached with MIMO. The baseline antenna configuration for MIMO is two transmit antennas at the cell site and two antennas at the terminal. The higher-order downlink MIMO and antenna diversity (four TX and two or four RX antennas) is also supported. The basic MIMO schemes applicable to the downlink are illustrated in Fig.1. These schemes can be applied depending on the scenario (urban and rural coverage) and UE capability.

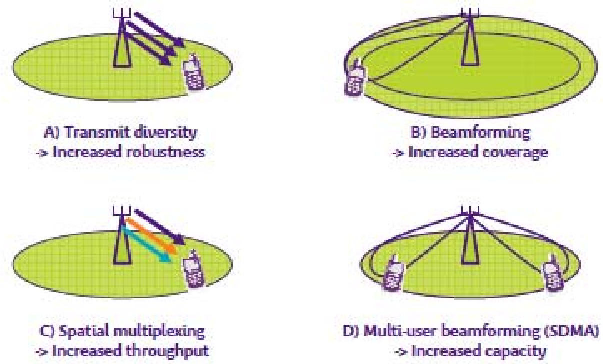

Fig. 1. MIMO schemes for LTE downlink [8]

System performance and individual end user experience depend on the propagation conditions, the mobile device feedback, which is based on measurements, and the scheduling algorithm in the eNodeB (Evolved NodeB). Packet Scheduling is one of LTE RRM (Radio Resource Management) functions, responsible for allocating resources to the users and, when making the scheduling decisions, it may take into account the channel quality information from the UEs, the QoS (Quality of service) requirements, the buffer status, the interference situation, etc. [6]. Like in HSPA or WiMAX, the scheduling algorithm used is not specified in the standard and it is eNodeB vendor specific.

The channel conditions are provided by the UE through the channel state feedback reports. The most important part of the channel information feedback is the CQI (Channel Quality Indicator) which informs the eNodeB about the link adaptation parameters the UE can suport at the time, the UE receiver type, number of antennas and interference situation experienced at the given time [9]. An example of frequency selective scheduling, meaning that the scheduler considers the channel variations in its resource allocation, for two users is depicted in Fig. 2.

In the simulations performed and presented in Section 4, three packet scheduling algorithms are used: Round Robin (RR), Proportional Fair (PF) and Best CQI. RR strategy lets the users take turns in using the shared resources, without taking the instantaneous channel conditions into account. It can be seen as fair scheduling in the sense that the same amount of radio resources (the same amount of time and/or RBs) is given to each user. However, it is not fair in the sense of providing the same service quality to all communication links. In that case more radio resources must be given to communication links with bad channel conditions. Furthermore, as RR algorithm assigns resources to the users regardless the channel information, it will lead to lower overall system performance [10].

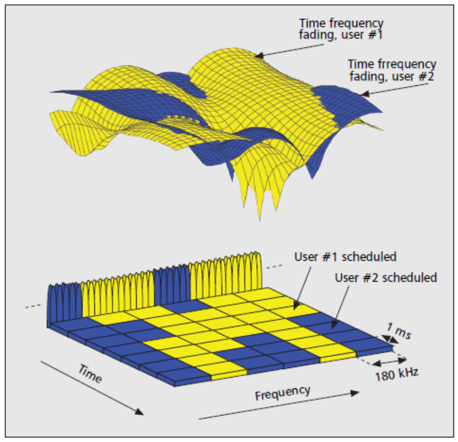

Fig. 2. Frequency selective scheduling illustration for two users in downlink LTE from [11]

In Best CQI scheduling the user with the best channel quality gets assigned, meaning that the users that experience a low thoughput (bad radio conditions) have lower chance to be served [10].

The PF strategy is an intermediate strategy, fairer than the Best CQI strategy, but with higher global performances than the RR scheduling [10]. The statements presented above on these three scheduling algorithms will be proven with the simulation results from Section 4.

3. Several aspects on the LTE simulator

The most important aspect of this simulator is that it can only test the downlink LTE. This simulator has the macroscopic pathloss, the shadow fading and the microscale fading modeled.

There are some parameters that cannot be modified:

- the eNodeBs have all 3 sectors;
- it cannot be configured less than 7 eNodeBs;
- there are 15 CQI's values used as it is depicted in Fig. 3;
- the UEs distribution in the simulated scenarios is random, so, it cannot be compared one's UE throughput in different scenarios;
- the traffic model used is infinite buffer.

There are several parameters that can be changed in this simulator:

- system bandwidth (1,4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz);
- number of UEs per eNodeB sector;
- speed at which the UEs move;
- number of transmit and receive antennas;
- distance between eNodeBs;
- eNodeB scheduler (Round Robin, Proportional Fair, Best CQI).

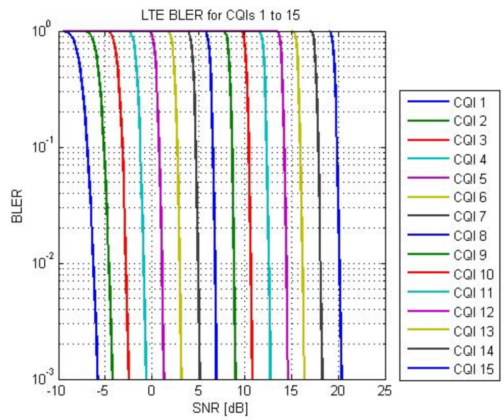

Fig. 3. LTE BLER for CQIs 1 to 15 [1]

For all the simulated scenarios presented in the next Section, the parameters from below were kept unchanged:

- TS 36.942 urban macro pathloss model [1];
- simulation time of 100 TTI's;
- 7 eNodeBs with 3 sectors each;
- minimum coupling loss that describes the minimum loss in signal [dB] between Base Station and UE or UE and UE in the worst case and is defined as the minimum distance loss including antenna gains measured between antenna connectors. Recommended values in [12] for urban areas is 70 dB;
- receiver noise figure set to 9 dB [12];
- thermal noise density set to -174dBm/Hz;
- uplink feedback channel delay set to 3 TTI's.

4. Simulation scenarios and results

For the first scenario simulated it was selected 2.1 GHz as carrier frequency, 20 MHz system bandwidth, SISO antenna technology, RR scheduler, 1 UE per eNodeB sector, meaning 21 UEs, UEs speed 5 km/h, Typical Urban as channel model, inter eNodeB distance 500 m. The UEs are randomly positioned in the cells.

The sector throughput and BLER for each eNodeB are shown in Fig. 4. It can be observed that for eNodeB 4 the value for BLER is NaN. This means that no user is assigned to this sector [1]. There is a maximum sector throughput of 70.54 Mbps, which is close to the value obtained with the TD RR scheduling model with 20 MHz system bandwidth presented in [2]. The throughput values vary from 3.06 Mbps to 70.54 Mbps due to the user position in the sector, the interference experimented from other users etc.

The second scenario was built in order to see the user speed influence on the throughput. Two things change from the previous scenario: UE speed (80 km/h) and the channel model that is more suited in this case – VehB [1].

The sector throughput for this second scenario is illustrated in Fig. 5. Comparing Fig. 5 with Fig. 4, the sector throughput is smaller in the second scenario because the feedback cannot follow the fast fading. Moreover, the network BLER increases when the user speed is higher. Though, it is expected LTE to perform well even for UEs that move with 300 km/h.

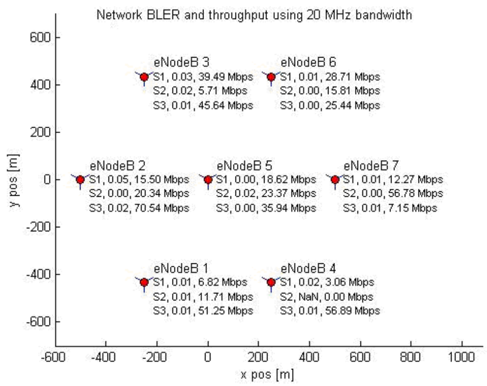

Fig. 4. Network BLER and throughput using 20 MHz transmission bandwidth and UEs speed 5 km/h

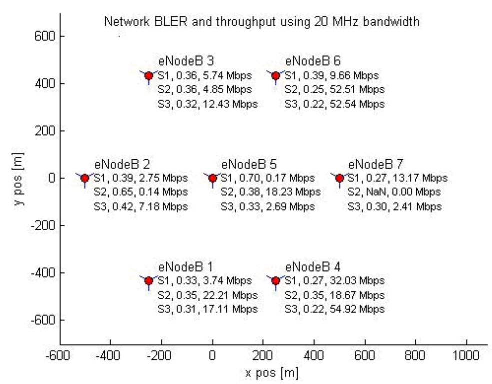

Fig .5. Network BLER and throughput using 20 MHz transmission bandwidth and UEs speed 80 km/h

Fig. 6 represents the throughput and BLER report for UE 18 (the one from eNodeB 4, sector 3). There are two curves for BLER. The green line represents the BLER as measured by the ACK/NACK ratio and the black line – the values applied by the link quality model [1].

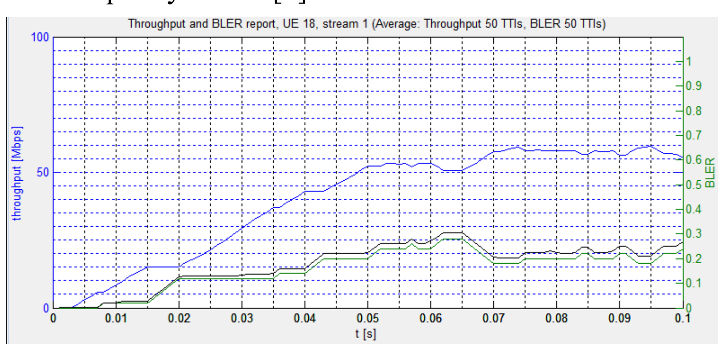

Fig. 6. Throughput and BLER report for UE 18 moving with 80 km/h

Fig. 7 depicts the CQI's values for UE 18. The blue line is the sent CQI report for the selected RB, the mean CQI for the whole frequency bandwidth is red and the CQI of the Transport Block sent to the UE is marked with black [1].

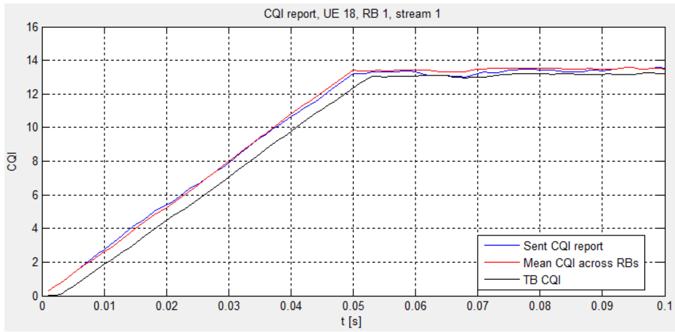

Fig. 7. The CQI report for UE 18

From Fig. 5, we chose one sector with small throughput, for example sector 2 of eNodeB 3, and plot the throughput, BLER and CQI for the corresponding UE – UE 8 – in Fig. 8 and Fig. 9. As expected, for UE 8 BLER shows higher values than for UE 18, as it moves with 80 km/h.

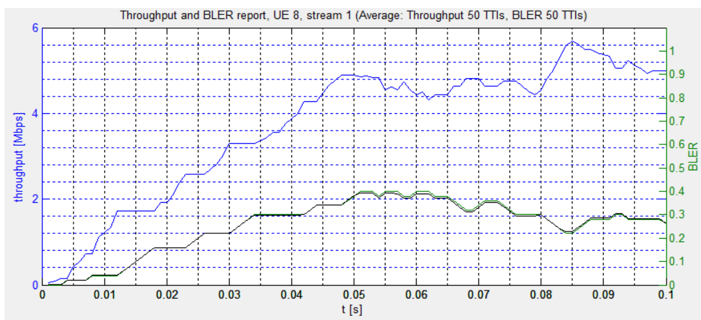

Fig. 8. Throughput and BLER report for UE 8 moving with 80 km/h

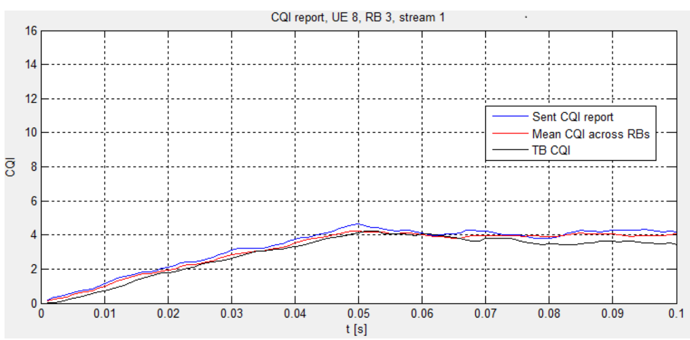

Fig. 9. The CQI report for UE 8

The CQI's values from Fig. 9 are very small compared to those from Fig. 7, which explains the throughput values. A third scenario focuses on the throughput obtained in 10 MHz system bandwidth, keeping all the parameters from scenario 1. The maximum sector throughput obtained in Fig. 10 is approximately half of the highest throughput value illustrated in Fig. 4.

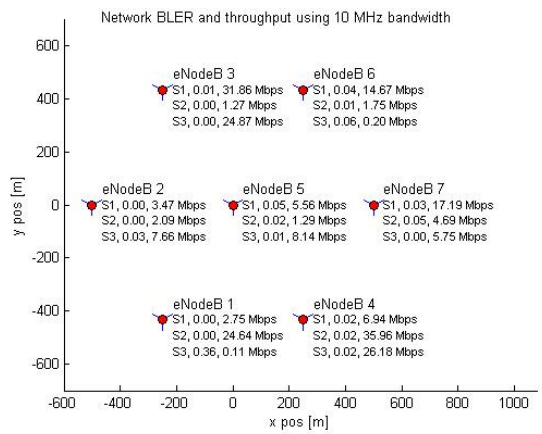

Fig. 10. Network BLER and throughput using 10 MHz transmission bandwidth and UE speed 5 km/h

In order to compare the scheduling algorithm impact on sector and user throughput, we built a scenario with 5 users per sector and selecting on turn, RR, Best CQI and PF strategies. All other parameters remain unchanged.

Fig. 11, 12 and 13 show the network BLER and throughput for all 3 scheduling strategies.

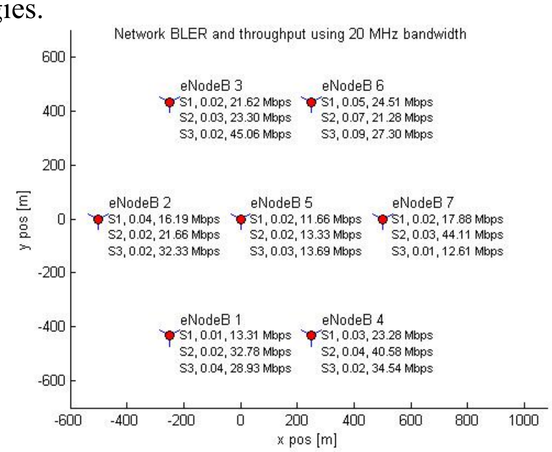

Fig. 11. Network BLER and throughput using 20 MHz transmission bandwidth, RR scheduler and UE speed 5 km/h

Overall, the sector throughput is higher with PF and Best CQI schedulers than RR strategy, because in the first two cases the channel conditions are taken into account when performing scheduling decisions, so they present that diversity gain that was mentioned in Section 3. The Best CQI algorithm offers a higher throughput if compared to PF scheduler, but it lacks in fairness (it schedules first the users experimenting the best radio conditions).

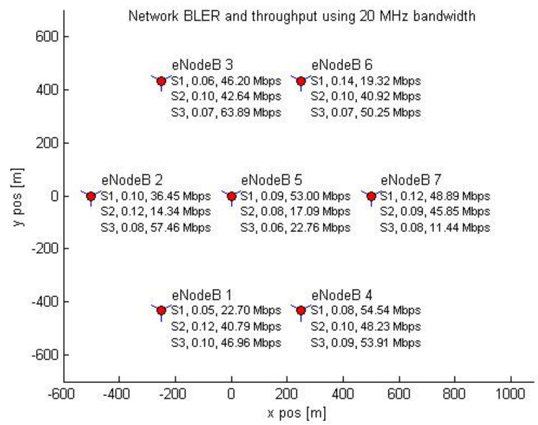

Fig. 12. Network BLER and throughput using 20 MHz transmission bandwidth, PF scheduler and UE speed 5 km/h

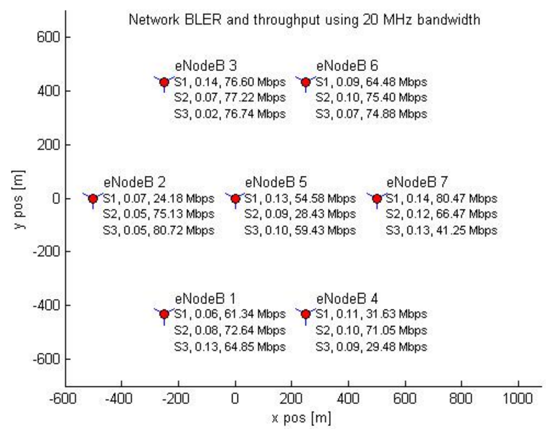

Fig. 13. Network BLER and throughput using 20 MHz transmission bandwidth, Best CQI scheduler and UE speed 5 km/h

In order to understand the impact of the packet scheduling algorithm on user throughput, Fig.14, 15 and 16 depict to different users' throughput (as the users don't keep their position regard the eNodeB when making various simulations, there is no other way to compare the user throughput).

As expected, the best CQI strategy offers the highest user throughput. Proportional Fair algorithm stands between RR and Best CQI, taking into account the channel information when it performs scheduling decisions, but it also tries to be fair by introducing the "averaging window" to compare average throughputs instead of instant ones.

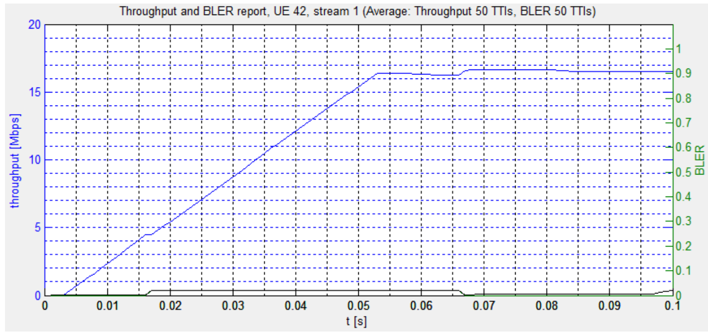

Fig. 14. Throughput and BLER report for UE 42 using RR scheduler

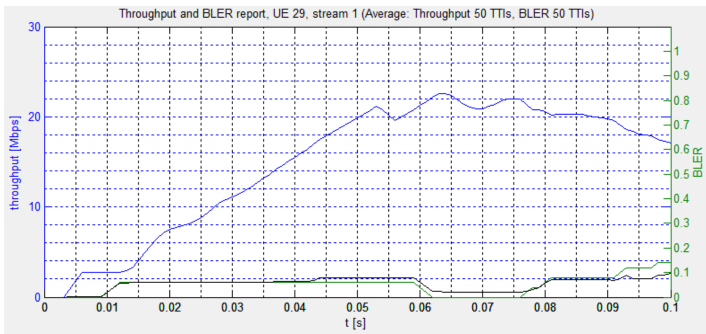

Fig. 15. Throughput and BLER report for UE 42 using PF scheduler

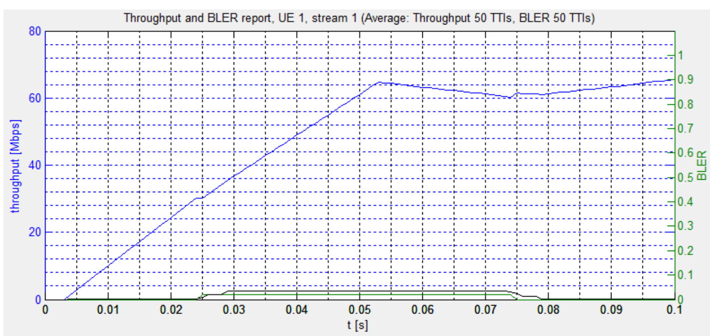

Fig. 16. Throughput and BLER report for UE 42 using Best CQI scheduler

All the above scenarios have considered SISO antenna technology. The following and the last simulation scenario takes MIMO 2x2 as antenna configuration. Because it is considered only one user per sector moving with 5 km/h, the network and BLER throughput figure (Fig. 18) is enough to analyze the performance. All other parameters are those from the first scenario.

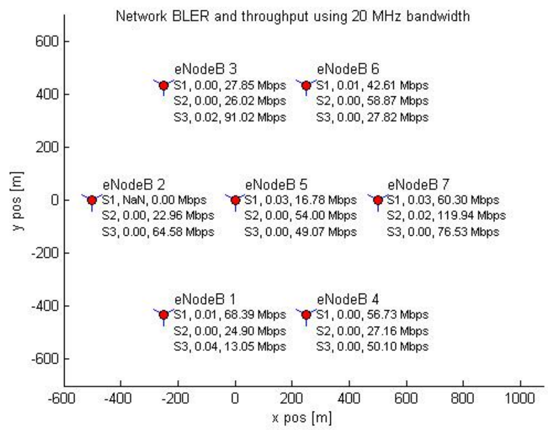

Fig. 17. Network BLER and throughput using 20 MHz transmission bandwidth, 2.1 GHz, RR scheduler, MIMO 2x2 and UE speed 5 km/h

With MIMO 2x2 it was expected a throughput increase and Fig. 17 confirms it. For the UEs experiencing bad radio conditions transmit diversity scheme was applied and for those having good radio conditions spatial multiplexing mode is used. The transition between the two modes depends on both mobile terminal and eNodeB.

5. Conclusions and future work

This paper evaluates the performance of downlink LTE using System Level Simulator from [1]. Sector throughput, user throughput and BLER are the performance indicators analyzed, and the CQI mapping is also presented in order to sustain the throughput values. The radio environment being modeled in the simulator, the results can be considered reliable in the design of a commercial LTE network.

First, it was analyzed the impact of the users speed and, as it was expected, there was a strong decrease in user and sector throughput because the feedback cannot follow the fast fading. Second, there was an evaluation of user throughput in 20 MHz and 10 MHz system bandwidth with Round Robin scheduling and the maximum user throughput obtained was close to that obtained in [13]. There has also been done a comparison of three scheduling strategies: Round Robin, Proportional Fair and Best CQI and as it was anticipated from the theory presented in Section 2, the Best CQI scheduler has the best performance (highest throughput), followed by PF while with RR the system performance was the lowest. Another scenario concerned the MIMO 2x2 performance.

LTE performance depends on lots of parameters and configuration chosen, but through these simulations, several LTE expectations have been achieved.

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REFERENCES

[1] *J. C. Ikuno, M. Wrulich, M. Rupp*, System level simulation of LTE networks, in Proc. 2010 IEEE 71st Vehicular Technology Conference, Taipei, Taiwan, May 2010. Available at: http://publik.tuwien.ac.at/files/PubDat_184908.pdf

[2] *3GPP TR 25.913v8.0.0 Release 8*, Requirements for evolved UTRA (E-UTRA) and evolved UTRAN (E-UTRAN)

[3] *H.A.M. Ramli, K. Sandrasegaran, R. Basukala, W. Leijia*, Modeling and simulation of packet scheduling in the downlink long term evolution system, 15th Asia-Pacific Conference on Communications, APCC 2009, pp. 68-71, 2009

[4] *H.A.M. Ramli, R. Basukala, K. Sandrasegaran, R. Patachaianand*, Performance of well known packet scheduling algorithms in the downlink 3 GPP LTE systems, IEEE 9th Malaysia nternational Conference on Communications, MICC 2009, pp. 815-820, 2009

[5] *F. Capozzi, D. Laselva, F. Frederiksen, J. Wigard, I.Z. Kovacs, P.E. Mogensen*, UTRAN LTE Downlink System Performance under Realistic Control Channel Constraints, IEEE 70th Vehicular Technology Conference Fall (VTC 2009-Fall), pp. 1-5, 2009

[6] *3GPP TS 36.300v8.12.0 Release 8*, Evolved universal terrestrial radio access (E-UTRA) and evolved universal terrestrial radio access network (E-UTRAN); Overall description; Stage 2

[7] *3GPP TS 36.211v8.9.0 Release 8,* Evolved universal terrestrial radio access (E-UTRA); Physical channels and modulation

[8] ****Orange Labs document,* 3GPP Standard Analysis – Release 8, September 2009

[9] *H. Holma, A. Toskala*, LTE for UMTS: OFDMA and SC-FDMA Based Radio Access, 2009 John Wiley & Sons

[10] *E. Dahlman, S. Parkvall, J. Sköld, P. Beming*, 3G Evolution: HSPA and LTE for Mobile Broadband, Academic Press, 2007

[11] *D. Astély, E. Dahlman, A. Furuskär, Y. Jading, M. Lindström, S. Parkvall*, LTE: The Evolution of mobile broadband, Communications Magazine, IEEE In Communications Magazine, IEEE, Vol. 47, No. 4. pp. 44-51, 2009

[12] *Technical Specification Group RAN*, E-UTRA; LTE RF system scenarios, 3GPP, Tech. Rep. TS 36.942, 2008-2009

[13] *O. Iosif, I. Banica*, On the analysis of of packet scheduling in downlink 3GPP LTE system, CTRQ 2011, The Fourth International Conference on Communication Theory, Reliability and Quality of Service, pp. 99-102, 2011