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The Adequate LTE Downlink Scheduling Scheme for Video Streaming Services

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ABSTRACT

The delivery of multicast channels over capacity limited radio links requires efficient utilization of the air interface that make best use of the resources. One of the key radio resource management mechanisms in LTE mobile networks is the packet scheduler, which coordinates the access to shared channel resources. The decision of scheduling strategy plays a key role in guaranteeing good end to end LTE system performance and user quality of experience. Many packet scheduling schemes for mobile access networks have been proposed and implemented. In the paper, the consequence of the choice of downlink scheduling scheme in video streaming service quality is investigated through LTE system level simulations. We examine several scheduling systems and analyze the sophisticated scheduling method which provides the best video quality.

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1. INTRODUCTION

Video streaming over the Internet has been a great success in the past decade. In general, video streaming requires a larger bandwidth than other types of Internet services such as Web browsing. This larger bandwidth requirement occasionally causes network congestion and server overload, especially for large-scale services [1]. It is challenging to provision Quality of Service (QoS) for video and maintain designed system performance given limited radio resources, unreliable radio propagation channel and high user demands. Managing the radio resources becomes a crucial point in the performance of any wireless network. The main goal of radio resource scheduling algorithms is to maximize the system throughput, decrease packet drop ratio, while satisfying the QoS of users and achieving certain level of fairness [2].

The Long Term Evolution (LTE) technology has adopted Orthogonal Frequency Division Multiple Access (OFDMA) as the downlink radio transmission scheme. The benefit of deploying OFDMA on downlink LTE is the ability of allocating capacity on both time and frequency, allowing multiple users to be scheduled at a time. In LTE, each downlink frame is of 10 ms duration, and consists of 10 sub frames. Each sub frame of duration 1 ms, which is called a transmission time interval (TTI), consists of two 0.5 ms slots. Each slot, in turn, consists of 7 OFDM symbols. And the downlink physical resource is represented as a time-frequency resource grid consisting of multiple Resource Blocks (RBs). An RB has duration of 0.5 ms (one slot) and a bandwidth of 180 kHz (12 subcarriers) [3]. The resource grid refers to a number of RBs in the available bandwidth. And scheduling decisions can be made each TTI.

Due to the central role of the scheduler in determining the overall system performance, there have been many published studies on LTE scheduling [2], [4-6]. In the paper we focus on evaluating LTE downlink system level performance with several radio resource scheduling algorithms for video streaming service. We investigate the impact of the choice of scheduling strategy on the throughput, on the fairness, and on the transmitted video quality. To make the analyses we use two types of MATLAB-based simulation tools. As the result of the research, it is able to recommend the adequate packet scheduler for the given LTE downlink parameters, in pursuance of achieving the best received video quality.

2. LTE DOWNLINK RADIO RESOURCE SCHEDULING

Packet scheduling is one of LTE RRM (Radio Resource Management) functions which responsible for allocating resources to the users. When making the scheduling decisions, it may take into account the channel quality information from the UEs, the QoS requirements, the buffer status, the interference situation, etc. In order to make good scheduling decisions, a scheduler should be aware of channel quality in the time domain as well as the frequency domain. From the viewpoint of downlink scheduling, the channel conditions are reported by the UE (User Equipment) through the channel state feedback reports over the uplink. The most significant part of the channel information feedback is the CQI (Channel Quality Indicator). The CQI notifies the eNodeB (Evolved Node B) about the link adaptation parameters the UE can support at the time, the UE receiver type, number of antennas and interference situation experienced at the given time [2].

In the research we analyze six different LTE downlink radio resource scheduling schemes, namely the round robin, max-min, resource fair, proportional fair, best CQI, and the max TP (maximum throughput). The considered schedulers pursue different goals in terms of system throughput as well as fairness among UEs perspective through LTE system level simulations.

Round Robin (RR) scheduling scheme is one of the simplest and most widely used scheduling algorithms, designed especially for time-sharing systems. The scheduler polls each flow queue in a cyclic order and serves a packet from any-empty buffer encountered. It can be seen as fair scheduling in the sense that the same amount of radio resources is given to each UE [7]. However, since RR intends to treat all flows equally, it will lead to the lack of flexibility which is essential if certain flows are supposed to be treated better than other ones.

The Max-Min scheduler allocates the resources in a way that equal throughput for all users is guaranteed. The scheduler maximizes the minimum of the UE throughputs [4]. Max-Min scheduler is Pareto optimal, meaning that the rate of one UE cannot be increased without decreasing the rate of another UE that has a lower rate than the one considered.

The Resource Fair (RF) scheduling strategy guarantees an equal amount of resources for all users while trying to maximize the total throughput [7].

Proportional Fair (PF) scheduling algorithm has received much attention due to its favorable trade-off between total system throughput and fairness in throughput between scheduled users. In PF scheduler, the priority for each UE at each RB is calculated firstly and then the UE with maximum priority is assigned the RB and the algorithm continues to assign the RB to the UE with next maximum priority [7]. This process continues until all RBs are assigned or all UEs have been served with RBs.

Best CQI scheduling scheme optimizes the UE throughput by assigning the RBs to the UE with the best radio link conditions, meaning that the UEs with low CQI value have lower chance to be served [8].

The Max TP scheduler is an approximate maximum throughput scheduling for downlink LTE which is proposed in [8].The goal of this sum rate maximizing scheduler is to allocate resources such that the sum of the user throughputs is maximized.

3. SIMULATION OVERVIEW

In the research, Vienna University's LTE System Level Simulator (LTE-SLS) is used to simulate the LTE network. And to evaluate the video transmitted quality over LTE network it uses the LTE Video Transmission Simulator (LTEVidSim).

3.1. LTE System Level Simulator (LTE-SLS)

In order to examine the impact of the choice of downlink scheduling strategy in LTE networks, we use the LTE System Level Simulator [9] which is publicly available [10]. In LTE-SLS, the physical layer is abstracted by simplified models that capture its essential characteristics with high accuracy and simultaneously low complexity. The simulator has the macroscopic path loss, the shadow fading and the micro scale fading modeled.

There are several parameters that cannot be modified, such that it cannot be configured less than 7 eNodeBs, there are 15 CQI BLER (Block Error Ratio) value curves that are used, the eNodeBs have all 3 sectors, the traffic model used is infinite buffer, and the UEs distribution in the simulated scenarios is random, so, it cannot be compared one's UE throughput in different scenarios [5-7].

Table 1. Simulation Parameters for LTE-SLS

Parameter	Value
Frequency	2.1 GHz
System bandwidth	15 MHz
Resources Blocks (RBs)	50 (1 RB = 180 kHz)

Parameter	Value
Transmission mode	OLSM (Open Loop Spatial Multiplexing)
nTX x nRX antennas	2x2
Simulation length	12000 TTIs
Latency time scale	25 TTIs [11]
Inter eNodeB distance	500 m
eNodeB (enhanced-NodeB) rings	2
Macroscopic path loss model settings environment	urban
Minimum coupling loss	70 dB [12]
eNodeB TX power	46 dBm [12]
UEs (User Equipments) position	UEs are located in target sector only, 3 UEs/sector
UE speed (assuming users are pedestrians)	3 km/h = 0.83 m/s
Scheduler	Round Robin Max-Min Resource Fair Proportional Fair Best CQI Max TP
Uplink delay	3 TTIs

Due to the simulator's limitations, we do modify the simulator module. Because in order to compare the scheduling algorithm impact on UE throughput, the UEs position with regard to the eNodeB location should be kept when making various simulation scenarios.

The downlink LTE system parameters used in the simulation are given in Table 1. We built a scenario with 3 mobile users per sector and selecting on turn, RR, Best CQI, Max Min, Max TP, Resource Fair, and PF scheduling strategies. All other parameters are remaining unchanged.

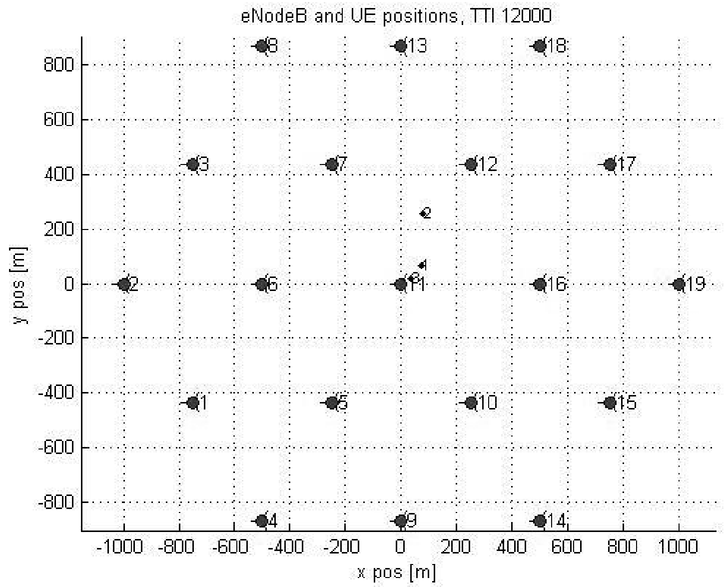

Figure 1. The fixed UEs position within an active eNodeB (No.11)

3.2. LTE Video Transmission Simulator (LTEVidSim)

LTEVidSim is a complete framework and tool-set for an evaluation of the quality of H.264/AVC (Advanced Video Coding) streaming transmission over a simulated LTE network [13]. The LTE-SLS simulation file results are used as LTE channel models for simulating the video streaming service transmission at LTEVidSim. Figure 2 shows the LTEVidSim block diagram. And the configuration parameter for LTEVidSim is shown in Table 2. The parameter setting is fixed for all scheduling scenarios.

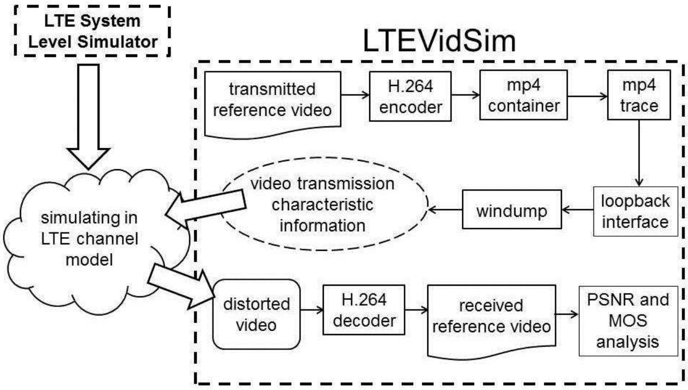

Figure 2. LTEVidSim Block Diagram [13]

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Table 2. Simulation Parameters for LTEVidSim

Parameter	Value
Reference Video	Flower garden
Number of frames	300 frames/sequence
GOP (Group of Picture) Length	6 [13]
H.264 profile	Baseline, without B (bi-predictive) frame
Video resolution (width x height)	176 x 144 pixels, QCIF (Quarter Common Intermediate Format)
Encoding parameters	a. Video bit rate = 0 (auto) b. Frame rate = 30 fps
Video transmission parameter	a. Maximum Tolerable Unit (MTU) = 450 byte b. Maximum tolerable delay = 72 ms [13] c. Stabilization time = 500 ms
Subsampling scheme	4:2:0

4. RESULTS AND ANALYSIS

In this segment we observe six different scheduling algorithms in terms of their attained data rate and fairness in order to evaluate the received video streaming quality. We quantify fairness using Jain's fairness index [14].

$$Jain's\ Fairness\ Index = \frac{(\sum_{i=1}^{n} x_i)^2}{n \sum_{i=1}^{n} x_i^2} \quad (1)$$

Where x_i is the throughput (in Mbps) of the i−th UE and n is the number of UEs. And PSNR (Peak-Signal-to-Noise-Ratio) analysis is used to measure the received objective video quality. PSNR measures the difference between the reconstructed video file and the original video file. As long as the video content and the codec type are not changed, PSNR is a valid quality measure [15].

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (2)$$

Mean Square Error (MSE) is the cumulative square between compressed and the original image.

The simulation results show that the best CQI and Max TP schedulers certify to perform the highest in system throughput, but achieve the lowest fairness among users while the Max-Min scheduler attains the opposite, as Figure 3 and Figure 4 show. The RR delivers the worst overall performances while the other ones behave similarly in between.

Both Best CQI and Max TP are sum rate maximizing resource allocation algorithms, which the priority of each user assigned is according to the CQI feedback value. There is a slight difference in the system throughput performance of them, because the RB assignment is not unique if both UEs feedback the same CQI value for a resource. The RR scheduler can maintain fairness for all of the connections and can prevent starvation, but, in doing so, violates the main objective of attaining high system performance for the LTE. The RF and PF schedulers tries to maximize the sum rate of all UEs while guaranteeing fairness with respect to the number of RBs a UE gets.

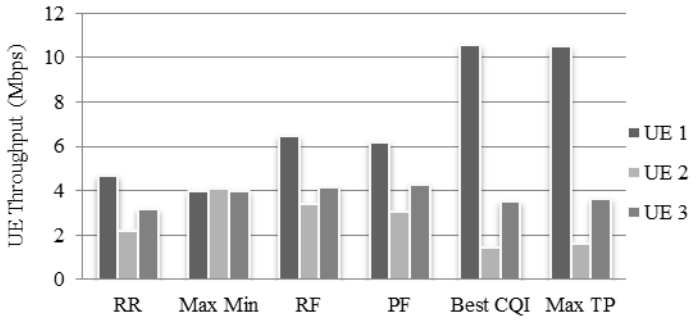

Figure 3. Individual UE throughput achieved with different schedulers

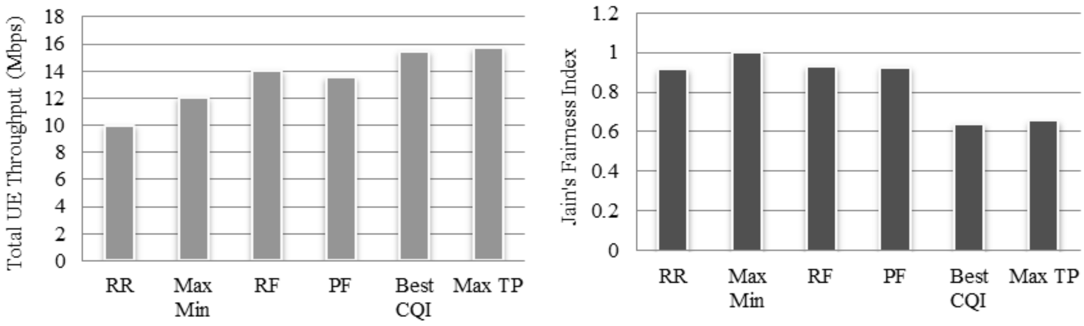

Figure 4. System throughput and fairness achieved with different schedulers

Figure 5 shows the effect of the choice of scheduler in the perceived objective video quality. Best CQI and Max TP scheduling scenarios are not able to be executed in LTEVidSim simulator due to one of the users (UE no. 2) in the cell suffers an extreme resource starvation. This condition resulting in not all users can receive the transmitted video. Resource starvation is similar to deadlock in that it causes a process to freeze. This is happened considering the sum rate maximizing schedulers only serve UEs with good channel conditions. Users are scheduled only on their best RBs, where the CQI values are hardly varying. Figure 5 also depicts that the quality of service depends not only on throughput. There are many influential factors that can contribute to video quality; one of them is BLER value. Streaming video is a packet-loss sensitive service; even low rates of packet loss can cause severe degradation in perceived quality.

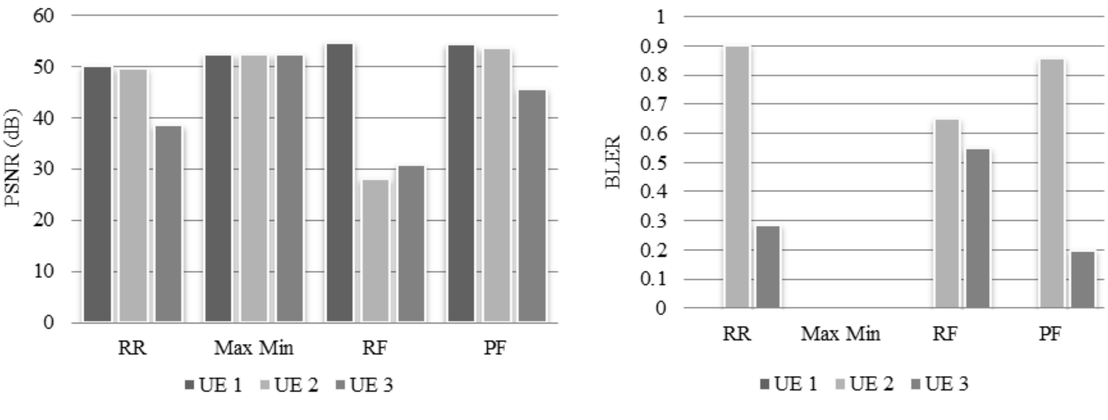

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Figure 5. Objective video quality and BLER obtained with different schedulers

The occurrence of packet loss can lead to decoding errors in one or more of the frame types on the receiving end of the video stream. If the packet loss occurs in an I-frame (intra frame), the error will propagate through all the remaining B-frames (Bi-directional predicted frame), and therefore be more likely to cause a visible impairment that may last up to several seconds. But if the packet loss occurs in a B-frame, however, the error does not propagate to subsequent frames and may not even be noticeable to the viewer.

5. CONCLUSION

The design of the scheduler in LTE has to consider the limitations of the wireless resources, the variations in the channel quality, and the type of services. The sum rate maximizing schedulers behave similar and outperform the others in terms of system throughput. In terms of fairness, the best fairness is achieved by the max min scheduler, which adjusts to its design goal. Good fairness is also achieved with the PF and RF schedulers. These two schedulers also deliver high sum data rate and consequently seem to be a good compromise. The RR scheduler clearly is a bad choice, because neither high fairness nor high throughput can be achieved. In terms of video streaming service quality, the max min, PF, and RF schedulers are the more suitable scheduling strategy. The quality of the received video is affected by several factors. The video quality degradation can occur when the video is encoded, during transmission of the packets across the LTE network, and/or during decoding and playback.

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