THE LTEVIDSIM - LTE VIDEO TRANSMISSION AND QUALITY EVALUATION SIMULATOR

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ABSTRACT

The immense growth of mobile video traffic due to significant user demand has sparked a great deal of research on how to provide better-delivered video quality through wireless networks. The mobile wireless network is characterized by harsh transmission conditions in terms of bandwidth limitation, device mobility, power constraints, time varying and an error prone environment, resulting in significant amount of loss and delay. It is challenging to transmit and access multimedia data over wireless communication channels. Some distortions may take place in the video at the time of transmission or processing. Here comes the need to evaluate the video delivered quality. This paper addresses the problem of evaluating the quality of video sequences encoded for and transmitted over Long Term Evolution (LTE) mobile network. The LTEVidSim is a MATLAB-based simulation tool-set for an evaluation of the quality of video transmitted over a simulated LTE network. It integrates the EvalVid and the Vienna LTE System Level Simulator. In this study, we analyse some of the thought-provoking research questions for video streaming over LTE network, and explain by some research examples how LTEVidSim can be applied.

Keywords: LTE, LTEVidSim, video streaming, video quality.

I. INTRODUCTION

In the smartphone era, there is a seemingly infinite variety of applications. Each has its own demands for network performance in terms of throughput and latency. According to the latest edition of the Ericsson Mobility Report [1], the fastest growing segment in mobile data traffic is video. Video traffic in mobile networks is expected to grow by around 60 per cent annually through to 2018. This abrupt increase in traffic has reduced the available bandwidth or even far exceeding the capacity of mobile networks. As a result, wireless access congestion is becoming more frequent, degrading the Quality of Experience (QoE) for mobile video consumers [2].

Video communication over mobile broadband is challenging due to limitations in bandwidth and difficulties in maintaining high reliability, quality, and latency demands imposed by rich multimedia applications [3]. The 3GPP Long Term Evolution (LTE) technology offers high performance and provides mobility. It addresses areas such as round-trip latency, higher peak rate, and spectral efficiency. LTE is capable of providing a true broadband user experience with average downlink speeds exceeding 10 Mbps in a typical outdoor environment with macro cell coverage. The combination of increased data rates in LTE network and emergence of advanced video technologies allow mobile operators to offer multimedia-based services with a high quality of experience to end users [4], [5].

Despite its advantages, LTE presents challenges for multimedia applications. LTE simplifies its network architectures and migrating to an all-IP architecture system. In IP networks, packet loss, delay, and jitter challenge real-time voice quality, and provide even greater challenges for video-centric applications. It is common for IP packets to be lost, or at least delayed so long that they are effectively lost. And unfortunately, video communication is much more sensitive to packet loss than audio communication, because the human eye can often detect small glitches in a video stream caused by relatively minor packet loss, to an extent whereby enjoyment and/or understanding are more severely affected [6]. In addition, video has many characteristics to specify its quality. Each of them is equally important to measure the quality of the video that is degraded when passed through a mobile network. Here comes the urgency for assessment of video quality and for this the comparison of quality between the original and the transmitted video that is distorted in the process with the use of some quality evaluation metric using a video quality evaluation tool.

II. LTEVIDSIM

The LTEVidSim is a MATLAB-based LTE video transmission and quality evaluation simulator. It is a complete framework and tool-set for an evaluation of the quality of video transmitted over a simulated LTE system level environments. LTEVidSim is targeted for researchers who want to evaluate the LTE network performance in terms of user perceived video quality. It supports a subjective video quality evaluation of the received video based on the frame-by-frame PSNR (Peak Signal to Noise Ratio) calculation. The LTEVidSim combines the EvalVid tool [7] which is developed by J. Klaue et al by using NS-2 and the Vienna LTE System Level Simulator [8]. The source codes of both simulators are publicly available [9], [10].

2.1 Several aspects on the LTEVidSim

Basically the LTEVidSim tool-set has a modular construction, which is making it possible to exchange both the network and the video codec. But as its name, we use

LTE network environment and an application for advanced video coding standard H.264 (H.264/AVC) as example.

The LTE network simulator could only test the downlink LTE. And there are several parameters that cannot be modified, such that it cannot be configured less than 7 eNodeBs, there are 15 CQI (Channel Quality Indicator) values 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 [11-13]. That is why for LTEVidSim, we do modify the original version of Vienna's LTE simulator so that the UEs position with regard to the eNodeB location could be kept when making various simulation scenarios to compare the UEs throughput.

2.2 LTEVidSim Block Diagram

Fig. 1 shows the LTEVidSim block diagram. There are several tools in the framework; each of them has its own purpose and usage.

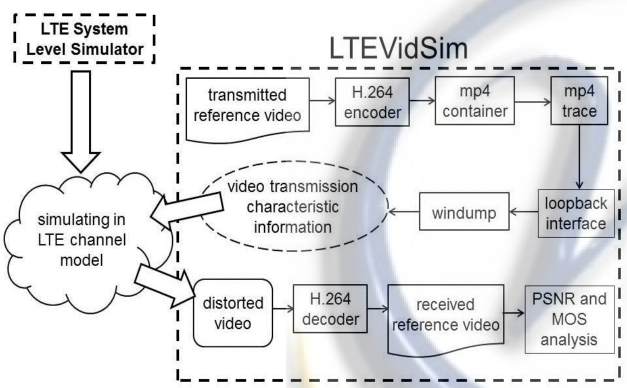

Fig. 1 LTEVidSim Block Diagram [14]

The components of LTEVidSim are:

a. **Reference Video** is a video source that needed. Raw uncoded video files are stored in the YUV format, since this is the preferred input format of many available video encoders. This scheme assigns both brightness and color values to each pixel. In YUV format, 'Y' represents the brightness, or luma value, and 'UV' represents the color, or chroma values.

b. **H.264/AVC Codecs** consist of H.264/AVC encoder and H.264/AVC decoder. This video coding standard is widely used by streaming internet sources, such as videos from Vimeo, YouTube, and the iTunes Store.

c. **Video Sender (VS)** which generates two trace files from the encoded video files, containing information about every frame in the video file and every packet generated for transmission. VS component consists of mp4 container and mp4 trace. The mp4 container contains the video trace file which has the information of the frame type, frame size, and the number of segments. While mp4 trace contains hint tracks to divide the data into packet-sized for transport over RTP (Real-time Transport Protocol) and then transmit them to a specified destination host. These two trace files represent a complete video transmission at the sender side and contain all information needed for further evaluation.

d. **Loopback Interface** is a virtual interface that is always stay-up even if the outbound interface is down. Any packet transmitted over the virtual loopback interface is immediately received by the self-same interface. In the LTEVidSim, the loopback interface is used to packet sniffing purpose..

e. **Windump** is a packet sniffer that runs under the command line. This component is the heart of the evaluation framework. Here the calculation of packet losses, frame losses, delay, and jitter takes place. From the evaluate traces, there are three types of information that can be determined such as:
   a. At sender side: transmission time-stamp and payload size of every packet sent.
   b. At receiver side: receiving time-stamp and payload size of every packet received.
   c. Type of RTP packet information which is packetized by mp4 trace.

Hence, it shows the characteristic of video transmission. The packet is regarded as loss if it arriving too late at the receiver. A maximum tolerable delay for the simulation is set at 72ms. The value is obtained from coherence time, T_c calculation using Rappaport's rule of thumb [15].

$$T_c = \frac{1}{f_d}\sqrt{\frac{9}{16\pi}} = \frac{0.423}{f_d} \quad (1)$$

Where f_d is a maximum Doppler frequency.

$$f_d = f_o \frac{v}{c} \quad (2)$$

f. **MOS and PSNR Analysis** as video quality measurement. There are basically two approaches to measure the digital video quality, namely subjective quality measure and objective quality measure. Subjective quality metrics always grasp crucial factors which are the impression of the user when watching the video. The human quality impression is usually given in a scale from 5 (best) to 1 (worst). This scale is called Mean Opinion Score (MOS) [7]. While the objective quality is measured by taking the average PSNR (Peak-Signal-to-Noise-Ratio) over all the decoded frames. PSNR computes the maximum possible signal energy to noise energy. 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 [16], [17].

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (3)$$

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

Table 1. PSNR to MOS conversion [7]

PSNR (dB)	MOS
>37	5 (Excellent)
31-36.9	4 (Good)
25-30.9	3 (Fair)
20-24.9	2 (Poor)
<19.9	1 (Bad)

III. EXEMPLARY SIMULATION SCENARIOS

In this section, we show two major of exemplary simulation scenarios that can be done by using LTEVidSim.

3.1 LTE Downlink Parameter Configurations

This first major scenario will be suitable for researchers who are willing to investigate the impact of the choice of LTE downlink network parameter settings on the system level performance and end user quality experience for video streaming service. There are several parameters that can be changed in this simulator such as system bandwidth (1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz), number of UEs (User Equipment) per eNodeB (evolved Node B) sector, speed at which the UEs move, number of transmit and receive antennas, inter eNodeBs distance, transmission mode, simulation length, and packet scheduler [8]. As we know, LTE network performance depends on lots of parameters and configuration chosen. Different network parameter settings will also have different performance results, so there will be many research studies that can be done.

An exemplary research using LTEVidSim tool-set is [18] which investigates the impact of the choice of scheduling strategy on the throughput, on the fairness, and on the transmitted video quality. The configuration of downlink LTE system parameters which is used in the research is given in Table 2. And the parameter settings for LTEVidSim are shown in Table 3. The scenario is using 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 including the UEs position with regard to the eNodeB are remaining unchanged.

The simulation results show that the best CQI and Max TP; which are sum rate maximizing schedulers; behave similar and outperform the others in terms of system throughput, but achieve the lowest fairness among users. While the Max-Min scheduler attains the opposite, as Fig. 2 and Fig. 3 show. The RR delivers the worst overall performances while the other ones behave similarly in between.

Table 2. Simulation Parameters for LTE System Level Simulator [18]

Parameter	Value
Frequency	2.1 GHz
System bandwidth	15 MHz
Resources Blocks (RBs)	50 (1 RB = 180 kHz)
Transmission mode	OLSM (Open Loop Spatial Multiplexing)
nTX x nRX antennas	2x2
Simulation length	12000 TTIs
Latency time scale	25 TTIs
Inter eNodeB distance	500 m
eNodeB (enhanced-NodeB) rings	2
Macroscopic path loss model settings environment	urban
Minimum coupling loss	70 dB
eNodeB TX power	46 dBm
UEs 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 (RR) Max-Min Resource Fair (RF) Proportional Fair (PF) Best CQI Max TP
Uplink delay	3 TTIs

Table 3. Simulation Parameters for LTEVidSim [18]

Parameter	Value
Reference Video	Flower garden
Number of frames	300 frames/sequence
GOP (Group of Picture) Length	6
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

In terms of the perceived video quality, the simulation results show that there are many influential factors that can contribute to video quality; one of them is BLER (Block Error Rate) value. BLER is a ratio of the number of erroneous blocks to the total number of blocks received. It is referred to as packet error rate. 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.

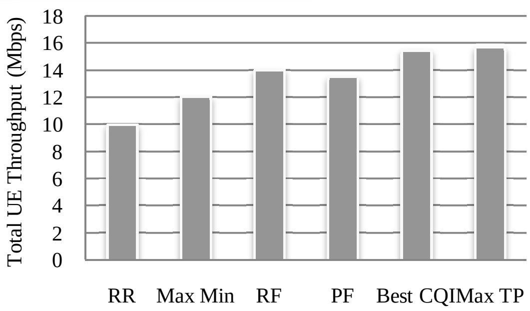

Fig. 2 System throughput achieved with different schedulers [18]

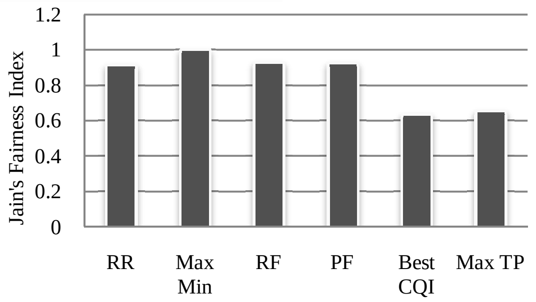

Fig. 3 Jain's Fairness Index achieved with different schedulers [18]

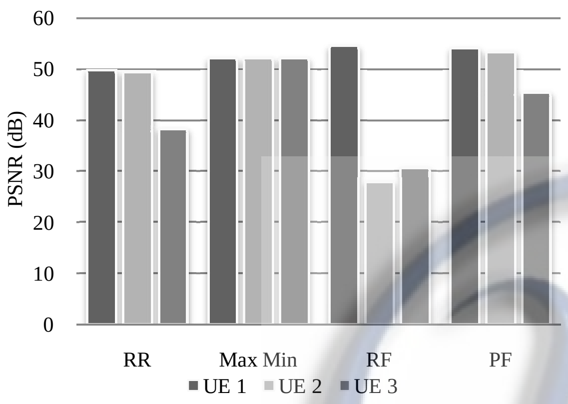

Fig. 4 Objective video quality achieved with different schedulers [18]

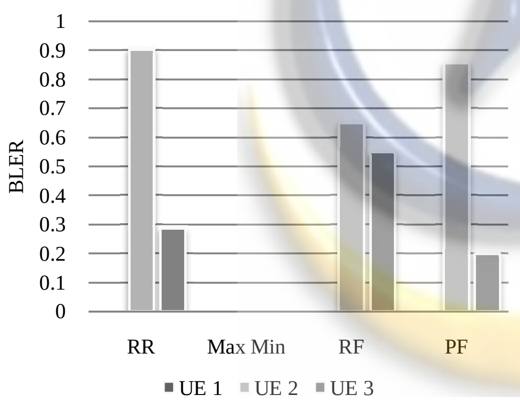

Fig. 5 BLER obtained in LTE network simulator for each scheduler [18]

In this simulation scenario, Best CQI and Max TP schedulers are unable to be executed due to one of the UEs in the cell suffers an extreme resource starvation. That is why for LTE video streaming service the max min, PF, and RF schedulers are the more suitable choice as packet schedulers. The performance comparison of different scheduling in terms of the received video quality is shown in Fig. 4, and the BLER obtained for each scheduler is shown in Fig. 5.

3.2 Video Parameter Configurations

The H.264/AVC is the most commonly used video compression standard nowadays that has achieved significant improvements in rate-distortion efficiency compared to the existing ones [19]. This video codec represents the most recent developments in video compression and has, since its definition, enjoyed wide adoption and deployment [20]. All multimedia services in 3GPP Release 9 specify support for the baseline profile of H.264/AVC. The given drastic technological progress has driven the video communications over LTE to be a popular research topic nowadays [21]. Indeed, limited radio resources, dynamics in network conditions, presence of wireless channel error and high user demands along with the strict requirements of video traffic to variable bit rates and low delay imposes challenges on video transmission over wireless networks.

Although many quality issues experienced by consumers of mobile video are caused by issues within the transport network, there are many other sources of quality issues with mobile video, ranging from issues introduced when the video is created, during the video is transcoded, when the video is transmitted, through issues introduced when displaying the video content. This second major scenario will be suitable for researchers who are willing to study the impact of video parameter configurations on the quality of an end user's experience. Video has many characteristics like frame rate, display resolution, bit rate, aspect ratio, etc. to specify its quality. Each of them is equally important to measure the quality of the video that is degraded when passed through a mobile network.

An exemplary study using LTEVidSim is [14] which examines several Group of Pictures (GOP) lengths on H.264/AVC video streaming transmission over the LTE network, and analyses the optimal GOP length, which provides the best video quality. The aim of this study is to find the optimal distance between the I-frame, in order to maximize the coding efficiency and minimize the quality distortion due to error propagation. This research also shows the impact of program's content on picture quality. The tests involved a wide array of test picture sequences, where each designed to stress encoders in different ways. There are four types of reference video that be used, which are flower garden, football, silent, and coastguard. Each video has different characteristic. All videos are tested using Baseline profile and the GOP lengths are varies from 2 to 35.

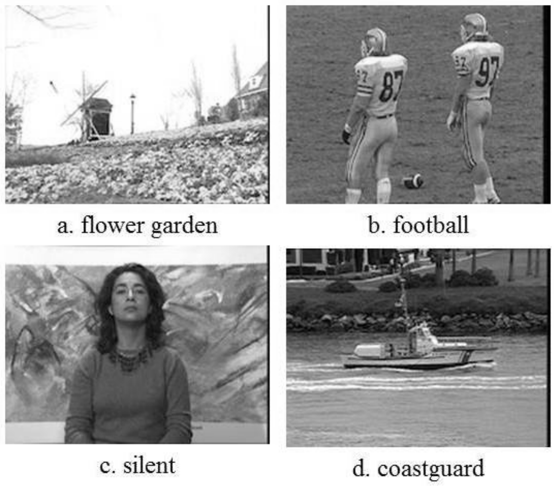

Fig. 6 The four video test sequences which are simulated [14]

The football video contains period of rapid motion, large object and a very complex background. The flower garden and the coastguard videos contain a moderate motion or a panning of the camera. But the coastguard has less detail information than flower garden video. And the last, silent video contains a little motion and it is very easy for the compression engine. It shows a talking gesture woman. With a little difference between frames, more bits can be used for detail.

The configuration of LTE downlink network parameters which is used is similar with what given in Table 2, but in this research there are 8 active UEs and only MaxMin scheduler is chosen. The LTE system level simulation file result is saved in results folder. The file is used as an LTE channel model for simulating each video simulation scenario at LTEVidSim.

Fig. 7 and Fig. 8 show the impact of video sequence characteristics on picture quality. The silent video has the best video quality than others, while the football video has the worst. For the silent video, with a little difference between frames, more bits can be used for detail. There is a little difference between the original and the compressed picture.

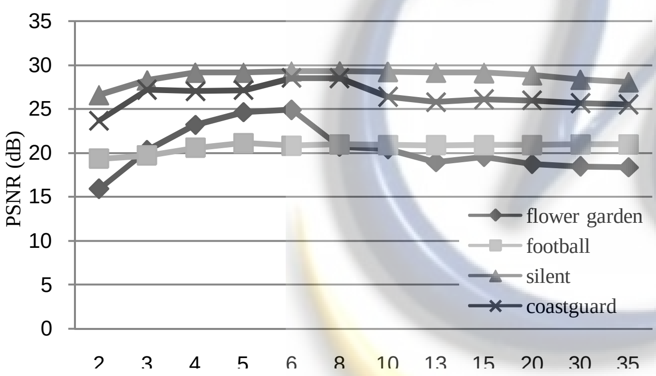

Fig. 7 GOP length effect on PSNR value based on video sequence characteristic [14]

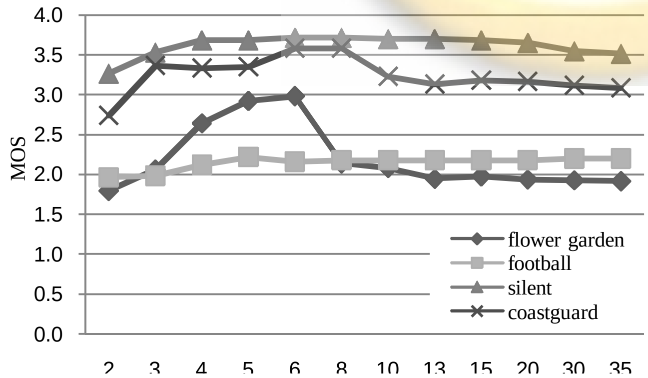

Fig. 8 GOP length effect on MOS value based on video sequence characteristic [14]

The simulation results show that by increasing the GOP length the video quality first increases, but after reaching the highest PSNR and MOS value, it starts to decrease. In the first increasing period the efficient coding plays major role, so higher GOP lengths leads to better quality. After the optimal GOP settings, when the video quality is the highest, the error propagation effect becomes more significant. Hence, using higher I frame intervals, the error spreading will cause significant distortion. For four types of reference videos that are used in the simulation, the optimal GOP is reached at $5 \leq$ GOP length ≤ 8.

IV. CONCLUSIONS

The LTEVidSim framework can be used to evaluate the performance of LTE downlink system level simulation thereof regarding user perceived video application quality. There are two major of simulation scenarios that can be done, by changing the LTE downlink network parameter configurations or by doing modification to the video parameter settings. The toolset currently supports H.264/AVC video streaming applications, but it can be easily extended to address other video codec standards. It is successfully tested with Microsoft Windows Operating System.

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