Bandwidth Scalability and Efficient 2D and 3D Video Transmission over LTE Networks

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***Abstract*—The recent Long-Term Evolution (LTE) standard, thanks to the provision of high data rates, will enable future immersive and interactive multimedia applications over wireless. In this paper, we study the performance of 2D and 3D video transmission over LTE networks. The LTE standard bandwidth ranges are considered in order to explore the impact of the LTE bandwidth scalability on the transmission of 2D and 3D video traffic to the end users. This dependency is investigated through the packet loss ratio (PLR) and average throughput as user-oriented metrics, and the cell spectral efficiency as a system-oriented metric. Furthermore, a PLR-based Admission Control (AC) strategy is introduced in the system for which the achieved trade-off between the system resource utilization and the quality level provided to the different users is investigated. The simulation results provide guidelines for combining bandwidth scalability and admission control strategies in LTE networks in order to achieve high system resource utilization and video quality for the LTE users.**

***Index Terms*—Bandwidth Scalability, LTE, 2D and 3D video, Admission Control**

I. Introduction

Immersive and interactive multimedia applications over wireless will be enabled by the recent LTE standard, thanks to the high data rates supported. The Third Generation Partnership Project (3GPP) LTE standard enables high data rate content transfer by supporting radio access with up to 100Mbps in full mobility wide area deployments and 1Gbps in low mobility local area deployments [1]. Furthermore, the high spectral efficiency benchmarks of 5-10 b/s/Hz for a single user and 2-3 b/s/Hz for the multiuser case enable reliable wireless transmission of voluminous content over the LTE networks. Conversely, the progress in multimedia compression/representation will foster the introduction of two-dimensional (2D) and three-dimensional (3D) multimedia communications, utilizing the ever-increasing available bandwidth for a variety of personalized services. These services would most likely contain various forms of video, since the projection in [2] reports that video would exceed 90% of the global consumer traffic and 66% of the world's mobile traffic by 2015.

This paper investigates the LTE bandwidth scalability feature for downlink transmissions of 2D and 3D video traffics to end users through a comprehensive performance simulation study. The observed results show the dependency of the system and user oriented metrics on the various LTE bandwidth sizes for increasing number of LTE users. Furthermore, the paper combines the bandwidth scalability with a simple admission control strategy in order to study the trade-off between the system resource utilization and the quality level provided to the 2D and 3D video users.

The paper is organized as follows. Section II compares and contrasts the related work in literature and the approach adopted in this paper. The system model is elaborated in Section III, where we provide scenario description, video traffic model, and the relevant performance metrics. Section IV presents the performance results for the relevant metrics, introduces admission control in the system and provides guidelines for combining admission control and bandwidth scalability for video traffic in LTE networks. Finally, Section V concludes the paper.

II. Related Work

The authors in [3] investigate the spectral efficiency as a function of LTE bandwidths. Three main factors that affect the spectral efficiency controlled by the system bandwidth are identified. The frequency domain scheduling gain is higher with a larger bandwidth, the overhead from common channel and control channel is low with larger bandwidths and the guard band with a 1.4 MHz bandwidth is higher than the case with larger bandwidths. As stated in [3], the spectrum utilization with 1.4 MHz is 77% whereas the spectrum utilization with larger bandwidths is 90%.

Spectral efficiency calculations are also proposed in [3] for both downlink and uplink schemes. It is concluded that the spectral efficiency is quite similar for the bandwidths of 5 to 20 MHz whereas there is a 15% difference for 3 MHz. Furthermore, the spectral efficiency for the 1.4 MHz is approximately 35-40% lower than for 10 MHz. Throughput results are also reported and the nominal spectral efficiency considered in the calculation is 1.74 bps/Hz/cell for both 1.4 and 20 MHz. As a result, it is recommended that LTE should be deployed using as large bandwidth as possible in order to maximize the LTE data rates and achieve optimum spectral efficiency.

The authors in [4] discuss the options for enabling multicast and unicast video services over WiMAX and LTE networks, and quantify and compare the video capacities of these networks in realistic environments. Furthermore, new techniques for further future enhancement of the video capacity and quality of user experience are discussed.

The authors in [5] present the key techniques in LTE and LTE-Advanced and their potential applications. Since the peak and average throughput are significantly improved compared to HSPA, these two technologies enable new applications such as real-time high-definition (HD) video sharing services which help provide new user experiences in wireless communications.

The authors in [6] provide a detailed performance comparison among LTE and mobile WiMAX in terms of spectral efficiency. They have used link level simulations to observe performance indicators, i.e., throughput for different Modulation and Coding Scheme (MCS) in different channel conditions.

The authors in [7] discuss the possibility of offering Multimedia Broadcast/Multicast Services over a single LTE network, proposing a MCS scheme based on spectral efficiency measurements to either maximize or achieve the target spectral efficiency. The presented results investigate the throughput, the block error rate and spectral efficiency for 1.4 MHz and 5 MHz system bandwidth, proposing three approaches capable of selecting the most efficient MCS in order to fulfill the operator‘s planning and scheduling and the users‘ needs.

The authors in [8] propose a novel cross-layer scheme for video transmission over LTE wireless systems. The scheme considers parameters from the application, Medium Access Control (MAC) and the physical layer. The scheme efficiency is observed through system throughput and the perceived video quality.

Reference [9] adopts a cross-layer resource allocation approach for H.264/SVC video transmission in LTE downlink. By using the parametrized rate distortion (RD) model in [10], the assigned number of bits for different users keeps predefined PSNR for the video sequences. The admission policy is based on a cross layer metric and it assigns OFDMA channel resource. Furthermore, the authors propose tracking algorithm for serving users in variant channel conditions. The results show the benefit of cross-layer optimization. A different approach for admission control in LTE can be found in [11], where the authors propose a framework for handling multi-class services.

In this paper we study the trade-off between the system resource utilization and the quality level provided to 2D and 3D video users over the LTE scalable bandwidths. Compared to referent literature, we observe all the scalable levels in the LTE bandwidth in combination with simple admission control algorithm that provides flexible tuning between system utilization and the experienced quality level for the LTE users. To our knowledge, similar study of 2D and 3D video transmission for scalable bandwidth sizes over LTE networks has not been considered in literature.

III. System Model

The system model discusses the proposed scenarios, the video traffic models and the relevant performance metrics investigated in this paper.

A. *Proposed scenarios*

The network comprises a single LTE cell, in which the users are uniformly distributed. In the centre of the cell, the Evolved NodeB (eNodeB) is positioned, whereas the users follow a random mobility model with moving distance ranged from 10m to 900m from the eNodeB. The users‘ mobility is pedestrian with constant speed of 3 km/h. Under these assumptions, we set up the following two scenarios:

- *Scenario (A)* investigates only 2D video users, where the number of 2D users in the correspondent cell varies from 1 user up-to 50 users;
- *Scenario (B)* investigates only 3D video users, where the number of 3D users in the correspondent cell varies from 1 user up-to 30 users.

The reason for setting scenario (B) with a smaller number of users is due to the fact that the system performance will degrade when serving more users. Both scenarios are simulated using the LTE-Sim [12] simulator. This simulator provides the possibility to set flexible bandwidths at the eNodeB. The selected bandwidth sizes in this study are those supported by the LTE standard, i.e., 1.4, 3, 5, 10, 15 and 20 MHz.

The serving eNodeB’s MAC layer controls the available Physical Resource Block (PRB)s by assigning them to the active flows which are competing for resources. At the MAC layer, the Modified Largest Weighted Delay First (M-LWDF) scheduler is implemented for serving the video flows. The reason why we choose the M-LWDF scheduling scheme in this study is because the simulation results presented in [13] show that the M-LWDF algorithm outperforms other packet scheduling algorithms in supporting video streaming services by providing a higher system throughput, lower system packet loss rate, guaranteeing a satisfactory level of fairness and supporting a higher number of subscribers.

In addition, the most relevant downlink parameters are also set according to the LTE standard (i.e., resource allocation at every Transmission Time Interval (TTI) equal to 1ms and composed of two time slots, whereas each time slot has 7 OFDM symbols spread over 12 consecutive sub-carriers and the FDD frame is composed of 10 TTIs). The simulation parameters are reported in Table I.

TABLE I
Simulation parameters for 2D and 3D video transmission over different LTE bands.

PARAMETERS	VALUE
Bandwidth	1.4, 3, 5, 10, 15, 20 MHz
Frame structure	FDD
Cell radius	1 km
E-UTRAN frequency band	1 (2.1 GHz)
Max delay	100 ms
3D video bit-rate	2.2 Mbps
2D video bit-rate	440 kbps
Scheduler type	M-LWDF
Video flow duration	19.980 sec
Simulation time	30 sec
UE speed	3 km/h
Path loss/channel model	Typical Urban (Pedestrian-A propagation model)
Simulation repetitions per bandwidth	10

B. Video traffic models

The 2D video traffic is a trace-based application that sends packets based on realistic video trace files, which are available on [14]. The selected video application is encoded at the rate of 440 kbps and this rate is labeled as the *nominal* data rate of the 2D video traffic.

Similarly, the 3D video traffic is a trace-based application with *nominal* data rate of 2.2 Mbps. Our 3D trace file is constructed based on a combination of left and right views of the 3D source video generated in [15].

The maximum transmission unit is set to 500 bytes for both scenarios (A and B), as in [15].

C. Performance metrics

The following three performance metrics are averaged over simulation repetitions and observed for the different bandwidth sizes: *Packet loss ratio*, *Average throughput* and *Cell spectral efficiency*.

The *packet loss ratio* is calculated by dividing the difference between the transmitted and received packets with the number of transmitted packets. The *average throughput* parameter is calculated by dividing the number of successfully received bits with the duration of the flow. The *cell spectral efficiency* is calculated by dividing the total number of received bits during simulation-time with the bandwidth size.

The packet loss ratio and the average throughput are user-oriented metrics, whereas the cell spectral efficiency is system-oriented metric.

IV. Performance Analysis

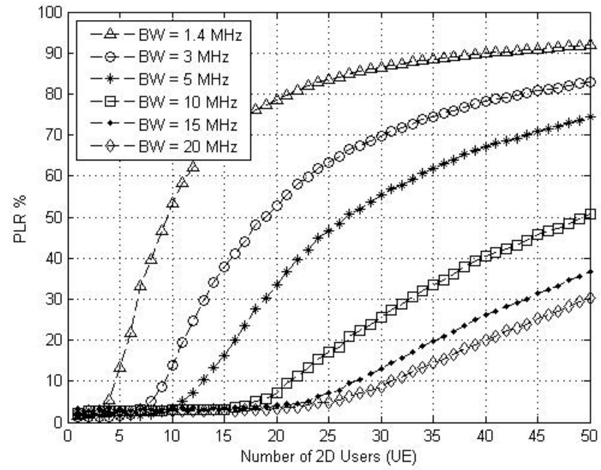
This section presents the performance analysis results. The LTE bandwidth sizes are set according to the standard, and the performance metrics are depicted as a function of the number of users in the LTE cell. Furthermore, an admission control strategy is introduced in the system, for which the trade-off between the system resource utilization and the efficiency of the video transmission is observed.

The system resource utilization is observed through the *spectral efficiency ratio*, whereas the transmission efficiency is evaluated based on the packet loss ratio and *average throughput ratio* in the LTE network. The spectral efficiency ratio and average throughput ratio are defined in section IV-B, where a simple admission control is described, which keeps sufficiently low packet loss ratio for the LTE users.

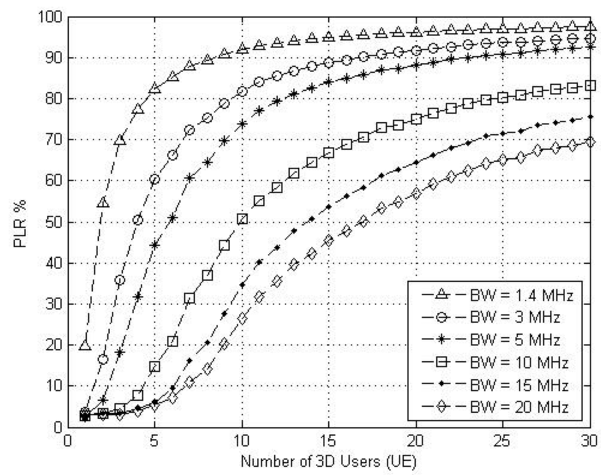
A. Performance metrics analysis

The Packet Loss Rate (PLR) for the 2D and 3D video transmission is depicted in Figure 1(a) and Figure 1(b). Regarding the 2D case, the increase of PLR is more noticeable for the lower bandwidth sizes when the number of users is increased, whereas for the 3D case, the PLR rapidly increases even for a small number of users in the lower bandwidth sizes.

The average throughput for 2D and 3D video traffic is higher as expected in the larger bandwidth sizes. Furthermore, the average throughput drops as the number of users in the cell increases. These effects are more evident for the 3D video, since the 3D video consumes larger portion of the network bandwidth. The results are depicted in Figure 2(a) and Figure 2(b).



(a) Packet loss ratio for 2D video users



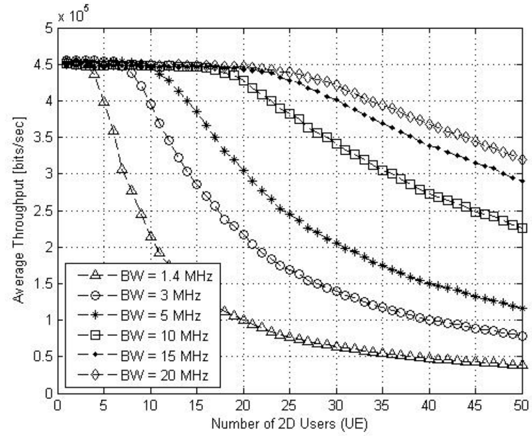
(b) Packet loss ratio for 3D video users

Fig. 1. Packet loss ratio for 2D/3D video transmission

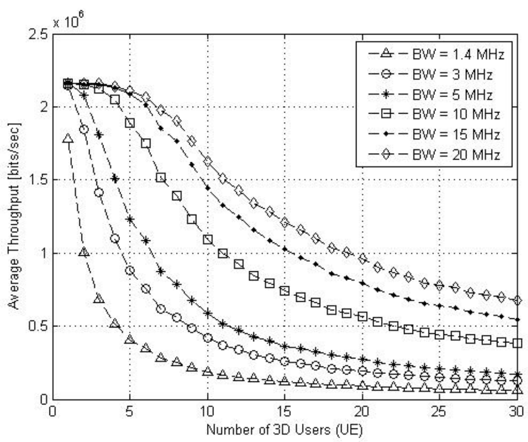
The spectral efficiency of the cell is depicted in Figure 3(a) and Figure 3(b). The cell is saturated for a high number of users and it has different saturation thresholds depending on the bandwidth size, i.e., a higher bandwidth size yields a higher spectral efficiency saturation threshold.

B. Admission Control

The considered admission control strategy is based on the packet loss parameter. Different PLRs are set to establish three different admission control strategies. Number of admitted users varies in accordance with the threshold decided, such that the higher the PLR the higher the number of admitted 2D and 3D users, as reported in Table II. According to our previous studies [16] and [17], the packet loss constraint for acceptable PLR is set to 10%, since this value still

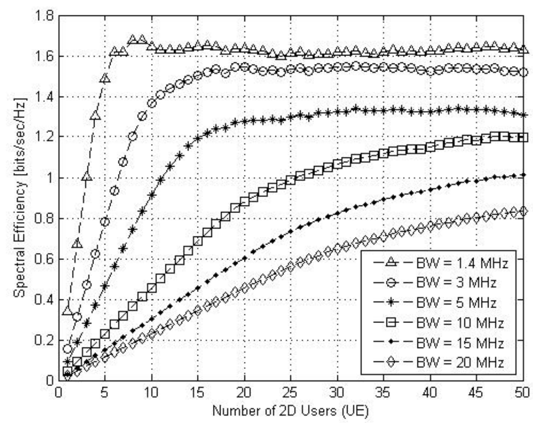


(a) Average throughput for 2D video users

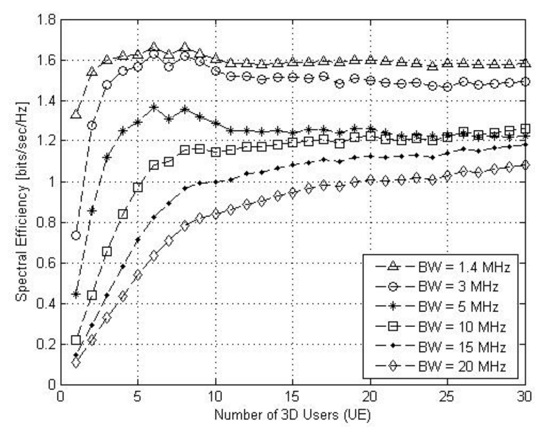


(b) Average throughput for 3D video users

Fig. 2. Average throughput for 2D/3D video transmission



(a) Spectral efficiency for 2D video users



(b) Spectral efficiency for 3D video users

Fig. 3. Spectral efficiency for 2D/3D video transmission

preserves good Peak Signal to Noise Ratio (PSNR) values for 3D video. The requirement for 3D video is more stringent compared to 2D video, hence the strategy is tailored according to 3D video and adopted for 2D video as well. When the PLR increases above 10%, the system will stop admitting users. The number of admitted users is reported in Table II for 10% PLR. Furthermore, the packet scheduling algorithm considered in this study plays a major role in the performance results obtained from the decision of the admission control. In other words, the aforementioned scheduler, i.e., the M-LWDF scheduler, is dependent on several factors which are delay of the packet, wireless channel state and a dropping probability value in order to control accordingly the decision of allocating PRBs to different users.

The effect of the admission control strategy is investigated through the introduction of two ratios, which capture the trade-off between the utilization of the system resources and the efficiency of the video transmission.

The spectral efficiency ratio α shows how much the deployed admission control approaches the maximum possible spectral efficiency in the cell. This ratio is obtained by dividing the achieved spectral efficiency of the admitted users in the particular bandwidth size and the maximum spectral efficiency of a multi-user LTE cell (2 b/s/Hz).

TABLE II
NUMBER OF ADMITTED USERS UNDER DIFFERENT PACKET LOSS RATIOS

	AC of 5%		AC of 10%		AC of 15%	
Bandwidth Size [MHz]	**2D Users**	**3D Users**	**2D Users**	**3D Users**	**2D Users**	**3D Users**
1.4	4	0	4	0	5	0
3	8	1	9	1	10	1
5	11	1	13	2	14	2
10	19	3	21	4	24	5
15	23	4	28	6	32	7
20	26	5	32	7	36	8

The average throughput ratio β shows how much the deployed admission control approaches the nominal throughput of the 2D and 3D video traffics. This parameter is obtained by dividing the average throughput of the admitted users in the particular bandwidth size and the nominal throughput of the 2D or 3D video service, respectively.

These ratios are calculated for the proposed admission control and listed in Table III. The spectral efficiency ratio has significantly higher values for the smaller bandwidth sizes for 2D video, whereas for the larger bandwidth sizes the 3D video results in higher spectral efficiency. Furthermore, the trend for 2D video is descending as the bandwidth size is increased. In contrast, the trend for the 3D video is relatively constant, regardless of the bandwidth size (except for 1.4 MHz case, when no users are admitted). The crossing point of the 2D and 3D video is the 10 MHz bandwidth size. The average throughput ratio has similar values in all bandwidth sizes for both types of video traffic. These values are very close to the maximum value $beta = 1$.

TABLE III
NORMALIZED RATIOS FOR THE PROPOSED ADMISSION CONTROL

Bandwidth Size [MHz]	2D Spectral Efficiency Ratio	3D Spectral Efficiency Ratio	2D Average Throughput Ratio	3D Average Throughput Ratio
1.4	0.650	0	0.991	0
3	0.651	0.367	0.955	0.973
5	0.553	0.427	0.938	0.944
10	0.451	0.419	0.948	0.930
15	0.396	0.411	0.939	0.914
20	0.337	0.353	0.932	0.897

From the presented analysis we can observe the following. The relationship between the system-oriented metric (cell efficiency) and user-oriented metrics (PLR and average throughput) can be tuned according to system design preferences. This relationship is highly dependent on the bandwidth size and the deployed admission control when 2D and 3D video is transmitted in the LTE network. By keeping a user-oriented constraint in the admission control design (PLR below 10%), we have shown that 2D video traffic provides high system resource utilization in the smaller bandwidth sizes (approximately 65%) compared to the larger bandwidth sizes (approximately 33%). In addition, we have observed that 3D video traffic provides relatively constant system utilization (between 35% and 42%) across the different bandwidth sizes (except for 1.4MHz case when there is no user admitted). Furthermore, the nominal throughput of the 2D and 3D video traffic is preserved (around 90%), regardless of the bandwidth sizes. Under these remarks, it can be emphasized that the cases where low system resource utilization is observed provide possibilities for servicing different traffic profiles in the LTE system.

V. CONCLUSION

The varying bandwidth sizes of the LTE network can be utilized in combination with various admission control strategies to facilitate a good trade-off between system-oriented metrics and user-oriented metrics. In this paper, we investigated this trade-off for 2D and 3D video traffics, through the cell efficiency, the packet loss ratio and the average throughput as relevant metrics. The proposed admission control is based on PLR and deployed in the different bandwidth sizes for the 2D and 3D video traffics, which have fixed nominal throughput. The effects of the admission control are observed through ratios that indicate the system resource utilization and the transmission efficiency of the 2D and 3D video traffics in the LTE cell.

Future work will include analysis of multi-cell system and investigation of PSNR for different 3D video sources.

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