SAP: Stall-Aware Pacing for Improved DASH Video Experience in Cellular Networks

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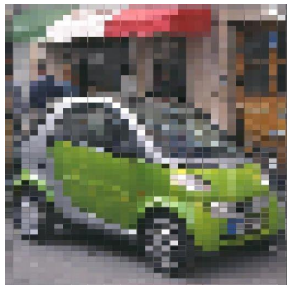
Motivations

MISL

**** 49.6% of video sessions experience video problems***

**** 40-50% of video sessions experience rebuffering events***



OPERA software MUX

http://fortune.com/2016/03/01/snapchat-facebook-video-views-2/
http://www.operasoftware.com/blog/industry-news-and-small-operators-worldwide-are-struggling-with-mobile-video-stalling
http://mux.com/blog/buffering-reduces-video-watch-time-by-40-according-to-research/

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Challenges

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Variable Traffic Demand

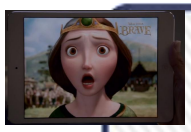
Highly Variable Links

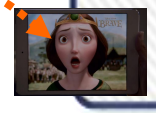
Shared Medium

Distinct link Conditions

Congestion Control

ISP Resource management



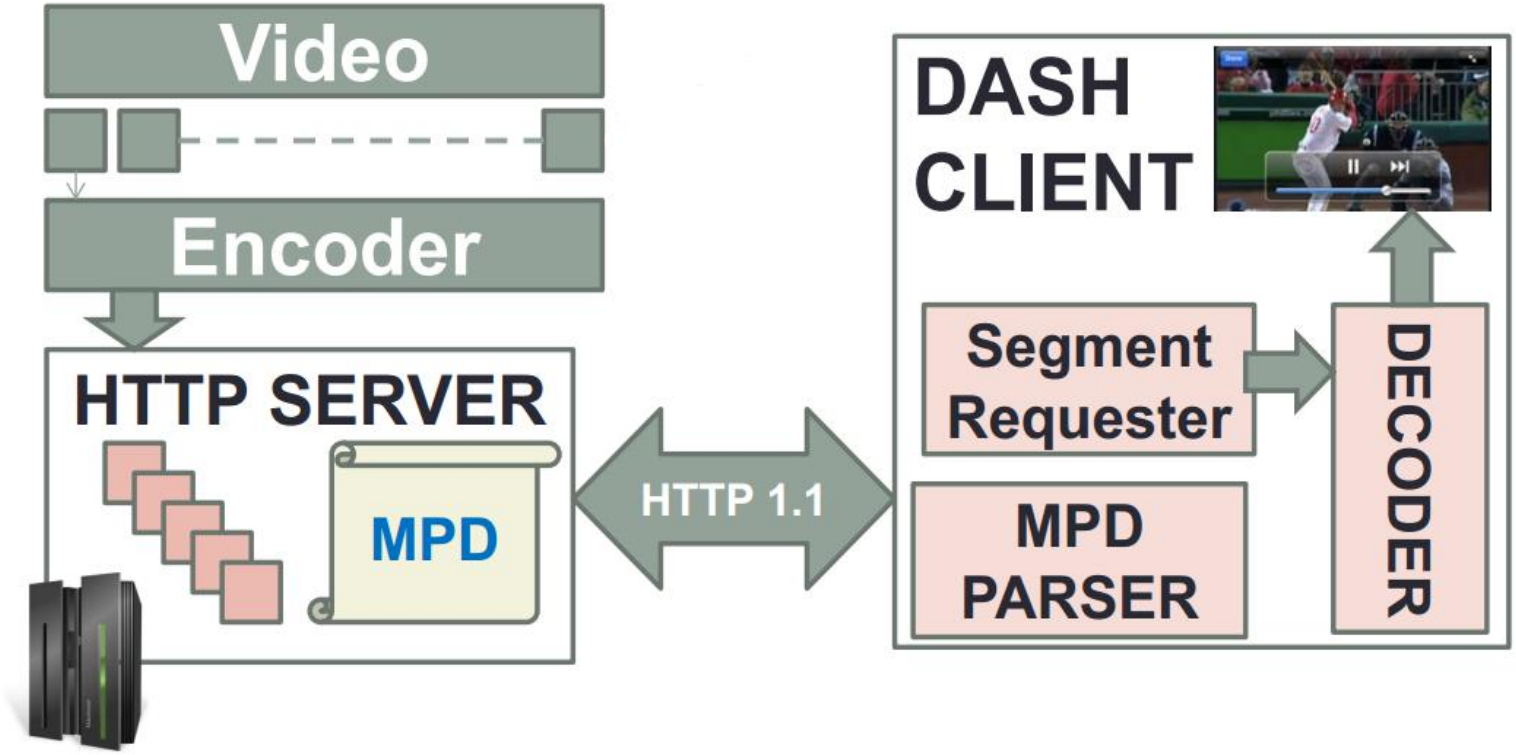


DASH Quality Control

Quality Control

Developing Video QoE-aware solutions is crucial to realize a satisfactory streaming performance for all system users

Dynamic Adaptive Streaming over HTTP (DASH)

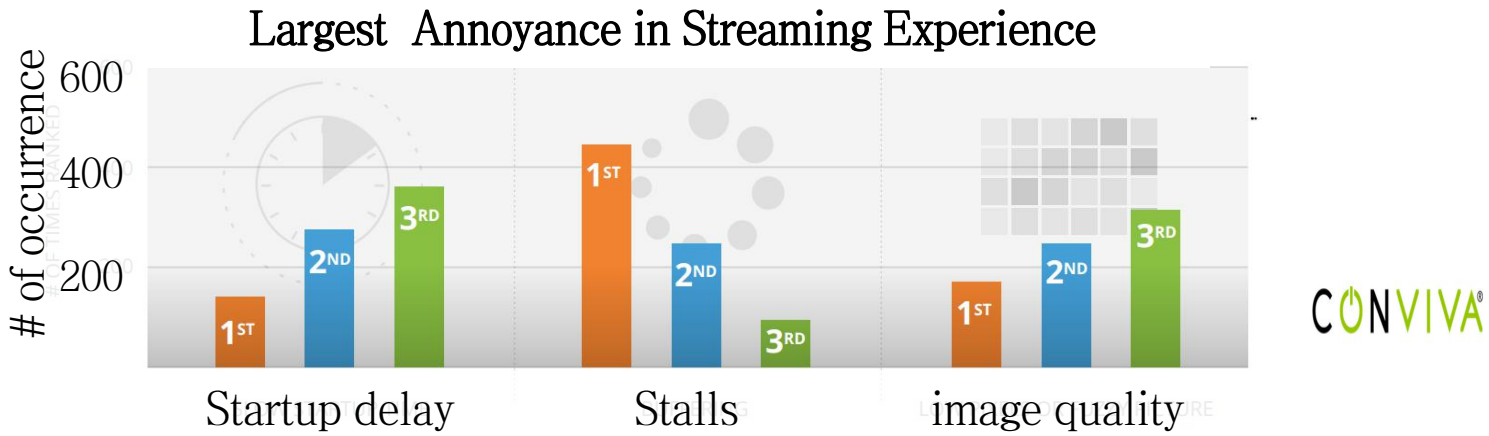


- Server And Network Assisted DASH (SAND) (ISO/IEC 23009–5:2017)
  - DASH Aware Network Element (DANE) coordinates multiple clients sharing the same network resources

DASH Quality of Experience

Visual Quality issues
- Poor image quality
- Noticeable quality switches

Temporal Quality issues
- Long initial startup delay
- Rebuffering frequency
- Rebuffering duration



http://lp.conviva.com/rs/901-ZND-194/images/CSR2015_HowConsumersJudgeTheirViewingExperience_Final.pdf

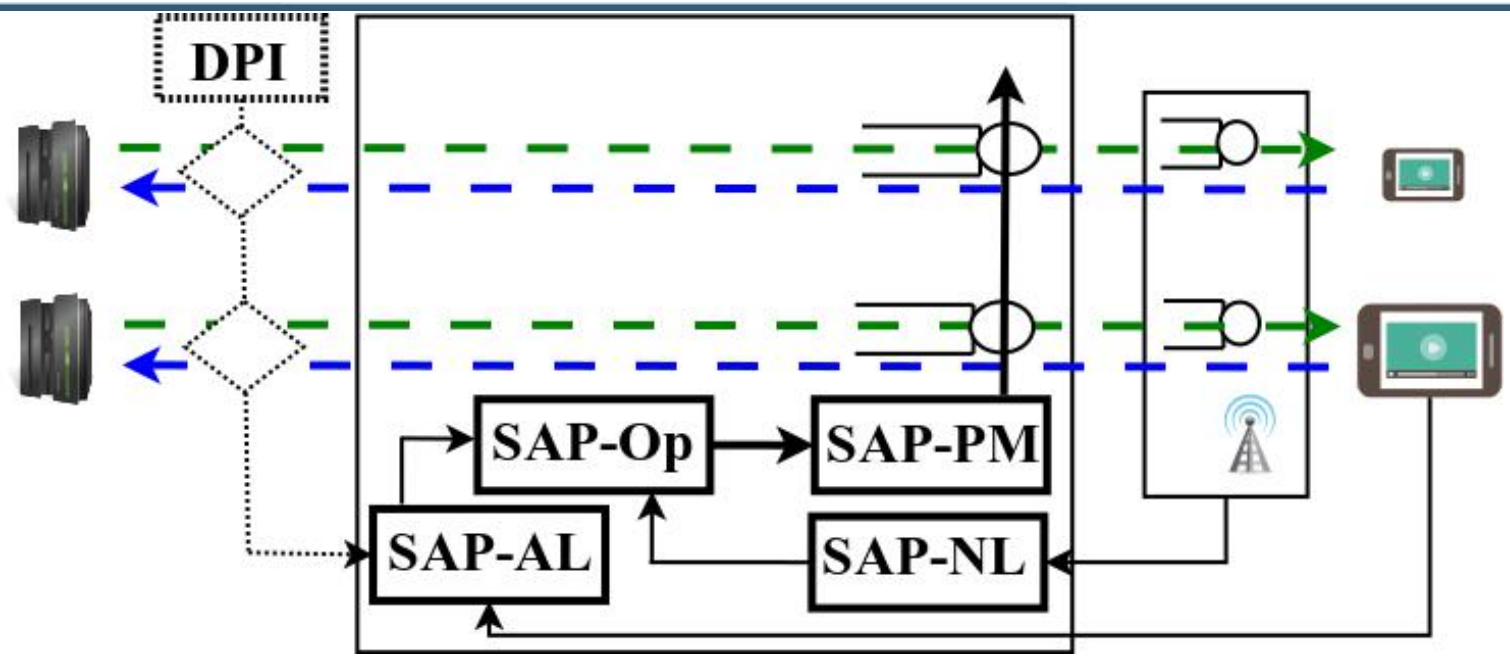
Outline

- SAP Design
- SAP Performance Evaluation
- Conclusions

SAP Assumptions

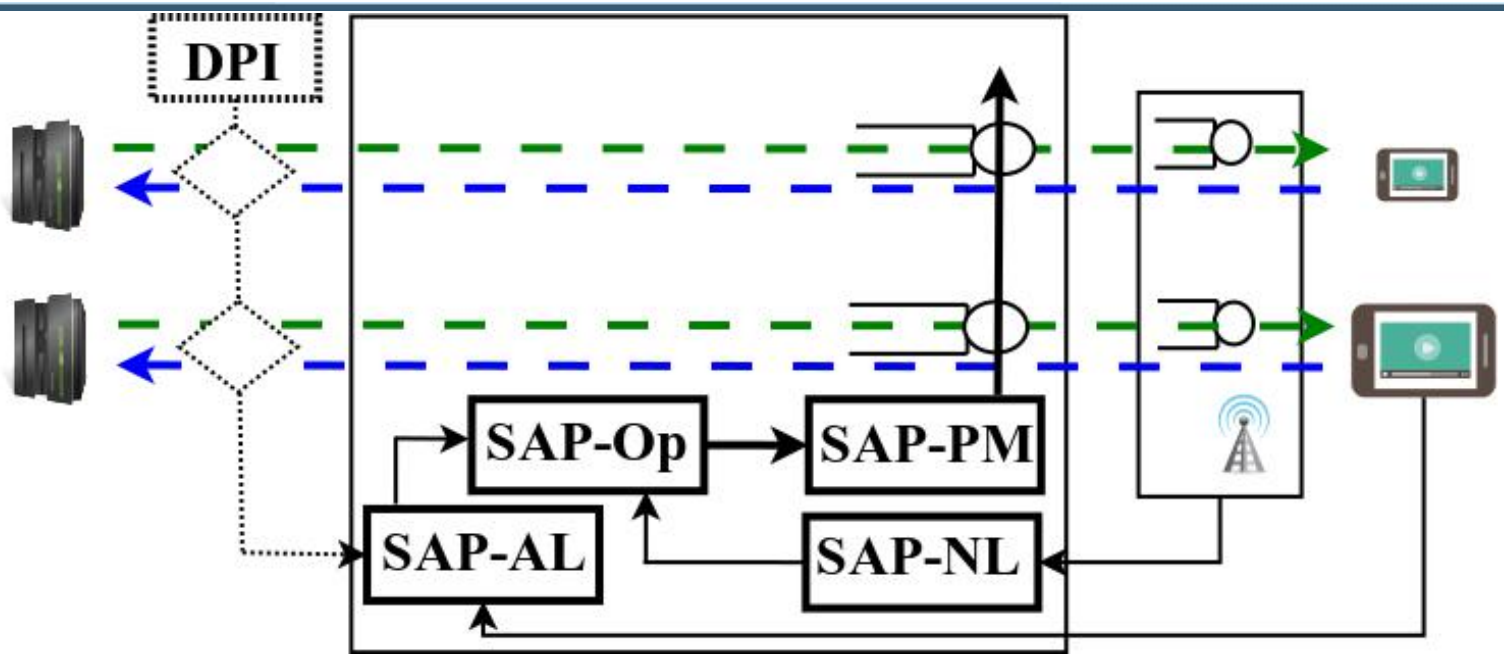
- A group of U DASH clients share a cellular base station (BS)
- Video traffic is assigned a portion of network resources (C)
- The BS resource management and video quality control are black–boxes to SAP
- Channel quality information per client is assumed available from the network

SAP Overview



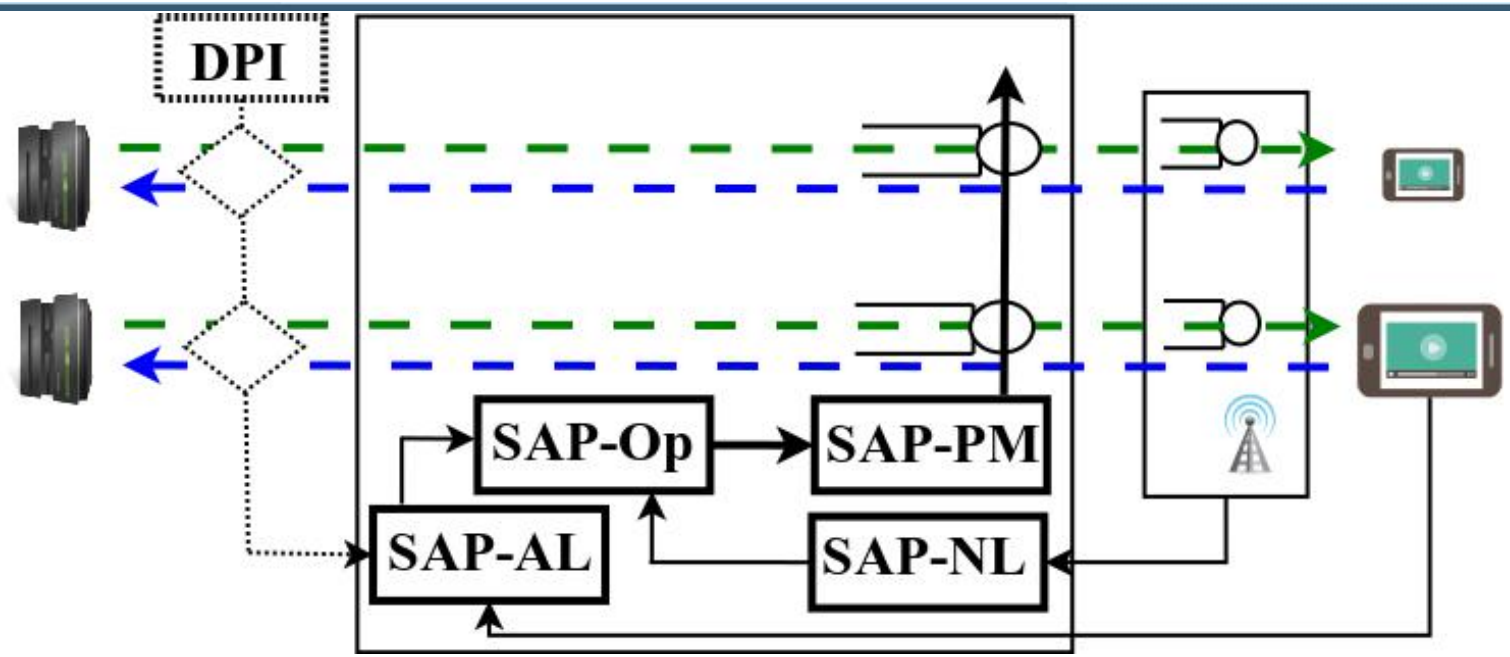
SAP-OP: an Optimized QoE-aware decision engine that determines the delivery rates of different streams based on joint application and network states

SAP Overview



SAP-PM: Pacing manager controls the delivery rate of different streams towards the bottleneck.

SAP Overview



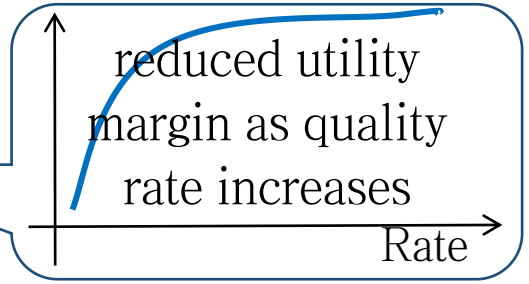
SAP-AL: an application state logger to maintain relevant application information for different clients

SAP-NL: an Network state logger to maintain relevant network information for different clients

SAP QoE-Oriented Pacing Optimizer

- Tunable quality utility inspired by VQM

$$\Upsilon_u(x_u) = (1 - e^{-\rho_u x_u / r_q})$$



Can Be tuned to accommodate device capability and or user priority.

- Stall penalty identified by the probability of segment stalling based on the segment size distribution

$$\pi_u = Prob(d_u > D_u) = Prob\left(\frac{S_{\vartheta_u}}{x_u} > D_u\right)$$

probability that segment fetch time is bigger than buffer level

  - New segment vs. ongoing segment

- No switching component!

SAP Optimization Program

$$\max_{x_i} \sum_{u=1}^{U} \Upsilon_u(x_u) - \beta\pi_u$$

maximize quality utility minus a stall penalty

such that

$$\sum_{u} x_u/\gamma_u < \zeta \quad C$$

constraint on allocated resources

$$x_u \in \{\hat{r}_1, ..., \hat{r}_Q\}$$

- Discrete non-linear program

Resource allocation (ms) — SAP (250–1000ms) — Quality adaptation (4+ seconds)

- Real-time performance is achieved by using *separable programming*

Collaborative vs. Non-collaborative SAP

- Collaborative SAP
  - SAP-AL implements a DASH Assisting Network Element (DANE) interface that receives status messages from the client
- Non-collaborative SAP
  - **Unencrypted session:**
    - ① Extract relevant information from MPD file
    - ② Estimate the buffer level
  - **Encrypted session:**
    - ① Buffer-level estimation
    - ② Educated arbitrary discrete rates
    - ③ Segment duration estimation

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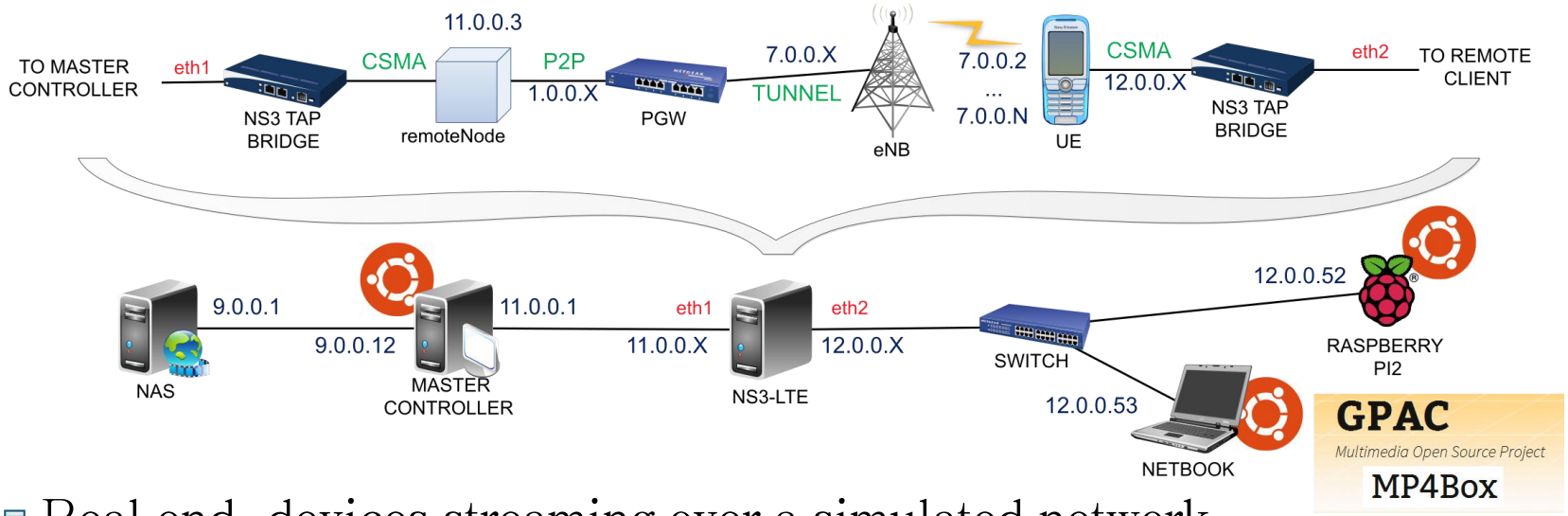
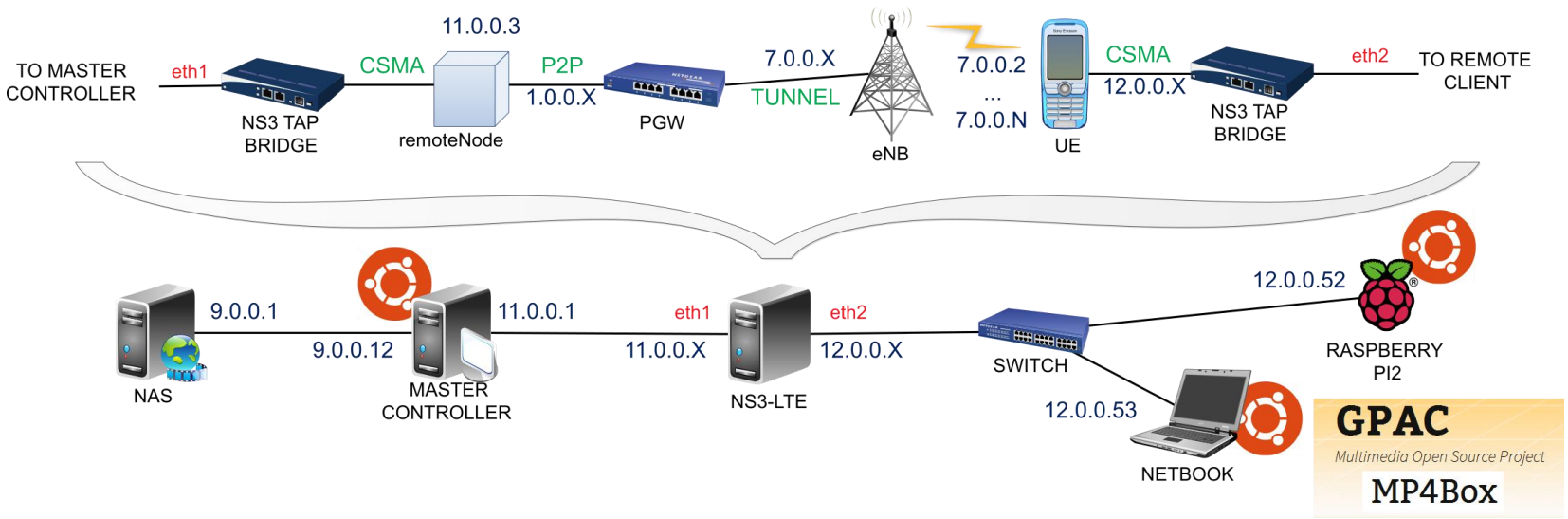
Performance Evaluation Setup



- Real end–devices streaming over a simulated network
- Real content using the public iVID video dataset
- Each video client is connected to a corresponding user equipment in the simulated network using a combination of virtual and real switches
- STATIC IP addresses and routes are defined in both physical and simulated nodes
- Master controller orchestrates the experiment and implements the traffic managers

Performance Evaluation Setup



- GPAC client is extended with multiple algorithms including BBA2, FESTIVE, CONV, ARBITER.
- GPAC is modified to allow configurable buffer size, initial buffering and rebuffering behavior.
- LTE scheduler in ns3 is modified to report the channel quality information to traffic managers
- Clients report application information to the master controller

Performance Evaluation

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- We compare the performance of three schemes including SAP, no traffic control (noTc), and AVIS [Mobicom 13]
- Traffic manager optimization programs are implemented using C and LINDO API
- Key performance metrics
  - r_{av}:The average received quality rate per session
  - n_{st}:The average number of stalls per session
  - t_{st}:The average stall duration per session
  - n_{sw}:The average number of switches per session
  - l_{sw}: The average switching level
  - x_q: objective QoE metric

$$x_q = max(0, 0.17 + 5.67\frac{q_{av}}{q_Q} - 6.72 * \frac{q_{std}}{q_Q} - 4.95\varphi)$$

  - $_q$: standard deviation of user QoE

Scenario 1: Collaborative Clients with Diverse Link

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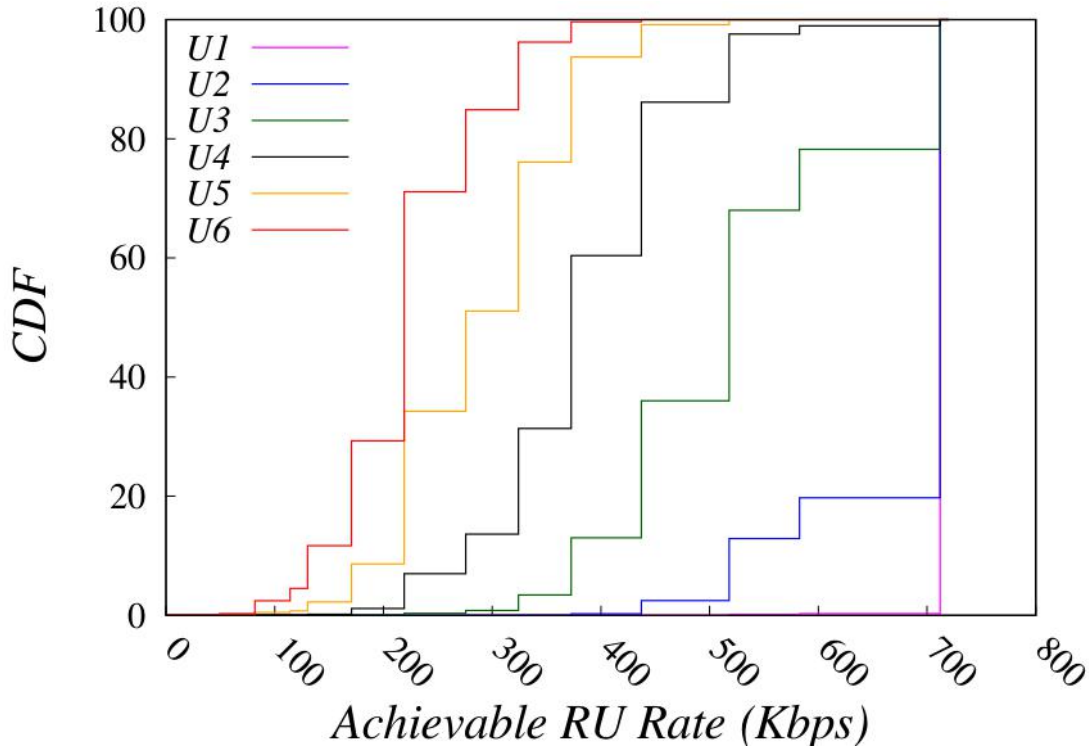
- Six clients located at incremental distances from an LTE eNodeB with 6 resource units (RU)
- Clients initiate video streaming with a one second gap



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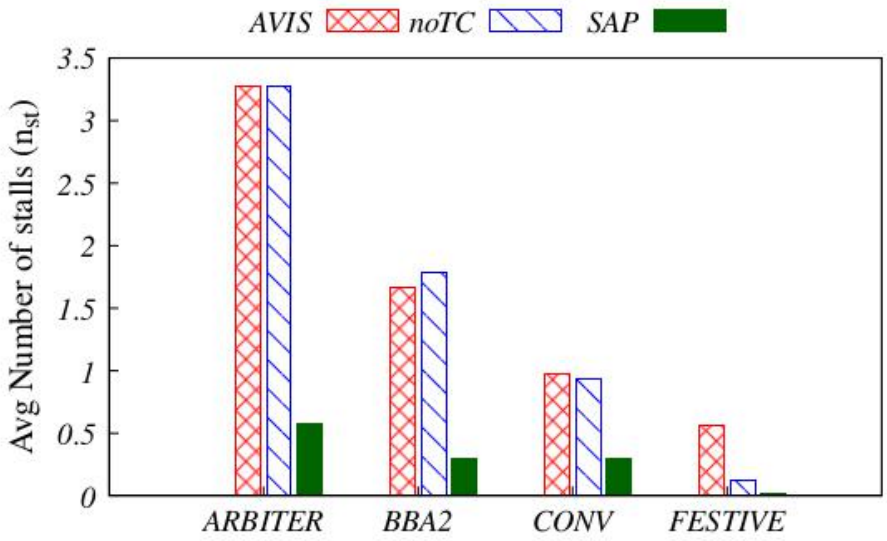
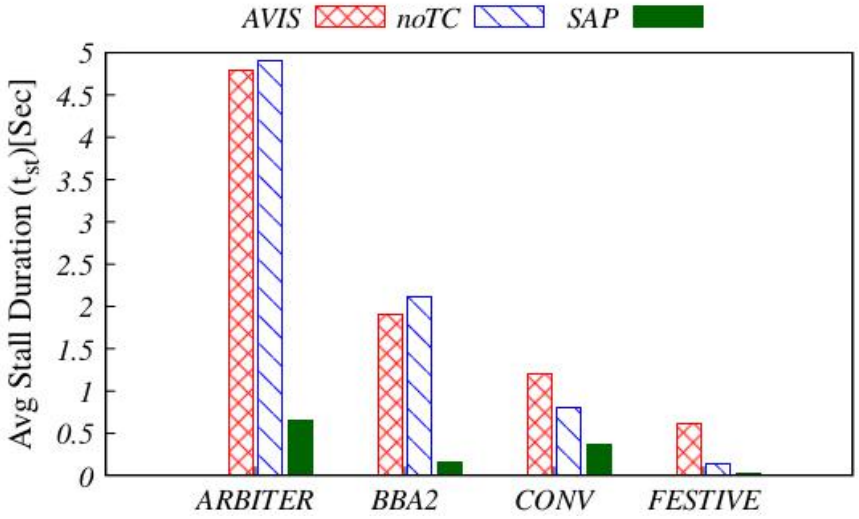
Scenario 1: SAP improves stall performance





SAP reduces the number of stalls and stall duration

Scenario 1: SAP improves stall performance

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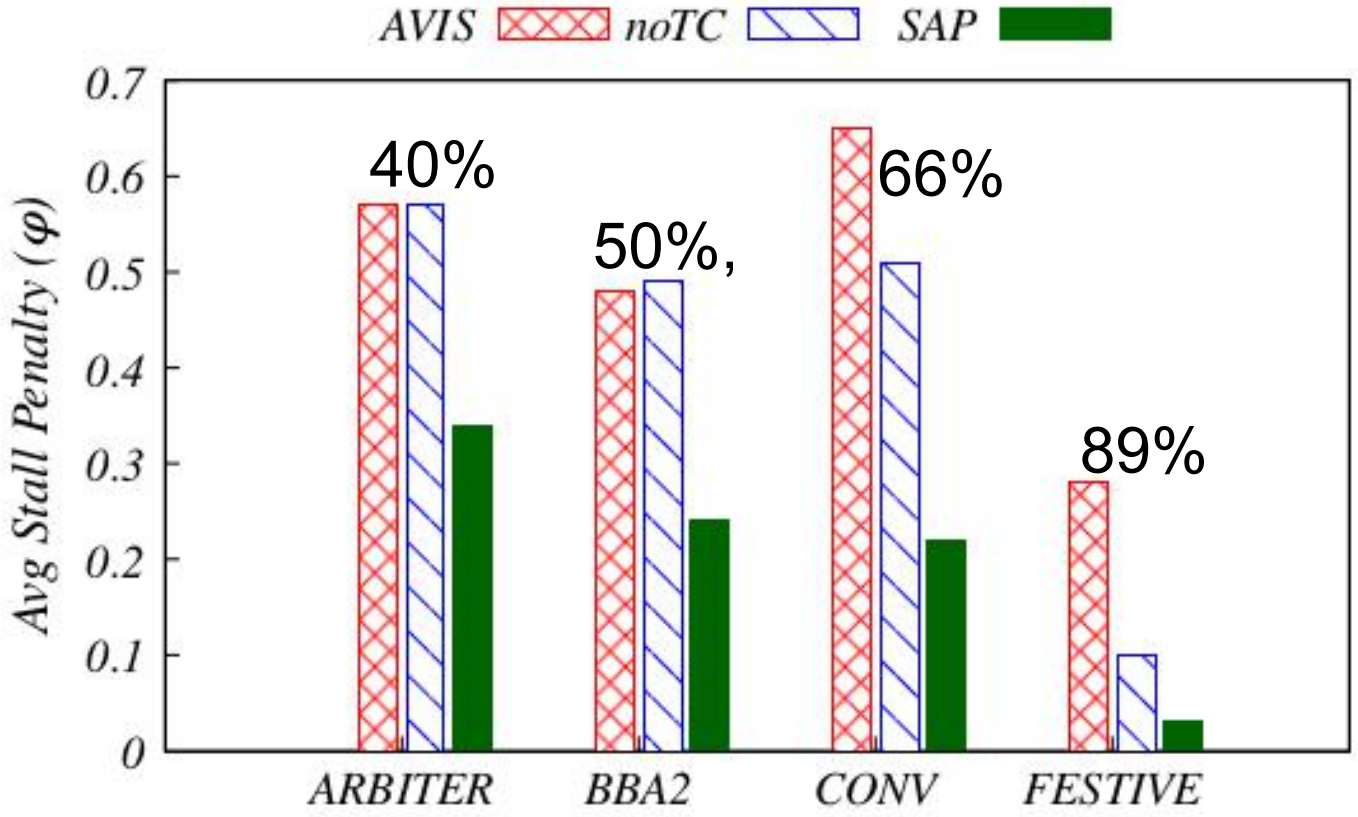
SAP significantly reduces the stall QoE penalty

$$\varphi = 0.875 * max(0, 1 + ln(f_{st})/6) + 0.008333 * min(t_{st}, 15)$$



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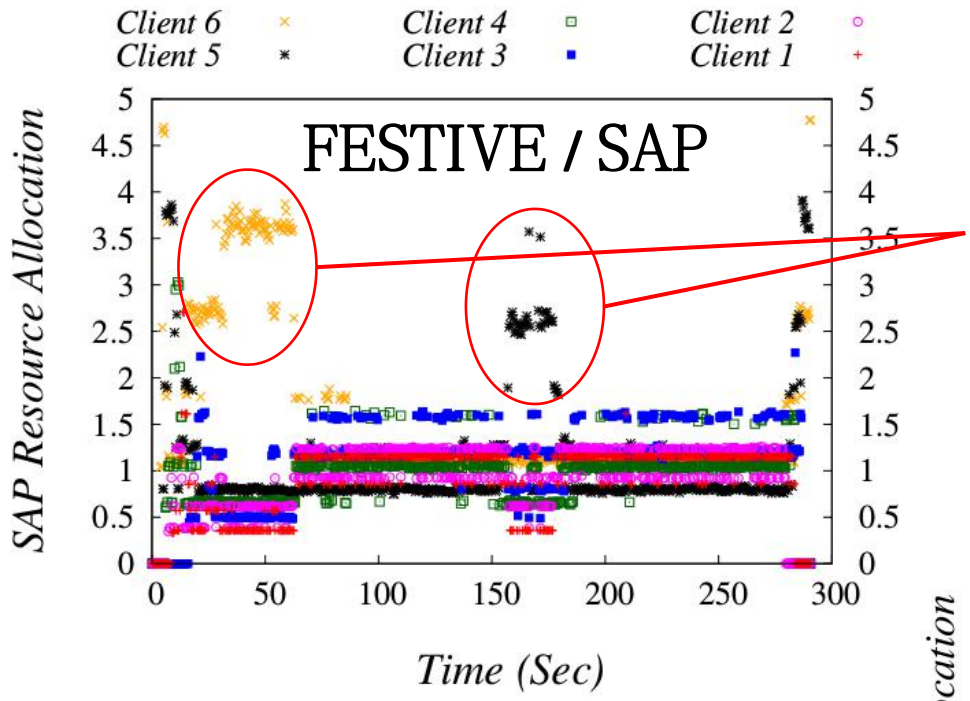
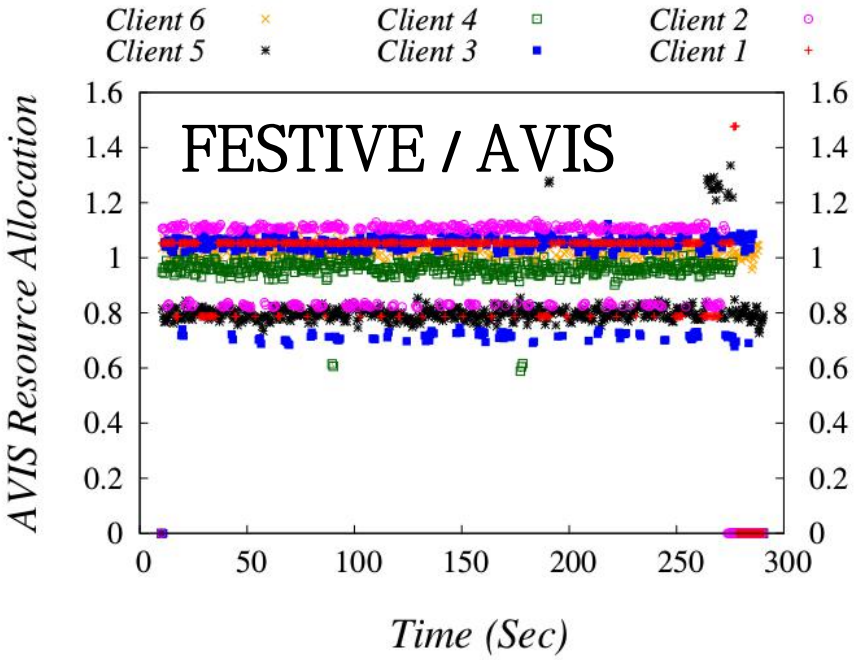
How SAP improves stall performance?

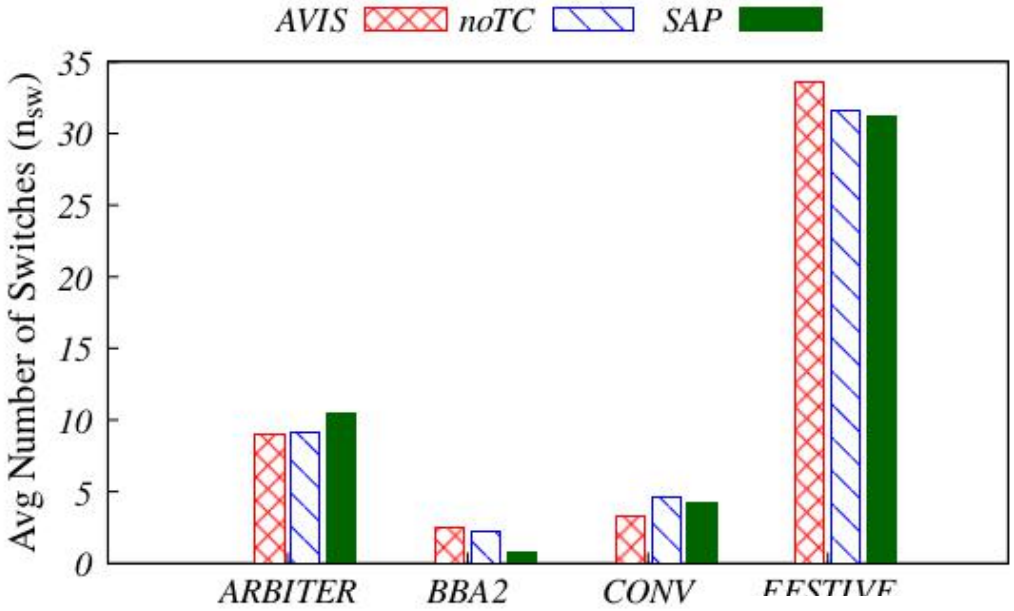


SAP reshuffles resources to support clients to avoid stalls when necessary

AVIS behavior is stall agnostic

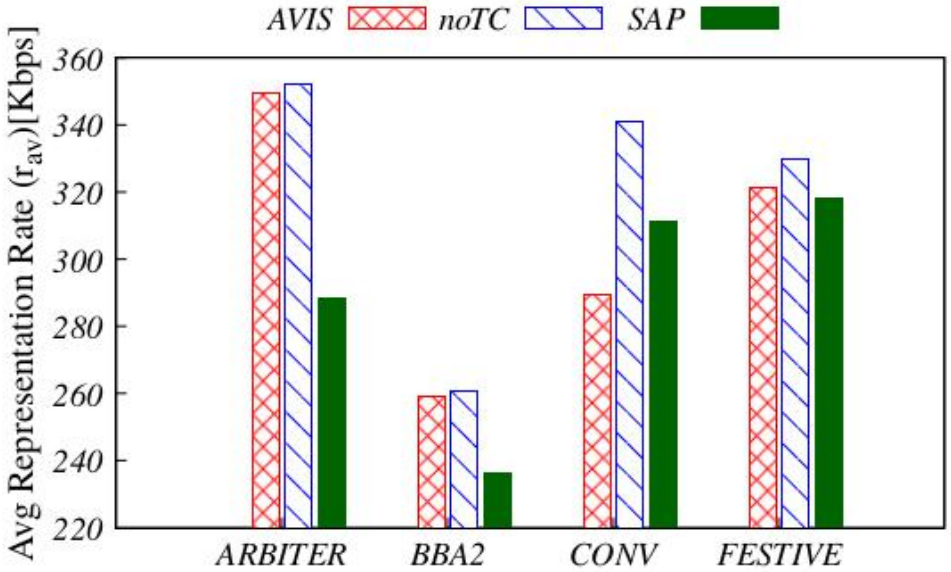


SAP impact on quality rate and switching frequency

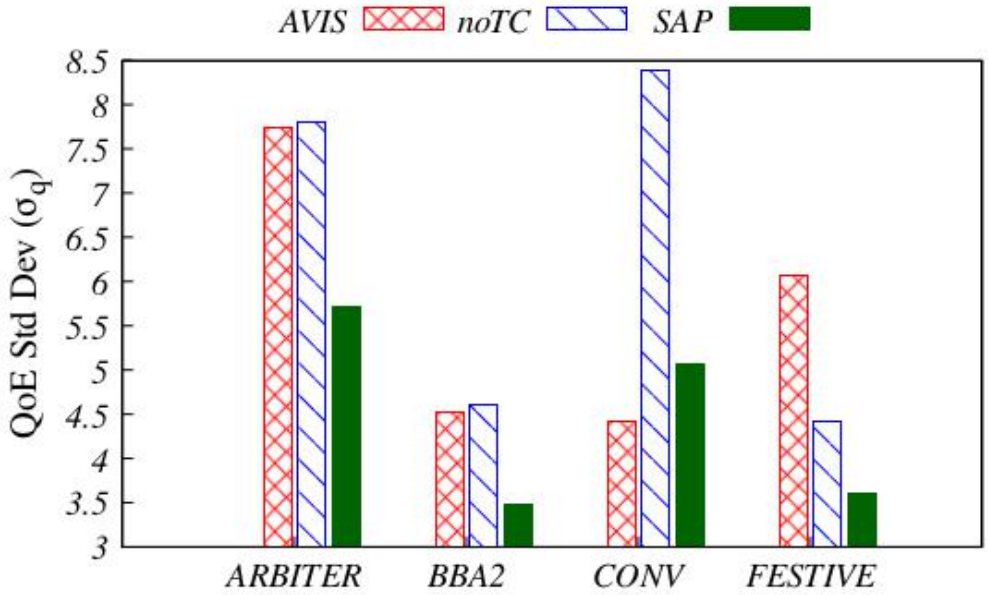


SAP has limited impact on representation switching

Traffic control reduces the average quality rate

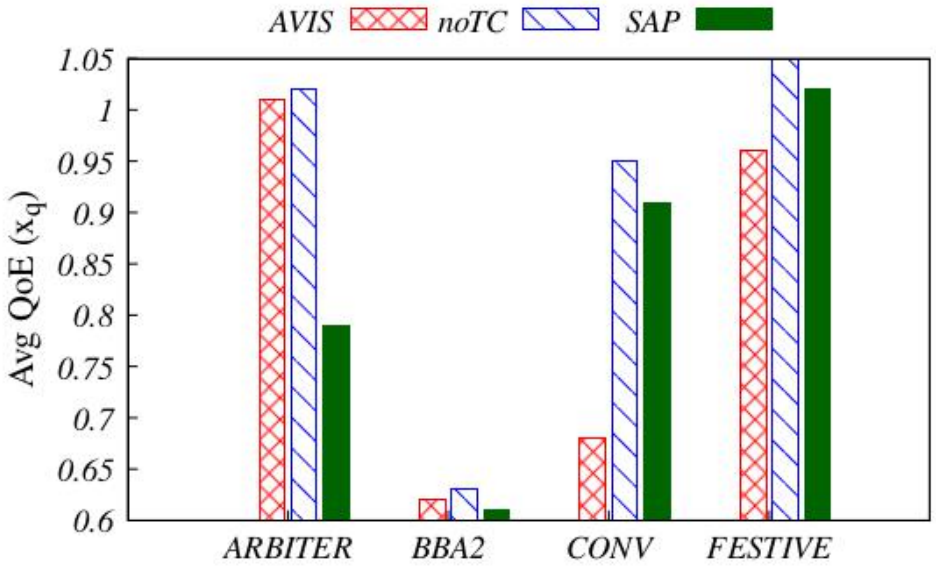


SAP ensures QoE fairness

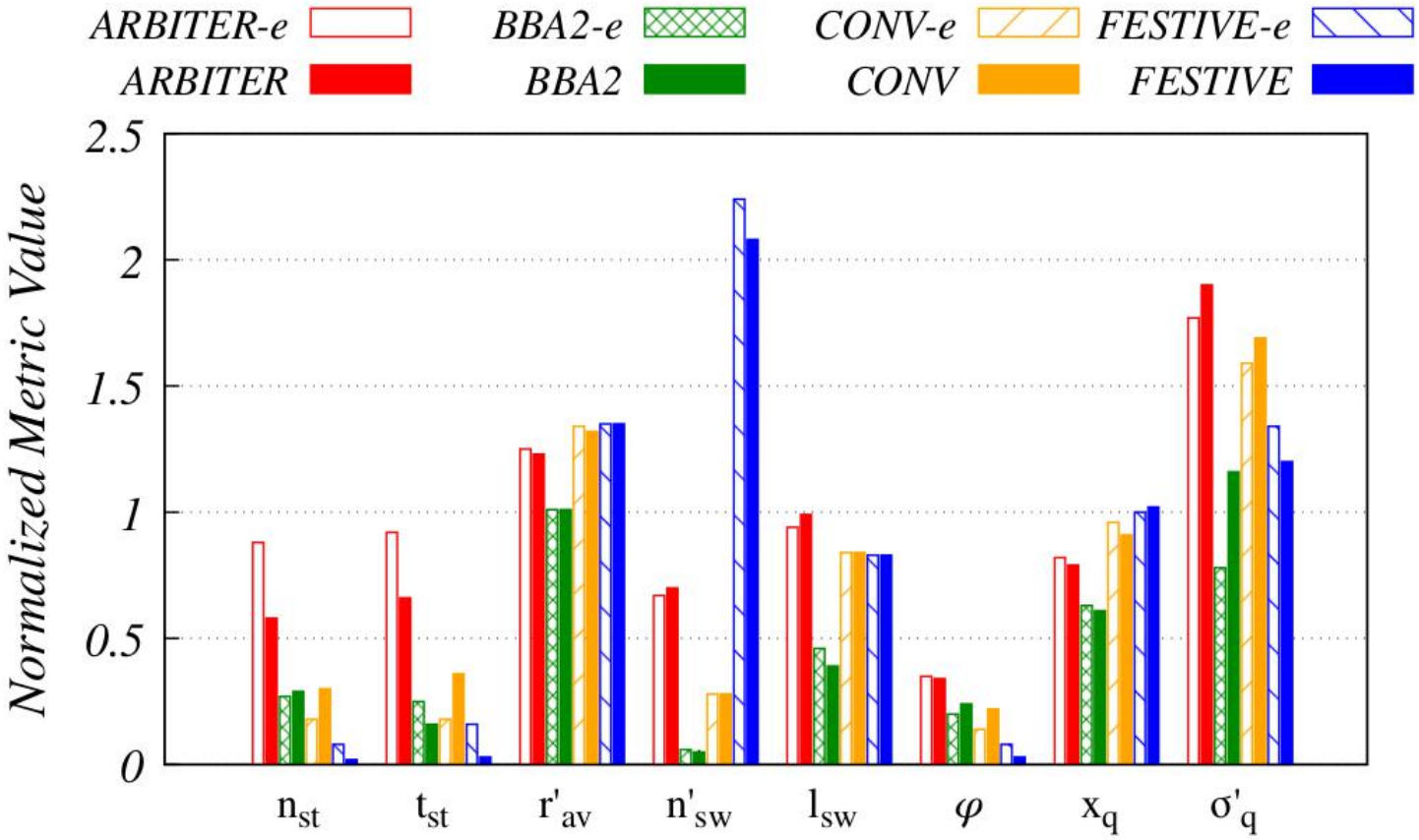


SAP noticeably reduces the QoE variation among users

While avoiding QoE extremes, the average QoE of all users drops



Collaborative vs. Non-collaborative SAP



SAP performs equally well when the buffer level estimator is used in the non–collaborative case

Conclusions

- The independent operation of client–based quality control and the base station downlink scheduling leads to a distinct QoE among users in cellular systems
- SAP indirectly integrates the quality control and scheduling loops using a QoE–aware framework based on joint network and application states
- SAP leads to a dramatic reduction, up to 90%, in the stall QoE penalty for different DASH client adaptation algorithms in a wide variety of operating conditions
- SAP reduces the QoE diversity by up to 40% leading to a fair QoE for video users operating in distinct channel conditions
- SAP achieves similar performance in both collaborative and non–collaborative scenarios

http://www.ucc.ie/en/misl/research/software/sap-testbed/
http://www.ucc.ie/en/misl/research/current/ivid_dataset/

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