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A hálózati QoS hatása a video-forgalomra – QoE és objektív metrikák korrelációja

The Effects of Network QoS to Video Traffic – Correlating QoE with Objective Metrics

Dr. Varga Pál – távközlési divízió vezető

The project was partially supported by the TÁMOP 4.2.2.C-11/1/KONV-2012-0001 project.
The project was implemented through the New Széchenyi Plan, co-financed by the European Social Fund.

Contents

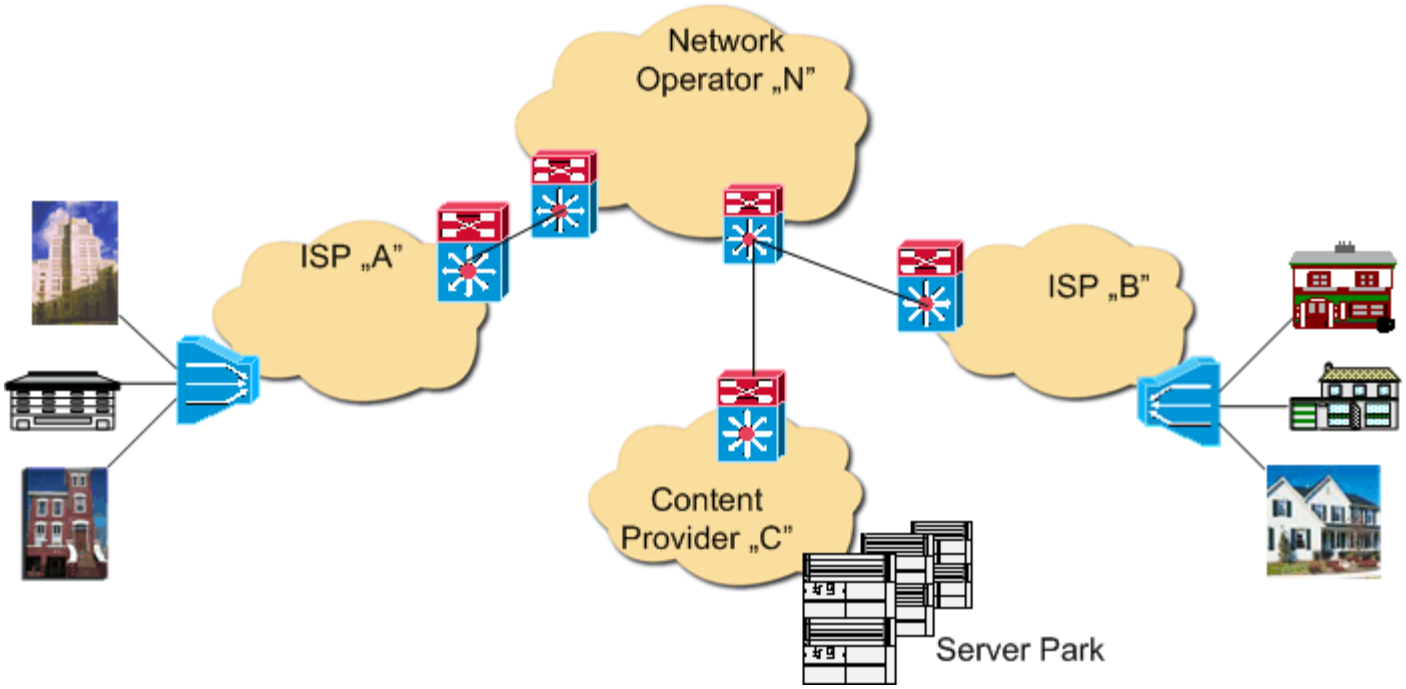
- QoE, QoS, SLA, KPI in General
- Problems of Video Quality
- Subjective metrics
- Objective metrics
  - PSNR
  - SSIM
  - VQM
- Case Study: an experiment on the correlation between QoE, QoS and Objective metrics

The main driver: user and subscriber demands

The user is satisfied with a service, if

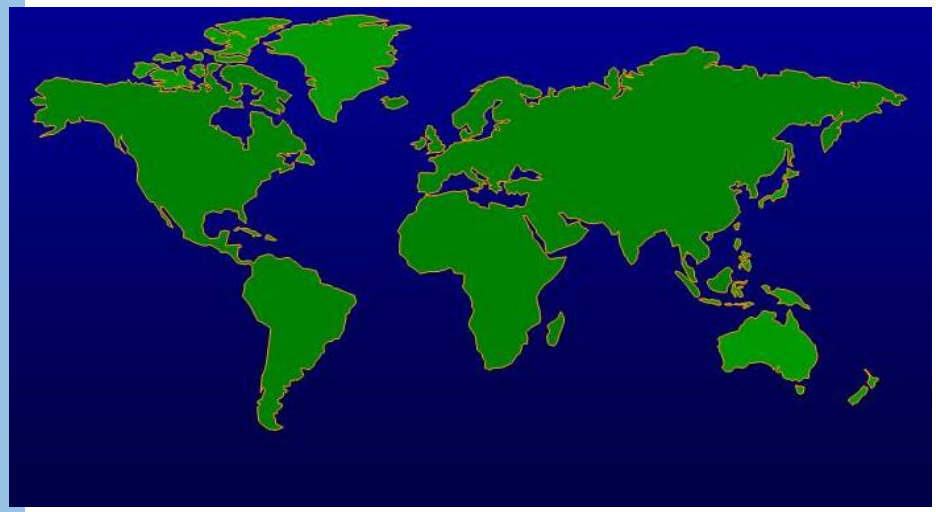
- ☑ his/her requests are **served**,
- ☑ the **quality** of the service is satisfactory,
- ☑ temporary problems become **solved** quickly.

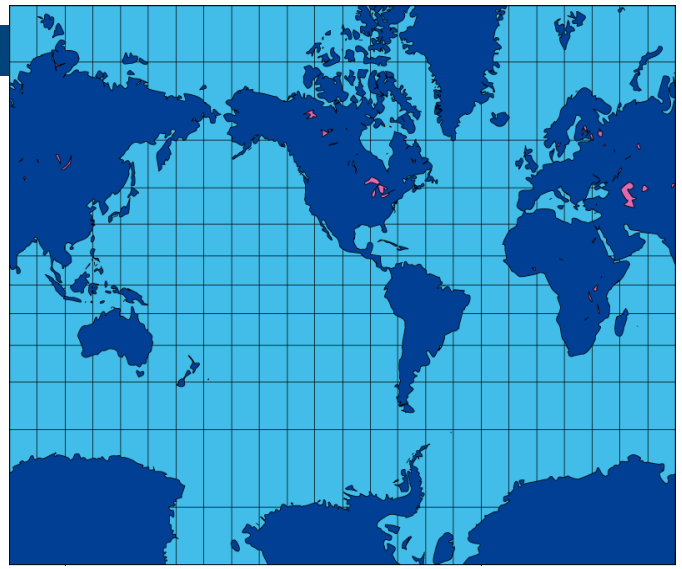
It is **irrelevant** from the users' point of view, who are the network and service providers in the path.



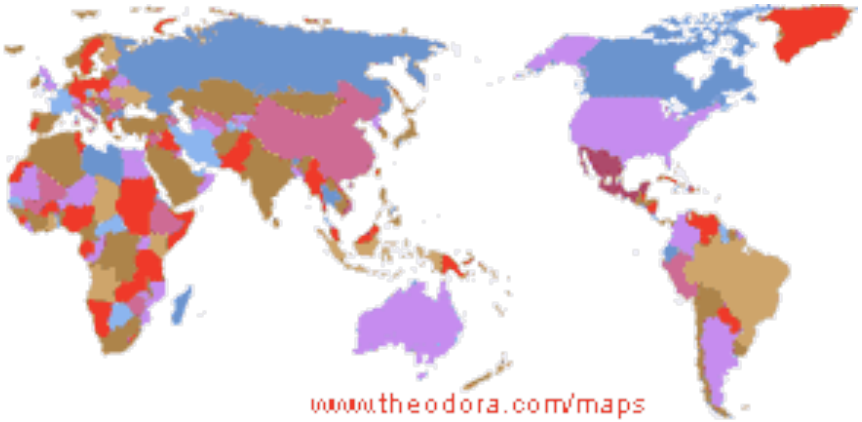
Local and global views

The World from Europe





The World from the Americas

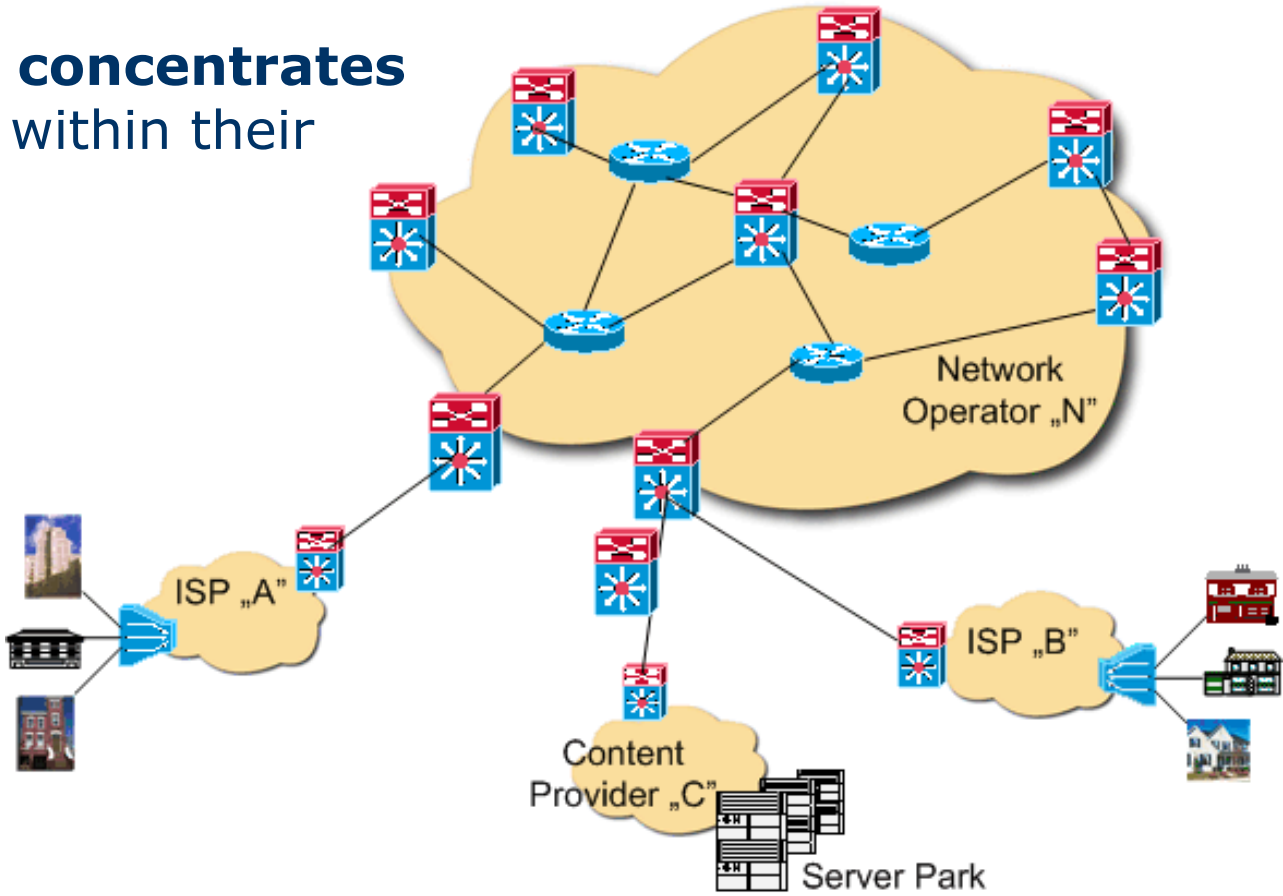


The World from the Pacific region

The „world” from the network provider’s point of view

The provider mainly **concentrates** on the performance within their responsibility.

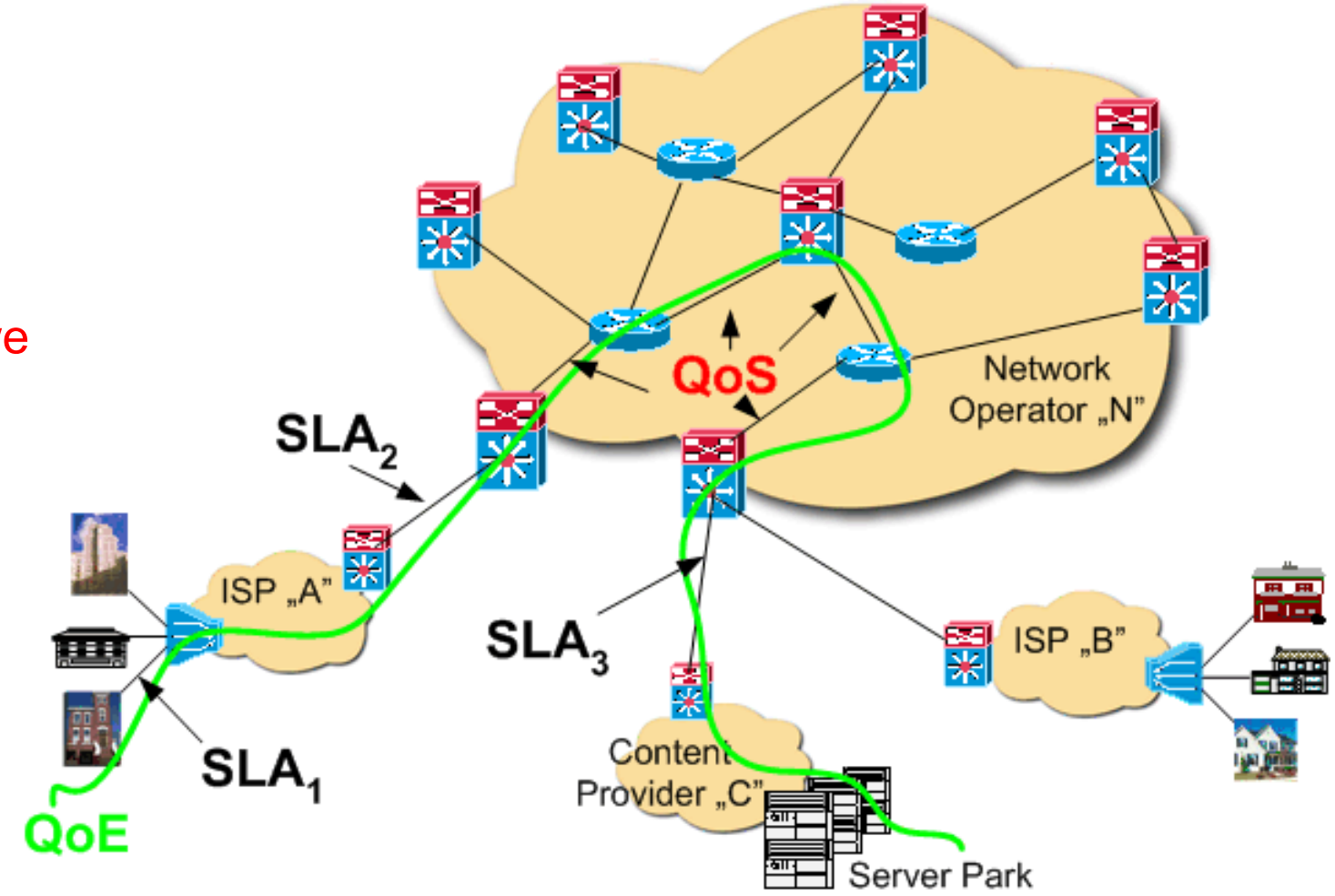
… in a lucky case!



SLA – QoS – QoE

…Is there a definite connection among them?

If not, then we need an effective service assurance system!



Video Quality

Video Quality Problems – a demonstration that hurts

Reference

Video Quality Problems – a demonstration that hurts

Blurry

Video Quality Problems – a demonstration that hurts

Added text

Video Quality Problems – a demonstration that hurts

Noisy

Video Quality Problems – a demonstration that hurts

Blocky

What is Image Quality Assessment?

- Image quality is a characteristic of an image that measures the **perceived** image degradation
- It plays an important role in various image processing application.
- Goal of image quality assessment is to supply quality metrics that can predict perceived image quality automatically.
- Two Types of image quality assessment
  - Subjective quality assessment
  - Objective quality assessment

Example of MOS score

- The MOS is generated by averaging the result of a set of standard, subjective tests.
- MOS is an indicator of the perceived image quality.

Mean Opinion Score (MOS)		
MOS	**Quality**	**Impairment**
5	Excellent	Imperceptible
4	Good	Perceptible but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

- MOS score of 1 is worst image quality and 5 is best.

Objective Quality Measure

- Mathematical models that approximate results of subjective quality assessment
- Goal of objective evaluation is to develop quantitative measure that can predict perceived image quality
- It plays variety of roles
  - To monitor and control image quality for quality control systems
  - To benchmark image processing systems;
  - To optimize algorithms and parameters;
  - To help home users better manage their digital photos and evaluate their expertise in photographing.

Objective evaluation

- Three types of objective evaluation
- It is classified according to the availability of an original image with which distorted image is to be compared
  - Full reference (FR)
  - No reference –Blind (NR)
  - Reduced reference (RR)

Objective Video Quality Metrics – MSE, PSNR, SSIM

- MSE – Mean Square Error

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (x_{ij} - y_{ij})^2$$

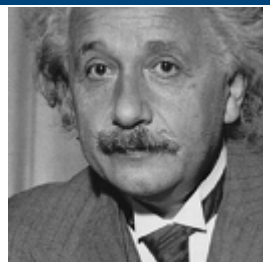
- PSNR - Peak signal-to-noise ratio

$$\mathrm{PSNR} = 10 \log_{10} \frac{L^2}{\mathrm{MSE}}$$

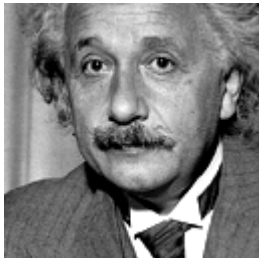
- SSIM (Structural Similarity Index) - based on human visual system.

$$SSIM = \frac{(2\overline{xy} + C_1)(2\sigma_{xy} + C_2)}{\left[(\bar{x})^2 + (\bar{y})^2 + C_1\right](\sigma_x^2 + \sigma_y^2 + C_2)}$$

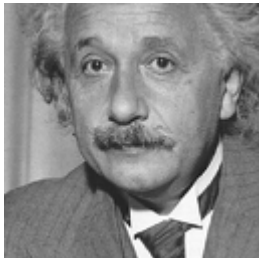
Original “Einstein” image with different distortions, MSE value



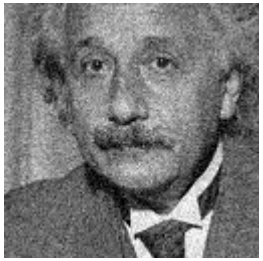
(a) Original Image MSE=0



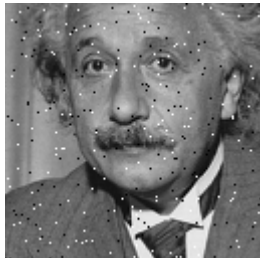
(b) MSE=306



(c) MSE=309

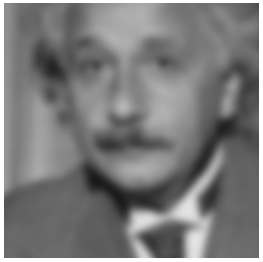


(d) MSE=309



(e) MSE=313

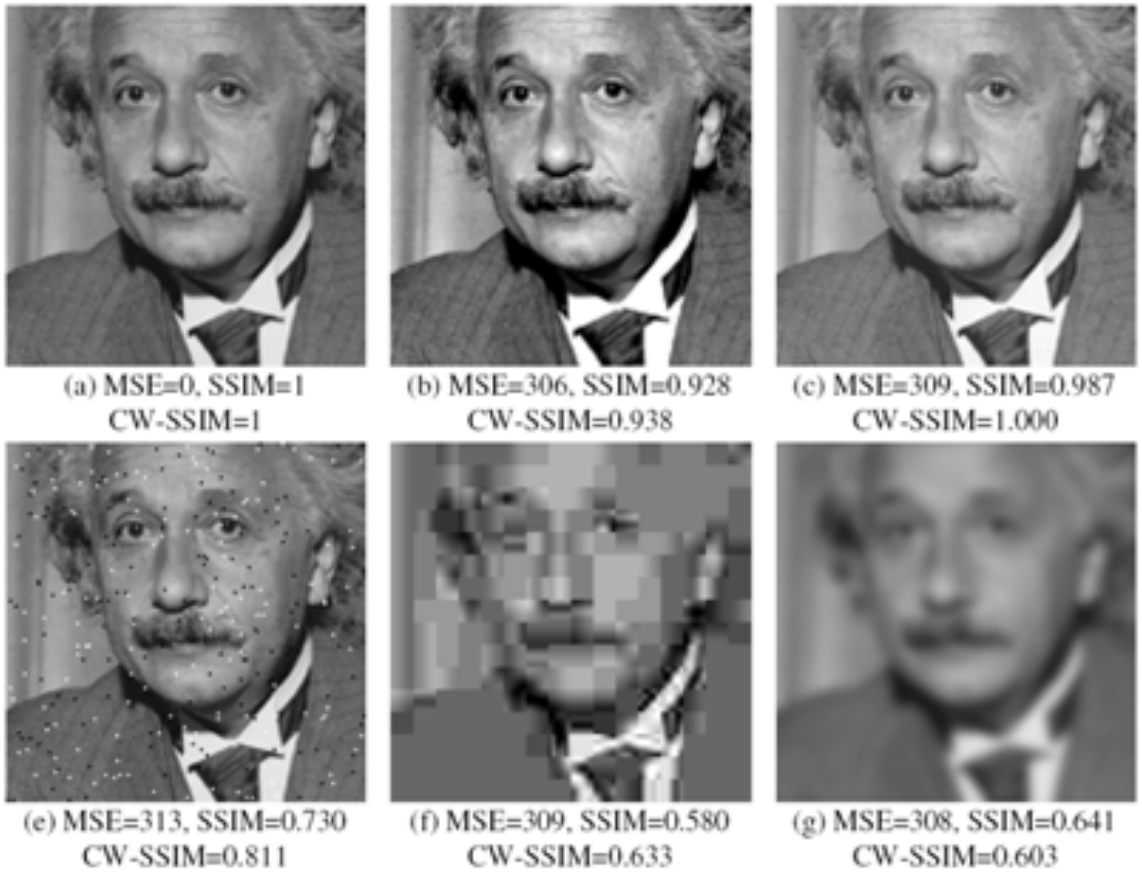
(f) MSE=309



(g) MSE=308

X. Shang, “Structural similarity based image quality assessment: pooling strategies and applications to image compression and digit recognition” M.S. Thesis, EE Department, The University of Texas at Arlington, Aug. 2006.

Example images at different quality levels and their SSIM index maps



(a) MSE=0, SSIM=1
CW-SSIM=1

(b) MSE=306, SSIM=0.928
CW-SSIM=0.938

(c) MSE=309, SSIM=0.987
CW-SSIM=1.000

(e) MSE=313, SSIM=0.730
CW-SSIM=0.811

(f) MSE=309, SSIM=0.580
CW-SSIM=0.633

(g) MSE=308, SSIM=0.641
CW-SSIM=0.603

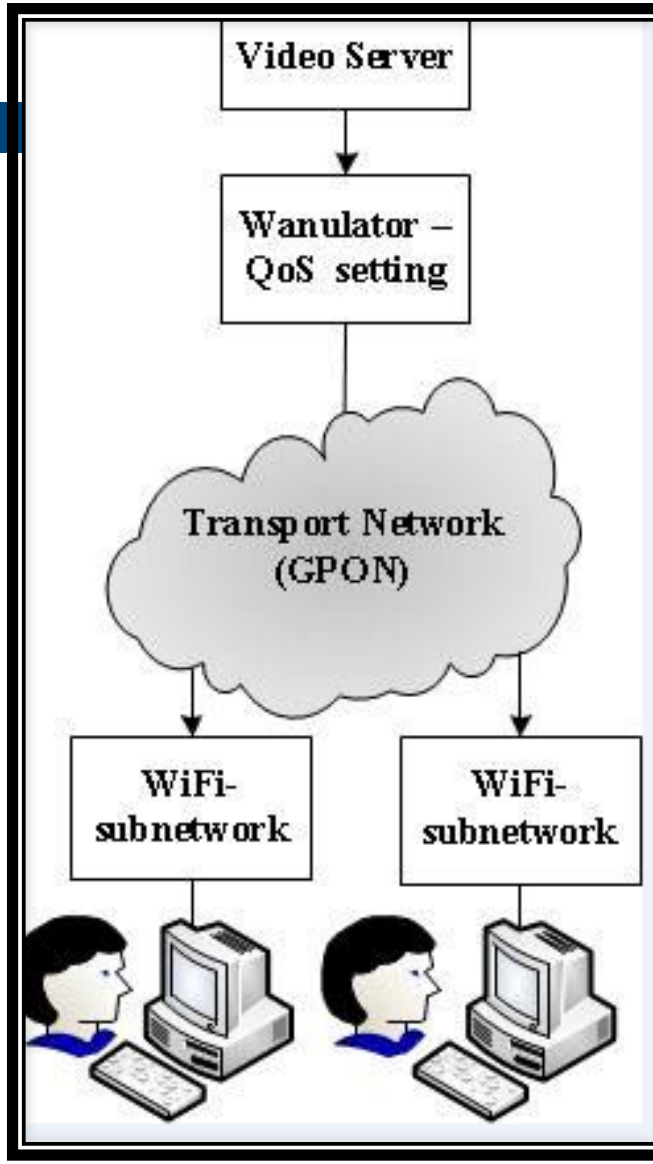
Objective Video Quality Metrics - VQM

- VQM – Video Quality Metric
  - **complex** algorithm using calibration and feature extraction steps
  - in the calibration phase it measures
    - contrast, brightness and spatial and temporal shift in the video
  - in quality features extraction phase, it
    - collects changes of spatial, temporal, chromatic properties
    - using Discrete Cosine Transformation (DCT)
  - In a next step it compares the extracted features of the original and reconstructed video to derive a quality parameter set.
  - In the final calculation the linear combination of the parameters are computed.

The effect of Network QoS on Objective and Subjective Video metrics

Measurement scenario

- Three types of results
  - volunteers watching and scoring video clips (MOS),
  - video quality metrics calculated for each clip (APSNR, OPSNR, VQM, and SSIM),
  - network QoS metrics (loss, jitter, and reordering).
- Aim-1: How do the changes of QoS parameters effect QoE (MOS)?
- Aim-2: How does QoS and QoE and Objective metrics correlate?
- Analysis of Video Streaming
- Screen-capture! (Fraps)



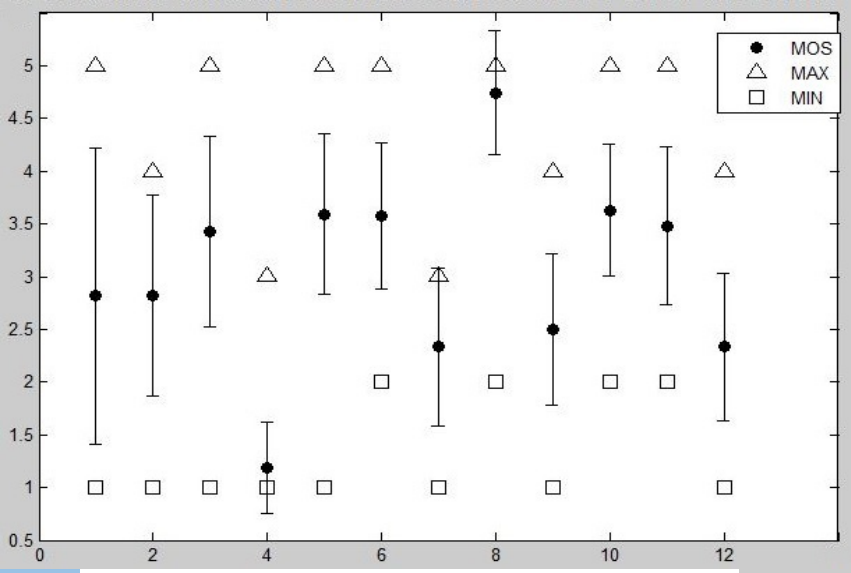
Measurement parameters

QoS metrics	480p	720p	1080p
jitter (ms)	2, 4, 6,… , 20	2, 4, 6,… , 20	1, 2, 3, … , 10
packet loss (%)	2, 4, 6,… ,20	2, 4, 6,… ,20	1, 2, 3, … ,10
reorder (%)	2, 4, 6,… , 20	2, 4, 6,… , 20	1, 2, 3, … , 10
combination of jitter, loss and reorder	2,4,..,10 2,4,..,10 2,4,..,10	2,4,..,10 2,4,..,10 2,4,..,10	0.2, 0.3, 0.4, 0.5, 1, 2

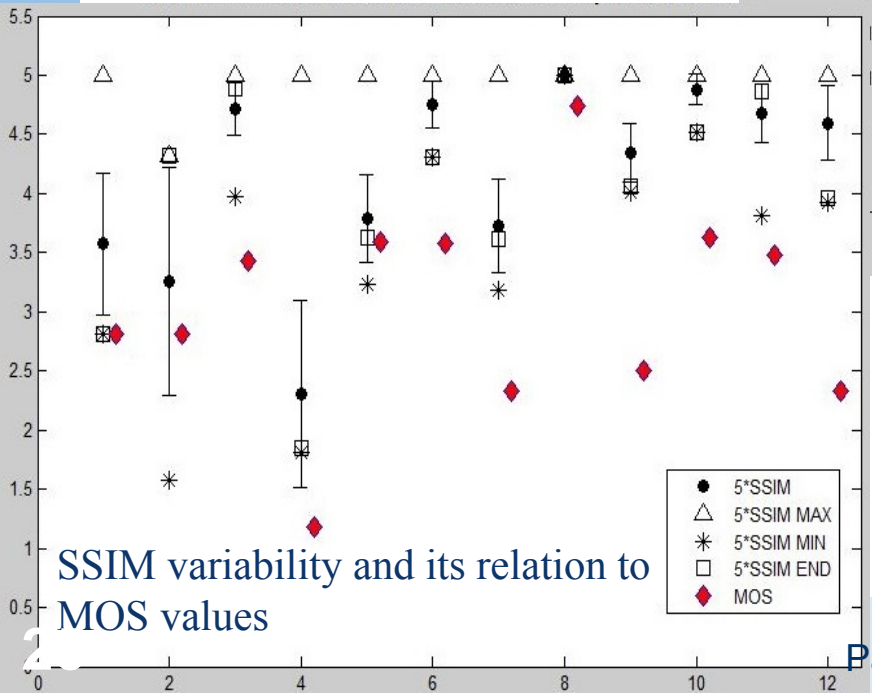
QoS degradation settings for the evaluated clips

		480p			720p			1080p	
Clip ID	J ms	L %	R %	J ms	L %	R %	J ms	L %	R %
1	0	0	4	2	2	2	0	1	1
2	2	4	4	0	6	0	0	6	0
3	2	0	0	4	0	0	1	0.2	0.2
4	0	16	0	0	0	10	0	1	2
5	4	2	2	2	4	4	4	0	0
6	0	4	0	2	0	0	0	0	2
7	4	0	0	0	8	0	1	0.4	0.4
8	0	0	0	0	0	0	0	0	0
9	0	6	0	4	2	1	0	2	0
10	2	2	2	0	0	4	1	0	0
11	2	4	2	2	1	1	0	4	2
12	0	0	6	0	0	6	0	0	4

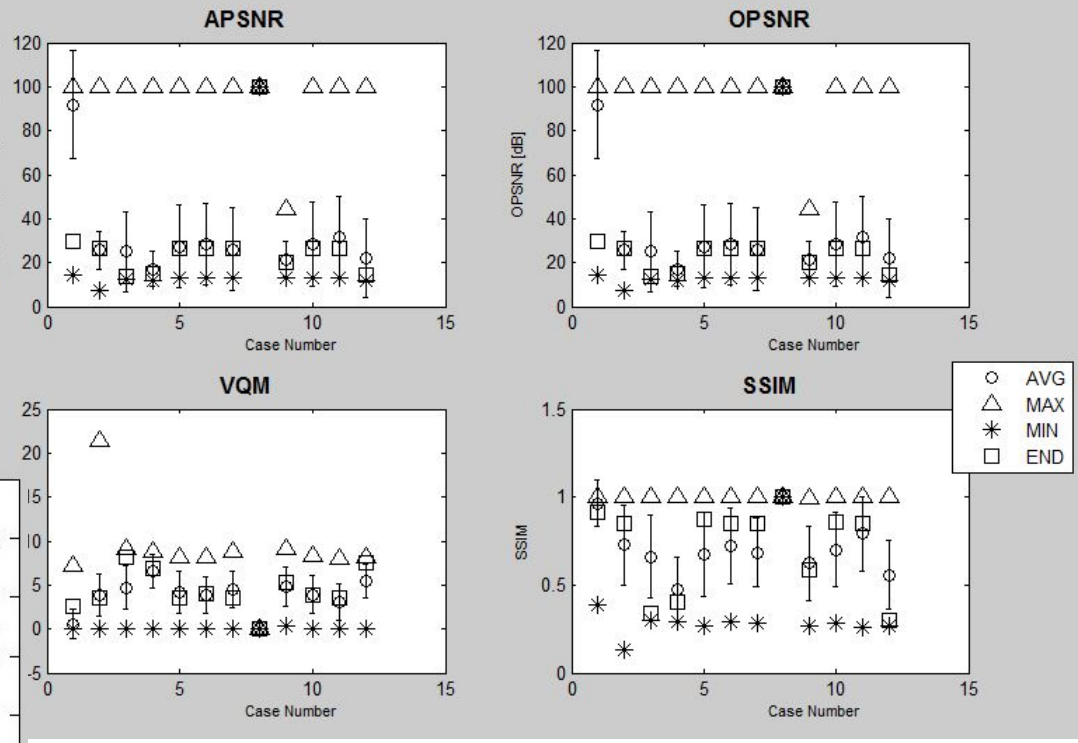
Evaluation – 480p



Human perception ratings for the 480p video set



SSIM variability and its relation to MOS values



Video quality metric results for the 480p video set

Some interesting findings

- Video #1 got the most various results
- Video #8 has scored high: avg. MOS 4.7 – but there were opinions for 2, too!

- SSIM correlates well with MOS – although humans „underrate”
- After watching a video of good quality (e.g. #8), they underrate the following ones even more
  - „memory effect”

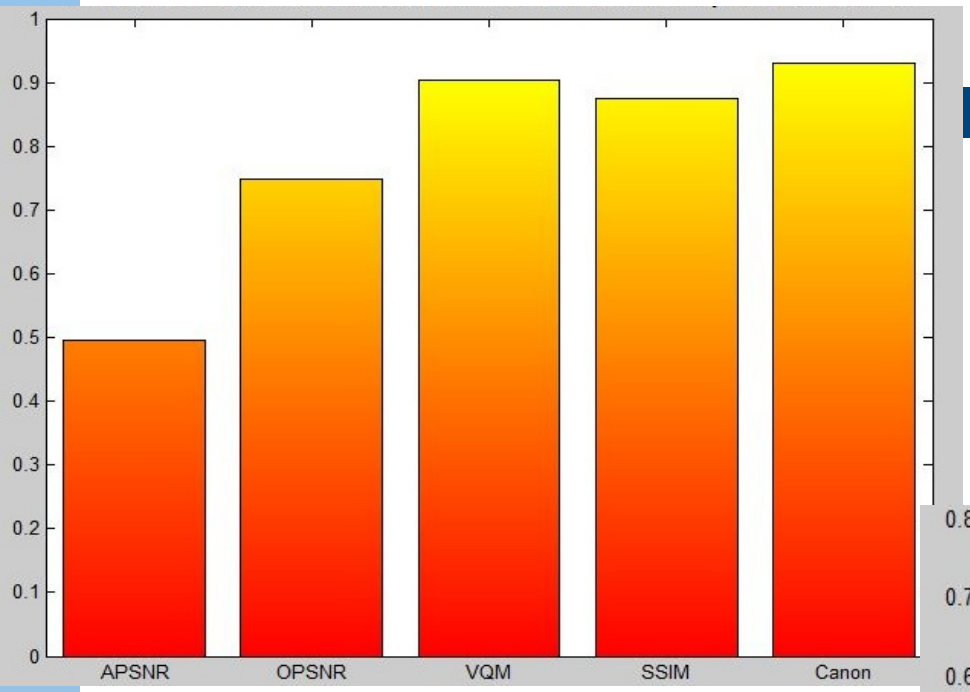
Some further interesting findings (with 720p)

- Generally, higher resolution videos are affected worse by the same QoS degradation than lower resolution ones
- Annoying errors around the beginning or around the end of the videos effect great underrating be humans
  - similar SSIM, but different MOS
- Overrating the videos after seeing a bad-quality ones
  - some videos have similar mean and “END” SSIM values
  - the video appeared *after* bad-quality clips – got much better MOS

Some even further even more interesting findings (with 1080p)

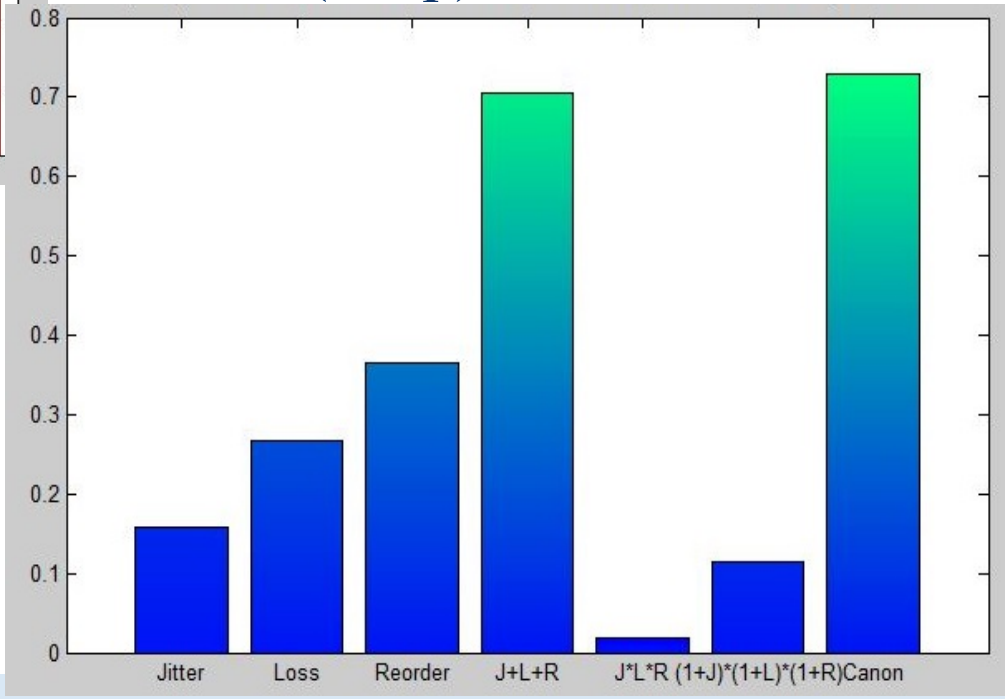
- Higher resolution – even worse MOS: caused by the same QoS degradation
- Under- and overrating phenomena – the memory effect – has more evidence here

Correlation of MOS and Objective metrics as well as QoS



Correlation of various, objective video quality metrics with MOS (720p)

Correlation of QoS metrics and MOS (720p)



Some findings on correlation

- APSNR and OPSNR show much lower correlation to MOS than the enhanced VQM and SSIM metrics
- sometimes (for 480p, 720p, 1080p cases) SSIM showed better correlation to MOS, other times VQM did; but their correlation was over 0.75 in all cases

- Simply correlating the jitter, loss or reorder values with the MOS value did not provide any focused result at all.
- Surprisingly, the naïve addition of “jitter+loss+reorder” did show high correlation with MOS for all three cases.
- A canonical representation – linear combination – on J, L, R can provide a slightly better match

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