Scheduling Techniques Evaluation in LTE systems with Mixed Data Traffic

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Abstract — **In this paper we implement and evaluate two scheduling techniques for mixed data traffic (VoIP and Video Streaming-VS) in LTE systems. We present results regarding resources allocation and traffic evaluation (mean throughput per user) for the Best CQI scheduler and compare to those for a Round Robin (RR) scheduler. Both services are delay-critical services but by prioritizing VoIP in the Best CQI scheduler, we achieve VoIP performance comparable to that in pure VoIP system. For VS users the remaining capacity is granted according to CQI. Comparing the schedulers results the required QoS (throughput per user) is reached for a greater number of VS users with the Best CQI scheduler.**

Keywords – LTE; mixed traffic; scheduler; CQI; resources

I. INTRODUCTION

The Long Term Evolution (LTE) system apply as radio interface technology the Orthogonal Frequency Division Multiple Access (OFDMA) providing data rates as high as 300 Mbps in 20 MHz of bandwidth. OFDMA, as the name implies is based on orthogonal frequency division multiplexing (OFDM) as modulation technique. OFDM enables the transmission of multiple parallel low data rate narrowband channels by sub-dividing a wider bandwidth into so-called subcarriers. As a consequence, different diversity dimensions can be exploited in an OFDMA system such as frequency and multiuser diversity [1].

In the frequency diversity, as the different subcarriers tend to present different channel fading states if separated by one or more coherence bandwidths, the subcarriers scheduled to a given user equipment (UE) may be chosen so that only subcarriers in good channel state are used by that UE.

In multiuser diversity each UE will be in a different location and consequently will experiment different channels fading states. A subcarrier with a low SNR for a given UE may be in better condition with respect to other UEs. These channel diversities require the use of radio resource allocation (RRA) schemes. A suitable RRA scheme can determine the use of some radio resources in order to provide a specific goal respecting some system conditions. Constrained optimization techniques are used to look for solutions that minimize or maximize a cost function while a set of constraints or restrictions are satisfied. RRA schemes adaptively assign the system radio resources (subcarrier, power, and bit rate) as a function of traffic load, channel condition, channel information availability, and QoS requirements [2].

The RRA in OFDMA systems can be divided into two main problems:

- Subcarrier allocation – the subset of subcarriers on which each UE will transmit is determined;
- Power allocation – the transmit power for each subcarrier is determined.

One notable aspect of these emerging systems is the plurality of services supported. Classifying the services and applications provided by wireless networks is not a trivial task because they are continuously evolving to integrated and complex applications [3]. Besides that, the services can be classified in terms of time dependency (time or non-time based), delivery requirements (real-time (RT) or non-real-time (NRT)), directionality (unidirectional or bi-directional), symmetry of the communications (symmetric or asymmetric), interactivity, and number of parties.

To evaluate radio resource allocation in multicarrier wireless systems there are several possible criteria to be considered when designing solutions to solve the optimization problems of resource allocation. The possible solutions are classified in accordance to their efficiency, applicability, guarantee of QoS, and fairness.

LTE operates as a purely scheduled system given that all traffic, including delay-sensitive services as VoIP or SIP signaling, needs to be scheduled. Consequently scheduler should be considered as a key element of the larger system design.

Several different scheduling rules have been introduced in the literature [4]. The max-CQI rule always selects the user having the highest CQI. This rule maximizes the total system throughput, but leads to very unfair division of resources as only users close to the base station have the chance to transmit. A good compromise between fairness and throughput can be obtained with the proportional fair (PF) scheduler based on a decision variable defined as the ratio of instantaneously achievable service and the average throughput.

The work reported in this paper consists of a Matlab module able to implement two scheduling techniques for a

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mixed traffic load (VoIP and VS) and to extract performance parameters regarding resources allocation.

II. LTE PERFOMANCES

A. System model

We introduce, according to 3GPP standard, the following terminology to be used in our paper:

(i) TTI: unit of time, 1 ms; resources are assigned at TTI granularity

(ii) eNodeB: evolved Node B, refers the base station

(iii) UE: user mobile

(iv) PDSCH: physical downlink shared channel, representing physical resources in time and frequency used to transmit data from eNodeB to UE

(v) PDCCH: bidirectional channel that transmits dedicated control information between an UE and the network; used by UEs when they have a RRC connection.

(vi) CQI: channel quality indicator, measure of the signal to noise and interference ratio (SINR) at the UE.

LTE is an OFDM system where spectral resources are divided in both time and frequency. A RB (resource block) consists of 180 kHz of bandwidth (12 subcarriers) for time duration of 1 ms. Thus, spectral resource allocation to different users on the downlink can be changed every 1ms at a granularity of 180kHz.

B. Scheduling for LTE

Scheduling is the process of dynamically allocating the physical resources to UEs based on scheduling algorithms.

The link adaptation in this context represents rate adaptation or MCS selection depending on CQI.

The scheduler may use different algorithms in order to decide which users are to be scheduled and which resources to be allocated to the scheduled users. These techniques may take different aspects into account such as spectral efficiency and fairness. Another important characteristic is required by the QoS parameters due to traffic users' diversity. As o consequence a QoS scheduler has to carefully balance maximization of total transmission rate versus various QoS parameters.

The prior work in this area can be divided into two classes according to traffic characteristics: scheduling for elastic (non-real-time) flows and that for real-time flows.

The policies to schedule a mixture of elastic and real time flows were studied in [4].

C. Traffic models

We consider mixed data traffic for evaluating the scheduling techniques: real – time traffic (VoIP) and streaming traffic (VS).

The model for the VoIP traffic is represented in Fig.1. The probability of transitioning from state 0 (silence or inactive state) is λ while the probability of staying in state 0 is (1- λ). The probability of transitioning from state 1 to state 0 is denoted μ while the probability of staying in state 0 is (1- μ). The updates are made at the speech encoder rate: $R = 1/T$, where T is the encoder frame duration (typically 20ms).

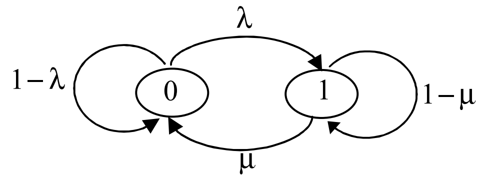

Figure 1. VoIP traffic model

The probabilities of being in state 0 and state 1 denoted p_0 and p_1 respectively are given in (1).

$$p_0 = \frac{\mu}{\lambda + \mu} \qquad p_1 = \frac{\lambda}{\lambda + \mu} \tag{1}$$

The voice codec (AMR 12.2) generates voice frames every 20ms consisting of 244 bits. The voice source rate is 12.2 kbps. The total protocols (RTP/UDP/IP/RLC) overheads per voice frame append a total number of 76 bits resulting in 320 bits (40bytes) transmitted over the air interface [3].

We assume that each frame of video data arrives at a constant time interval *T* determined by the number of frames per second. Each video frame is decomposed into a fixed number of slices, each transmitted as a single packet. The size of these packets/slices is modeled as a truncated Pareto distribution. The video encoder introduces encoding delay intervals between the packets of a frame. These intervals are also modeled by a truncated Pareto distribution [3]. Finally the video streaming traffic model parameters are given in Table 1. We also consider the video source rate at 64 kbps.

TABLE 1 VIDEO STREAMING TRAFFIC PARAMETERS

Parameter	Statistical characterization
Interr-arrival time between the beginning of each frame	Deterministic at 100ms (10 frames per second)
Number of slices in a frame	Constant, 8 slices per frame
Slice size	Truncated Pareto, mean 10 bytes
Interr-arrival time between slices	Truncated Pareto, mean 6ms

III. SIMULATOR DESCRIPTION

For implementing and testing for mixed traffic loads the studied scheduling techniques we have used the LTE System level simulator describe in [6]. The simulator is able to evaluate the performance of the downlink Shared Channel of LTE SISO and MIMO networks using Open Loop Spatial Multiplexing and Transmission Diversity transmit modes.

The LTE system level simulator has a modular code with a clear structure based on objects results. This implementation offers a high degree of flexibility and is suitable for adding and testing new functionalities and algorithms. The physical layer used in system level simulations is build by simplified and accurate models. The main part of the simulator consists of a link measurement model used for link adaptation and resources allocation and a link performance model used to determine the link Block Error Ratio (BLER).

The simulator allows a list of parameters that can be configured consisting of: *general parameters* (frequency, system bandwidth, number of transmit and receive antennas, length of simulations in TTI); *network layout and macroscopic pathloss parameters* (number of eNodeBs rings, inter eNodeBs distance, macroscopic pathloss model: free space, COST231, TS36942, TS 25814); *shadow and microscale fading*; *UE and eNodeB settings*.

One simulation is performed by defining a Region of interest (ROI) in which the eNodeBs and UEs are located and a simulation length in Transmission Time Intervals. UE transmission and movement are simulated only in this area. The simulation results are stored in an output file and can be used for developing new scheduling techniques and for evaluating the performance of the mobile network. In addition, it provides plotting of the result traces: *eNodeB and UE position*; *sector throughput and BLER*; *sent CQI report and distribution*.

IV. EXPERIMENTS AND RESULTS

The module we build is able to implement two scheduling techniques allowing for a mixed traffic load (VoIP and VS) and to evaluate performance parameters regarding resources allocation. The module, implemented in Matlab, is based on a main component connected with: a mixed traffic generator module (VoIP and VS), a scheduler module (Round Robin and Best CQI) and a module that plots the results. In practical work we exploit the LTE system level simulator v1.0r247 described in [6]. The simulated radio network consists of a hexagonal grid of six eNodeBs with a central eNodeB. The inter-eNodeB distance is 500m. The number of RBs is 25 and corresponds to the bandwidth of 5 MHz. We consider 20 users attached to the central eNodeB, randomly distributed in ROI, as in Fig. 2.

We randomly selected the traffic type (VoIP or VS) associated to each user. Users become active during simulation time according to Poisson distribution. Simulation time is set at 1000 TTI (1000 ms).

In the first scenario we implemented a Round Robin scheduling technique were the two traffic types was treated equally without any prioritizations. If the number of active users is smaller than the resources for each user is allocated the same number of RBs, otherwise only one RB is allocated per user.

The scheduler used in the second scenario gives highest priority to the voice users. The remaining resources are allocated to the VS users according to their CQI. For each active user starting with the user with the greatest CQI the program computes the number of required RBs function of reported CQI and the amount of user data to be sent in the current TTI. The users are scheduled in this way until all RBs are attributed. For the scheduled user the program compute the number of bits transmitted per TTI and the mean throughput (considering the last 50 TTIs for averaging)

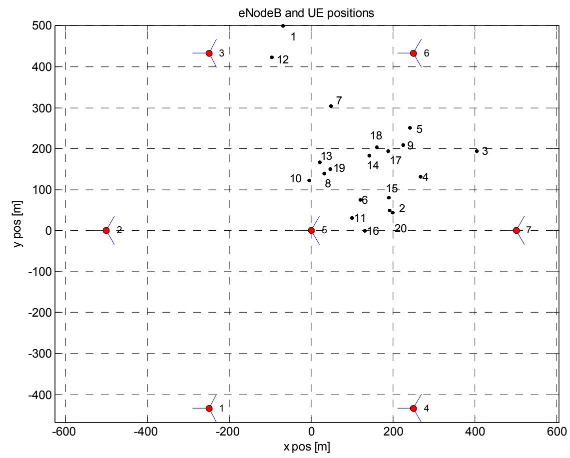

Figure 2. eNodeBs and UEs positions

Fig. 3 represents the throughput of all VoIP users in the cell. For a single user, Fig. 4 and Fig. 5 represent the mean throughput according to RR and respectively to Best CQI scheduler. As the figures show, the Best CQI scheduler allocates the appropriate number of RBs for voice users, maximizing the remaining number of resources for VS users.

Fig. 6 shows the throughput of all VS users in the cell. For a single user, Fig. 7 represents the mean throughput according to RR scheduler. The number of RBs allocated by the scheduler is insufficient compared with the number of RBs required by the service (VS).

Fig. 8 illustrates the mean throughput according to the Best CQI scheduler. As the figure show, this scheduler allocates the appropriate number of RBs for the user that has a good CQI. The users with a low CQI value are rejected by the scheduler. Despite this behavior the granted users experience a better QoS by compare with the RR scheduled users.

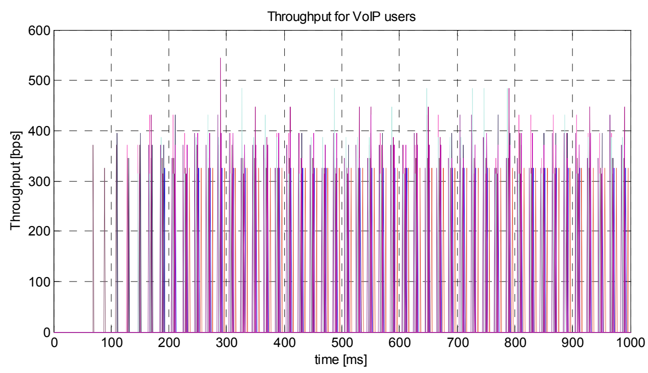

Figure 3. VoIP users throughput

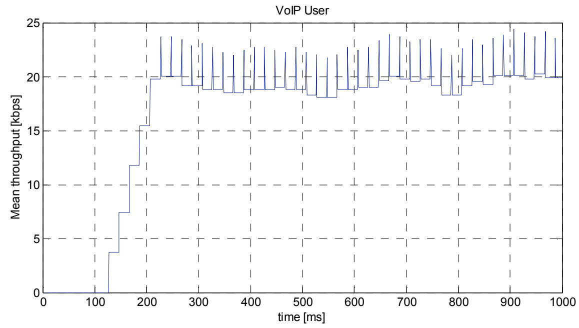

Figure 4. VoIP user throughput - RR scheduler

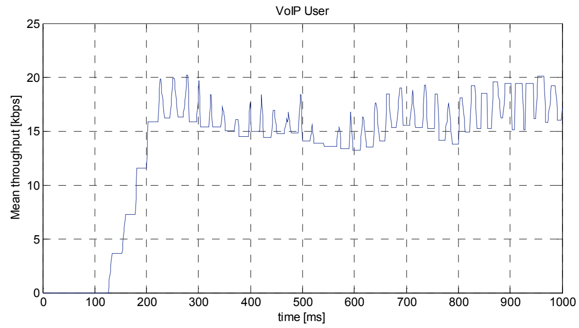

Figure 5. VoIP user throughput – Best CQI scheduler

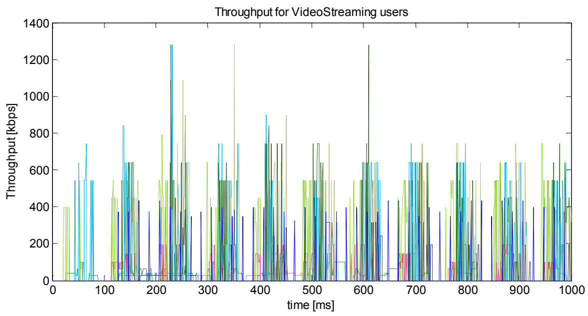

Figure 6. VS users throughput

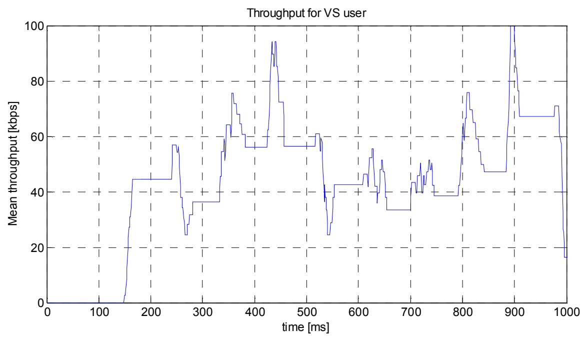

Figure 7. VS user throughput - RR scheduler

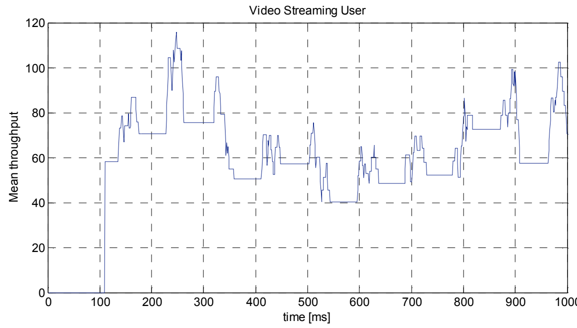

Figure 8. VS user throughput – Best CQI scheduler

V. CONCLUSIONS

The results presented in this paper are produced by the Matlab module designed to implement two scheduling techniques for a mixed traffic load (VoIP and VS) and to evaluate performance parameters of the LTE network. New scheduling policies as well as new features offered by LTE specifications can be easy implemented.

The main conclusions are: - the Best CQI scheduler allocates the appropriate number of RBs for voice users, maximizing the remaining number of resources for VS users; - the scheduler allocates the appropriate number of RBs for the VS user that has a good CQI; - users with a low CQI value are rejected by the scheduler; - the granted users experienced a better QoS by compare with the RR scheduled users.

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