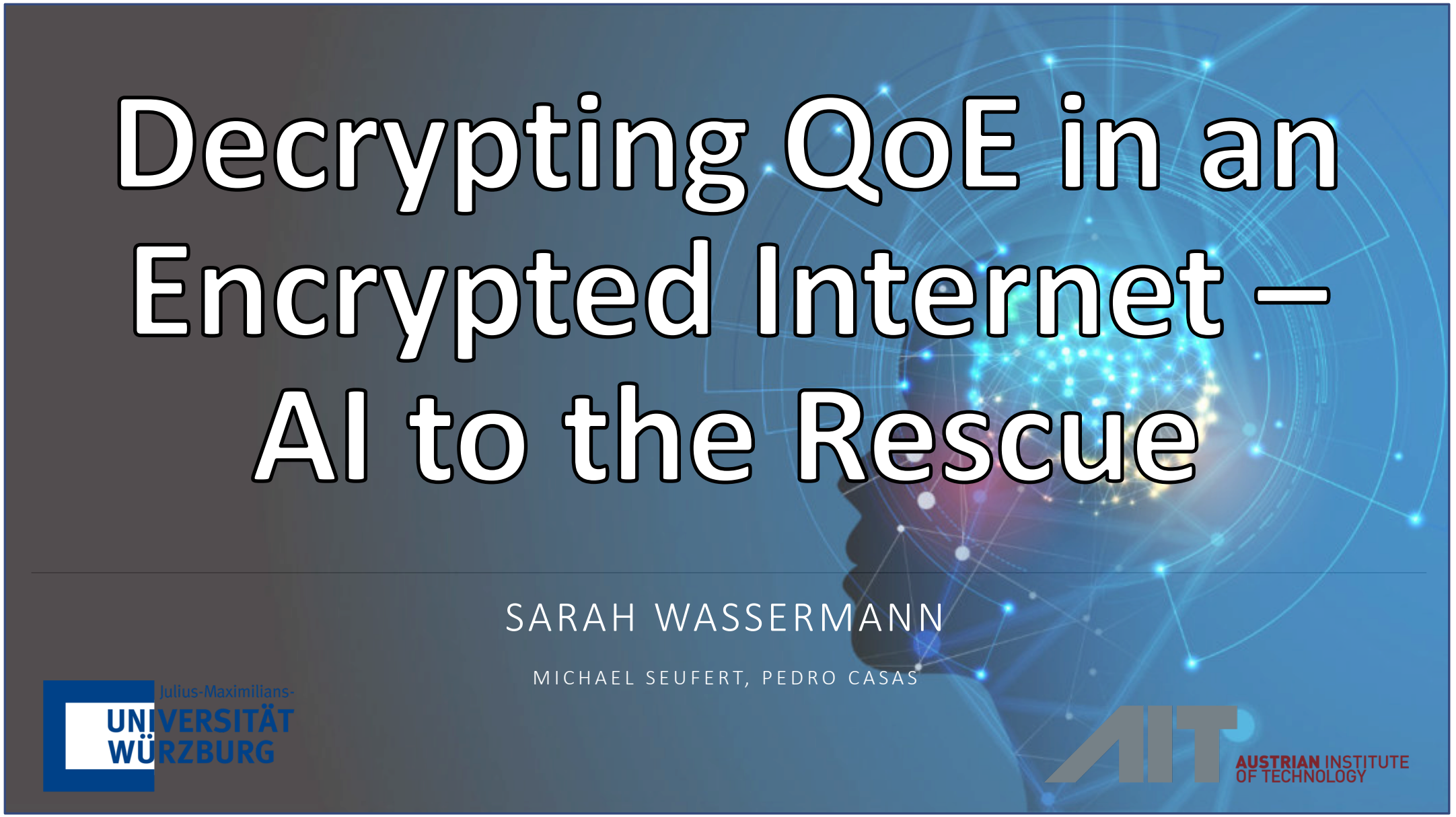
Decrypting QoE in an Encrypted Internet – AI to the Rescue



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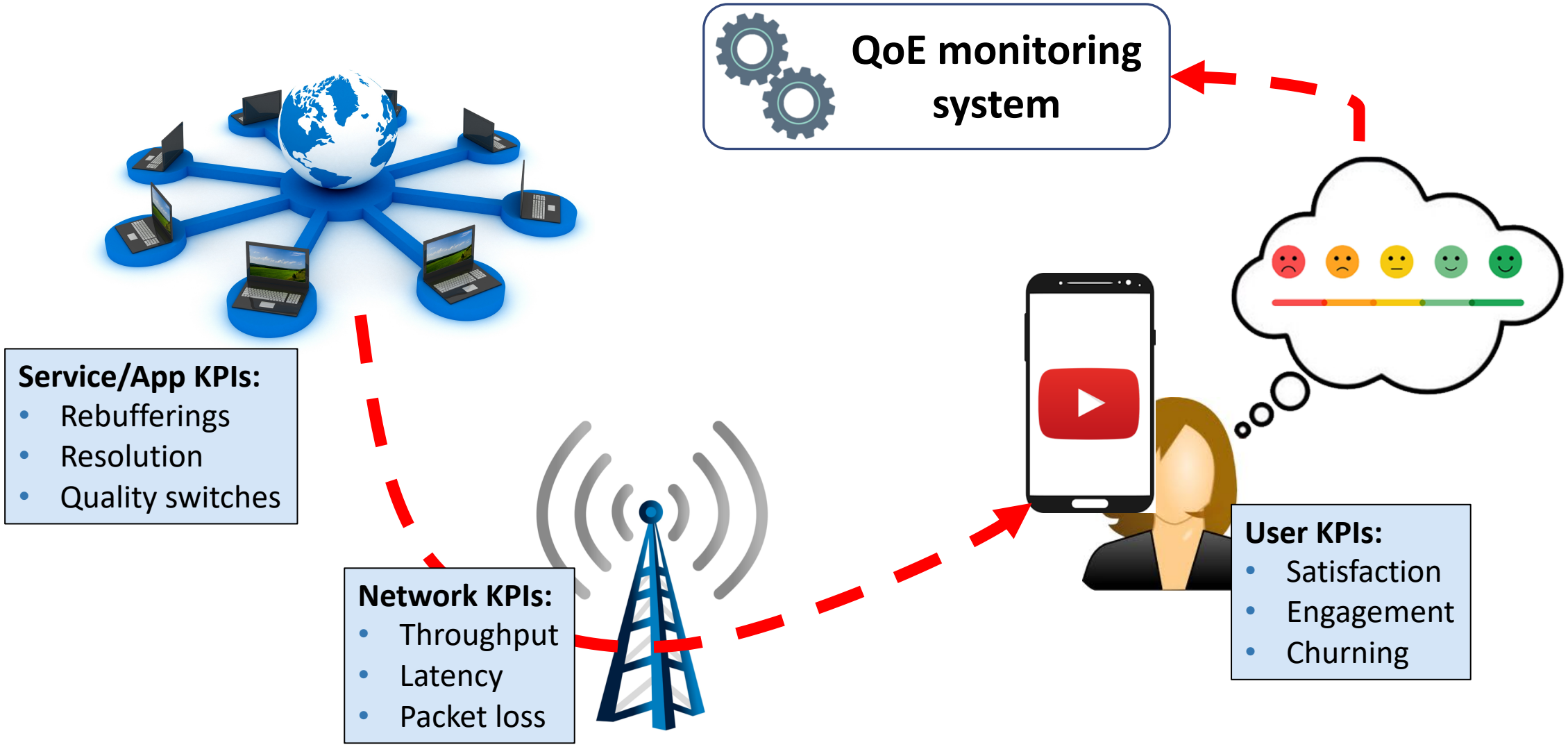
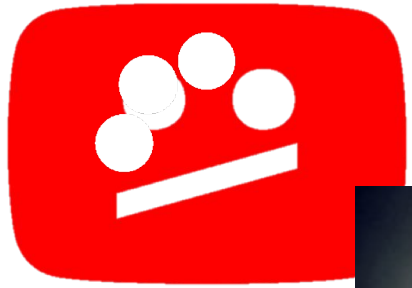
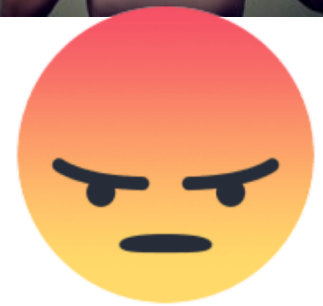
QoE Monitoring



Why is QoE Relevant?

- **Customer experience**
  - Strong competition between service providers
  - Customer perception becomes more and more relevant
  - Service providers need to avoid customer churn and attract new users
- **User engagement**
  - Poor quality (for ex. many rebufferings) reduces user engagement



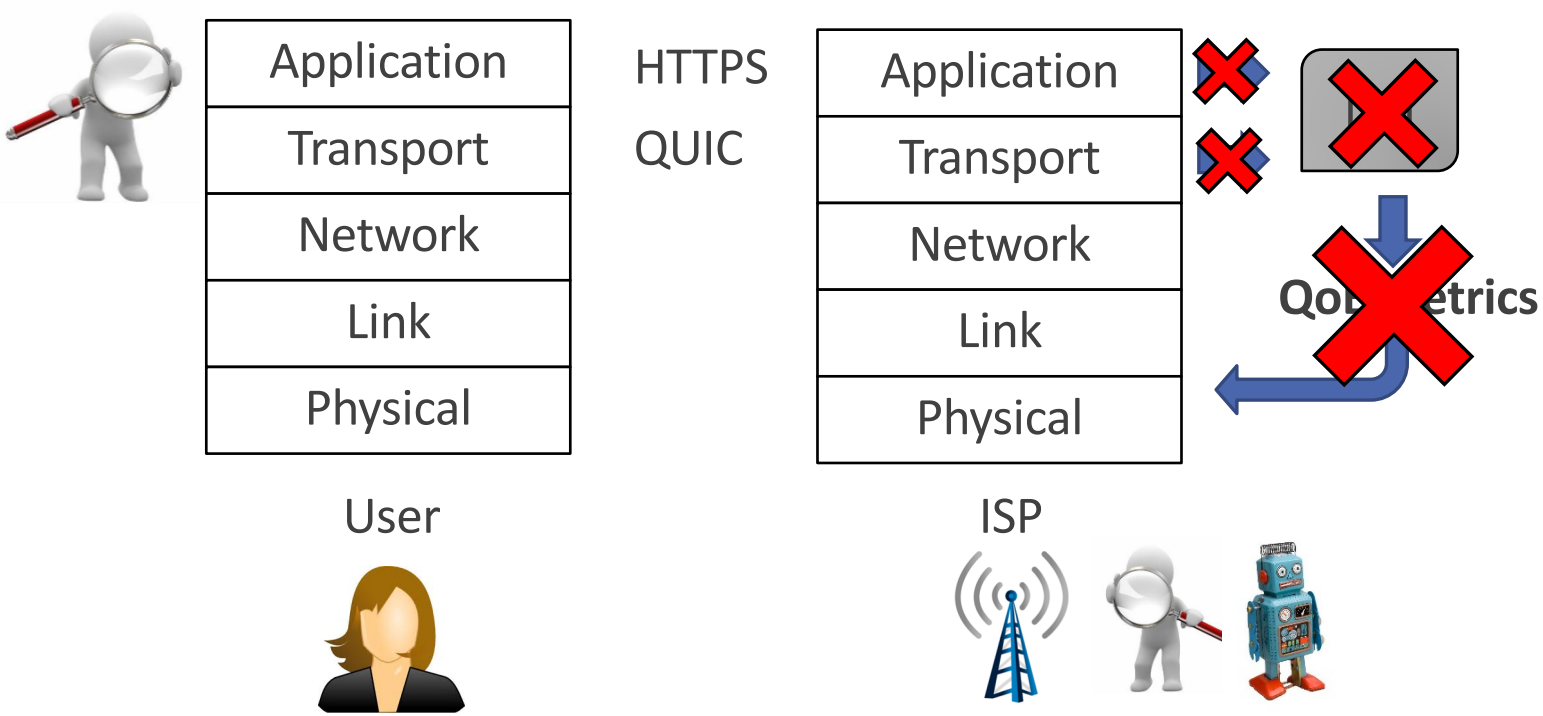


Service providers need to integrate QoE into the core of their network-monitoring systems

Impact of Bad QoE

- Bad QoE has significant impact on large companies
- *Amazon*
  - Every additional 100 ms of page-load time could cost them 1% of their sales, and a page-load slowdown of just one second could turn into a $1.6 billion loss in sales each year
  - If page takes additional 400 ms to load, 5–9% users browse away
- *Google*
  - Slowing search results down by 400 ms, they could loose 8 million searches per day (Google Ads!)

Difficulties with End-to-End Encryption (1)



- **HTTPS** and **QUIC** make previous approaches no longer applicable – **lack of visibility for ISPs**
  - Solution I – **monitoring directly at the end devices**
  - Solution II – **monitoring at the network core**

Difficulties with End-to-End Encryption (2)

- **Monitoring directly at the end devices**
  - **Advantage**: we can capture application-layer quality metrics (stallings, quality switches, etc.)
  - **Drawback**: the metrics are hard to capture directly from the official video app; need root access or an embedded player

- **Monitoring at the network layer**
  - **Advantage**: we can capture network-level information without having root access on the smartphone, easy to do with the Android API
  - **Drawback**: because of E2E encryption, standard in-network monitoring tools become inaccurate

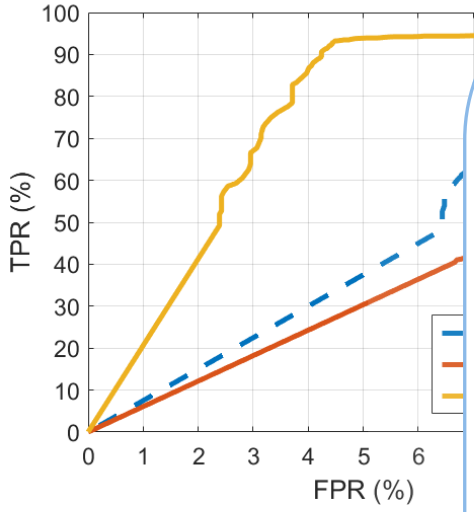
Modelling Mobile Video-Session Quality with AI (1)

- Prediction of session-based video-quality metrics for YouTube mobile
- Dataset: 3000+ sessions recorded from 360+ Android users worldwide between 2014 and 2018, using YoMoApp

Can we predict video quality solely based on data extracted from encrypted network traffic?

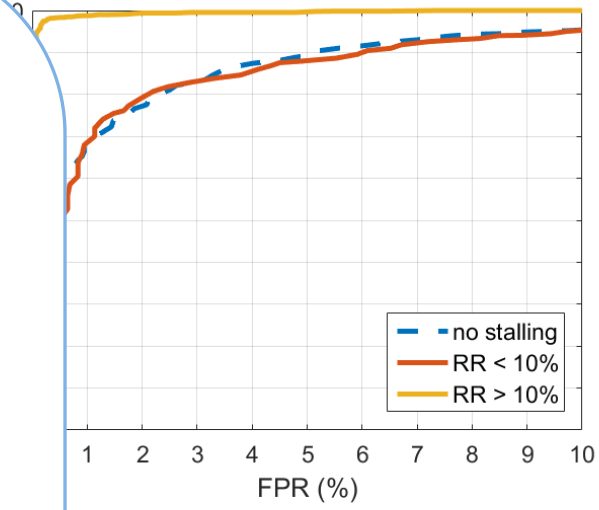
- 275 network-related features extracted from encrypted traffic
  - Easily accessible through the Android API, without root privileges
- After feature selection, 30 features yield almost identical prediction accuracy
- Highly encouraging results, high true-positive rates (TPR)
- Random forest used as a prediction model

Modelling Mobile Video-Session Quality with AI (2)



stallings ROC

1. **# stallings**
   - No stalling
   - 1 or 2 stallings
   - > 2 stallings
2. **# quality switches**
   - No switches
   - > 0 switches
3. **Rebuffering ratio**
   - No rebuffering
   - Rebuffering ratio < 10%
   - 10% ≤ rebuffering ratio



ebuffering ratio ROC curve

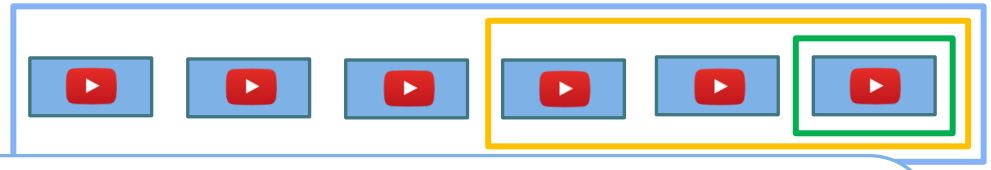
Beauty is in the Eye of the Smartphon
N. Wehner, **S. Wassermann**, P. Casas,
in Proceedings of the 14th Internation

Machine Learning Models for YouTub
S. Wassermann, N. Wehner, P. Casas
in Proceedings of the Workshop on AI

On the Analysis of YouTube QoE in Cellu
S. Wassermann, P. Casas, M. Seufert, F. Wam
in Proceedings of the 12th IFIP Wireless and Mobile Networking Conference (WMNC), Paris, France, 2019

Stream-based Video-Quality-Metric Prediction (1)

- Stream-based predictions in much finer time granularity, every second
- 3 different groups of features (207 in total)
- SVM…
- Tree-based models gave best results
- Feature selection shows cumulative features are the most relevant ones

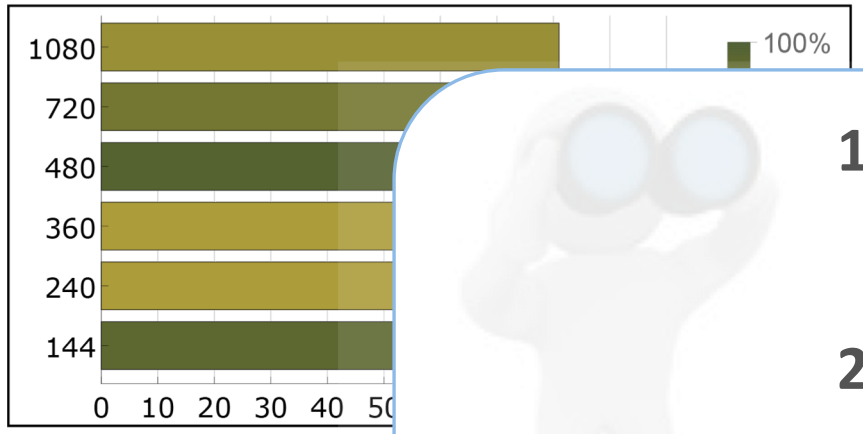


Can we predict video quality with network traffic while streaming a video?

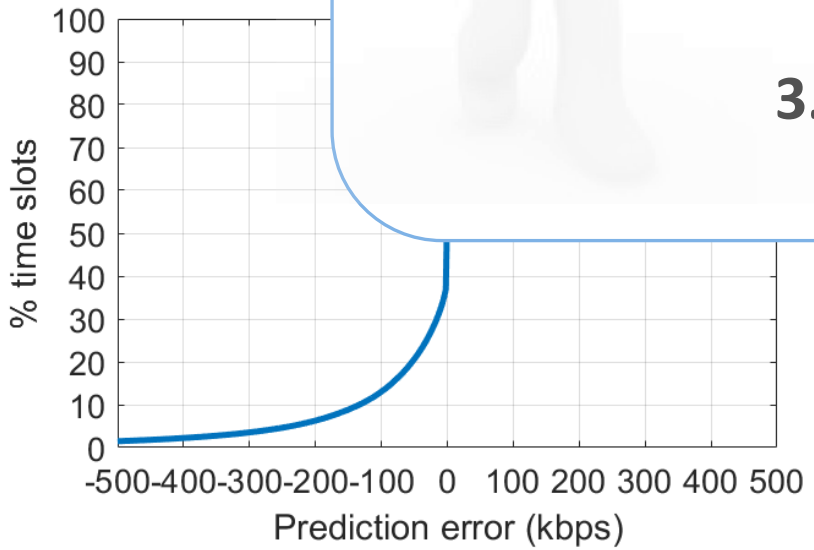
Stream-based Video-Quality-Metric Prediction (2)

- A few words about the dataset…
  - 15,000+ YouTube sessions with more than 4,600,000 time slots collected between June 2018 and February 2019
  - TCP and QUIC sessions
  - Monitoring framework based on Selenium and JavaScript scripts, measuring all relevant metrics at the different layers of the communications stack
  - Diverse recording conditions: WiFi/cellular, different ISPs, different geographic locations, etc.
  - Bandwidth limitations: 20Mbps, 5Mbps, 3Mbps, 1Mbps, 300kbps + fluctuations

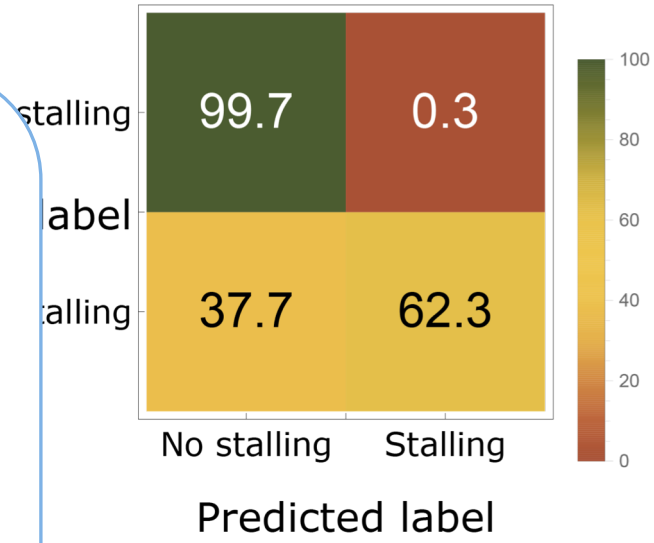
Stream-based Video-Quality-Metric Prediction (3)



1. **Resolution**
   - 144p, 240p, 360p…
2. **Average bitrate**
   - Exact value
3. **Stallings**
   - Stalling or not?



Average bitrate error

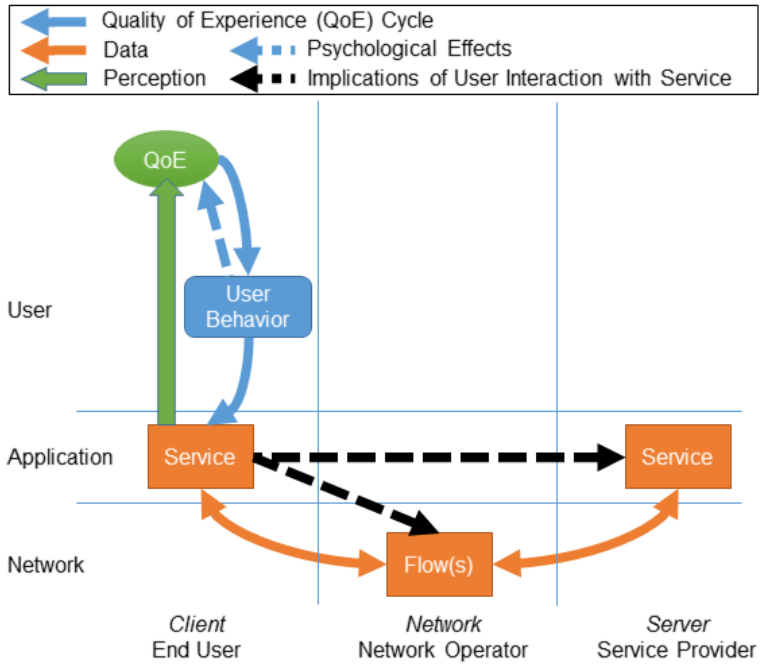


Stream-based Video-Quality-Metric Prediction (4)

- **What are we doing differently from others?**
  - Operational deployment is the most important point for us
  - Very fine-grained analysis (1 sec. resolution)
  - The used features are completely knowledge independent (for ex. no chunk detection)
  - 3 different sets of features (snapshot, trend, cumulative)
  - Very diverse dataset (WiFi/cellular network, different ISPs and geographic locations, different network conditions)
  - Constant-time feature computation

Towards Proactive QoE-aware Traffic Management

- ISPs transition to QoE-aware traffic management, aiming to improve quality of Internet applications
- The relationship between network and QoE mostly considered as a one-way street
- **BUT QoE influences user behaviour which in turn influences network traffic!**
- Some user interactions might give information about QoE!
- Moving towards proactive QoE-aware traffic management
  - Adjust network conditions in time to avoid QoE degradations
  - Predict changing conditions and requirements
  - Predict quality metrics
  - Predict user interactions



Considering User Behavior in the Quality of Experience Cycle: Towards Proactive QoE-aware Traffic Management
M. Seufert, **S. Wassermann**, P. Casas
in IEEE Communications Letters, vol. 23, no. 7, pp. 1145-1148, 2019

Thanks for listening!