IQX vs WFL:
Towards Fundamental Laws for QoE

Peter Reichl, Bruno Tuffin, Raimund Schatz
FTW Telecommunication Research Center Vienna
Université Européenne de Bretagne
INRIA Rennes Bretagne-Atlantique

COST IS0605 MC Meeting Rennes, May 9-10, 2011

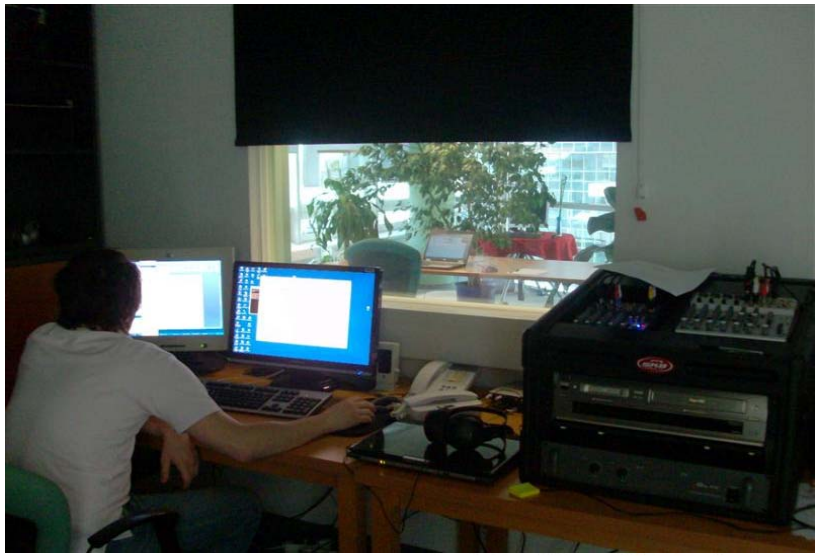
Agenda

- From Charging for QoS to Charging for QoE
- Logarithmic utility functions and the Weber-Fechner Law
- The IQX hypothesis: an exponential law for QoE
- Conclusions

From QoS to QoE

- Strong trend: back to user-perceived quality = „Quality of Experience“
- Most wide-spread 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, 2009]
- Example metric: Mean Opinion Score (MOS)

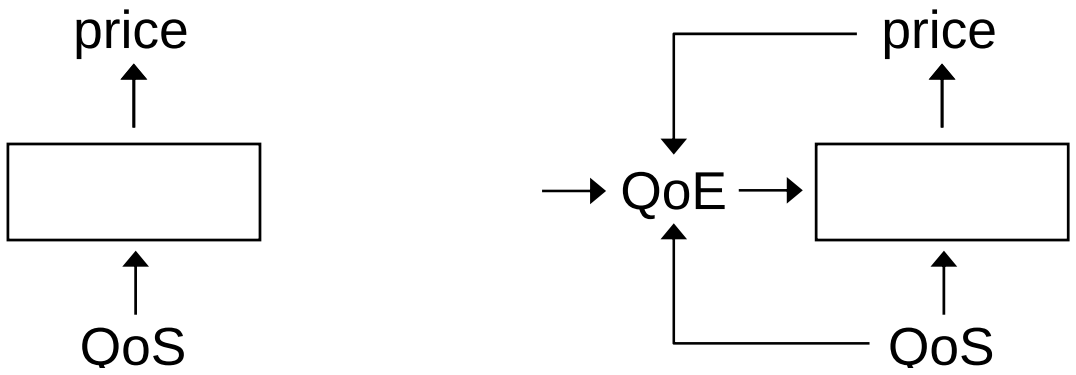
MOS Value	Quality
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad



- Methodological focus: user trials

From QoS to QoE: Charging Perspective

- A simple model



- Note: double role of charging under QoE
  - Contribution to user expectation
  - Result of quality evaluation
- Result: some sort of a fixed point problem

$$QoE = QoE(p) \qquad \text{(user experience)}$$

$$p = p(QoE) \qquad \text{(service tariff)}$$

Some Related Work: M3I

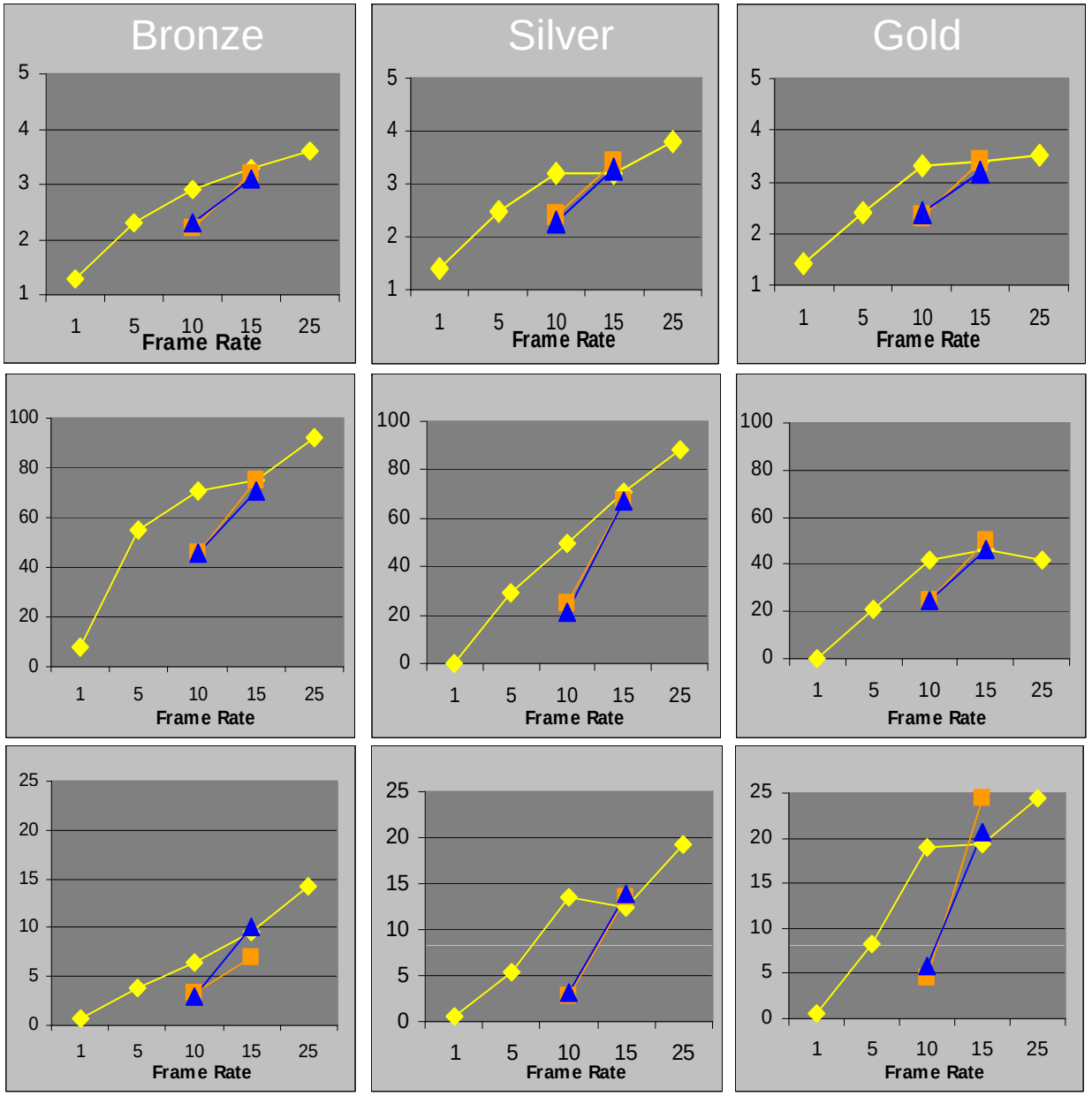
- M3I: Market-Managed Multiservice Internet (EU FP5)
- General idea: quantitative and qualitative investigation of user attitudes and behaviour in a dynamic/differential pricing environment for Internet services
- Different experiments conducted at BT in 2000/2001:
  - Experiment 1: effect of QoS stability on user attitudes
  - Experiment 2: effect of different network conditions on subjects‘ willingness-to-pay
  - Experiment 3: user behaviour while buying QoS
- User provide quantitative ratings of quality and service acceptability
- Additional interviews about qualitative attitude towards dynamic pricing

Experiment 1 (QoS Stability)

- Focus: impact of stable/variable QoS for multimedia service
- Test material: two 30 sec audio-video clips
- Manipulated parameters:
  - Video quality level (1/5/10/15/20 frames per sec) – number and degree of QoS changes (0/10/20 changes per min)
- Test method:
  - 5-grade MOS scale for quality rating, binary for acceptability
  - Willingness-to-pay response panel
- Main conclusions:
  - Quality perception tied to expectations, e.g. acceptability depends on subjective importance of task
  - Constant quality preferred over variable quality
  - People will pay for good quality (if perceived as such)

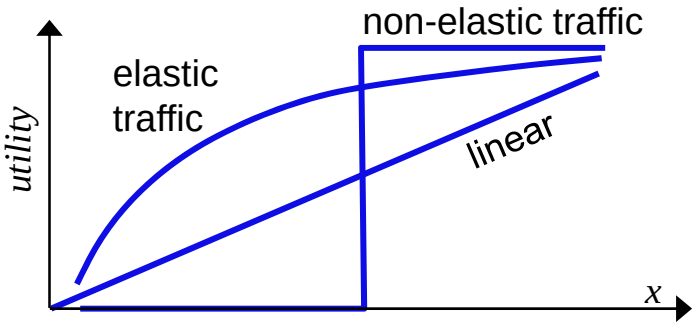
Experiment 1: Results

- Quality rating [MOS]:
- Acceptability rating [%]:
- Willingness-to-pay [pence per min]:



Utility and Willingness-to-Pay

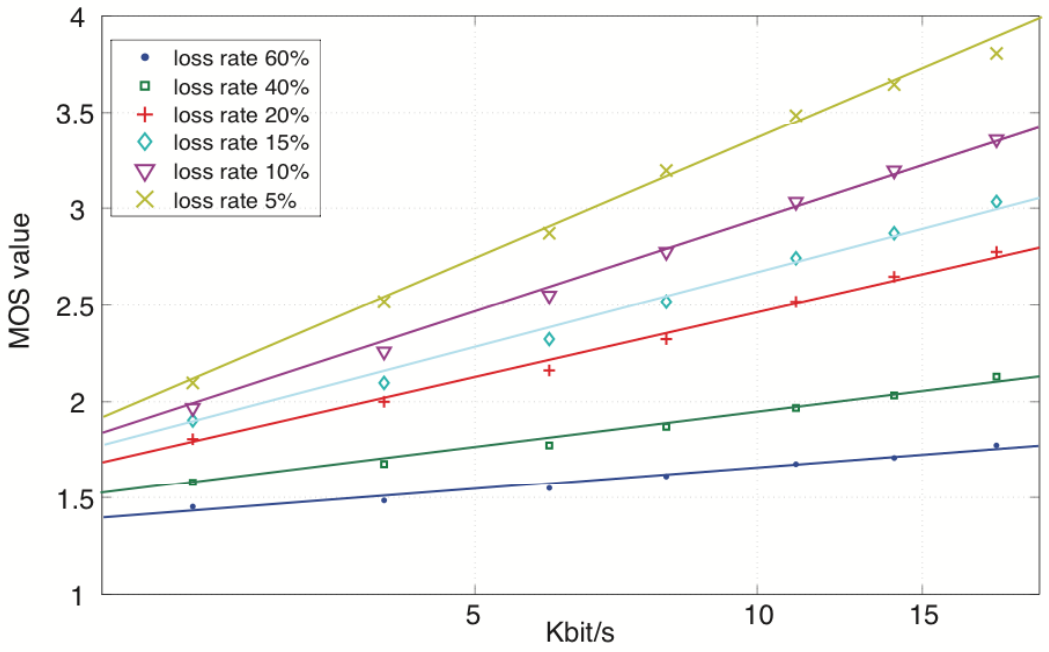
- Basic question: what is the „value“ of a resource/service for the end customer?
- Formal answer: $u_i(x)$:= utility function for customer i to receive service x



- Usual assumptions: monotonically increasing, concave, …
- Typical candidate: logarithm function
  - mathematically feasible
  - many nice properties, up to proportional fairness (Kelly et al.)
- But: isn‘t there a better justification??
- Inspiration: recent results from QoE trial evaluations

Example 1: VoIP Quality under PSQA

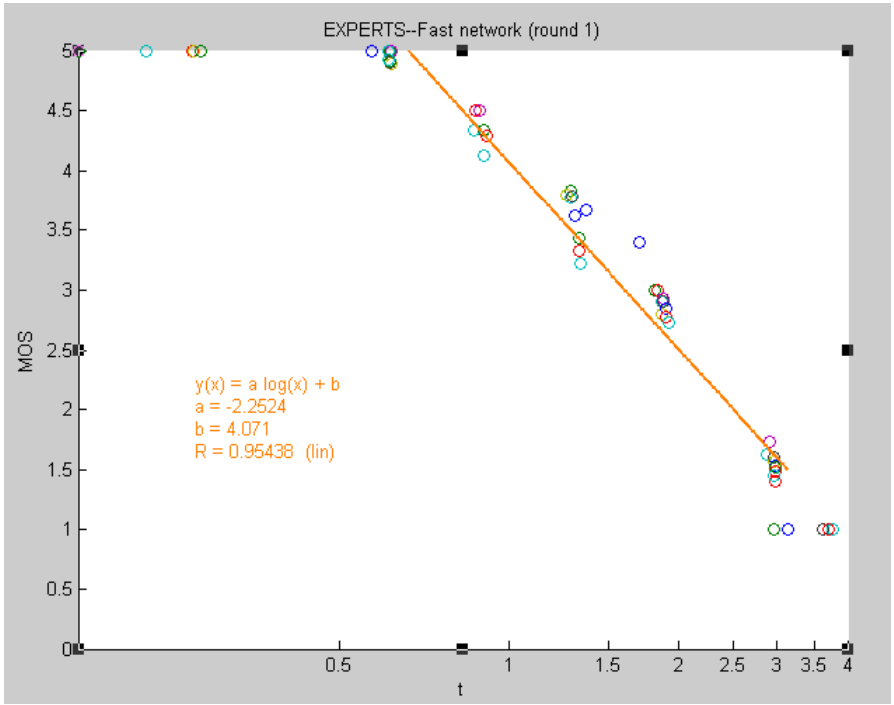
- Rubino, Varela et al.: Pseudo-Subjective Quality Assessment (PSQA)
  - automated evaluation tool for QoE of multimedia applications
  - basic approach: learning tool based on Random Neural Networks
- Scenario: Speex codec, bitrates varying from 2.4 to 24.8 kbps
- Results (logarithmic scaling of bitrate on x-axis):



[Rubino et al. 2007]

Example 2: QoE for Web Browsing

- Ibarrola, Liberal et al.: Web QoE under IP network latency
  - two-step web browsing task: access search page + results page
  - network conditions varied from very slow to very fast
- Result: end user satisfaction depends logarithmically on total session time (waiting time as function of network latency)

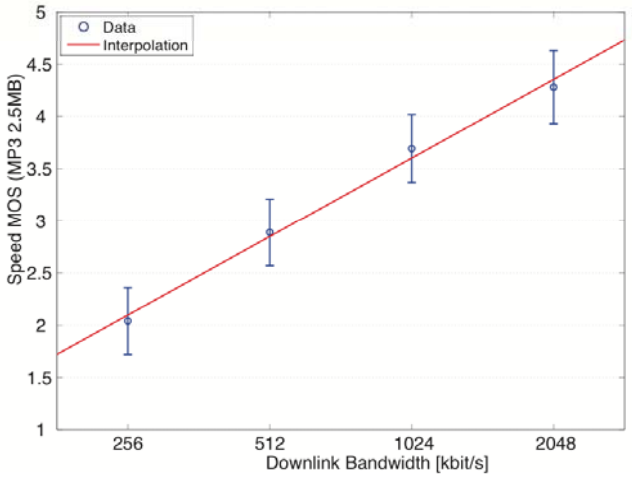


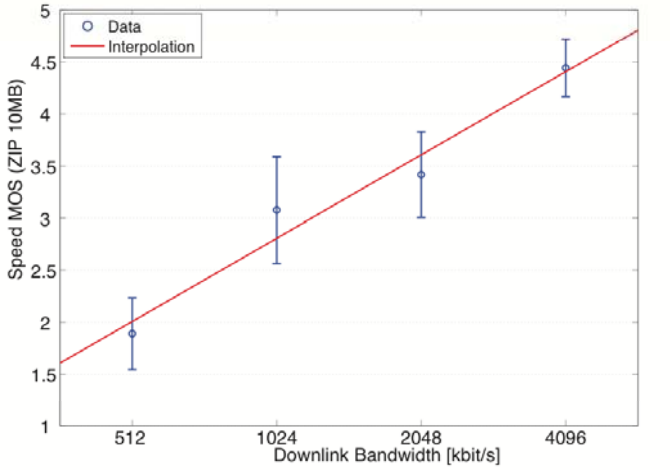
[Ibarrola et al. 2009]

Example 3: QoE for Mobile Broadband

ftw Creating Communication Technologies

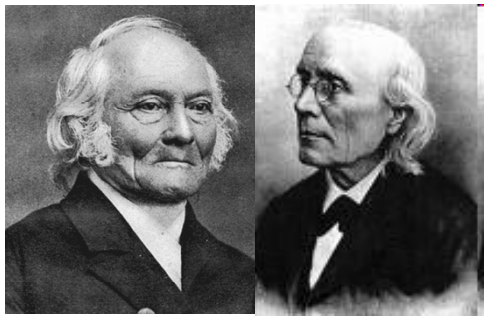
- FTW Project ACE: Advancing the Customer Experience
- Goal: predict user satisfaction with a service based on traffic data from a passive network monitoring tool
- File download scenario: users download single MP3 and ZIP files at different network speeds (256 – 4096 kbps)
- Result: logarithmic dependencies between bandwidth and MOS





Weber-Fechner Law

- Once upon a time (in fact 1834): E. H. Weber, G. Fechner and the birth of psychophysics



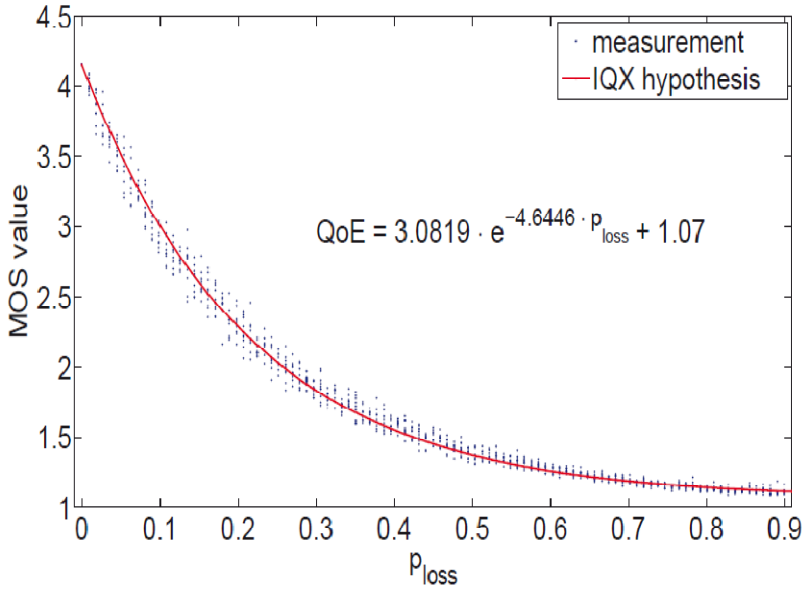
- Idea: operation of the human sensory system traced back to „just noticeable differences“
- Formally: differential perception dP directly proportional to relative change dS/S of physical stimulus

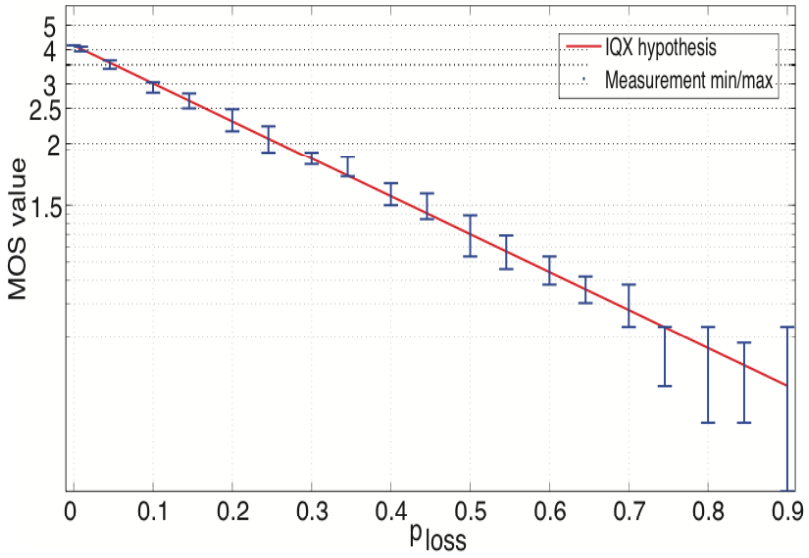
$$dP = k \cdot \frac{dS}{S} \quad \Rightarrow \quad P = k \cdot \log \frac{S}{S_0}$$

- Well-known principle for human vision, hearing, smelling, touching, even numerical cognition…
- QoE context: $\frac{dQoE}{dQoS} = \frac{k}{QoS}$

The IQX Hypothesis

- Scenario: QoE as function of single impairment factor (e.g. loss rate)
- Claim (Hossfeld et al.): negative exponential dependency
- Note: role exchange of stimulus (QoS) and response (QoE)
- Results (original and logarithmic scaling on y-axis):





Interpreting the IQX Hypothesis

- Basic assumption: subjective sensibility of the QoE is the more sensitive, the higher this experienced quality is

$$\frac{dQoE}{dQoS} = -\tilde{\beta} \cdot (QoE - \gamma)$$

- Analogy: experienced quality of restaurant

  → „single spot on the clean white table of a five star restaurant … appears much less severe in a beer pub“

- But: „experience correlation“ between loss rate scenarios???

Interpreting the IQX Hypothesis

- What the restaurant example perhaps really means (with p = price / willingness-to-pay / …):

$$\frac{dQoE}{dQoS} = \frac{dQoE}{dp} \cdot \frac{dp}{dQoS}$$

user experience

service tariff

- Important note: different role of QoS parameter
  - WFL: QoS as trigger
  - IQX: QoS as impairment
- Open question: Two sides of the same medal??

Conclusions

- Utility functions as key ingredient to economic modeling
- Recent results confirm logarithmic nature of QoE
- Most important examples: VoIP, mobile broadband
- The special case of the IQX hypothesis
- Next steps: further user trials (probably part of ETICS)

Thank You Very Much For Your Attention!

Questions & feedback always welcome:

reichl@ftw.at

Some References

- P. Reichl, B. Tuffin, R. Schatz: *Logarithmic Laws in Service Quality Perception: Where Microeconomics Meets Psychophysics and Quality of Experience*. Telecommunication Systems Journal (Springer), in print.
- ITU-T SG 12: *Definition of Quality-of-Experience*. COM12 - LS 62 – E, TD 109rev2 (PLEN/12), Geneva, Switzerland, 16-25 January 2007.
- P. Reichl, B. Tuffin, R. Schatz: *Economics of Logarithmic Quality-of-Experience in Communication Networks*. 9th Conference of Telecommunication, Media and Internet Techno-Economics (CTTE), Ghent, Belgium, June 2010.
- T. Hossfeld, D. Hock, P. Tran-Gia, K. Tutschku, M. Fiedler: *Testing the IQX Hypothesis for Exponential Interdependency between QoS and QoE of Voice Codecs iLBC and G.711*. 18th ITC Specialist Seminar on Quality of Experience, Karlskrona, Sweden, May 2008.
- M. Varela: *Évaluation Pseudo–subjective de la Qualité d'un Flux Multimédia*. PhD Thesis, University of Rennes 1, France, 2007.
- P. Reichl, S. Egger, R. Schatz, A. D'Alconzo: *The Logarithmic Nature of QoE and the Role of the Weber-Fechner Law in QoE Assessment*. Proc. IEEE International Conference on Communications (ICC'10), Cape Town, South Africa, May 2010.
- G. Rubino, P. Tirilly, M. Varela: *Evaluating Users' Satisfaction in Packet Networks Using Random Neural Networks*. ICANN (1) 2006: 303-312.