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Impact of Wireless Channel Parameters on Quality of Video Streaming

S. Paulikas, P. Sargautis, V. Banevicius
Department of Telecommunication Engineering, Vilnius Gediminas Technical University,
Naugarduko str. 41-210, LT-03227, Vilnius, Lithuania, phone: +370 5 2744977, e-mail: sarunas.paulikas@el.vgtu.lt

Introduction

Video streaming over wireless channels is a challenging task, because of the high throughput required to communicate and the time-varying nature of the wireless channel parameters. As a consequence, substantial amount of research has been devoted to achieving an increase in the end-to-end quality of video delivery over wireless networks. The video quality is influenced by two different types of distortion which arise, on the one hand, from the effects of lossy compression introduced by the source encoding (source distortion), and on the other hand, from the lossy transmission channel (loss distortion) [1]. Quality control of videos from the source (capture device) to the final destination (display and its environment) presented to the human user is essential for video applications and services. Peak signal to noise ratio and other similar measures long time have been the most popular quality criteria used by to evaluate and optimize the performances of digital video processing schemes [2]. Over the two past decades, objective video quality estimation methods have been extensively studied, and many criteria have been designed [3, 4].

This paper continues the research started in [5] on estimation of video quality of wireless video streaming at the end-user's side. In this research was found that it is possible to construct an algorithm to predict the quality obtained by user of streamed video clip from data stream parameters such as place, type and number of lost video frames. However, these stream parameters not always can be easily obtained at the end-user's device, because of it will require the intrusion into video codec. Manufacturer usually implements video codecs in device firmware or hardware that is copyright preserved.

On the over hand, several recent research works [6–8] ties quality of service to communication's channel throughput. The channel throughput can be used as QoS indicator perceived by an end-user in the presence of a bottleneck. Publication [9] presents expression for video clip, coded in MPEG-2, evaluated by heuristic equation $\Delta\text{MOS} = m/(a \times \text{bitrate})^n$, where ΔMOS (difference MOS) – the quality metric, with values between 0 and 1, a bitrate is expressed in Mb/s, for low movement $n = 1.125$ and $m = 0.21$, $a = 3.57$.

So, in this article we will present a research on impact of wireless channel parameters such as throughput and jitter on quality of video streaming. These wireless channel parameters can be easily obtained by monitoring IP level data streams in end-user's device by fairly simple software agent.

Here our investigation will be performed using the H.264/AVC coding standard based video streaming over wireless channel to mobile devices.

Mobile Video Streaming

Mobile video streaming is characterized by low bit rates and low resolutions. The commonly used resolutions are Quarter Common Intermediate Format (QCIF, 176 × 144 pixels) for cell phones, Common Intermediate Format (CIF, 352× 288 pixels) and Standard Interchange Format (SIF or QVGA, 320× 240 pixels) for data-cards and palmtops. The mandatory codec for UMTS (Universal Mobile Telecommunications System) streaming applications is H.263 but the 3GPP release 6 [10] already supports a baseline profile of the new H.264/AVC codec (ITU-T Rec. H.264). Due to video compression improvement of the newest video coding standard H.264/AVC, video streaming for low bit and frame rates is allowed while preserving its perceptual quality. This is especially suitable for video applications in 3G wireless networks.

The H.264/AVC is based on conventional block-based motion-compensated video coding, but has several new features that significantly improve rate-distortion performance over prior standard such as MPEG-2, MPEG-4 and H.263 [1]. Also special attention is given to the improvement of robustness to data errors or losses that appear during video transmission through different networks. The standard defines a network abstraction level (NAL) that maps H.264/AVC video coding layer (VCL) data to different transport layers.

The H.264/AVC standard has eleven profiles and sixteen levels. The profile specifies encoding algorithms and the level presents bit-rate constraints on parameter values and thus restricts computational complexity.

In general, mobile digital video transmission systems consist of a video encoder, a digital transmission method (e.g., Internet Protocol—IP), and a video decoder. The H.264/AVC encoder produces a sequence of compressed video frames that are encapsulated in to IP packets. In such situation the transmission impairments usually result in dropped or repeated data packets (corrupted video frames sequence) that causes the video decoder to produce pauses in the decoded video clip.

In this article we will focus on H.264/AVC baseline profile that was approved by 3GPP and it is designed for lower-cost applications with limited computing resources such as wireless applications, video telephony and video conferencing. Bit streams conforming to the baseline profile generally shall obey the following constraints: only I and P frame (slice) types may be present, NAL unit streams shall not contain type values in the range of 2 to 4, inclusive, and max bit rates are 64 kbps (level 1), 128 kbps (level 1b), 192 kbps (level 1.1), 384 kbps (level 1.2) and 768 kbps (level 1.3).

Experiment Setup

For the experiments there was set up video streaming test-bed (Fig. 1). The test-bed consists of video streaming server, wireless modem and mobile end-user device. As a video streaming server we used a PC running VLC player software. It is open source GPL software that is capable of producing unicast or multicast RTP and UDP video streaming. As an end-user device was employed laptop computer also running VLC player for monitoring of video quality and Wireshark software for measurement of IP channel parameters.

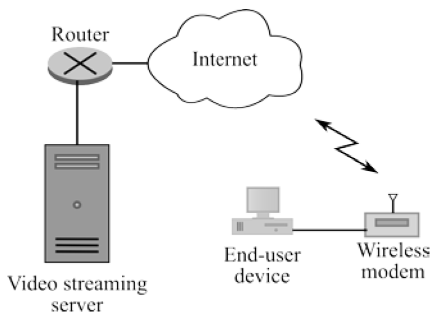

Fig. 1. Video streaming test-bed

In the experiments we employed tree types of wireless data transmission technologies: WiFi, WiMAX and 3G. It must be noted that test-bed set up for 3G channel measurements was a little bit different. In this case the wireless modem was connected to video streaming server while end-user device was connected to Internet. It was determined by a fact that we did not have the global IP address on 3G network. So we have to assign global IP address to server and perform a multicast video streaming.

For the video streaming we used 45 seconds long test video clip where newscaster presents some news. The test video clip is in general slow motion with some high motion elements as sharp hands gestures.

Video clip was streamed using 15 fps H.264/AVC encoding at three different average video stream bitrates: 64, 128 and 192 kbps, and two resolutions: CIF and QCIF, set as codec's parameters.

The purpose of performed experiments was to find out the minimal requirements for wireless channel throughput and jitter to obtain acceptable quality video. Here, the term "acceptable" means that played video clip was smooth without noticeable picture "freezing".

Minimal requirements for wireless channel throughput were obtained using data stream control program `tc`. For example, in order to limit downlink throughput the `tc` program must be executed with such arguments:

```
tc qdisc add dev (network interface) handle ffff: ingress
tc filter add dev (network interfac) parent ffff: protocol ip prio 50 u32 match ip src 0.0.0.0/0 police rate (max troughput) Kbit burst 10k drop flowid :1
```

As it is well known, wireless channel parameters are varies in time. In order to eliminate this, we each experiment, e.g. required WiFi channel throughput for 64 kbps video stream, repeated several times.

Experimental Results

The first experiment was carried out to find how much overhead adds encapsulation of pure H.264/AVC video stream in UDP packet. During that experiment we were streaming a video clip coded with three different average bitrates: 64, 128 and 192 kbps. At the end-user device using Wireshark program we were measuring bitrate of obtained data stream. Obtained results are summarized in Figs. 2 and 3.

Max data in UDP packet is 65 507 bytes (65 535 − 8 byte UDP header− 20 byte IP header), so the minimal header overhead is only 0.03 %. However, the minimal amount of data in UDP packet will depend on imposed limits in software (VLC in our case) that encapsulates video data to UDP packet.

During experiment, the measured overhead (see Figs. 2 and 3, bars lighter areas) is almost identical for all investigated wireless technologies and do not depend on video clip resolution, but depend on bitrate. For 64 kbps it is about until 42 %, for 128 kbps – about 25 % and for 192 kbps – about 17 %.

In the second experiment, using traffic shaping program `tc`, we step by step were limiting the video streaming channel throughput in order to find out the minimal throughput for wireless channel to obtain acceptable quality video clip at end-users side. As one can expect because of streamed data overhead was almost identical across employed wireless technologies the required minimal throughput also will be similar among them. However, according to measurements (see Figs. 2 and 3, white areas in charts) the required minimal throughput strongly depends on wireless technology at higher data rates. The highest throughput is required for 3G. It is more than 1.5 – 2 times greater than for WiFi.

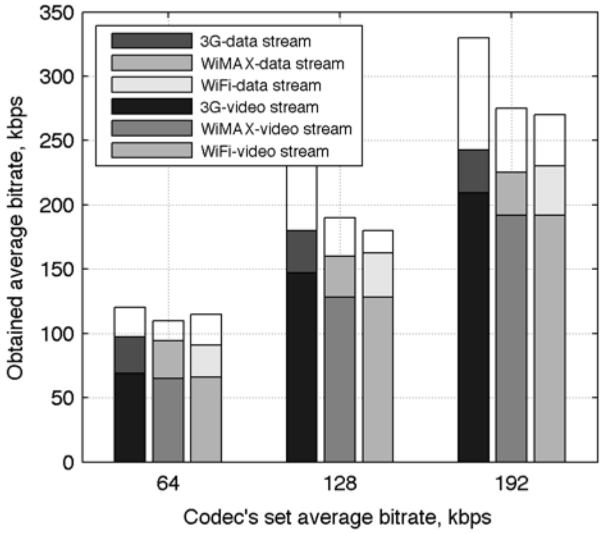

Fig. 2. Transmission technology overhead and minimal channel throughput for CIF images

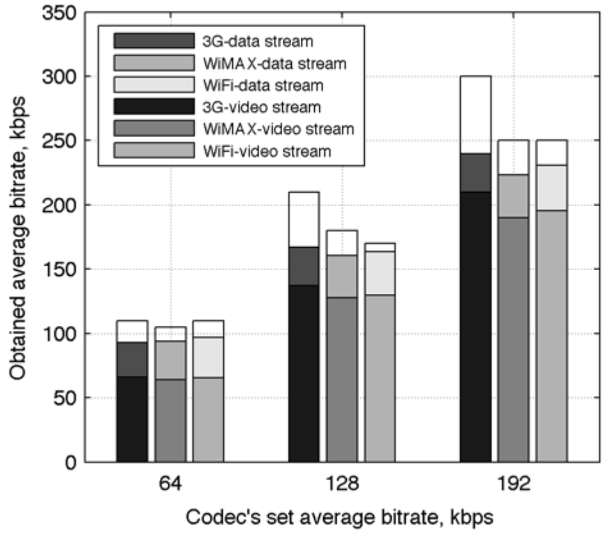

Fig. 3. Transmission technology overhead and minimal channel throughput for QCIF images

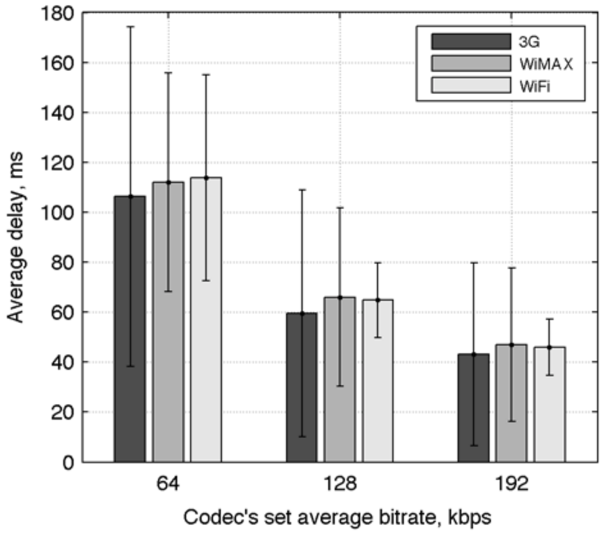

Fig. 4. Transmission technology average delay and jitter for CIF images

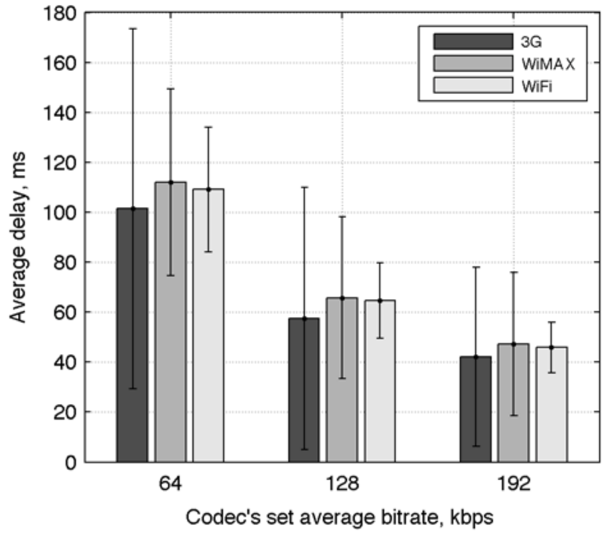

Fig. 5. Transmission technology average delay and jitter for QCIF images

To find out the reason of that difference we examined a jitter of received video data packets when channels throughput for all wireless technologies was set to required minimal throughput for qualitative video streaming over 3G.

As it can be seen from Figs. 4 and 5, the average delay is almost constant across technologies, and graphs are almost identical for streamed video clip of CIF and QCIF resolution.

However, the standard deviation of jitter (indicated by error-bars) – a difference between individual packets delays – is very different. The jitter of video streaming over 3G is more than 1.5 times greater than over WiMAX and more than 2 times greater than over WiFi. It could explain requirement for higher throughput for qualitative video streaming over 3G, as increased throughput usually will reduce jitter.

Conclusions

Experimental results show that in order to obtain acceptable quality video at end user's side the highest throughput is required for video streaming over 3G while comparing with WiMAX and WiFi wireless technologies.

The requirement for minimal channel's throughput is depended on jitter of received video data packets. The biggest jitter will lead to increase for minimal channel's throughput.

Obtained experimental results let assume that it is possible to construct method to predict the quality (with some probability) of obtained video clip using only transmission channel parameters, such as current throughput and jitter that can be easily obtained at the end-user's device by monitoring IP level data stream parameters. Knowing the current throughput for some determined time period we could tie it to quality degradation of received video clip.

Acknowledgements

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The problem of estimation of video quality obtained by end-user for mobile video streaming is addressed. Widely spreading mobile communication systems and increasing data transmission rates expand variety of multimedia services. One of such services is video streaming. So it is important to assess quality of this service. Consumers of video streaming are humans, and quality assessment must account human perception characteristics. Existing methods for user experienced video quality estimation as quality metrics usually use bit-error rate that has low correlation with by human perceived video quality. More advanced methods usually require too much processing power that cannot be obtained in handled mobile devices or intrusion into device firmware and/or hardware to obtain required data. However, recent research shows that channels throughput dedicated to some service (e.g. video streaming) can be tied to QoS perceived by an end-user indicator. This paper presents a research on impact of wireless channel parameters such as throughput and jitter on quality of video streaming. These wireless channel parameters can be easily obtained by monitoring IP level data streams in end-user's device by fairly simple software agent for indication of video streaming QoS. Ill. 5, bibl. 10 (in English; abstracts in English and Lithuanian).

Š. Paulikas, P. Sargautis, V. Banevičius. Belaidžio kanalo parametrų įtaka transliuojamo vaizdo kokybei // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 2(108). – P. 27–30.

Plintant mobiliojo ryšio sistemoms bei didėjant duomenų perdavimo spartai, daugėja ir multimedijos kategorijos paslaugų pasiūla. Taigi svarbu įvertinti šių paslaugų kokybę. Vaizdo transliavimo paslaugos vartotojai yra žmonės, todėl kokybė turi būti vertinama atsižvelgiant į žmogaus suvokiamą vaizdo kokybę. Dauguma vaizdo kokybės vertinimo metodų yra paremti klaidų atsiradimo tikimybe, kuri mažai susijusi su žmogaus suvokiama vaizdo kokybe. Pažangesniems metodams dažniausiai reikalingi dideli skaičiavimo pajėgumai, kurių neturi mobilūs įrenginiai, arba reikia įsiterpti į gamintojo programinę ir (arba) aparatinę įrangą, siekiant gauti reikiamus duomenis. Tačiau neseniai atlikti tyrimai rodo, kad kanalo pralaida skirta konkrečiai paslaugai teikti, gali būti susieta su vartotojo patirtos QoS indikatoriumi. Straipsnyje nagrinėjama belaidžio kanalo parametrų, tokių kaip pralaida ir šytavimas, įtaka transliuojamo vaizdo kokybei. Šie belaidžio kanalo parametrai gali būti nesunkiai gaunami galinio vartotojo įrenginyje įdiegtu QoS funkcija, stebint IP lygmens duomenų srautą. Il. 5, bibl. 10 (anglų kalba; santraukos anglų ir lietuvių k.).