Poster: Wi-Fi User's Video QoE in the Presence of Duty Cycled LTE-U

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ABSTRACT

Recent advances in LTE operating in unlicensed spectrum (LTE-U) has grabbed a lot of attention from industry and academia. The duty cycled LTE-U is shown to be fair with Wi-Fi technology by following an ON-OFF cycle for its transmission. However, the effect of LTE-U on the video quality of Wi-Fi users has not been studied in the literature. In this work, we study the video quality performance of a Wi-Fi user in the presence of LTE-U, in a testbed system. Our results show that the parameters that contribute to the video QoE (Quality of Experience) of Wi-Fi users get adversely affected as the fraction of channel utilized by LTE-U increases, but the same is not shown to be true with another Wi-Fi. We found that poor video QoE of Wi-Fi users in the presence of LTE-U is because of a large number of packet collisions and less channel access time due to ON cycle of LTE-U.

KEYWORDS

Quality of Experience; LTE-U; IEEE 802.11 (Wi-Fi)

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1 INTRODUCTION & MOTIVATION

The use of LTE in unlicensed spectrum (LTE-U) is a promising solution to satisfy the increasing mobile data demand. The fair coexistence of LTE-U with Wi-Fi is achieved by duty cycle (ON-OFF cycle) based transmission mechanism in LTE-U [1, 5]. Since, the increase in video traffic demand is expected to reach 82% by the year 2021 from 73% of total data usage over the Internet in 2017 [6], it is essential to study and analyze the effect of LTE-U, with different duty cycles, on video Quality of Experience (QoE) of a Wi-Fi user.

Figure 1: Coexistence testbed setup.

2 EXPERIMENTAL SETUP

To study the QoE of Wi-Fi users in the presence of LTE-U, we have created a testbed setup with Wi-Fi and LTE-U nodes. The experiments are carried out on Wi-Fi – Wi-Fi (WW) and Wi-Fi – LTE-U (WL) scenarios. In WW scenario, two Wi-Fi APs are set to operate on the same channel with one AP serving its Wi-Fi user running a video application and another AP with its Wi-Fi user running an iPerf application with UDP traffic. Similarly, in WL scenario, the second Wi-Fi AP and its users has been replaced with one LTE-U eNodeB and one LTE-U user. The center frequency for LTE-U and Wi-Fi is set to 5.22 GHz (*i.e., Wi-Fi channel 44*) with bandwidth of 20 MHz. LTE-U is employed with LTE-U/LAA application framework [2] using an USRP RIO board consisting of an LTE-U eNB and an LTE-U user, both embedded within the same hardware. For Wi-Fi network, we used a commercial "Netgear N600 wireless dual band router" as an AP with the maximum data rate of 54 Mbps. Our testbed setup is shown in Fig. 1. We have developed an application using the IONIC framework to calculate the QoE in terms of Mean Opinion Score (MOS) for YouTube videos, considering the impairment being caused by various QoE deciding parameters.

2.1 Measurement of QoE metric

For the QoE metric, we calculate the MOS value using the QoE model proposed in [3]. The model estimates the MOS

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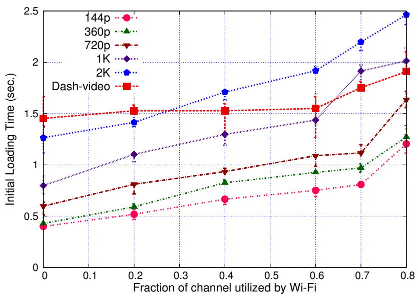

Figure 2: Initial loading time in WW scenario.

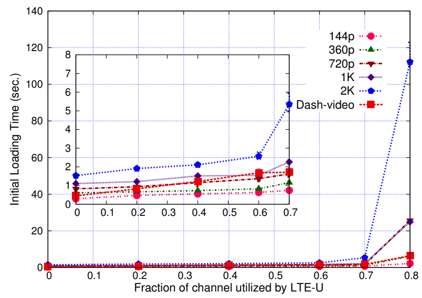

Figure 3: Initial loading time in WL scenario.

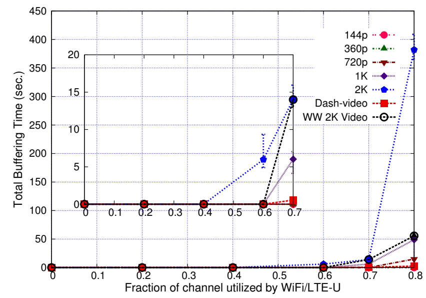

Figure 4: Buffering time in WL & for 2K video in WW scenario.

value from the R-value which includes the level of impairment being caused by various QoE deciding parameters like initial loading time, total buffering time, number of stalls, average video quality, and average video quality switching magnitude. The MOS value is calculated as follows:

$$MOS = 1 + 0.035R + 7.10^{-6}R(R-60)(100-R), \quad (1)$$

$$R = 100 - I_{ID} - I_{ST} - I_{LV} + C1 * I_{ID} * \sqrt{I_{ST} + I_{LV}} + C2 * \sqrt{I_{ST} * I_{LV}}, \quad (2)$$

where I_{ID}, I_{ST}, and I_{LV} represent impairments due to the initial loading time, stalls, and level variation, respectively. C1, C2 are constants with values 0.15 and 0.82, respectively.

2.2 Working of YouTube Player

DASH (Dynamic Adaptive Streaming over HTTP) [4] is a video streaming technology that adaptively streams videos based on the link bandwidth between the client and the server. DASH encoded videos are chunked into small segments (2, 5, or 10 sec). DASH server stores these segments in different quality versions and client fetches these segments of appropriate quality according to its channel condition which helps in maintaining video QoE of the Wi-Fi user.

YouTube player stores the fetched segments in a playback buffer which is associated with a parameter called as buffer threshold level (λ) (typically, 10 sec). λ is the buffer occupancy level up to which the video content should be fetched before rendering content to the user after stalling, *i.e.*, if stalling occurs, the YouTube player will first fill its playback buffer up to λ sec before resuming the video. The same happens when the video is first loaded.

3 PERFORMANCE EVALUATION

With our experimental testbed setup explained in Section 2, we have studied the performance of QoE of the Wi-Fi user in WW and WL scenarios for different video qualities like 144p, 360p, 720p, 1K, 2K and DASH.

The MOS values are calculated using Eqn. (1) for the videos of different qualities in Wi-Fi with varying fraction of channel utilized by another node (LTE-U eNodeB in WL scenario and Wi-Fi AP in WW scenario). The fraction of the channel utilized by LTE-U (η_L) is defined as the fraction of time LTE-U eNodeB is ON in a given duty cycle period. In our experiments, the duty cycle period is considered 10 ms. The fraction of the channel utilized by Wi-Fi AP (η_W) is defined as the fraction of traffic generated with respect to the maximum capacity of the channel. It is achieved by generating UDP traffic using iPerf in another Wi-Fi network operating on the same channel.

Initial Loading Time: This parameter represents the time taken by the video to load on to the device of the user, *i.e.,* it is the time taken by the first video frame to get displayed on to the device of the user. The higher value of this parameter results in poor QoE of the user by causing a high level of impairment to the MOS value. Figs. 2 and 3 show the initial loading time for WW and WL scenarios, respectively.

In WW and WL scenario, as we increases the value of η_L and η_W respectively, the number of packet collisions for Wi-Fi AP serving the video content increases and degrades its chances to access the channel. This results in high initial loading time and high level of impairment to the MOS value of the video.

As we increase the video quality at fixed values of η_L and η_W in WL and WW scenarios, respectively, the amount of data needed to fill the buffer up to λ increases, resulting in higher initial loading time of the video.

Total Buffering Time: It is the total time for which the video gets stalled during its playback time. The higher value of this parameter results in lower MOS value of the video and poor video QoE. Fig. 4 shows the total buffering time with increasing value of η_L.

In the WL scenario, with the increase in the value of η_L, the packet collisions for Wi-Fi AP serving video content increases and Wi-Fi AP gets less channel access time to serve its user. This results in high total buffering time causing a high level of impairment to the MOS value of the video. Whereas the DASH video can maintain lower buffering time because of its ability to dynamically adapt the video quality with the channel's bandwidth available to the user.

In the WW scenario, we have observed that lower quality videos don't stall at any value of η_W as the AP is getting

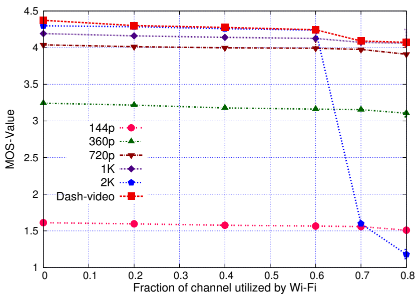

Figure 5: MOS value of a video in WW scenario.

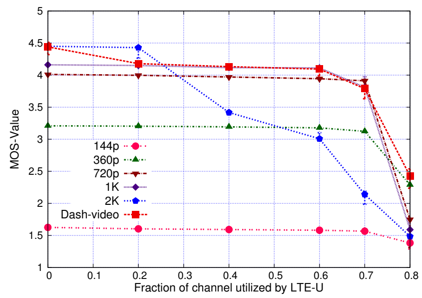

Figure 6: MOS value of a video in WL scenario.

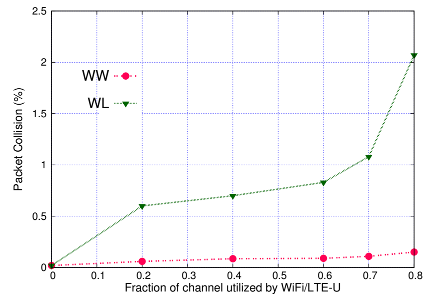

Figure 7: Packet collision (%) in WW and WL scenarios.

sufficient channel bandwidth to play the video without any stalling except for 2K quality video. In Fig. 4, we can observe a sharp increase in the total buffering time for the 2K video once the channel utilization goes beyond the value of 0.6, as the channel bandwidth available to the Wi-Fi user is not sufficient enough to play 2K quality video.

MOS Value: Figs. 5 and 6 show the MOS values for WW and WL scenarios, respectively.

In WL scenario, for a given video quality, increase in the value of η_L results in drop in MOS value due to increase in the number of packet collisions and high level of impairment being caused by QoE deciding parameters. DASH video achieves highest MOS value at all the values of η_L due to its ability to dynamically switch the video qualities according to the channel condition.

In WW scenario, the video with static quality can maintain the MOS value for all values of η_W as the Wi-Fi AP is being able to serve its user continuously with the better channel bandwidth and thus video never goes through stalling and results in high MOS value. We have seen that the buffering time for the 2K video increases sharply from 0.6 fraction of the channel utilization (Fig. 4). Thus, MOS value for the 2K video is adversely affected resulting in poor video QoE of the user.

3.1 Packet Collisions

One of the major reason for such a poor video QoE in WL scenario compared to WW scenario is due to more packet collisions in WL scenario. The packet collisions in both the scenarios are shown in Fig. 7. The high number of packet collisions are observed in WL scenario as compared to WW scenario. In the case of WL scenario, the LTE-U packets can collide with both Wi-Fi DATA packets and Wi-Fi ACK packets, but in WW scenario, only the DATA packet collisions happen and not ACK collisions. Moreover, in the unlicensed band, the collision of packets between LTE-U eNodeB and Wi-Fi AP results in Wi-Fi AP to back-off while LTE-U keeps on transmitting on the channel. The collisions of Wi-Fi-Wi-Fi packets results in back-off for both of the Wi-Fi AP's, and hence both have a fair chance of accessing the channel for next packets. Due to these factors, in WL scenario the video segments are not received in the stipulated time frame resulting in poor video QoE of the user as compared to that in WW scenario.

4 CONCLUSION AND FUTURE WORK

In this poster, the degradation of video QoE of Wi-Fi users is shown when Wi-Fi AP is under the influence of LTE-U eNodeB operating in the same unlicensed channel. We have also shown how the parameters that are contributing to video QoE get adversely affected by the ON fraction of LTE-U. In LTE-U, if the load on the channel is high, LTE-U selects lower ON fraction and vice versa. In the considered scenario, the Wi-Fi AP has only one user generating low load on the channel, and thus LTE-U may select the higher value of ON fraction, and that leads to degradation of video QoE of the Wi-Fi user as shown in this paper. Therefore, LTE-U has to select the ON fraction properly so that the performance of Wi-Fi users are not affected unfairly.

In future, we plan to work on improving the video QoE of Wi-Fi users in LTE-U and Wi-Fi coexistence scenario and would like to see the effect of different LTE-U duty cycle periods on the video QoE of the user.

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