Quality of Experience on Smartphones

Network, Application, and Energy Perspectives

Selim Ickin & Markus Fiedler

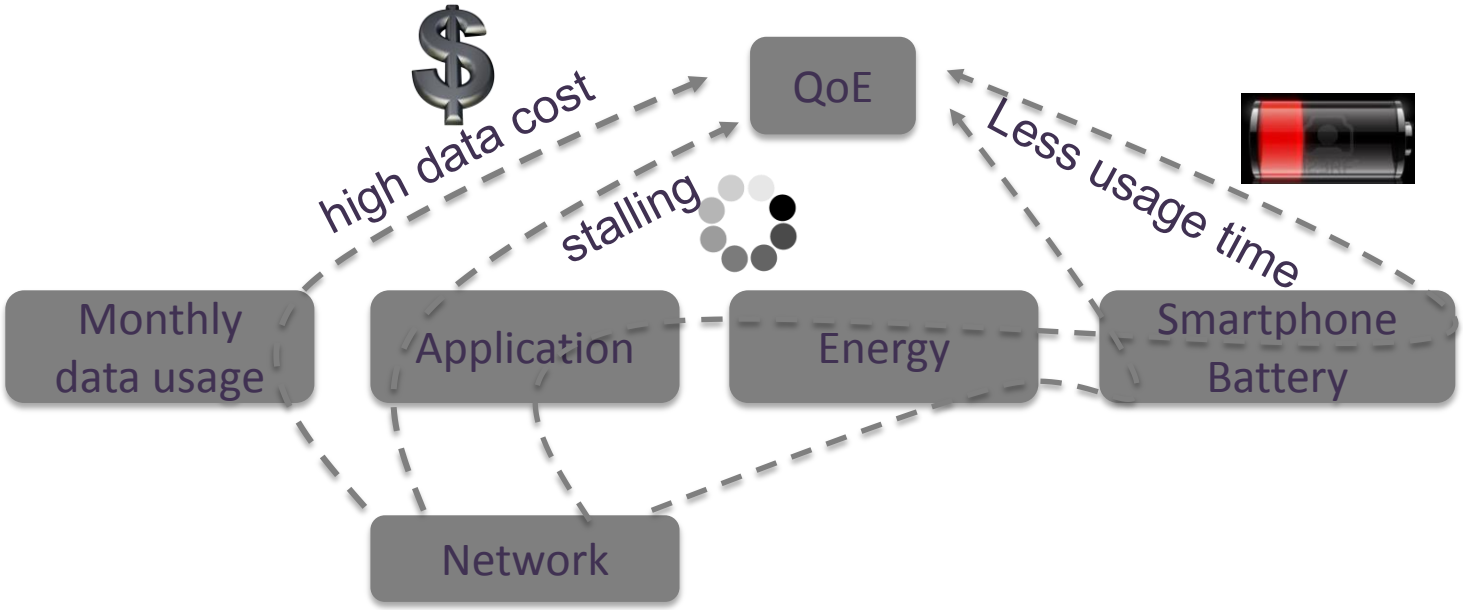
BLEKINGE TEKNISKA HÖGSKOLA · BTH ·

Analogy: congested city traffic

- Occasional stops while driving
  - both “annoying” and “fuel-consuming”
- Smartphone users in a music festival
  - high amount of application data traffic
  - application freezes, unresponsive apps
  - users crave for battery

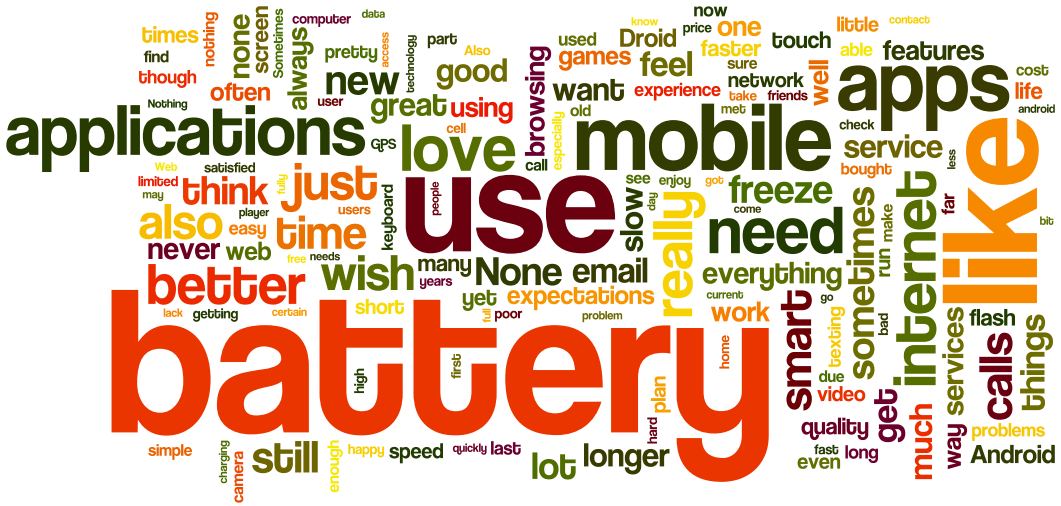
Sony’s Battery Charging Station

Potential impacts of network distortions causing freezes



Most important influential factors on QoE [1]

Battery, user interface, app/network performance, phone features, app/connectivity cost, user routines, user lifestyle



The most important factors influencing QoE

- Energy consumption
- Temporal impairments (freezes) in video

Metrics

Network

- Packet delay variation (PDV)
- Maximal Burst Size (MBS)

Application

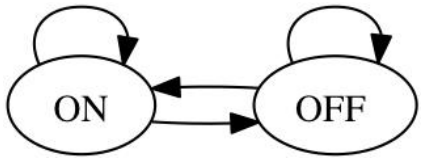
- Inter-picture time (D_p)
- User's quality indications
  - Mean Opinion Score (MOS)
  - Other quality indications (freeze, qualitative)

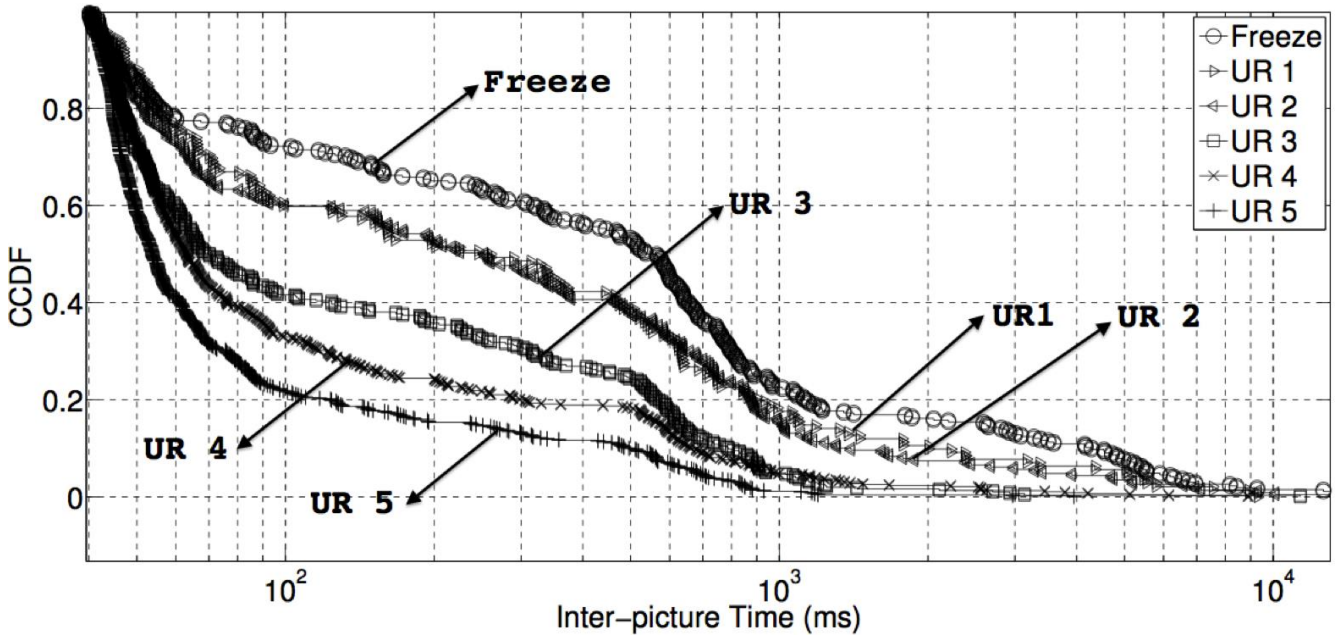
Energy

- Power consumption (P_n)
- Duration (t)

Exponential ON-OFF model in 3G based video streaming [2]

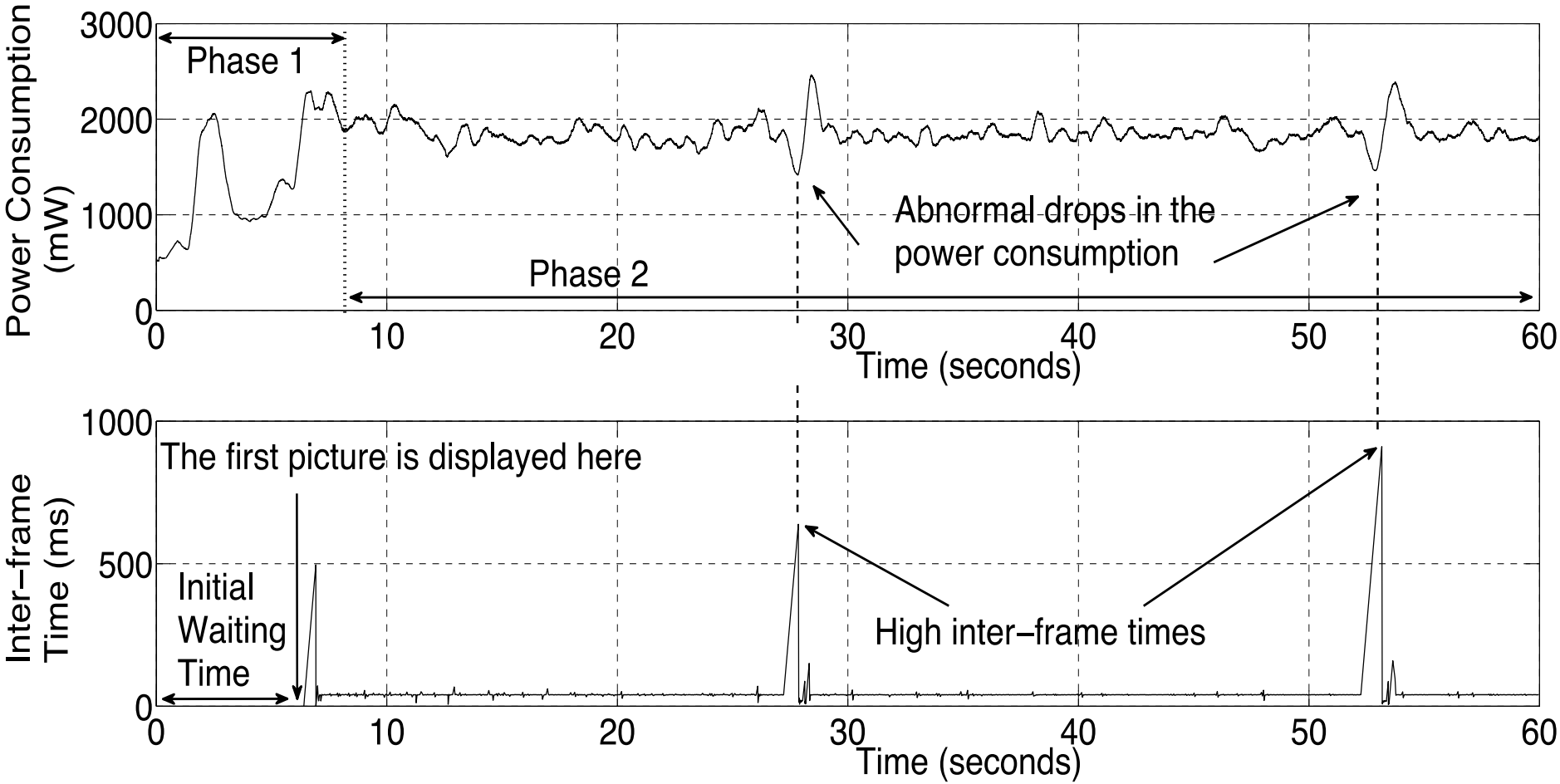
- Data ON duration
  - Mean ON duration = 9.7 s
- Data OFF duration
  - Mean OFF duration = 642 ms



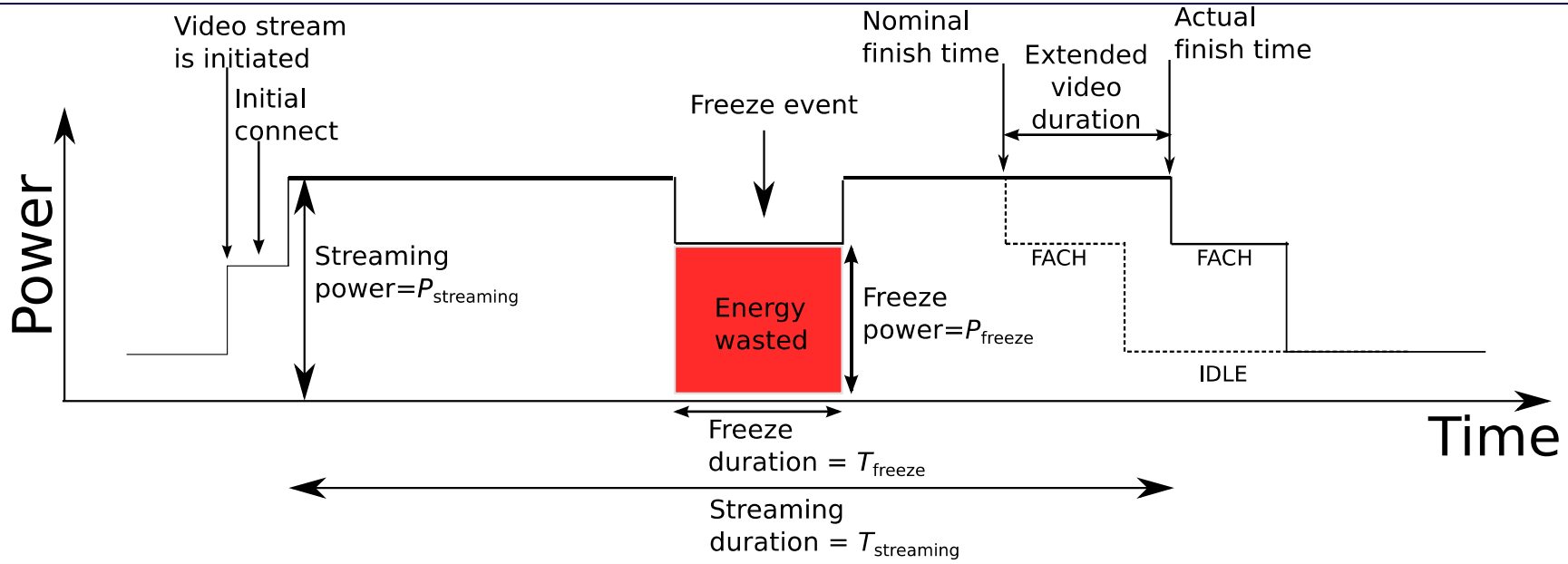


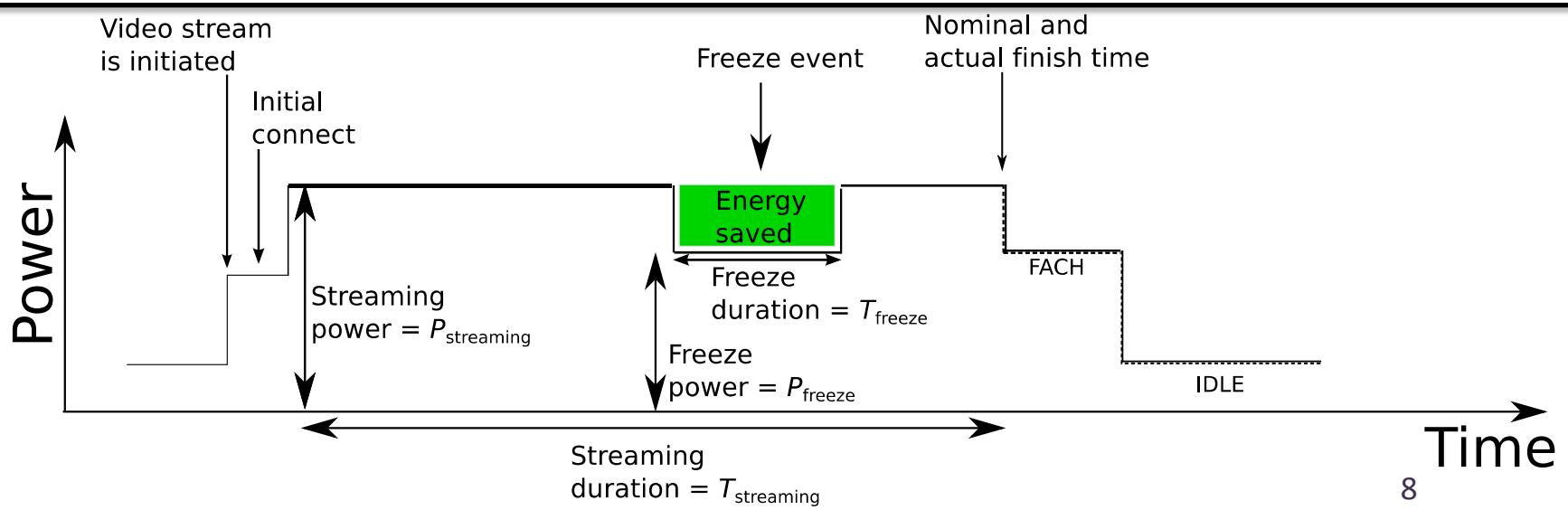
UR = 5	152 ms
UR = 4	282 ms
UR = 3	321 ms
UR = 2	768 ms
UR = 1	831 ms
Freeze	1289 ms

Power consumption phases and inter-picture time [3]



Video energy consumption [4]





QoE models in different perspectives

- Network (*PDV* vs. *MOS*) [5]
  - UR = –9.10 $(PDV_{EWMA}/\text{ms})^{0.08}$ + 16.18; $R^2 = 0.68$
  - UR = –59.96 $MBS_{[\text{packets/ms}]}^{-0.036}$ – 51.71; $R^2 = 0.78$
- Application (P_{OFF} vs. *MOS*) [4]
  - $MOS = 4.59\, e^{-3.44\, POFF}$; $R^2 = 0.73$
- Energy [4]
  - If there are video jumps (such as in UDP-based streams), up to apprx. 5 J energy can be saved
  - If there are no video jumps (such as in TCP-based streams), the higher the amount of freezes, the higher the energy consumption (and the more energy is wasted)

$$MOS = 4.59e^{-18.59\frac{E_{saving}/\text{J}}{T_{video}/\text{s}}}$$

$$MOS = 4.59e^{-4.72\frac{E_{waste}/\text{J}}{T_{video}/\text{s}}}$$

Conclusion

- Network
  - Maximal Burst Size (BS) and Packet Delay Variation (PDV) are strong indicators of QoE
  - A power-law model fits slightly better than an exponential model
  - Exponential weighted moving average improves the correlation (imitating human forget factor)
- Application
  - Two state ON / OFF exponential model applies to mobile video streaming
  - Obtained QoE model as exponential function of the OFF probability (P_{OFF})
- Energy
  - QoE models above are leveraged to obtain MOS per joule
  - For TCP-based streams: better to avoid freezes to save energy!
  - For UDP-based streams: Some energy can be saved by skipping video content while keeping MOS untouched.

References

1. S. Ickin, K. Wac, M. Fiedler, L. Janowski, J. H. Hong, and A. K. Dey, “Factors influencing Quality of Experience of commonly-used mobile applications,” IEEE Communications Magazine, 50(4):48–56, 2012.
2. S. Ickin, M. Fiedler, K. Wac, P. Arlos, C. Temiz, K. Mkocha, “VLQoE: Video Quality of Experience Instrumentation on the Smartphone,” Mul- timedia Tools and Applications. Special Issue on Advances in Tools, Techniques and Practices for Multimedia QoE, Springer US, 74(2):381–411, 2014.
3. S. Ickin, M. Fiedler, K. Wac, “Energy-based anomaly detection in Quality of Experience,” in Proc. 16th International Symposium on Wireless Personal Multimedia Communications (WPMC), pp 1–6, USA, 2013.
4. L.G. Ballesteros, S. Ickin, M. Fiedler, J. Markendahl, K. Tollmar, and K. Wac, “Energy Saving Approaches for Video Streaming on Smartphone based on QoE Modeling,” in Proc. 13th IEEE Annual Consumer Commu- nications & Networking Conference (CCNC), 2016.
5. S. Ickin, K. D. Vogeleer, M. Fiedler, D. Erman, “The effects of Packet Delay Variation on the perceptual quality of video,” in Proc. IEEE 35th Conference on Local Computer Networks (LCN2010), pp 663–668, 2010.

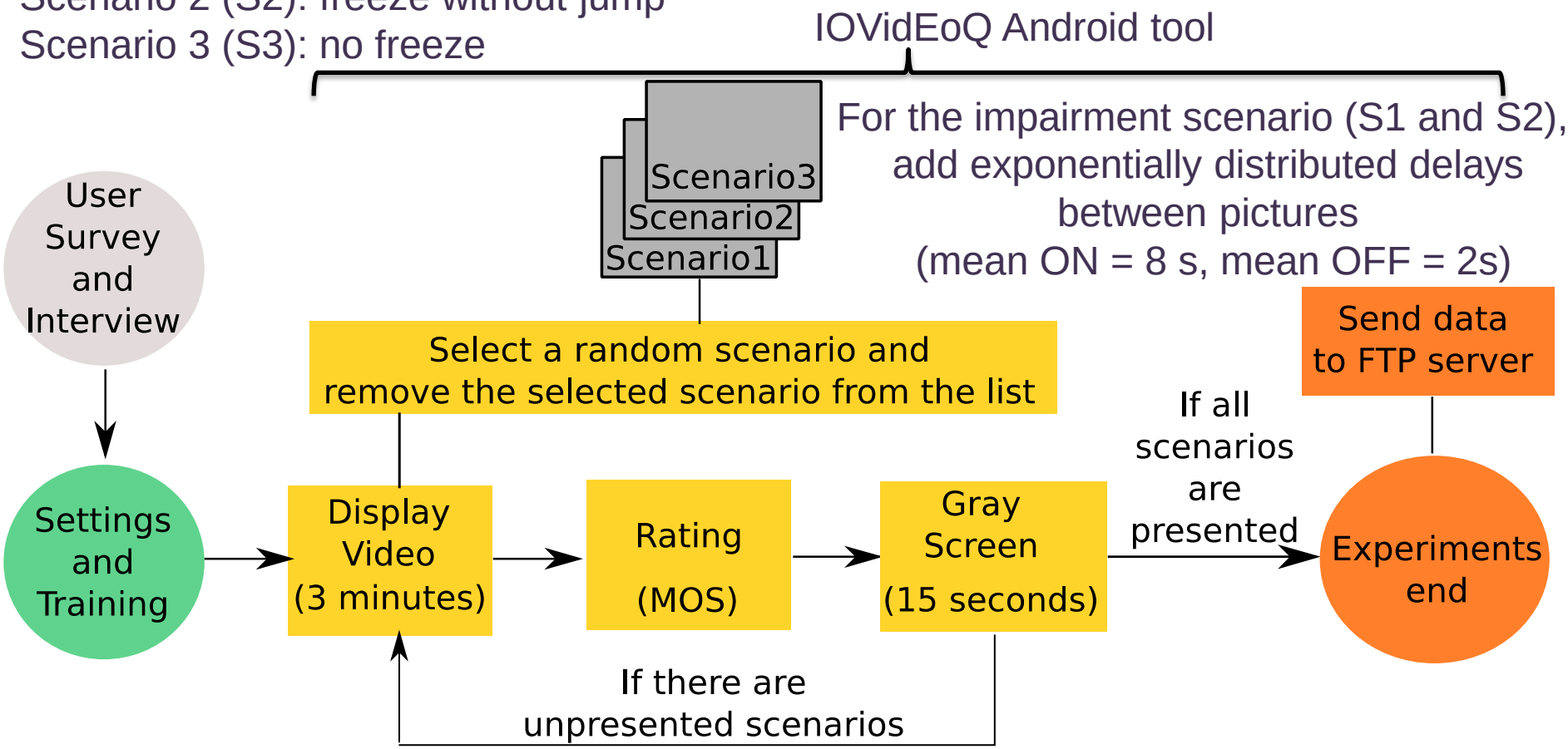
Thank you!

#ICIN2016

BLEKINGE TEKNISKA HÖGSKOLA · BTH ·

User experiment procedure

Scenario 1 (S1): freeze with jump
Scenario 2 (S2): freeze without jump
Scenario 3 (S3): no freeze



- 30 users, average age 29, 14 females, 3 countries
- S4 and Nexus 5, Super AMOLED, 16M colors, 1080 x 1920 pixels.