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The Impact of Video Streaming on Quality of Experience over 802.11n Dual Band networks: Experimental Evaluation

R. Bruzgiene[1], L. Narbutaite[1], T. Adomkus[1], R. Cibulskis[1]
[1]*Department of Telecommunications, Kaunas University of Technology, Studentu St. 50–452, LT-51368 Kaunas, Lithuania*
rasa.bruzgiene@ktu.lt

***Abstract*—Today's users can access even video broadcasting services, however, video streaming over wireless networks is especially difficult due to the factors, influencing the wireless communication process: the signal strength, the interference from other wireless links and so on. So it is very important to analyze the parameters of video streaming over 802.11 wireless networks, evaluating the influence of different frequency bands on the characteristics of video Quality of Experience: Mean Opinion Score, Peak Signal to Noise Ratio and others. The experimental investigations of video streaming over 802.11n wireless network, which operates in simultaneous 2.4 GHz and 5 GHz frequency bands, are presented in this paper. The experimental investigations showed that there is big impact of the video multicast streaming on Quality of Experience characteristics over dual band wireless network. Due to this, the authors recommended the approach for the equipment of video streaming over 802.11n dual band wireless network, according to the analysis of experimental results and the existing wireless streaming problems in the network.**

***Index Terms*—Dual band, IEEE 802.11n, MOS, PSNR, video streaming.**

I. INTRODUCTION

Wireless networks with IEEE 802.11n [1] standard are growing rapidly and offer the availability to access to the real time streaming media services at any place. While the new 802.11ac and 802.11ad standards are focused on Multi - media streaming services and the users' needs for multi – gigabit WiFi (*Wireless Fidelity, Wireless Internet*) [2], the 802.11n wireless network gives the current commercial benefits for the providers offering real time video streaming services, video applications and etc. The users are able to use multiple services at the same time as the equipment, which supports 802.11n standard, can operate in simultaneous 2.4 GHz and 5 GHz frequency bands. However, such transmission of the services is affected by many factors, influencing wireless video or data streaming process [3]: external wireless links, the wireless signal strength, the signal propagation and etc. Such real time video transmission the users evaluate by their subjective perceived video quality [4], if the wireless streaming process are affected or interrupted. The perceived video quality or Quality of Experience (QoE) can be evaluated by the objective video quality metrics [5]: Mean Opinion Score (MOS), Peak Signal to Noise Ratio (PSNR), Structural Content (SC) and others. Generally, the QoE of the video streaming over dual band 802.11n network is a main problem for the providers.

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So the task of this research work was to investigate the IP video transmission over 802.11n dual band network, evaluating the wireless video streaming impact to the video Quality of Experience. The experimental results were used for the objective QoE evaluation. Based on the results of the experiments, the authors recommended the approach for the equipment used for IP video transmission over 802.11n dual band network.

II. IMPLEMENTATION OF EXPERIMENTS AND OBJECTIVE VIDEO QUALITY METRICS

The experimental investigations were carried out in the laboratory of Telecommunications technology and the structure of network, used for the experiments, is presented in Fig. 1.

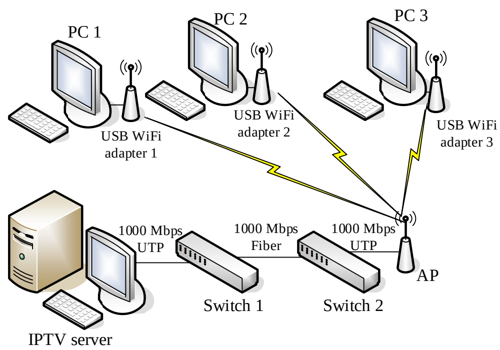


Fig. 1. The structure of 802.11n WLAN network, used for the experiments.

The tested network consisted of one IP video server, two switches and one access point, which operated in simultaneous 2.4 GHz and 5 GHz frequency bands. The clients' equipment consisted of three personal computers (PC) with USB Wi-Fi adapters. The detailed list of the equipment, used during the experiments, is presented in Table I. The open source Video LAN Media player (VLC Player v 2.1.2) was used in all clients' PCs and video server for the IP video streaming, pause and playback. The parameters of 802.11n WLAN network collected using

WirelessMon v 4.0 Build 1008 software.

TABLE I. THE SETUP FOR THE EXPERIMENTS.

Type of the device	Device model
Access point	D-Link DIR-825/A Dual Band, MIMO 2 × 2 for 2.4 GHz, 14 dBm and 2 × 2 for 5 GHz, 11.5 dBm
Access point	Asus RT-N56U Dual Band, MIMO 2 × 2 for 2.4 GHz, peak gain 3.8 dBi and 3 × 3 for 5 GHz, peak gain 5.1 dBi
USB WiFi Adapter	D-Link DWA-160 Dual Band MIMO 2 × 2\ Buffalo WLI-UC-GNM Wireless N150 SISO 1 × 1
Switch	Cisco Catalyst 3560G
Video server	IPTV Server
User device	Client PC

The authors created the experimental 802.11n network in such way, that it would be able to evaluate the propagation of the wireless signal under the line of sight (LOS) and non-line of sight (NLOS) conditions (Fig. 2).

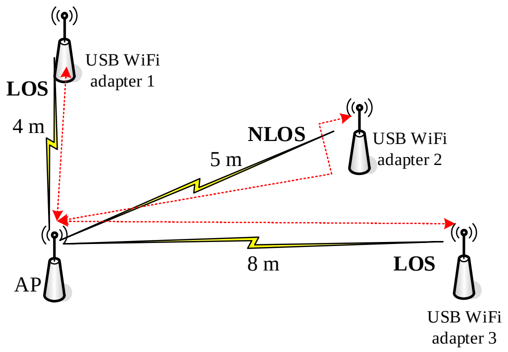


Fig. 2. The structure of the experiments performance under LOS and NLOS conditions.

The two clients were in 4 meters and 8 meters distance and one client was in 5 meters distance from the access point. The evaluation of the signal propagation under different conditions can help to assess the influence of IP video streaming parameters on the client's visible video quality.

The main aspect of all experiments concentrated into the measurements of the parameters, which can affect the user's perceived quality of IP video service. The experiments were carried out in different scenarios (Table II).

TABLE II. THE SCENARIOS OF THE EXPERIMENTS.

No	Parameters of the network	Scenarios
1.	2.4 GHz frequency band, channel 6, 40 MHz signal bandwidth	2 types of APs Multicast streaming of 2.3 Mbps data rate 3 clients with Buffalo USB Wi-Fi Adapters 3 types of IP video
2.	5 GHz (5180 MHz) frequency band, channel 36, 40 MHz signal bandwidth	2 types of APs Multicast streaming of 2.3 Mbps data rate 3 clients with D-Link USB Wi-Fi Adapters 3 types of IP video
3.	Simultaneous 2.4 GHz and 5 GHz dual band, 40 MHz signal bandwidth	2 types of APs Multicast streaming of 2.3 Mbps data rate 3 clients with USB Wi-Fi Adapters 2 types of IP video: secured and unsecured

The measured parameters depended on the scenario of the experiment: the wireless signal strength; the video streaming bitrate (at the client's side) for the scenarios No. 1 and No. 2; the wireless signal strength; the time for the one frequency band changing to other for the scenario No. 3. The users evaluated the perceived quality of IP video using the values of the subjective Mean Opinion Score (MOS). The snapshots of different types IP video were performed during the experiments (for scenarios 1, 2). The total number of the snapshots is 50 for the each type of IP video. These snapshots were used for the objective MOS evaluation of the streamed IP video over wireless 802.11n network. The different types of IP video service were streamed to the users (Table III). AVC/H.264 video compression method was used.

TABLE III. THE TYPES OF IP VIDEO, USED IN THE EXPERIMENTS.

Type No	Video data rate, kbps	Video frame rate, frames per second	Video image resolution, pixels
1.	1836	25	656 × 368
2.	1034	23	640 × 336
3.	1664	23	704 × 288

The objective evaluation was performed using Matlab software. The metrics, which were used in Matlab, are expressed in equations below [6]: Mean Square Error (*MSE*) and Peak Signal to Noise Ratio (*PSNR*):

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j) - f'(i,j))^2, \quad (1)$$

$$PSNR = 10\log\frac{(2^n - 1)^2}{MSE}, \quad (2)$$

where $f(i,j)$ describes original picture of the IP video; $f'(i,j)$ – describes transmitted picture to the user PC; $M \times N$ – the resolution of IP video in pixels.

The main metric, which value can be converted to objective MOS value, is PSNR (Table IV) [7].

TABLE IV. MOS VALUE ACCORDING PSNR VALUE [7].

MOS value	PSNR value, dB
5 (Excellent)	>37
4 (Good)	31 - 37
3 (Fair)	25 - 31
2 (Poor)	20 - 25
1 (Bad)	<20

The results of the experiments and evaluated objective IP video quality metrics were expressed on the dependency of PSNR values. These results are presented in Sector III.

III. RESULTS OF THE VIDEO STREAMING QUALITY OVER 802.11N DUAL BAND NETWORK

The results of the experimental investigations during scenarios No. 1 and No. 2 showed that the IP video multicasting over 802.11n wireless network, which operates in 2.4 GHz and 5 GHz frequency bands, has a very different impact on the objective and subjective video quality. Received Signal Strength Indicator (RSSI) was measured during the experiments. RSSI values for 2.4 GHz wireless signals were in the interval of [-27; -29] dBm, and for 5 GHz wireless signals were in the interval of [-33; -37] dBm. Such RSSI values are evaluated as very good quality of wireless signals, which influence is insignificant to the video QoS. As the wireless signals propagated through multipath reflections, the reflection coefficient was used for the evaluation of the wireless signals multipath. For most materials, the decrease in transmitted power between 2.4 GHz and 5 GHz is less than 1 dB [8]. So the reflection coefficient was equal to 1. Since both access points offer different output transmit power, the results were re-calculated for normalized output power. First the authors set up the minimum mean square error ($F(\gamma)$) equation for the dB power measurements as in [9]

$$F(¥) = \sum_{i=1}^{n} \left[S_m(d_i) - S_c(d_i) \right]^2, \tag{3}$$

where S_m – is the measured signal path loss, S_c is the calculated signal path loss using the formula for free space path loss.

Then the path loss exponent γ was evaluated differentiating $F(\gamma)$ relative to zero $\frac{\partial F(¥)}{\partial(¥)} \to 0$. In our case, γ_1 = 1.95 for 2.4 GHz and γ_2 = 2.76 for 5 GHz.

The authors noticed that multicasting of the different types of IP video over experimental wireless network has influenced the video bitrate at the client's PC. In order to assess the variation of the video bitrate, the authors estimated the ratio between the video data rate and the average video bitrate. The influence of this ratio to the evaluated PSNR, using the access points of different models, is presented in Fig. 3–Fig. 4. The marking 1T, 2T and 3T mean the video type number.

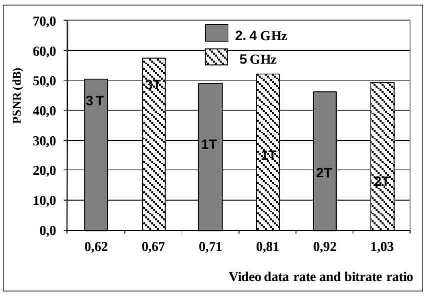


Fig. 3. The influence of video data rate and bitrate ratio to PSNR, using the first AP.

According to the results in Fig. 3, the use of the first access point allows evaluating the results of all three types of P video wireless streaming as the streaming of an excellent video quality (Fig. 3). However, the values of PSNR for the wireless streaming of 1 and 3 types IP video are below 37 dB, using the 2.4 GHz and 5 GHz frequency bands (Fig. 4). It means, that the streaming of these video is with the visible errors to the users (Table IV).

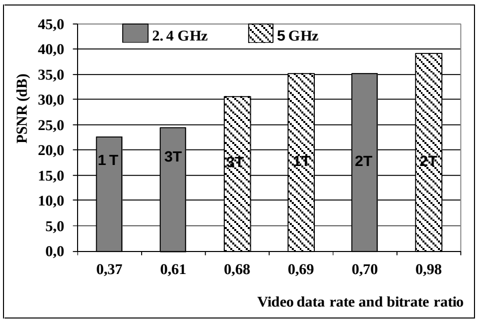


Fig. 4. The influence of video data rate and bitrate ratio to PSNR, using the second AP.

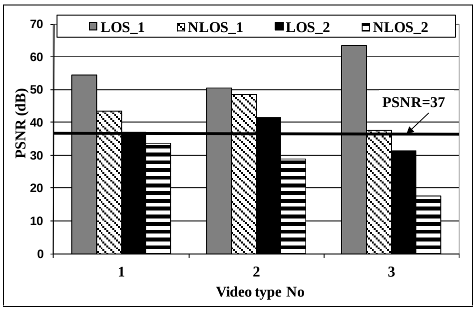
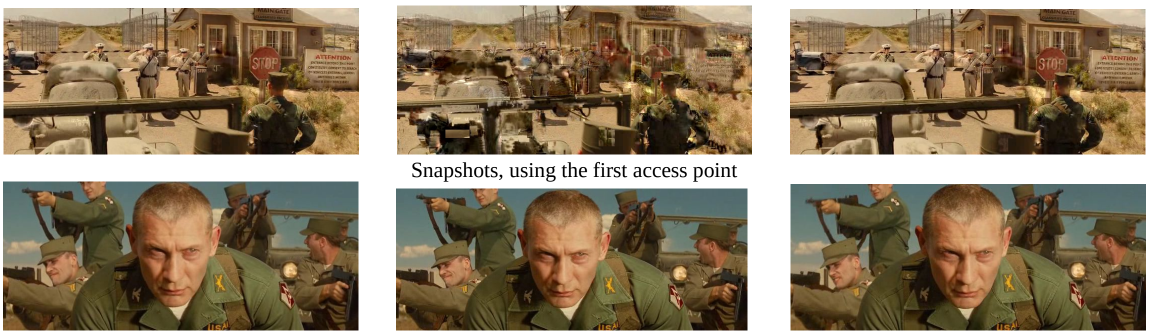


Fig. 5. The influence of LOS and NLOS conditions to the PSNR value of different type of video.

According to the results in Fig. 5, the wireless streaming of IP video type No. 2 is evaluated as an excellent video quality under LOS and NLOS conditions. The different is only for the video streaming under NLOS condition, when the second AP was used in the wireless network. It is concluded that, IP video streaming service over 802.11n dual band network is very influenced by the parameters of the access point.

The comparison of the perceived quality of the snapshots, when 802.11n network operated in 2.4 GHz and 5 GHz frequency bands, is presented in Fig. 6. The influence of different frequency bands to PSNR of the snapshots from the video type No. 3 are presented in Fig. 7 and Fig. 8.

According to the results in Fig. 7 and Fig. 8, the quality of wireless streaming of the IP video with 1664 kbps data rate and higher video resolution are influenced by the use of the different frequency bands.



a) b) c)

Fig. 6. The comparison of the perceived quality of the snapshots, when 802.11n network was operating in 2.4GHz and 5GHz frequency bands: a) original picture; b) received picture, using the 2.4 GHz frequency band; c) received picture, using the 5 GHz frequency band.

The 802.11n network, which operates in dual bands, is used 30 % effectively, if IP video are streamed over 5 GHz frequency band. The use of 2.4 GHz frequency band impacts the occurrence of video errors or video stream buffering.

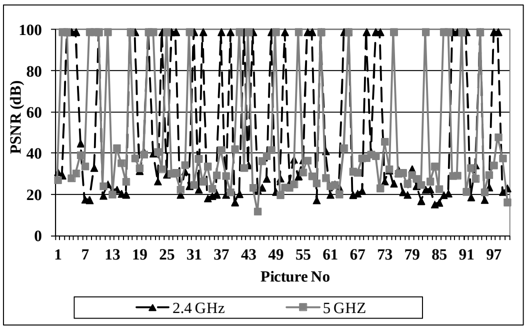


Fig. 7. The influence of different frequency bands to PSNR of the snapshots (using the first AP).

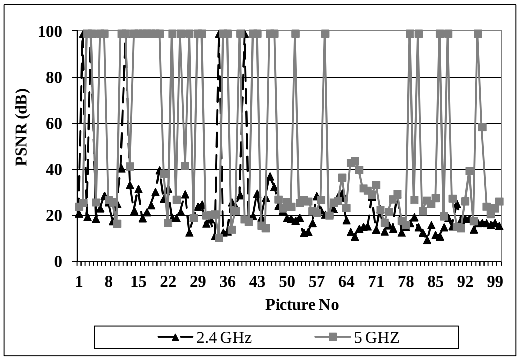


Fig. 8. The influence of different frequency bands to PSNR of the snapshots (using the second AP).

These video errors were evaluated by the objective video quality metrics and the results are presented in Fig. 9.

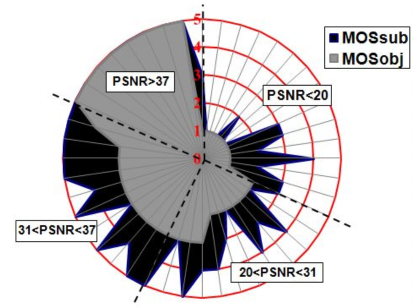


Fig. 9. The comparison of the subjective and objective MOS evaluation.

The comparison of the subjective and objective video quality evaluation showed, that MOS values difference in 2 times, if PSNR values are between 31 dB and 37 dB. That means the level of the user's visual perception for poor and good quality assessment is rather restrictive. It is concluded, that the user's perceived quality will not be affected, if IP video transmission would be switched from one frequency band to another (Fig. 6). In this case, it would be possible to reduce the wireless video streaming errors or video stream buffering without interruption to the perceived IP video quality. Due to this, authors carried out the experiments for scenario no. 3, in order to evaluate the switching time of the secured and unsecured IP video streaming (Fig. 10). The experiments' results showed that the switching time for secured IP video is about 35 s. It is about 40 % longer switching time compared with the switching of unsecured IP video.

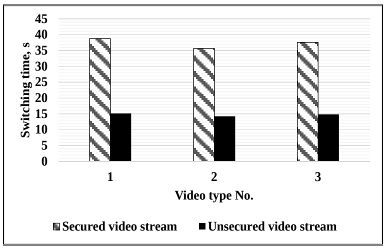


Fig. 10. The comparison of the switching time of secured and unsecured IP video transmission.

In this case, it is very important to evaluate the characteristics of the used access point, since different manufacturers' devices have a different duration for the video stream buffering.

IV. Conclusions

The results of the experimental investigations showed that the subjective and objective IP video quality evaluation difference in 2 times. That means the level of the user's visual perception for poor and good quality assessment of IP video multicasting over dual band 802.11n network is rather restrictive.

The 802.11n network, which is operating in dual bands, is used 30 % effectively, if IP video are streamed over 5 GHz frequency band. The switching time of the IP video transmission from 2.4 GHz to 5 GHz frequency band, is 40 % longer for secured IP video compared with the switching of unsecured IP video. For this reason, it is very important to evaluate the characteristics of the used equipment, which impact the quantity of IP video errors and the time of video stream buffering over dual band 802.11n wireless network.

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