Quality of Experience – More Than Just Another Buzzword?

Dr. Raimund Schatz, Dr. Peter Reichl
Telecommunications Research Center Vienna (FTW)

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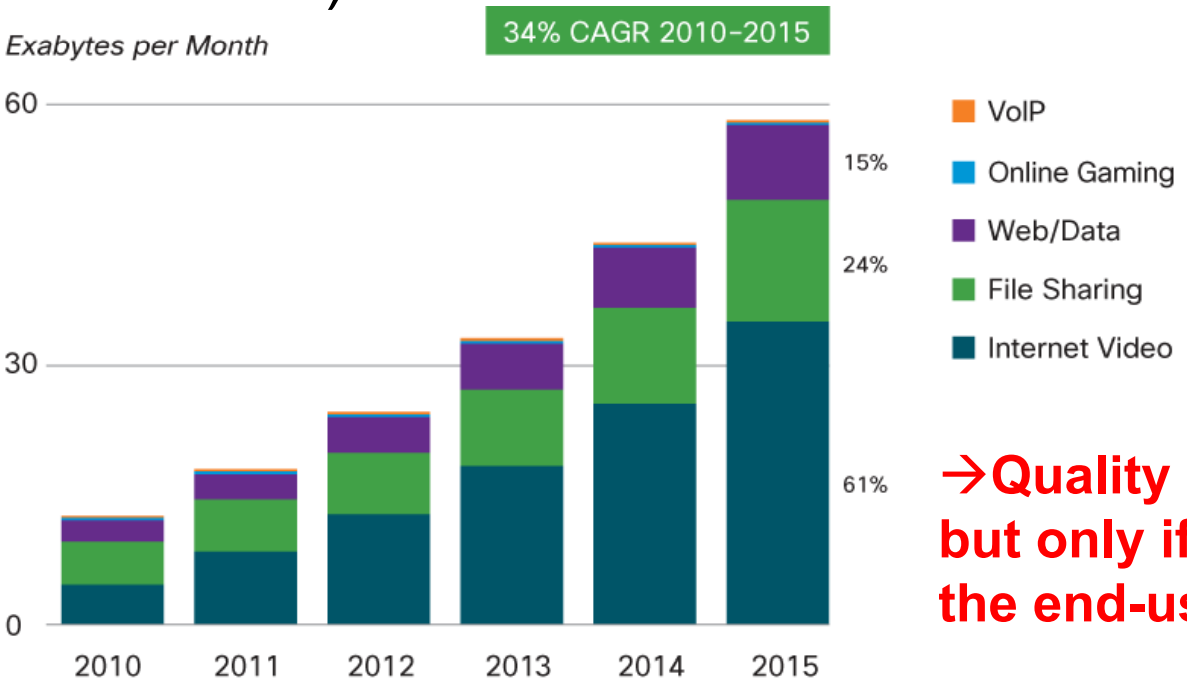
Motivation: Quality as Increasingly Important Factor

- Global explosion of traffic volume
- Intensifying competition among Telco‘s and ISPs

→ How to keep customers happy (while staying in business)?



→Quality as key differentiator, but only if it is also noticed by the end-user!

Global Consumer Internet Traffic Volume (Forecast).
Source: Cisco VNI 2011.

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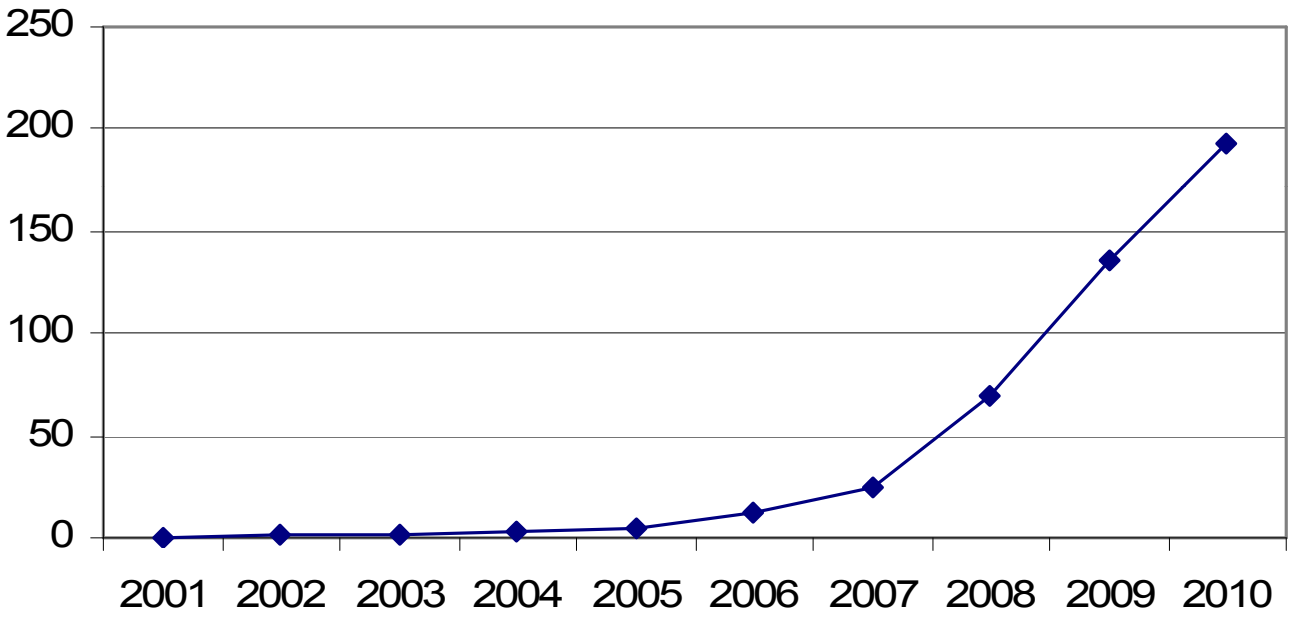
Quality of Experience as Hot Topic

QoE-related publications in IEEE database:



Number of conference or journal articles in IEEE database with “QoE” or “Quality of Experience” in metadata

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QoE: Some Definition Attempts

- QoE as reloaded buzzword:

  „QoE has been defined as an extension of the traditional QoS in the sense that QoE provides information regarding the delivered services from an end-user point of view" [Lopez et al. 2006]

- QoE as a usability metric:

  "QoE is how a user perceives the usability of a service when in use – how satisfied he/she is with a service in terms of, e.g., usability, accessibility, retainability and integrity" [Soldani 2006]

- QoE as a hedonistic concept:

  "QoE describes the degree of delight of the user of a service, influenced by content, network, device, application, user expectations and goals, and context of use" [Dagstuhl Seminar May 2009]

- QoE as the ultimate answer to life, universe and everything:

  "Quality of Experience includes everything that really matters"

  [Kilkki@LinkedIn 2008]

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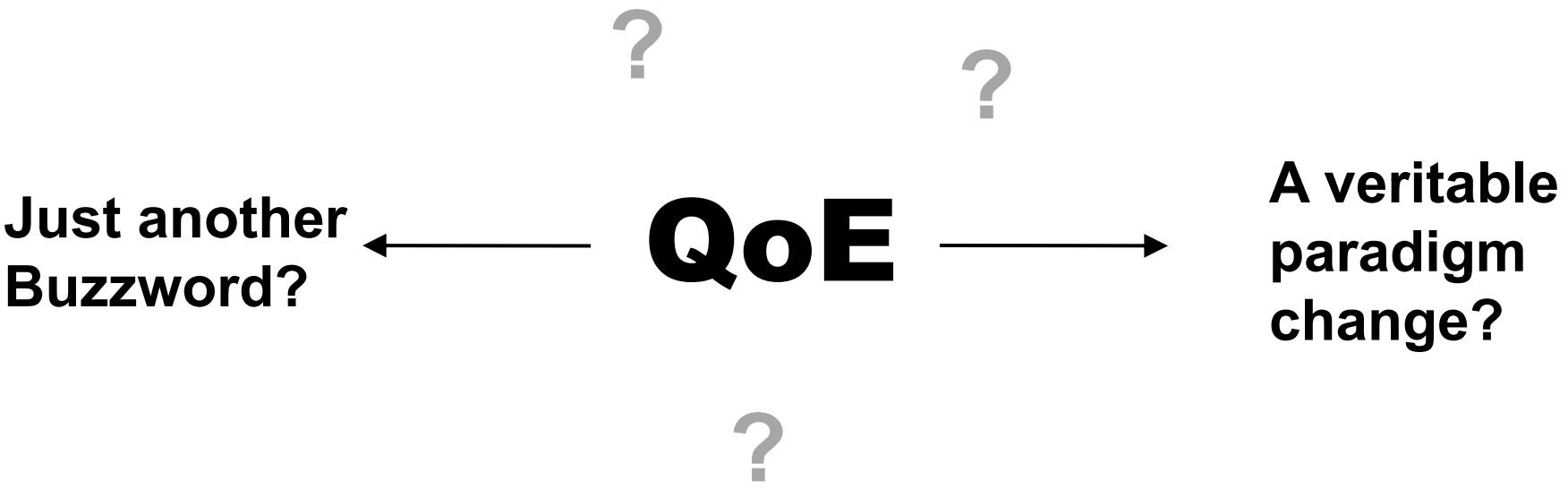
The Key Question



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Three Perspectives

Concept Evolution and Definition

QoE

Research

Practical Value and Applications

Note: due to time constraints, this talk focuses on the research perspective

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Perspective 1: Concept Evolution and Definition (in a nutshell)

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QoE as Response to QoS

The problem (almost ten years ago):

Quality of communication networks & services had been primarly understood and measured from a **technical** perspective:

DELAY JITTER BIT-RATE PACKET LOSS PACKET-ERRORS = QoS = Quality

BUT: does this approach adequately reflect the needs of end-users (= us)?

The underlying point:

It pays off to consider the **human being** as center of the universe …

→ **Perceived QoS, end-user QoS, etc.**

→ **Quality of Experience (QoE)**

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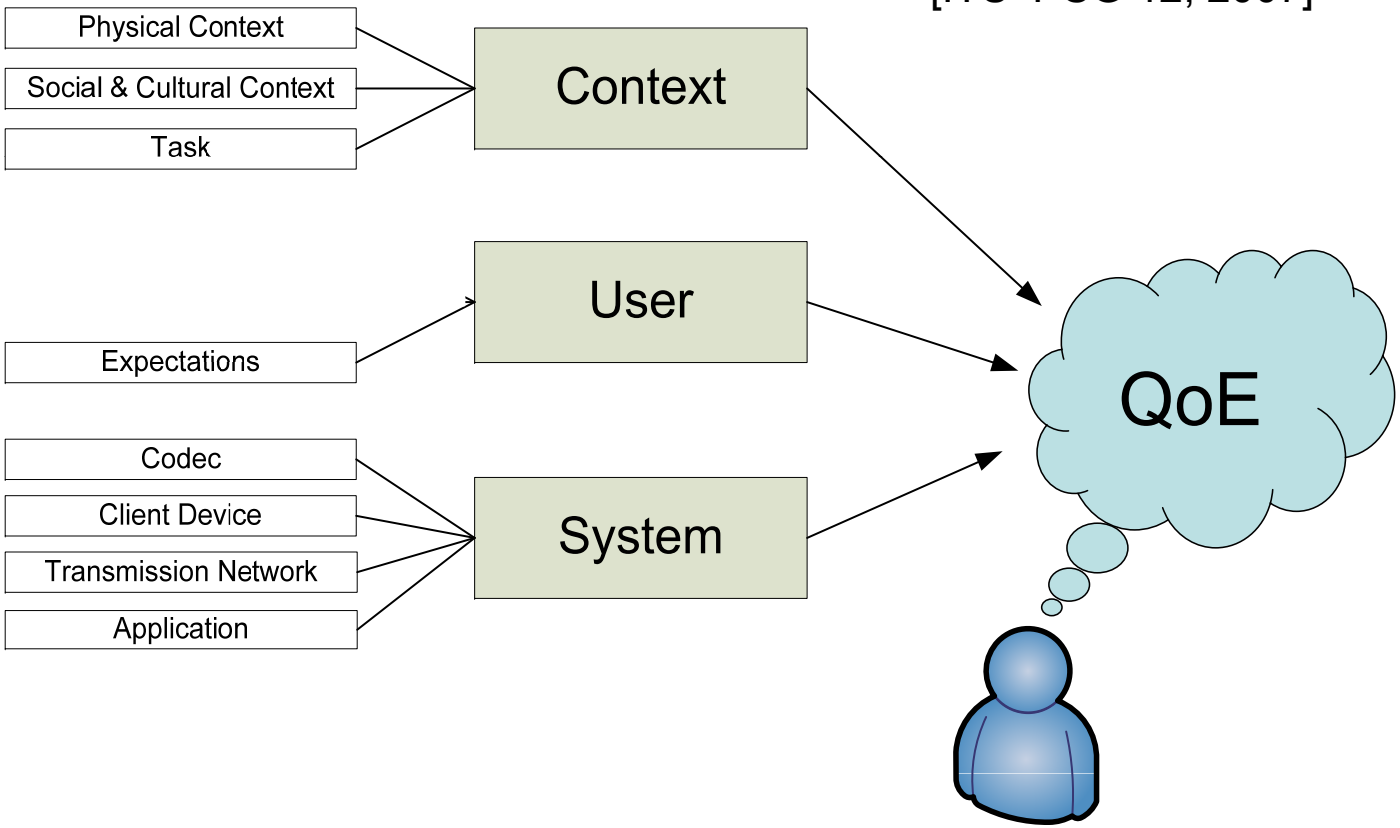
Looking back: Scope (D)evolution of QoS

- Current definitions of QoS:
  - *"ability of the network to provide a service at an assured service level"* [Soldani 2006]
  - *"capability of a network to provide better service to selected network traffic … described by the following parameters: delay and jitter, loss probability, reliability, throughput and delivery time"* [Markaki 2007]
- Original definitions (more than 10 years ago):
  - *"collective effect of service performance which determines the degree of satisfaction of a user of the service"* [ITU-T Rec. E.800, 1994]
  - *"a set of qualities related to the collective behavior of one or more objects"* [ISO/IEC 13236, 1998]
  - *"used to define the network's capability to meet the requirements of users and applications"* [Kilkki 1999]

In that respect, QoE has inherited the original agenda of QoS!

QoE: Most Widely Used Definition

"Overall acceptability of an application or service as perceived subjectively by the end-user …
… includes the complete end-to-end system effects …
… may be influenced by user expectations and context."
[ITU-T SG 12, 2007]



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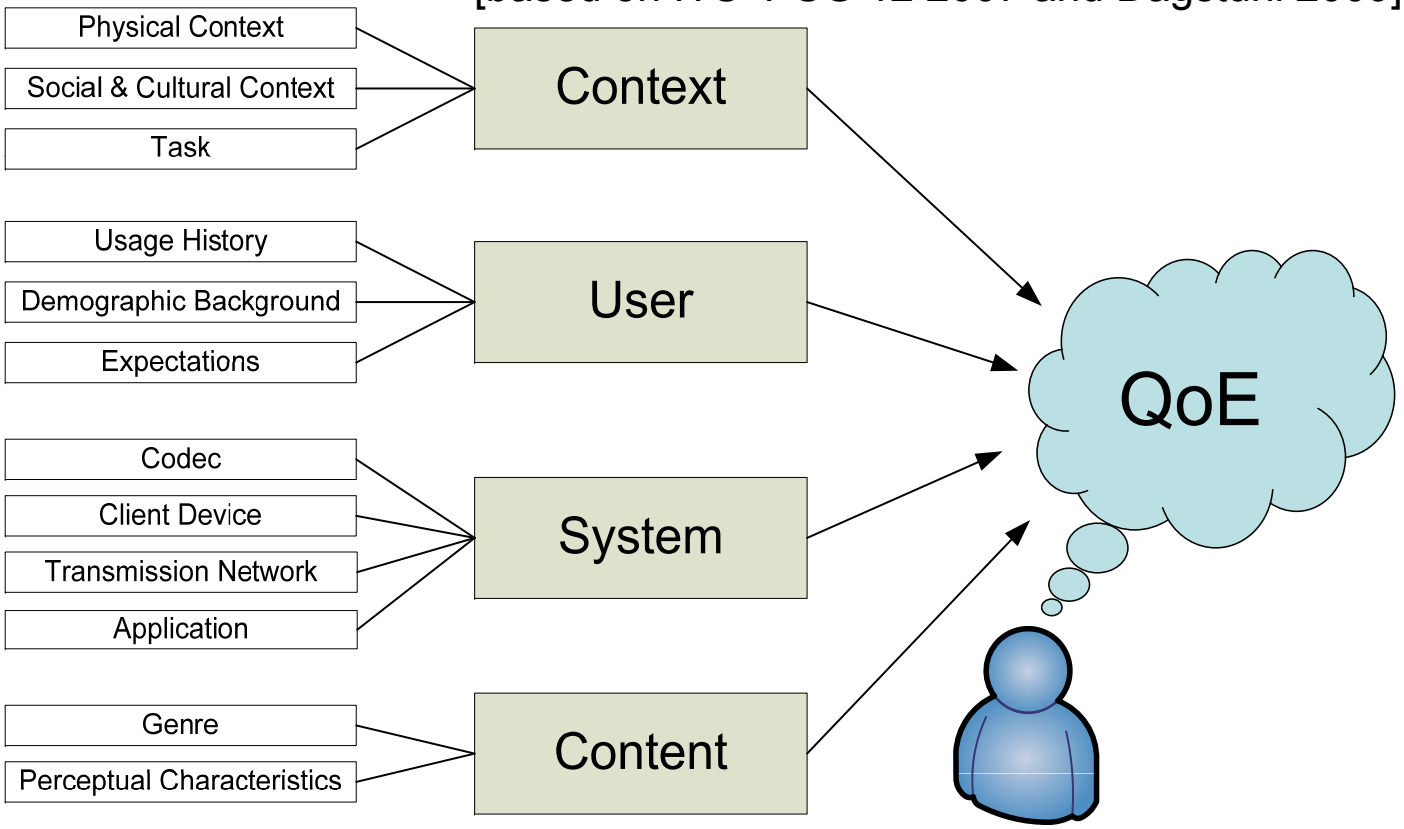
QoE: Definition Suggested Here

"Degree of delight or annoyance of the user of an application or service as perceived subjectively …
… includes the complete end-to-end system effects …
… may be influenced by user state, content and context."
[based on ITU-T SG 12 2007 and Dagstuhl 2009]



→ a holistic and user-centric understanding of quality

Perspective 2: QoE Research (by example)

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Key Characteristics: User-centricity and Interdisciplinarity

- User involvement = essential requirement

→ Interdisciplinarity is key to successful QoE research

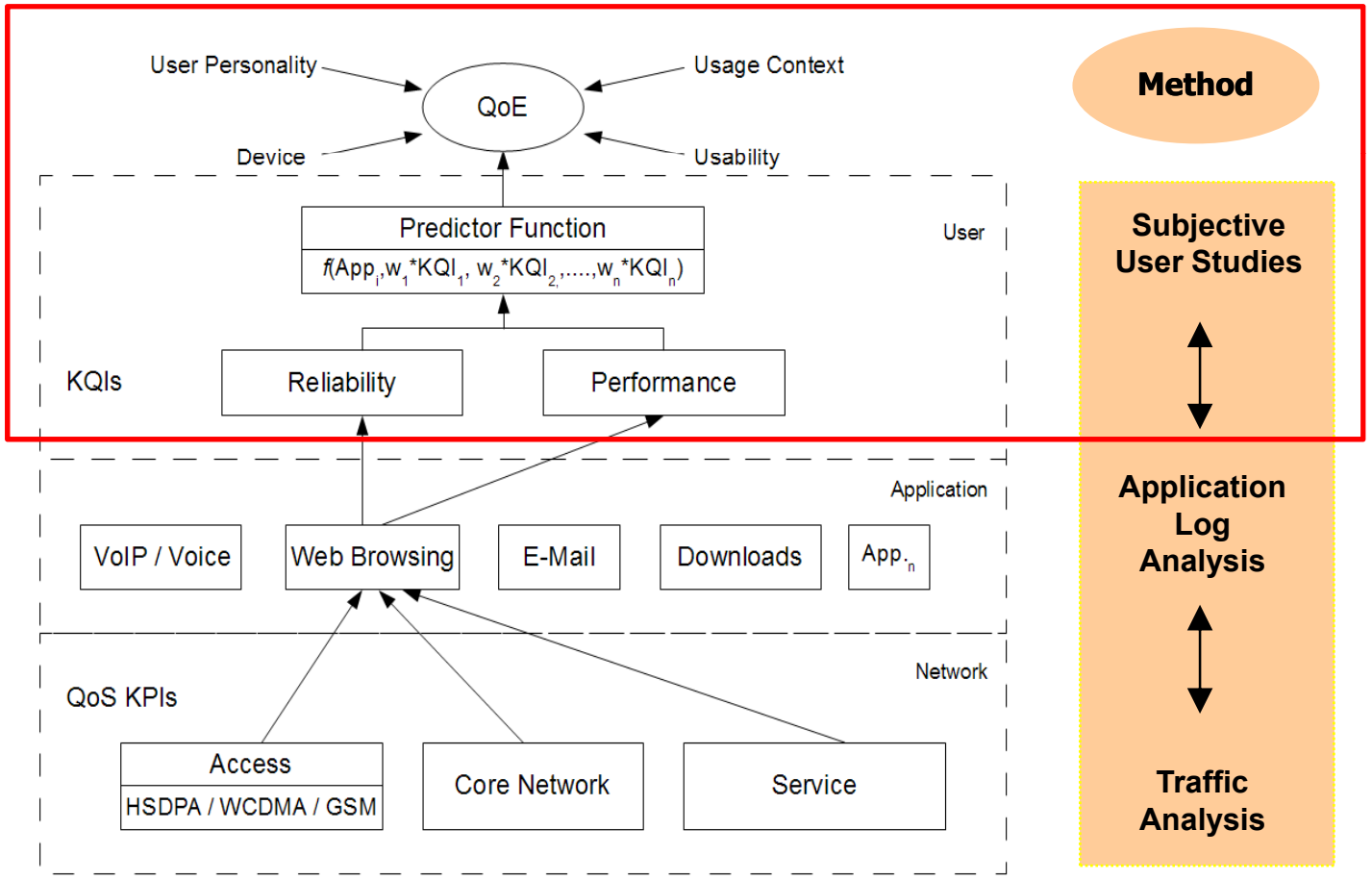
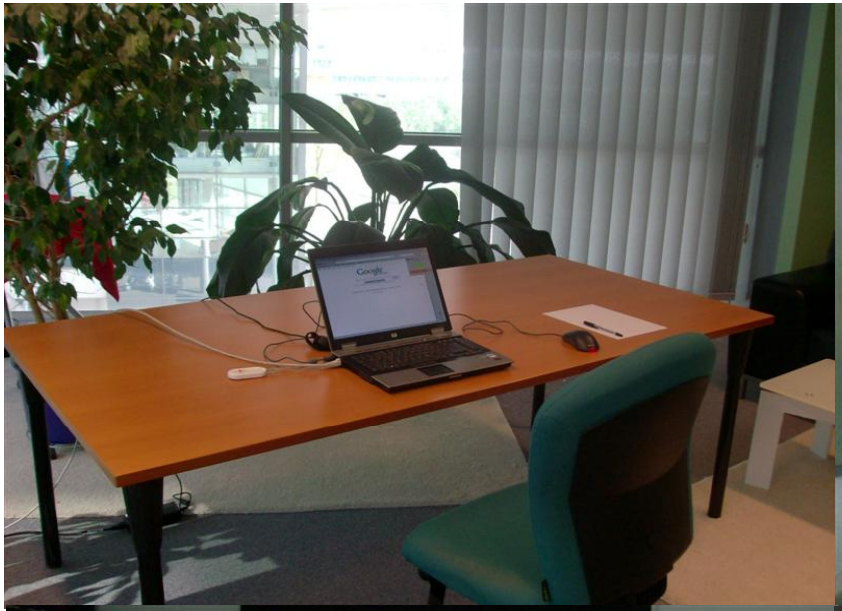
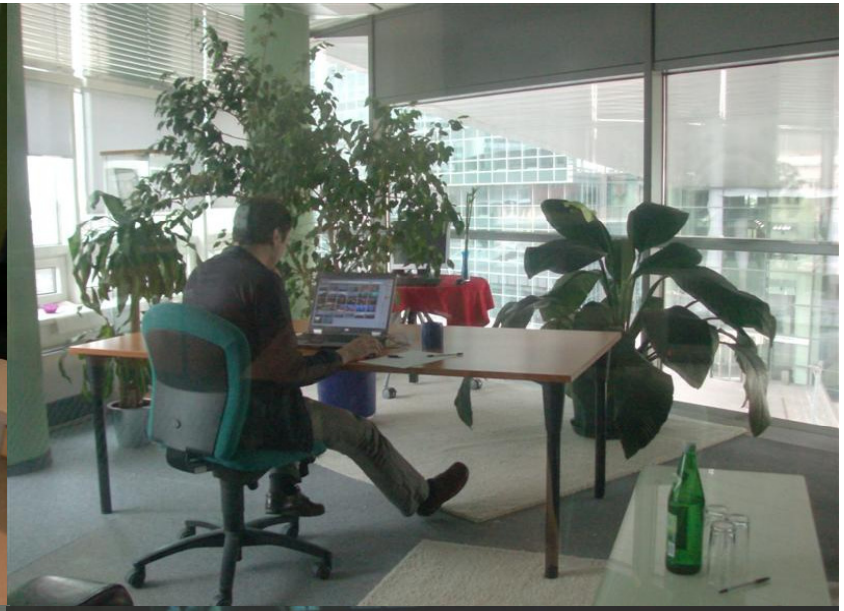
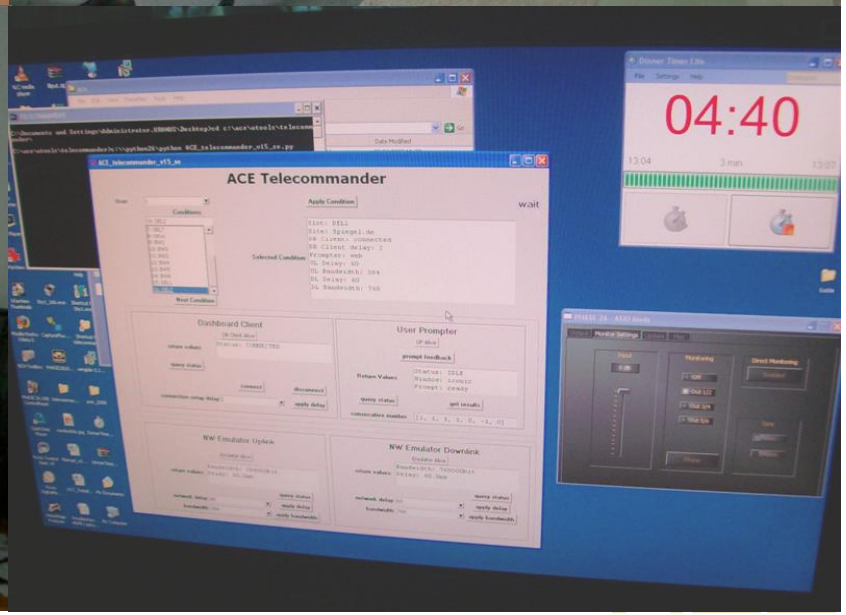


Illustration: QoE Lab User Studies at FTW







Example: Web Browsing QoE as f*(bandwidth)*

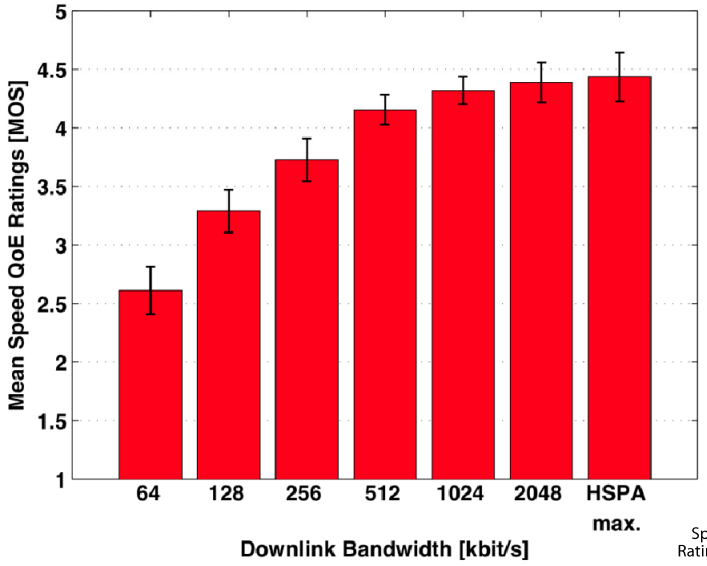
Findings:

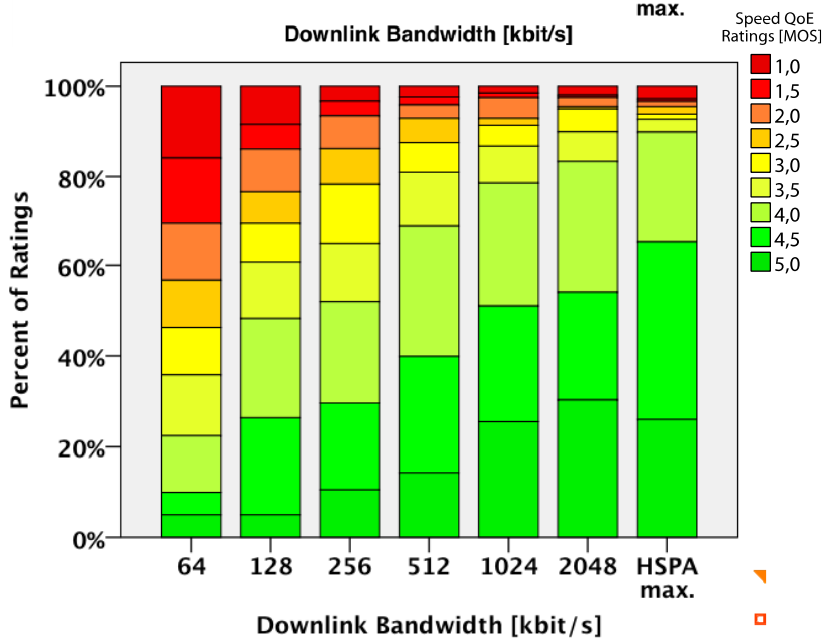
- Initially, MOS increases *logarithmically* with rising bandwidth

- *Saturation* around 1-2 Mbit/s dependent on web page type (weight, complexity)

- Note: diversity of user ratings reflects diversity in user perception

→ **In QoE, there is no "one-size-fits-all"**





MOS … Mean Opinion Score (1=bad, 5=excellent)

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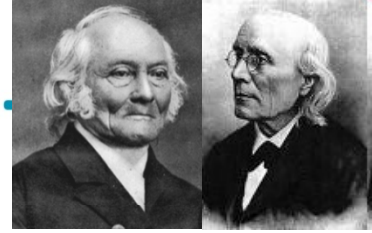
Towards Universal Laws for QoE …

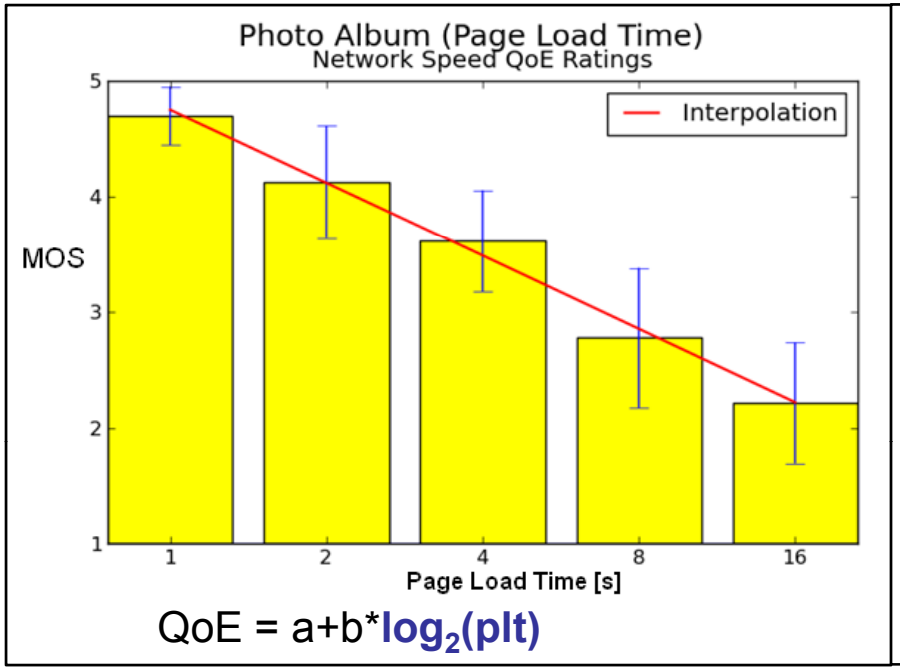


Psychophysics: Law of Weber-Fechner (1834)

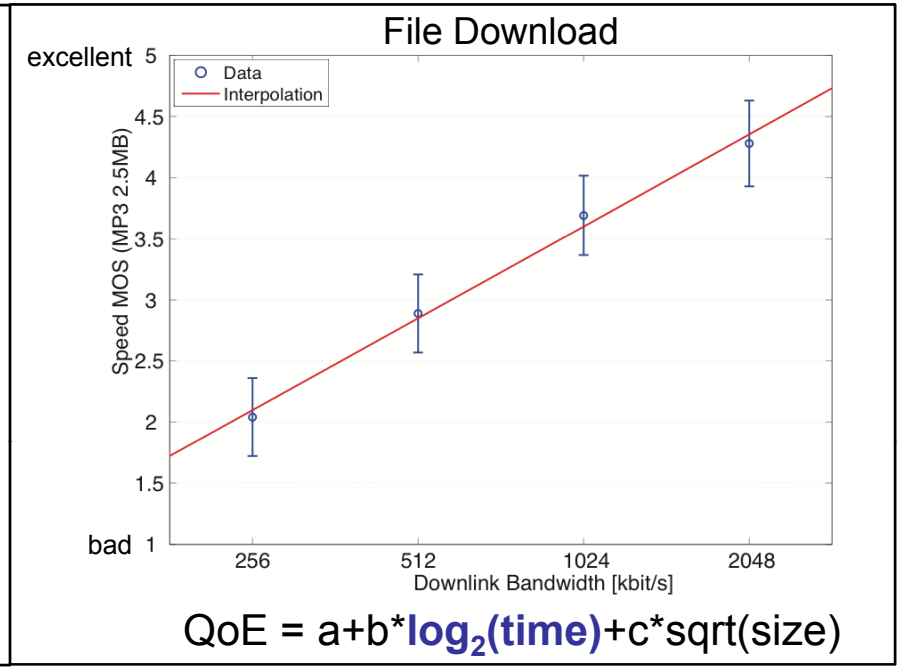
- Models **logarithmic** relationship between changes of stimulus S (e.g. weight) and perception P (e.g. heaviness)
- Mathematical expressions: $dP = k \cdot \frac{dS}{S} \longrightarrow P = k \cdot \ln \frac{S}{S_0}$
- Well-known principle e.g. for human vision, hearing, smelling, touching, numerical cognition …

→ Can we explain and model QoE phenomena on behalf of such universal laws and principles?

Towards Universal Laws for QoE …



QoE = a+b*$\log_2(plt)$



QoE = a+b*$\log_2(time)$+c*sqrt(size)

→ Interdisciplinary research challenges:

- Applicability of Weber-Fechner law to QoE
  - VoIP: log. impact of bitrate
  - Web: log. impact of waiting times (cf. Reichl, Tuffin, Schatz, 2011)
- Further laws explaining QoE?
  - VoIP: exp. impact of loss → IQX Hypothesis (cf. Hossfeld et al., 2008)

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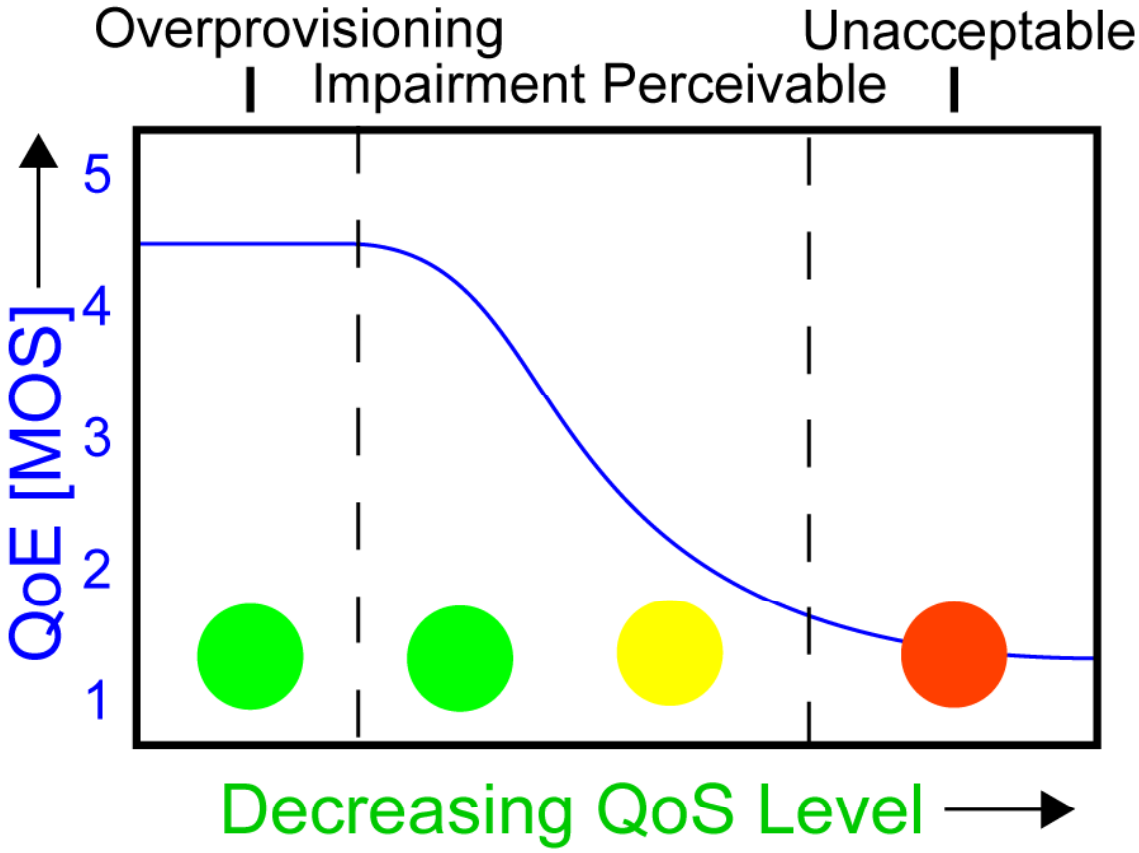
Typical Relationship between QoS and End-User Quality Perception



Non-linearities and saturation effects = characteristic for QoE

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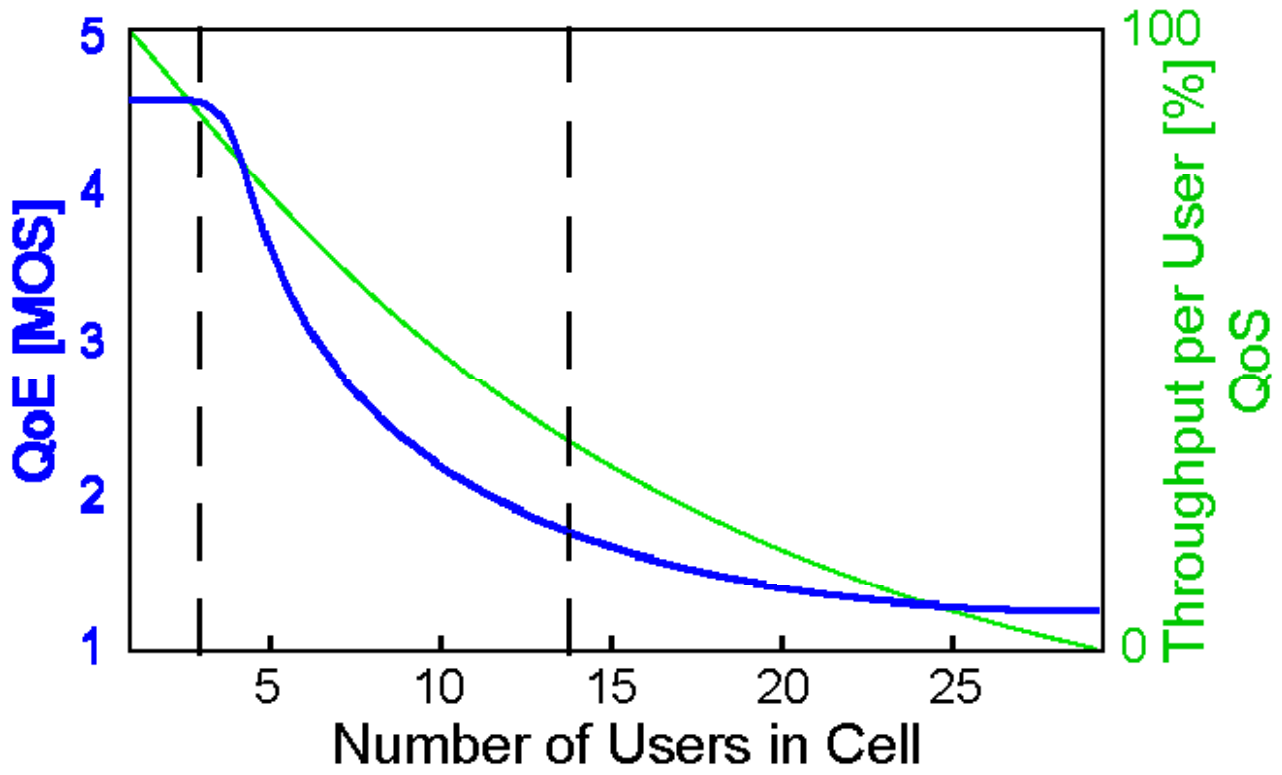
Example Scenario: QoE of a Mobile Video Streaming Service



- General point: **QoE != QoS**
- Impact: different approaches towards resource management (bandwidth allocation, monitoring, dimensioning) required, particularly for wireless networks, virtualized environments, etc.

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Perspective 3: Practical Value and Applications (in a nutshell)

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Practical Value: QoE Applications

- Fundamental relationships and laws of quality perception
  - QoE as f(System, User state, Content, Context)
  - Law of Weber-Fechner, IQX Hypothesis, etc.
- Guidelines for
  - Network planning and parametrization
  - Application, service or algorithm design
- QoE Models and Metrics for
  - Predicting QoE based on technical measurements
- QoE Measurement/Prediction Systems for
  - Monitoring and documenting health of system/network based on user-centric KQIs (page load time, stalling events)
- QoE-centric Network Management in order to
  - Ensure optimal end-user experience in economic ways
  - Distribute resources fairly among users

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QoE Applications: Afterthoughts

- Most of aforementioned categories already addressed by projects/products (but far from perfect):
  - E.g. Voice and IPTV video quality monitoring systems
  - E.g. ITU/ETSI/3GPP recommendations and guidelines

- Biggest challenge: QoE-centric Network Management
  - Huge obstacles: complexity, required interoperability & flexibility
  - Helpful: experimental testbeds, virtualization, etc.
  - Required: standardization and harmonization efforts →

→ Which concepts, architectures and technologies will truly help us realizing the vision of the user-centric network?
(for discussion!)

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Conclusions

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Conclusions

QoE …

… is definitely more than a buzzword

… is based on consequent integration of the end-user perspective

… requires interdisciplinary research efforts

… has strong economic and scientific potential

… *complements* QoS perspective rather than replacing it

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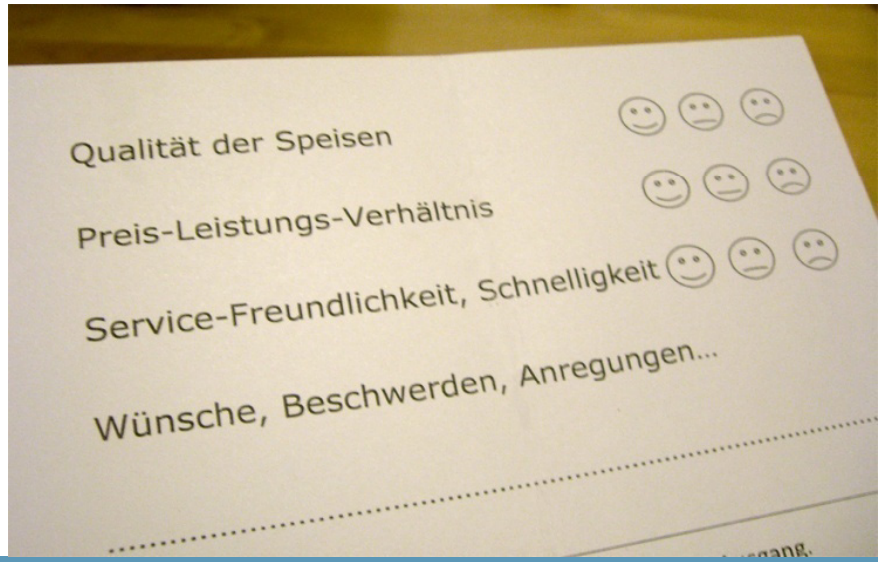
Thank You for Your Attention!

Dr. Raimund Schatz
FTW
User-centric Interaction and Communication Economics
Donau-City-Straße 1
1220 Vienna, Austria
schatz@ftw.at

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