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Supplementary material for paper "In-Network YouTube Performance Estimation in Light of End User Playback-Related Interactions", I. Bartolec, I. Orsolic, L. Skorin-Kapov, in Proceedings of QoMEX 2019, Berlin

List of features selected for ML model training

1. Feature engineering

The feature set consists of both downlink and uplink traffic statistics as given in the table below. Traffic statistics are derived based on pcap files captured during the streaming of YouTube videos to a mobile Android device. Traffic is captured on a wifi router in a laboratory environment (Figure 1.1).

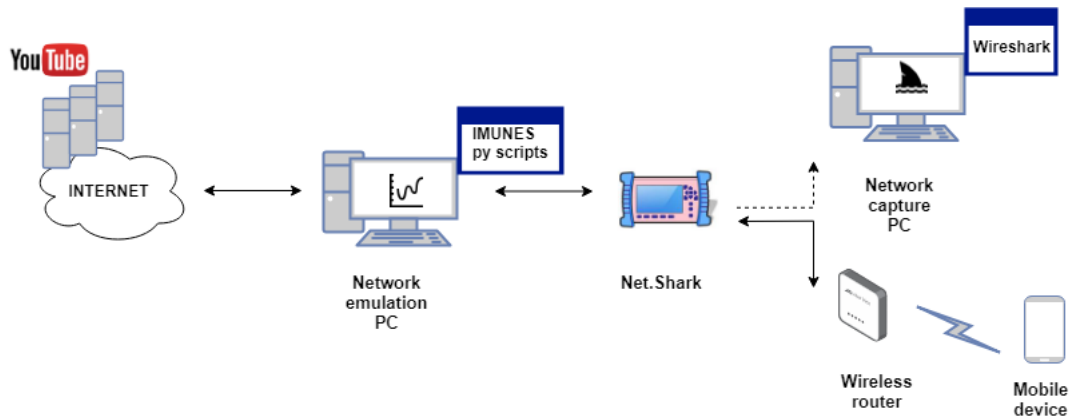


Figure 1.1: Laboratory setup.

Table 1.1: Description of all calculated features.

Feature name	Feature description
<i>averageThroughputDL</i>	Average downlink throughput [<i>Mbps</i>]
<i>avgPacketSizeDL</i>	Average downlink packet size [<i>Bytes</i>]
<i>percOfUsedTransTimeDL</i>	Percentage of 100ms-intervals with downlink traffic larger than 0 Bytes
<i>numOfPacketsLarger100BUL</i>	Number of uplink packets larger than 100 Bytes (number of segment requests)
<i>avgSizeLarger100BUL</i>	Average uplink packet size, including only packets larger than 100 Bytes
<i>stdSizeLarger100BUL</i>	Standard deviation of uplink packet size, including only packets larger than 100 Bytes
<i>avgThroughputFirst5s</i>	Average downlink throughput first 5 s of video watchtime [<i>Mbps</i>]
<i>avgThroughputFirst10s</i>	Average downlink throughput first 10 s of video watchtime [<i>Mbps</i>]
<i>avgThroughputFirstHalf</i>	Average downlink throughput in first half of video watchtime [<i>Mbps</i>]
<i>avgThroughputSecondHalf</i>	Average downlink throughput in second half of video watchtime [<i>Mbps</i>]
<i>avgThroughputFirst20p</i>	Average downlink throughput first 20% of video watchtime [<i>Mbps</i>]
<i>avgThroughputLast20p</i>	Average downlink throughput last 20% of video watchtime [<i>Mbps</i>]
<i>avgThroughputMid20p</i>	Average downlink throughput mid 20% of video watchtime [<i>Mbps</i>]
<i>avgSizeIn5sIntervalsDL</i>	Average of amounts of downlink data transferred in 5 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn5sIntervalsDL</i>	Harmonic mean of amounts of downlink data transferred in 5 s intervals [<i>Bytes</i>]
<i>medianSizeIn5sIntervalsDL</i>	Median of amounts of downlink data transferred in 5 s intervals [<i>Bytes</i>]
<i>minSizeIn5sIntervalsDL</i>	Minimum of amounts of downlink data transferred in 5 s intervals [<i>Bytes</i>]

<i>maxSizeIn5sIntervalsDL</i>	Maximum of amounts of downlink data transferred in 5 s intervals [<i>Bytes</i>]
<i>stDevSizeIn5sIntervalsDL</i>	Standard deviation of amounts of downlink data transferred in 5 s intervals [<i>Bytes</i>]
<i>avgSizeIn3sIntervalsDL</i>	Average of amounts of downlink data transferred in 3 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn3sIntervalsDL</i>	Harmonic mean of amounts of downlink data transferred in 3 s intervals [<i>Bytes</i>]
<i>medianSizeIn3sIntervalsDL</i>	Median of amounts of downlink data transferred in 3 s intervals [<i>Bytes</i>]
<i>minSizeIn3sIntervalsDL</i>	Minimum of amounts of downlink data transferred in 3 s intervals [<i>Bytes</i>]
<i>maxSizeIn3sIntervalsDL</i>	Maximum of amounts of downlink data transferred in 3 s intervals [<i>Bytes</i>]
<i>stDevSizeIn3sIntervalsDL</i>	Standard deviation of amounts of downlink data transferred in 3 s intervals [<i>Bytes</i>]
<i>avgSizeIn2sIntervalsDL</i>	Average of amounts of downlink data transferred in 2 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn2sIntervalsDL</i>	Harmonic mean of amounts of downlink data transferred in 2 s intervals [<i>Bytes</i>]
<i>medianSizeIn2sIntervalsDL</i>	Median of amounts of downlink data transferred in 2 s intervals [<i>Bytes</i>]
<i>minSizeIn2sIntervalsDL</i>	Minimum of amounts of downlink data transferred in 2 s intervals [<i>Bytes</i>]
<i>maxSizeIn2sIntervalsDL</i>	Maximum of amounts of downlink data transferred in 2 s intervals [<i>Bytes</i>]
<i>stDevSizeIn2sIntervalsDL</i>	Standard deviation of amounts of downlink data transferred in 2 s intervals [<i>Bytes</i>]
<i>avgSizeIn1sIntervalsDL</i>	Average of amounts of downlink data transferred in 1 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn1sIntervalsDL</i>	Harmonic mean of amounts of downlink data transferred in 1 s intervals [<i>Bytes</i>]
<i>medianSizeIn1sIntervalsDL</i>	Median of amounts of downlink data transferred in 1 s intervals [<i>Bytes</i>]
<i>minSizeIn1sIntervalsDL</i>	Minimum of amounts of downlink data transferred in 1 s intervals [<i>Bytes</i>]
<i>maxSizeIn1sIntervalsDL</i>	Maximum of amounts of downlink data transferred in 1 s intervals [<i>Bytes</i>]
<i>stDevSizeIn1sIntervalsDL</i>	Standard deviation of amounts of downlink data transferred in 1 s intervals [<i>Bytes</i>]
<i>averageThroughputUL</i>	Average uplink throughput [<i>Mbps</i>]
<i>avgPacketSizeUL</i>	Average uplink packet size [<i>Bytes</i>]
<i>avgSizeIn5sIntervalsUL</i>	Average of amounts of uplink data transferred in 5 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn5sIntervalsUL</i>	Harmonic mean of amounts of uplink data transferred in 5 s intervals [<i>Bytes</i>]
<i>medianSizeIn5sIntervalsUL</i>	Median of amounts of uplink data transferred in 5 s intervals [<i>Bytes</i>]
<i>minSizeIn5sIntervalsUL</i>	Minimum of amounts of uplink data transferred in 5 s intervals [<i>Bytes</i>]
<i>maxSizeIn5sIntervalsUL</i>	Maximum of amounts of uplink data transferred in 5 s intervals [<i>Bytes</i>]
<i>stDevSizeIn5sIntervalsUL</i>	Standard deviation of amounts of uplink data transferred in 5 s intervals [<i>Bytes</i>]
<i>avgSizeIn3sIntervalsUL</i>	Average of amounts of uplink data transferred in 3 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn3sIntervalsUL</i>	Harmonic mean of amounts of uplink data transferred in 3 s intervals [<i>Bytes</i>]
<i>medianSizeIn3sIntervalsUL</i>	Median of amounts of uplink data transferred in 3 s intervals [<i>Bytes</i>]
<i>minSizeIn3sIntervalsUL</i>	Minimum of amounts of uplink data transferred in 3 s intervals [<i>Bytes</i>]
<i>maxSizeIn3sIntervalsUL</i>	Maximum of amounts of uplink data transferred in 3 s intervals [<i>Bytes</i>]
<i>stDevSizeIn3sIntervalsUL</i>	Standard deviation of amounts of uplink data transferred in 3 s intervals [<i>Bytes</i>]
<i>avgSizeIn2sIntervalsUL</i>	Average of amounts of uplink data transferred in 2 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn2sIntervalsUL</i>	Harmonic mean of amounts of uplink data transferred in 2 s intervals [<i>Bytes</i>]
<i>medianSizeIn2sIntervalsUL</i>	Median of amounts of uplink data transferred in 2 s intervals [<i>Bytes</i>]
<i>minSizeIn2sIntervalsUL</i>	Minimum of amounts of uplink data transferred in 2 s intervals [<i>Bytes</i>]
<i>maxSizeIn2sIntervalsUL</i>	Maximum of amounts of uplink data transferred in 2 s intervals [<i>Bytes</i>]
<i>stDevSizeIn2sIntervalsUL</i>	Standard deviation of amounts of uplink data transferred in 2 s intervals [<i>Bytes</i>]
<i>avgSizeIn1sIntervalsUL</i>	Average of amounts of uplink data transferred in 1 s intervals [<i>Bytes</i>]
<i>hMeanSizeIn1sIntervalsUL</i>	Harmonic mean of amounts of uplink data transferred in 1 s intervals [<i>Bytes</i>]
<i>medianSizeIn1sIntervalsUL</i>	Median of amounts of uplink data transferred in 1 s intervals [<i>Bytes</i>]
<i>minSizeIn1sIntervalsUL</i>	Minimum of amounts of uplink data transferred in 1 s intervals [<i>Bytes</i>]
<i>maxSizeIn1sIntervalsUL</i>	Maximum of amounts of uplink data transferred in 1 s intervals [<i>Bytes</i>]
<i>stDevSizeIn1sIntervalsUL</i>	Standard deviation of amounts of uplink data transferred in 1 s intervals [<i>Bytes</i>]

For each target variable (KPI) we select relevant features using Wrapper methods. Tables 1.2 and 1.3 summarize target variables and their selected features used for Random Forest trained models. The number of trees used for model training was 100.

Table 1.2: Selected features for KPI classification models (Dataset D1)

Target variable	Selected features (predictors)
Longest resolution {hd:h, sd:s}	<i>percOfUsedTransTimeDL</i> , <i>avgThroughputFirstHalf</i> , <i>avgThroughputSecondHalf</i> , <i>hMeanSizeIn5sIntervalsDL</i> , <i>stDevSizeIn1sIntervalsDL</i> , <i>hMeanSizeIn5sIntervalsUL</i> , <i>medianSizeIn1sIntervalsUL</i> , <i>stDevSizeIn1sIntervalsUL</i>
Initial delay {short:s, long:l}	<i>avgPacketSizeDL</i> , <i>percOfUsedTransTimeDL</i> , <i>avgThroughputLast20p</i> , <i>avgThroughputMid20p</i> , <i>medianSizeIn3sIntervalsDL</i> , <i>minSizeIn3sIntervalsDL</i> , <i>maxSizeIn3sIntervalsDL</i> , <i>medianSizeIn3sIntervalsUL</i> , <i>medianSizeIn1sIntervalsUL</i>
Avg. video bitrate {high:h, medium:m, low:l}	<i>averageThroughputDL</i> , <i>numOfPacketsLarger100BUL</i> , <i>avgSizeLarger100BUL</i> , <i>avgThroughputFirst5s</i> , <i>avgThroughputFirst20p</i> , <i>avgThroughputLast20p</i> , <i>stDevSizeIn3sIntervalsDL</i> , <i>averageThroughputUL</i>
Avg. video bitrate {high:h, low:l}	<i>averageThroughputDL</i> , <i>percOfUsedtransTimeDL</i> , <i>stDevSizeIn5sIntervalsDL</i>

Table 1.3: Selected features for KPI classification models (Dataset D1+D2)

Target variable	Selected features (predictors)
Longest resolution {hd:h, sd:s}	<i>percOfUsedTransTimeDL</i> , <i>avgThroughputFirstHalf</i> , <i>avgThroughputFirst20p</i> , <i>avgThroughputLast20p</i> , <i>maxSizeIn5sIntervalsDL</i> , <i>maxSizeIn2sIntervalsDL</i> , <i>avgSizeIn1sIntervalsDL</i>
Initial delay {short:s, long:l}	<i>numOfPacketsLarger100BUL</i> , <i>stdSizeLarger100BUL</i> , <i>avgThroughputFirst5s</i> , <i>avgThroughput10s</i> , <i>avgThroughputSecondHalf</i> , <i>avgThroughputFirst20p</i> , <i>avgThroughputMid20p</i> , <i>hMeanSizeIn5sIntervalsDL</i> , <i>minSizeIn5sIntervalsDL</i> , <i>stDevSizeIn5sIntervalsDL</i> , <i>avgSizeIn3sIntervalsDL</i> , <i>hMeanSizeIn3sIntervalsDL</i> , <i>stDevSizeIn3sIntervalsDL</i> , <i>minSizeIn2sIntervalsDL</i> , <i>maxSizeIn1sIntervalsDL</i> , <i>avgSizeIn5sIntervalsUL</i> , <i>meanSizeIn5sIntervalsUL</i> , <i>maxSizeIn5sIntervalsUL</i> , <i>avgSizeIn3sIntervalsUL</i> , <i>maxSizeIn3sIntervalsUL</i> , <i>minSizeIn2sIntervalsUL</i> , <i>medianSizeIn1sIntervalsUL</i> , <i>minSizeIn1sIntervalsUL</i>
Avg. video bitrate {high:h, medium:m, low:l}	<i>averageThroughputDL</i> , <i>avgPacketSizeDL</i> , <i>numOfPacketsLarger100BUL</i> , <i>avgThroughputFirstHalf</i> , <i>avgThroughputSecondHalf</i> , <i>avgThroughputLast20p</i> , <i>avgThroughputMid20p</i> , <i>stDevSizeIn5sIntervalsDL</i> , <i>hMeanSizeIn1sIntervalsDL</i> , <i>medianSizeIn5sIntervalsDL</i> , <i>stDevSizeIn1sIntervalsDL</i> , <i>avgPacketSizeUL</i> , <i>maxSizeIn2sIntervalsUL</i>
Avg. video bitrate {high:h, low:l}	<i>avgThroughputSecondHalf</i> , <i>avgThroughputFirst20p</i> , <i>maxSizeIn5sIntervalsDL</i> , <i>maxSizeIn3sIntervalsUL</i> , <i>maxSizeIn2sIntervalsUL</i>