Dr. Pedro Casas

Telecommunications Research Center Vienna – FTW

Taming QoE in Cellular Networks

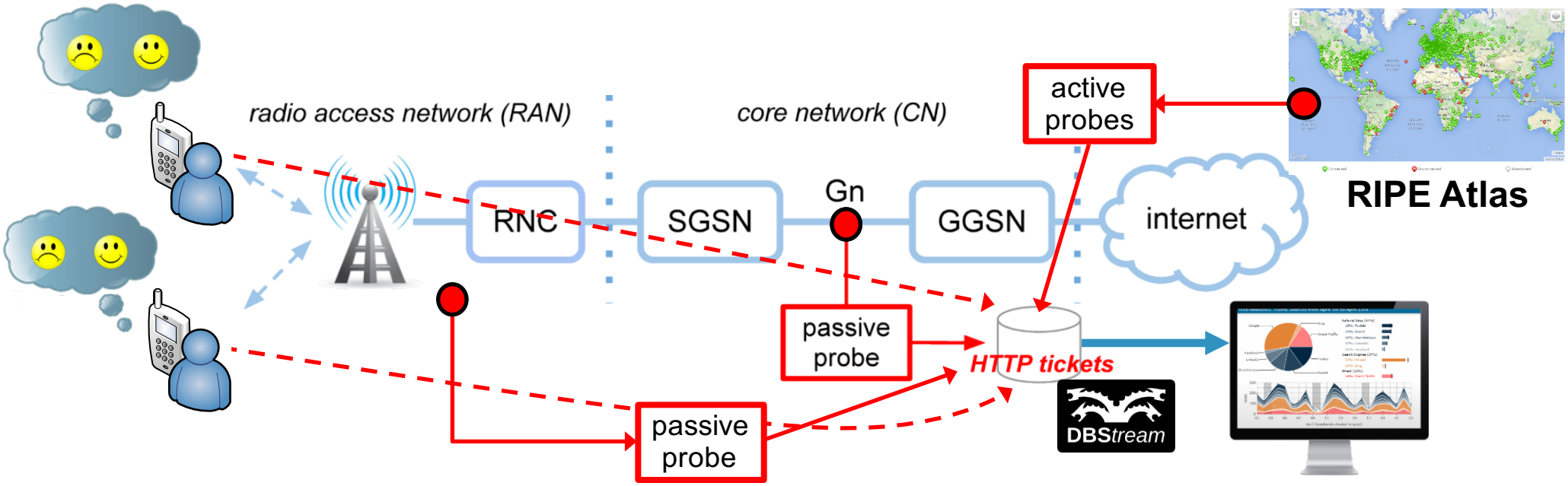
From Subjective Lab Studies to Measurements in the Field

P. Casas, *B. Gardlo, M. Seufert, F. Wamser, R. Schatz*

RAIM 2015

October 31, 2015, Yokohama, JP

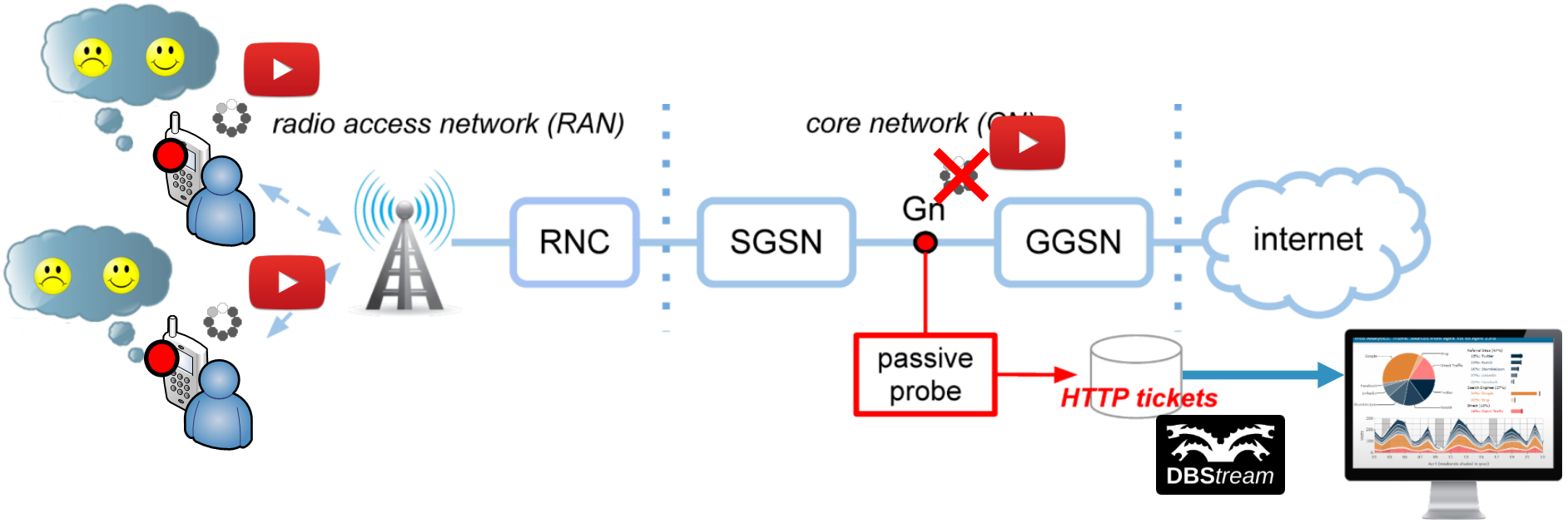
QoE in Cellular Networks: the Context (1/2)



- **Passive DPI Monitoring and Analysis System** developed by FTW (including Big Data Analytics platform for on-line analysis - **DBStream**)
- **Deployed at the core of a EU nationwide cellular network since 2008**
- From **Gn(s)** to **radio interfaces** and others, also including **distributed active measurements** (RIPE Atlas)
- **QoE** is becoming **highly relevant to celular ISPs** → potential guiding paradigm for 5G
- **Crowdsourced-monitoring: adding passive measurements @end-devices**

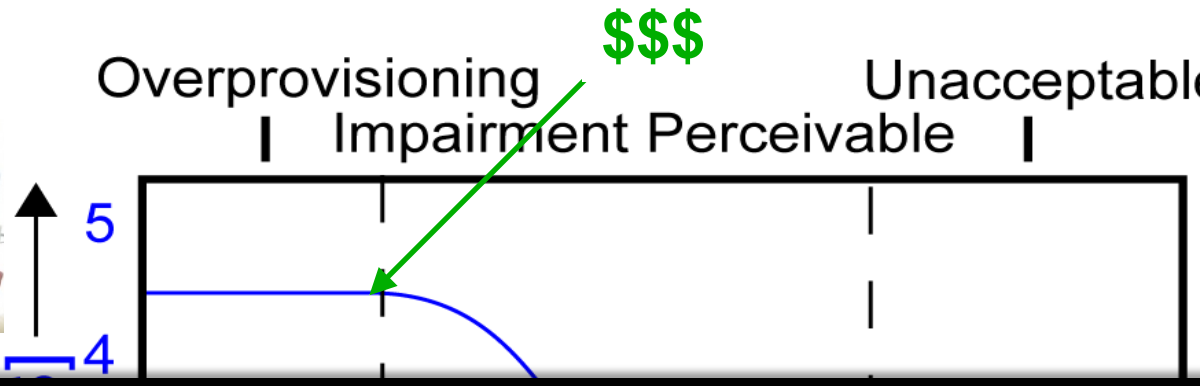
DBStream goes open source → https://github.com/arbaer/dbstream

QoE in Cellular Networks: the Context (2/2)



- ISPs are **loosing visibility @the core** due to **E2E encryption**
- E.g. → in 2012 we presented **YOUQMON** (ACM PER)**, YouTube QoE @core**
- In 2015 we introduced **YoMoAPP** (ACM MOBICOM), **YouTube QoE @smartphones**

"Simple" Question: How Much Bandwidth do I Need?



This talk sheds light on this question by

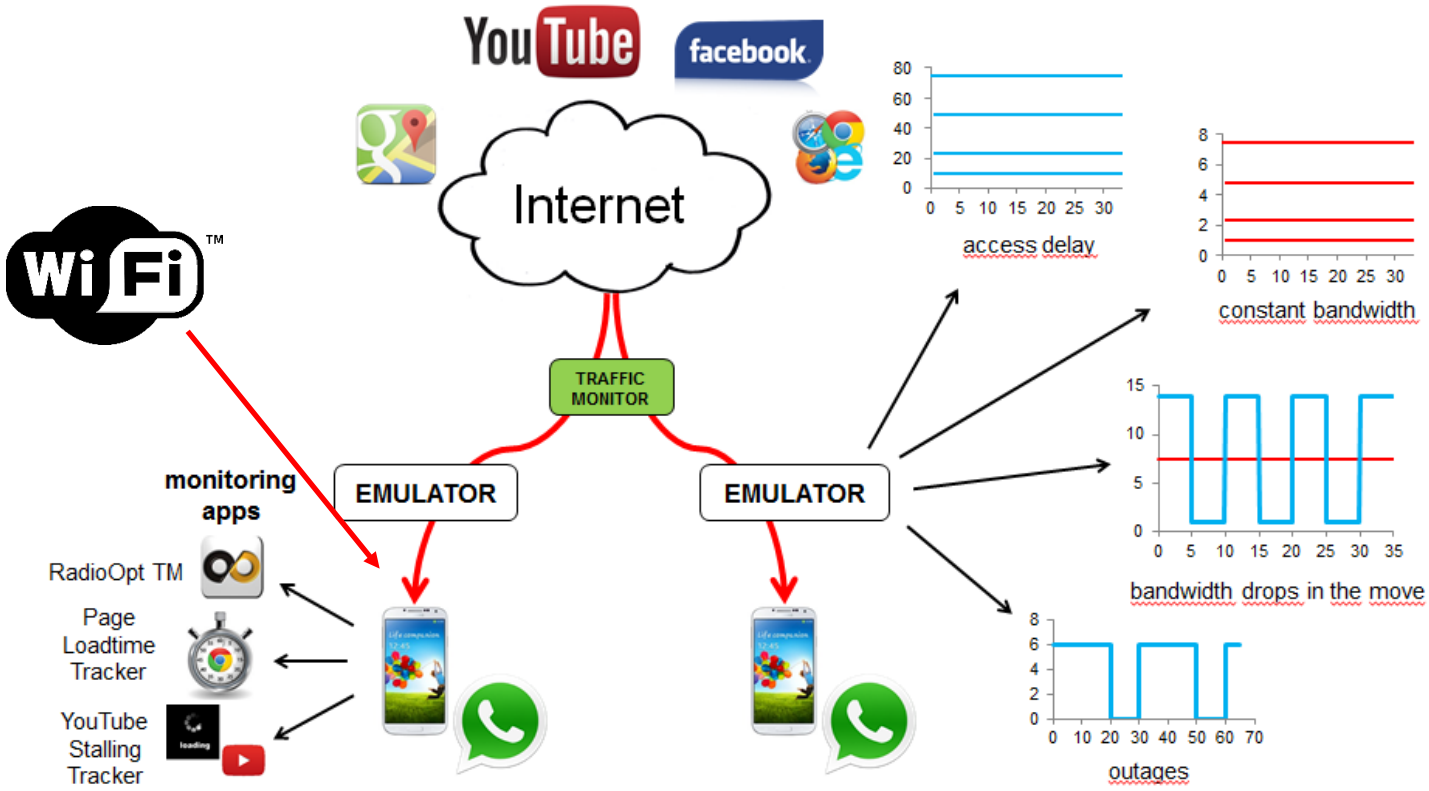
Conducting Subjective QoE Lab Studies for Popular Apps in Mobile Devices

Complementing results with **measurements in the field** = in–device measurements + crowdsourced QoE feedback in **operarional cellular ISPs**

- **Cellular ISP**: (cost-efficiency and happy customers, spe **good and what excellent?**
- **Regulator/Policy makers** → which are the **thresholds to target?** (e.g., EU H2020)

Technical Setup – Testbed

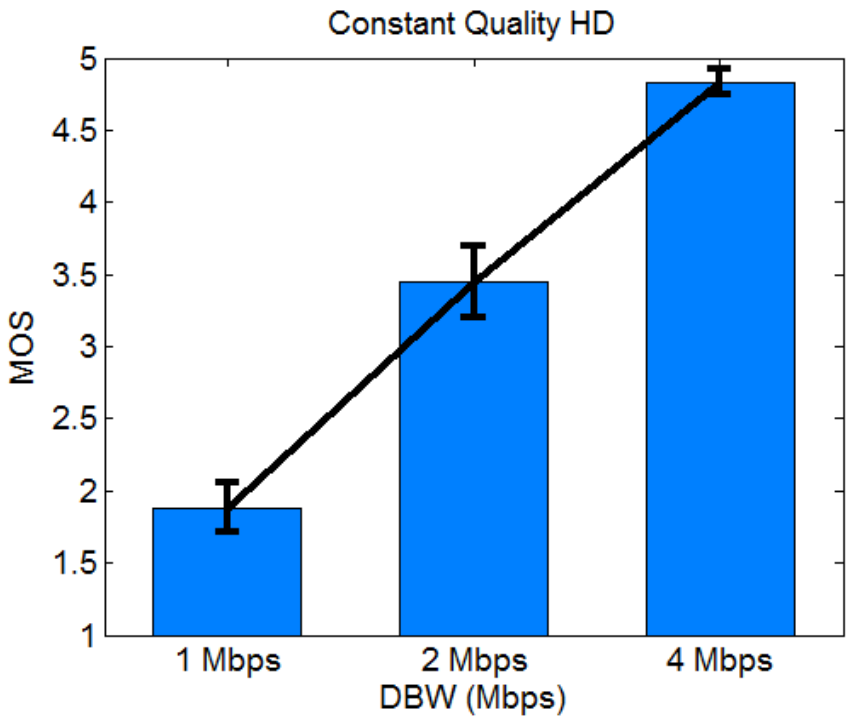
Subjective study to evaluate QoE in smartphones, including fluctuations

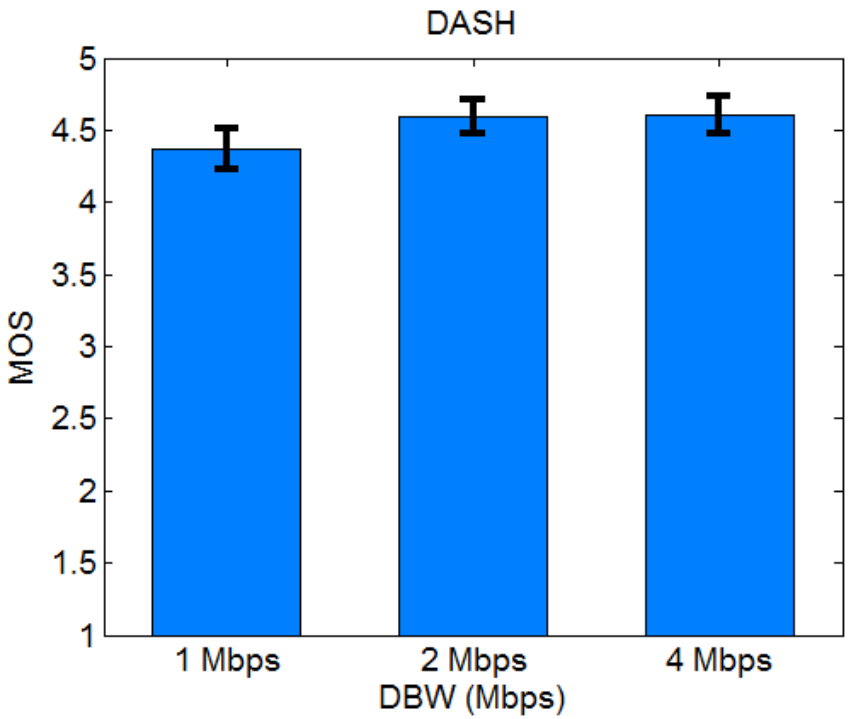


- **QoS parameters:**
  - **Downlink bandwidth → constant values**
  - **Downlink bandwidth → fluctuations/outages**
  - **Network RTT @access**

- **Demographics:**
  - **50 participants** (45/55% m/f)
  - 60/40% students/employees
  - **average age 23**

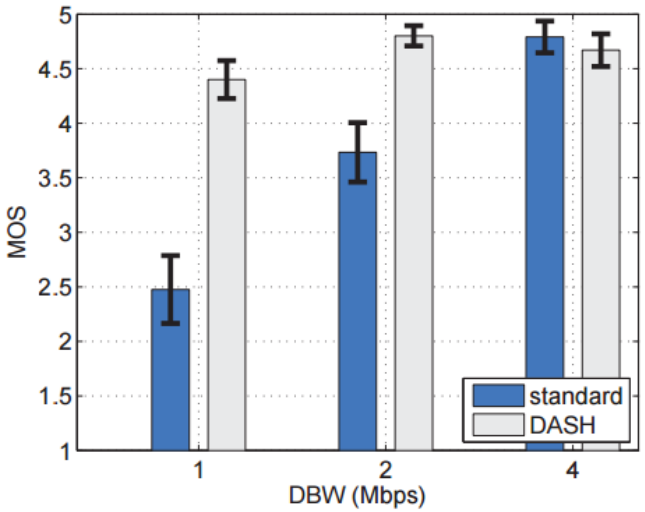
YouTube QoE Results



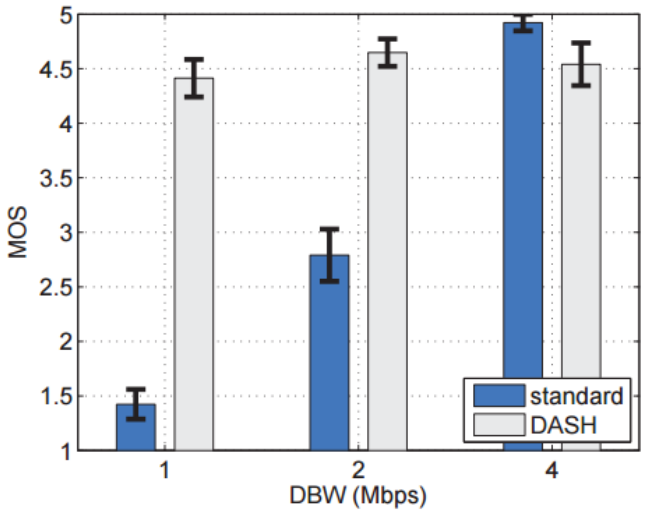


- DASH is rapidly moving to YouTube Mobile
- Significant **QoE variations** depending on the **usage of DASH**
- In **DASH**, **stallings** are **compensated** by video **quality degradations,** which **do not impact the QoE of the customers (NEW! See next)**
- In the general scenario, **4 Mbps to achieve excellent QoE**

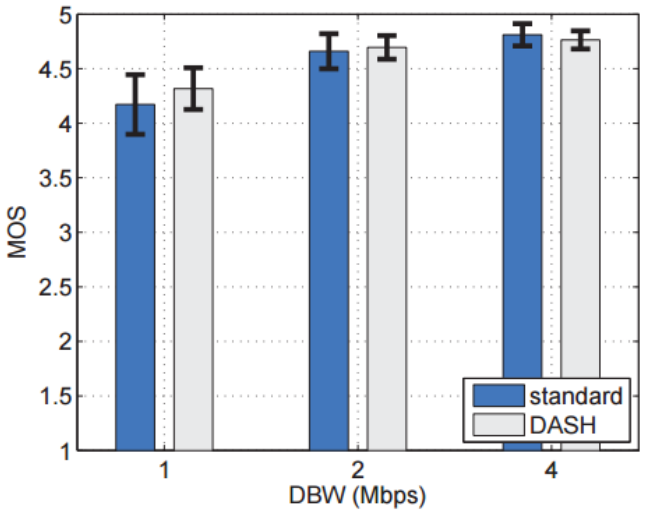
YouTube QoE Results: main QoE KPIs



(a) Initial Delay



(b) Stalling

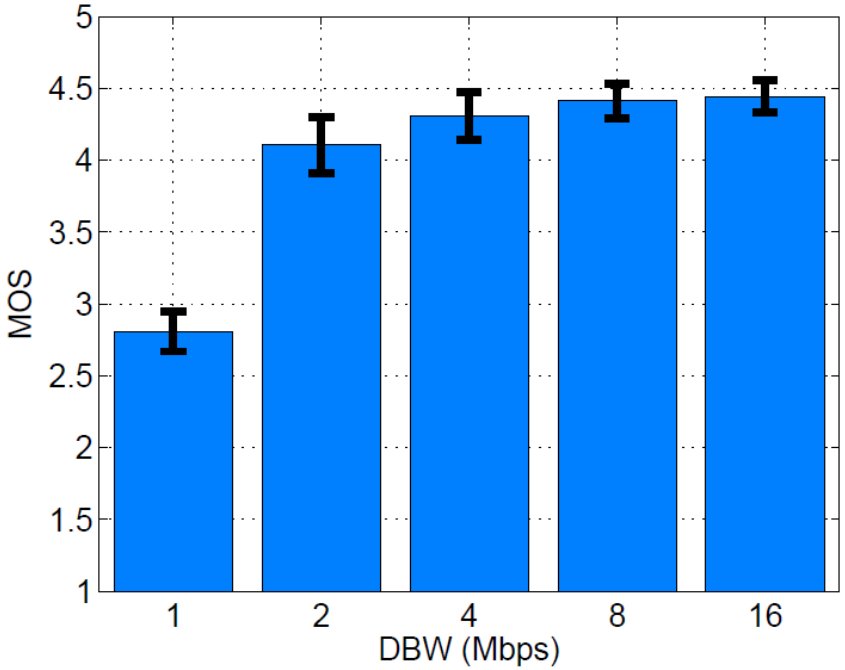


(c) Video Image Quality

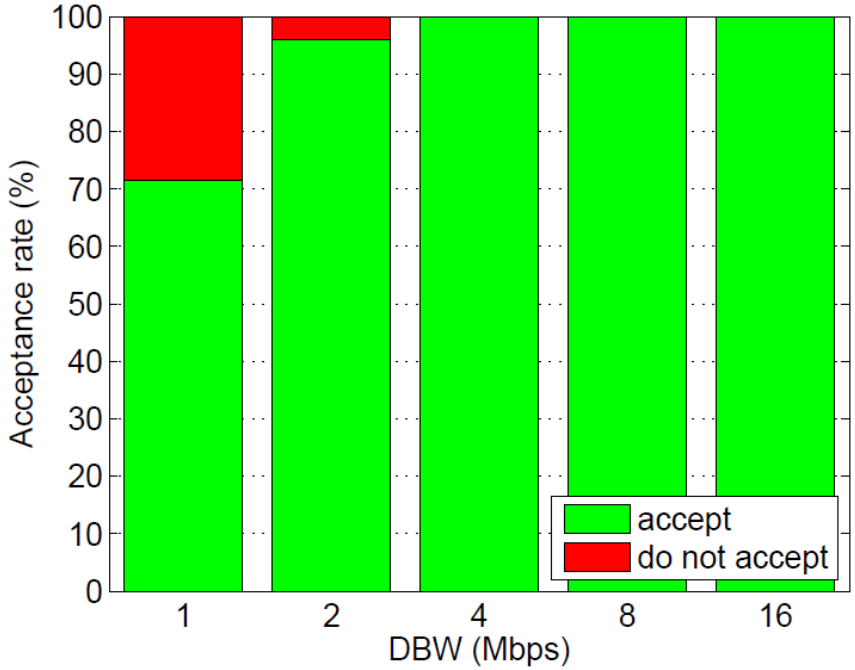
- main QoE KPIs in HTTP streaming: **stalling**, initial delay, and **video image quality**
- as expected, **stalling** has a much **stronger impact** on the **users QoE**…
- interestingly, **DASH also reduces significantly the initial delay**
- accepted → quality switches induced by DASH have an important impact on QoE…
- in **smartphones**, where displays are rather small wrt standard devices, **quality switches** do **not** seem to have **an important impact** on the **perception** of the user

QoE in Gmaps Mobile

- highly interactive app → important impact of throughput bottlenecks
- **downlink bandwidth < 2 Mbps** turns to be **overkilling** in terms of **QoE**
- **saturation** begins **after 2 Mbps/4 Mbps**
- **excellent QoE above 4 Mbps** (error bounds)



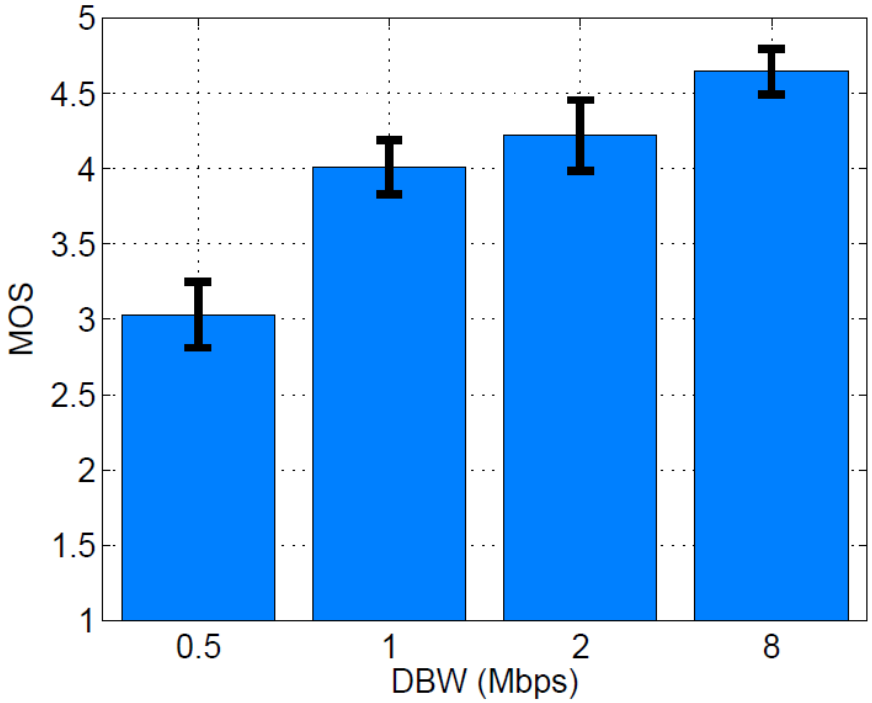
(a) Overall quality (MOS)



(b) Acceptance rate

QoE in Facebook Mobile

- **Excellent QoE** for **DBW > 2 Mbps**
- **Saturation** starting **after 1 Mbps / 2 Mbps**,
- QoE slightly improves for higher DBW, but potentially linked to confidence bounds (**difficult to have a 8 Mbps bottleneck @access**)



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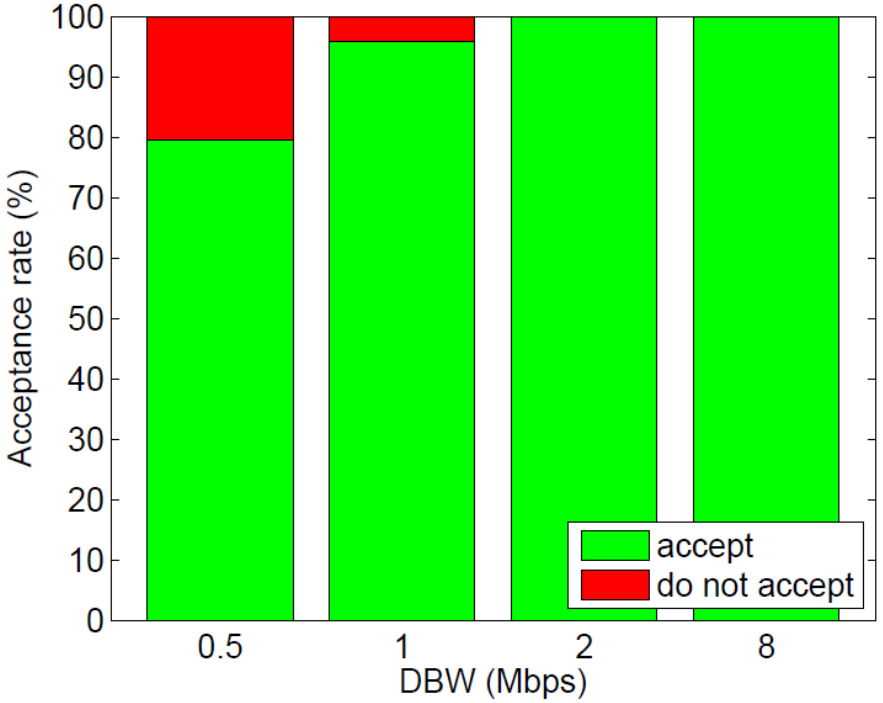


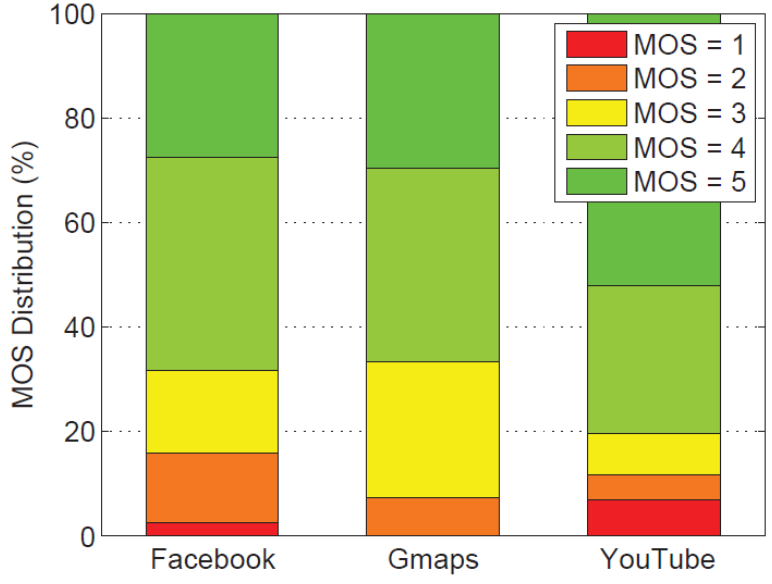
(b) Acceptance rate

QoE @Smartphones in the Field

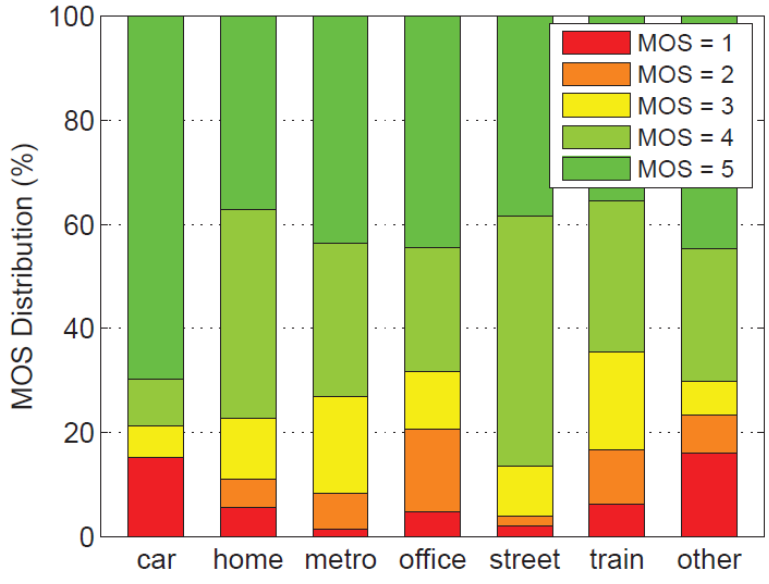
- same approach as lab study...
- but **participants using their own devices** in the field…
- with their **own cellular operators/contracts** (30 participants)
- **crowdsourced QoE feedback** → rating/QoE feedback tools
- **passive traffic measurements at the end-devices**

What, Where, and How?

- **Most of ratings** for **YouTube**, @home & @underground (great coverage @Wien)
- **Most MOS** ratings correspond **to high QoE**
- **Impact of App selection** → MOS distribution looks very similar for all apps (rather good/stable network QoS)
- **Impacts of Mobility (location)** → low impact of "mobility-based" locations (i.e., dist. for undergroud similar to home, office and street) → good network QoS



(c) MOS dist. per App



(d) MOS dist. per location

Traffic Monitoring KPI Elaboration

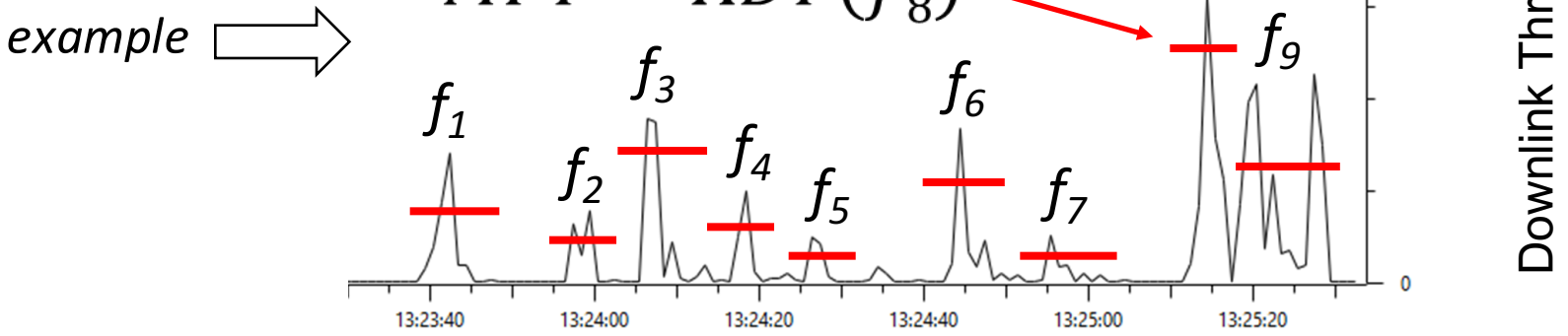
→ Given a session S composed of n flows f_i, we consider the **Maximum Flow Throughput (MFT)** as the **main KPI mapping to QoE** (e.g., in YouTube **RSSI shows poor correlation when coverage is excellent, i.e., RSSI > - 91.7 dBm**)

- For each flow f_i, our Traffic Monitor computes the Average Downlink Throughput ADT, namely $ADT(f_i)$. Then, **the MFT is computed as follows:**

$$MFT = \max_{f_i \in S} (ADT(fi))$$

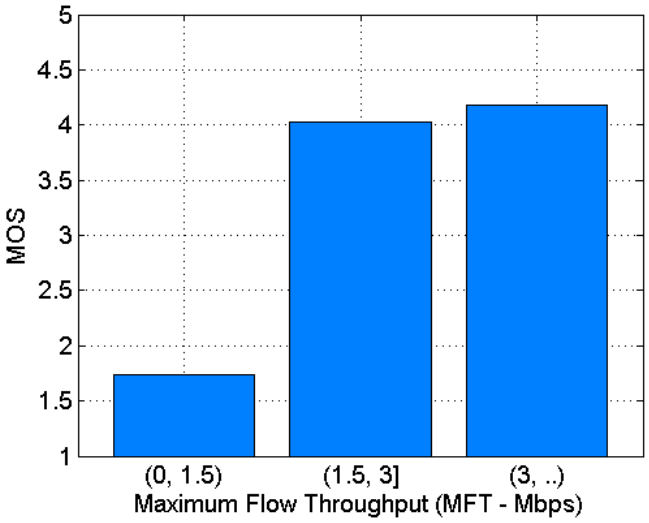
S

example

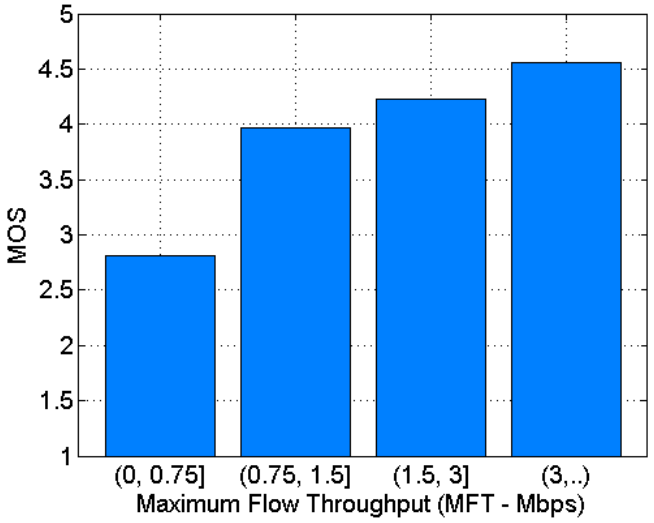


How do Obtained Results correlate with the Lab

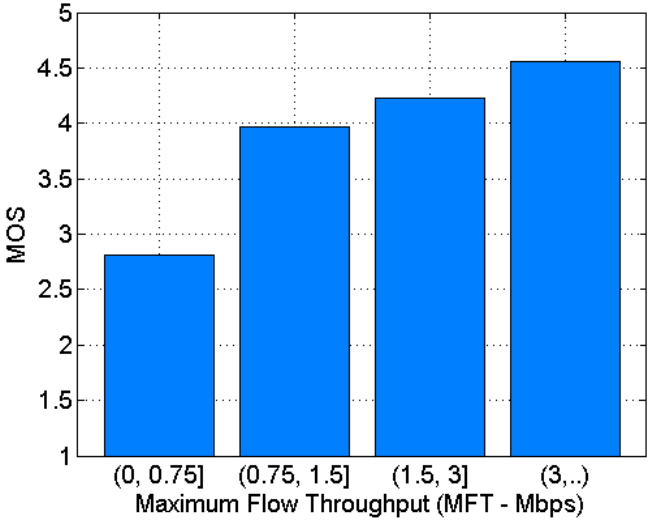
- **MFT measurements** relate well to **QoE and** to **Lab** results for applications such as Gmaps and Facebook **when filtering-out small flows**
- **Applications such as YouTube require** additional **measurements at the application layer** (e.g., stallings, quality-levels, video bitrate, etc.) → promising results from tools developed for YouTube (YoMoAPP @Mobicom)
- Observations similar to Lab (**difficult to estimate QoE for 1 Mbps < MFT < 4 Mbps,** and most **ratings for MFT > 5 Mbps with MOS = 4 or 5**)



(a) YouTube QoE vs. MFT



(b) Gmaps QoE vs. MFT



(c) Facebook QoE vs. MFT

Conclusions

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- **QoE in Smartphones:** a DBW above 2 Mbps results in good QoE, but excellent QoE is attained for DBW > 4 Mbps
  - Cellular ISPs should target such dimensioning thresholds to avoid user dissatisfaction
- **YouTube**: highly dependent on DASH/non-Dash, but **above 4 Mbps result in excellent QoE**
- The downlink **Maximum Flow Throughput (MFT)** of a session **represents a good KPI for QoE estimation.**
- **Obtained QoE-based thresholds in the lab are a-priori consistent with measurements in real cellular networks**

Thanks You for Your Attention!

Pedro Casas, casas@ftw.at

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