Thesis summary:
Machine learning for Quality of Experience in real-time applications

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Internet real-time communication (RTC) platforms include any application that streams audio and video in real-time, such as video-conferencing applications (VCAs) and cloud gaming. These applications have seen a considerable surge in popularity in recent years, especially during and after the COVID-19 pandemic. VCAs are the main enabler of remote working, which has become the de-facto standard way of work for many companies. Nowadays there are countless proprietary VCA applications on the market. In this context, it is becoming increasingly important to maximize the Quality of Experience (QoE) of users of RTC applications.

In this thesis, we explore ways to monitor and control the network, in order to improve the QoE of RTC applications, using Machine Learning (ML) techniques.

We first give a vast overview of the most popular video-conferencing applications on the market today, how they operate, what protocols they use and how we can distinguish them in a traffic mix.

Second, we propose a comprehensive application-level observability system for the network layer, that leverages Machine Learning. It contains two ML classifiers, trained offline, that predict network characteristics, such as the RTC application being used and the type of media traffic exchanged (e.g. audio, video, screen sharing etc.). In the event of worsening network conditions, the network control can apply select management techniques, such as bandwidth allocation or path selection, to improve the conditions. The system inspects the packet headers in a traffic mix and makes decisions based on packet statistics collected over time bins before or during a video call. We prototype the classifiers and show their effectiveness in providing application-level details for video-conferencing applications.

We also release the module used to systematically calculate network traffic features from raw packets as a standalone software. It can be used for analysis of RTC applications and ML feature construction for different kinds of networking tasks.

Finally, we propose a network control system for the application layer: a congestion control algorithm for real-time applications, that uses Reinforcement Learning. In a scenario with an RTP sender and receiver, it gains information about the network conditions at the receiver-side, such as receiving rate, one-way delay and loss ratio and predicts the available bandwidth in the next time bin. Using this information, it controls the sending rate of the sender, thereby mitigating network congestion. This algorithm is envisioned to work at the client side, in the RTC application.

To sum up, this thesis explores the use of Machine Learning to improve networking: we use ML classification algorithms to differentiate media types in real-time traffic. We apply Natural Language Processing techniques to classify video-conferencing applications based on domain names and we employ Reinforcement Learning (RL) for Rate adaptation of RTC on the application layer. Results show that these techniques are promising for real-time traffic monitoring, visibility and management.