Towards a Small Buffering Delay in Adaptive Video Streaming

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Motivation

State-of-the-art rate adaptation is not suitable for *low-latency* dynamic streaming,

due to a lack of explicit stabilization of client buffer dynamics.

In case the client buffer is at its maximum level (the maximal buffering delay),

- interactions with TCP's flow control may lead to a *biased throughput feedback*, and result in undesirably variable and low video quality;[1]
- *ON-OFF streaming pattern* occurs, and may cause unfairness with multiple video streaming sessions.[2]

In contrast to existing solutions that focus on buffer control at near-zero buffer levels,

a stabilization of buffer dynamics with a filled buffer is an open issue.

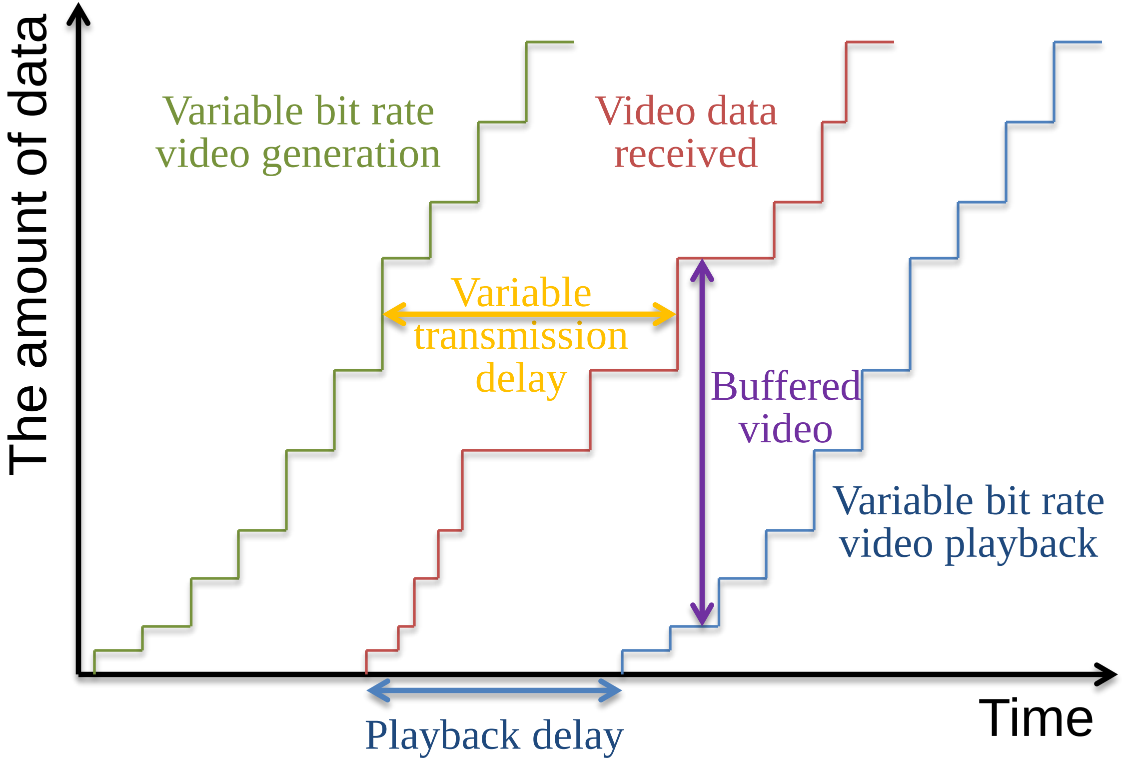
[1] T. Huang, R. Johari, and N. McKeown. Downton abbey without the hiccups: buffer-based rate adaptation for HTTP video streaming. In *Proceedings of the ACM SIGCOMM workshop on Future human-centric multimedia networking* (FhMN), 2013.

[2] S. Akhshabi, L. Anantakrishnan, A. Begen, and C. Dovrolis. What happens when HTTP adaptive streaming players compete for bandwidth?. In *Proceedings of the 22nd international workshop on Network and Operating System Support for Digital Audio and Video* (NOSSDAV), 2012.

Outline

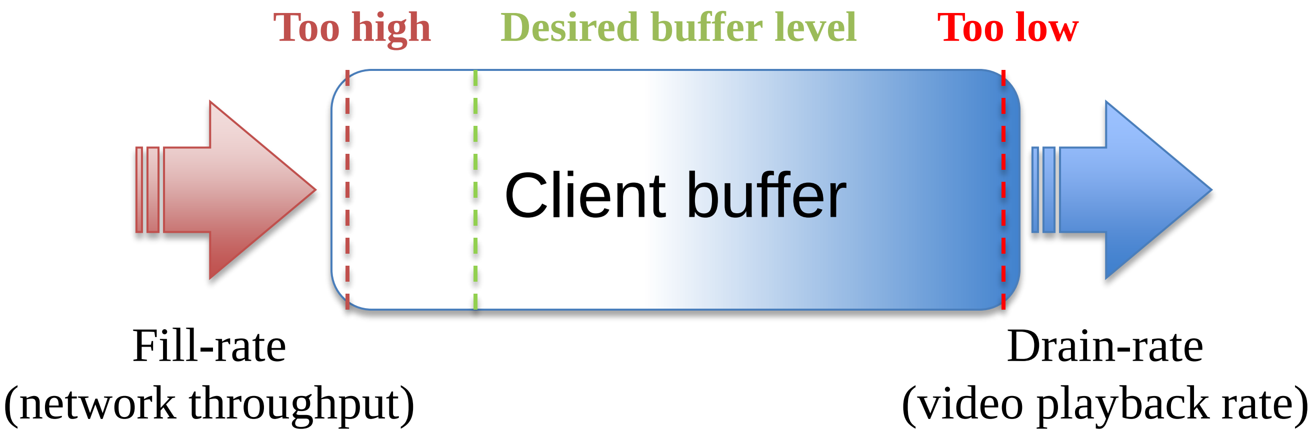
- ✓ Motivation
- ❑ Rate control for buffer stabilization
  - Buffering delay
  - Modeling buffer dynamics
  - Rate selection
- ❑ Prototype implementation
  - Server-based streaming architecture (Open-Loop rAte Control, OLAC)
  - Transport protocol configuration
- ❑ Results

Buffering Delay



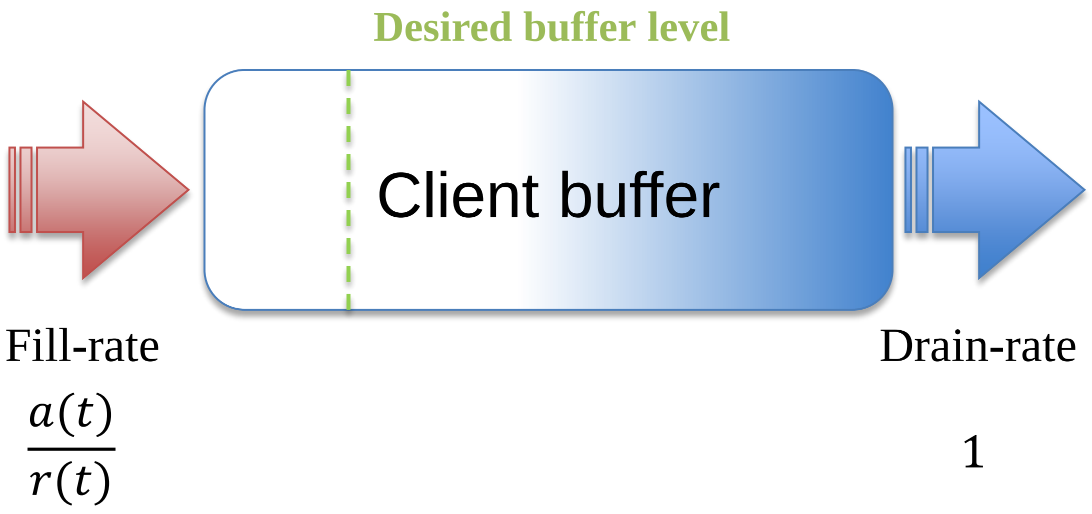
- **Buffering Delay** is buffered video in seconds.
- We achieve ***low-latency*** dynamic video streaming with buffering delays as low as the chunk-duration.

A Model of Buffer Dynamics



Quality Selection Stabilizing the buffer to the desired level by regulating the drain-rate, i.e. by selecting a video bit rate for the chunk.

A Model of Buffer Dynamics

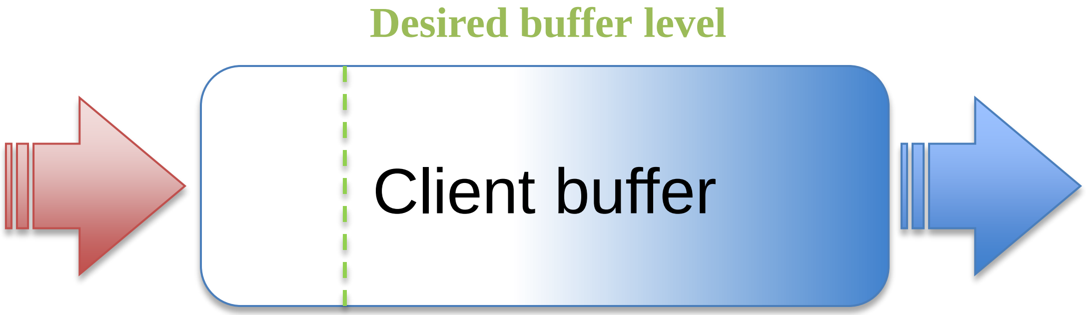


Express the buffer level in **seconds of video**.

$a(t)$: the throughput rate achieved at the time t

$r(t)$: the selected video bit rate at the time t

A Model of Buffer Dynamics



Fill-rate

$$\frac{a[i]}{r[i]} \cdot t[i]$$

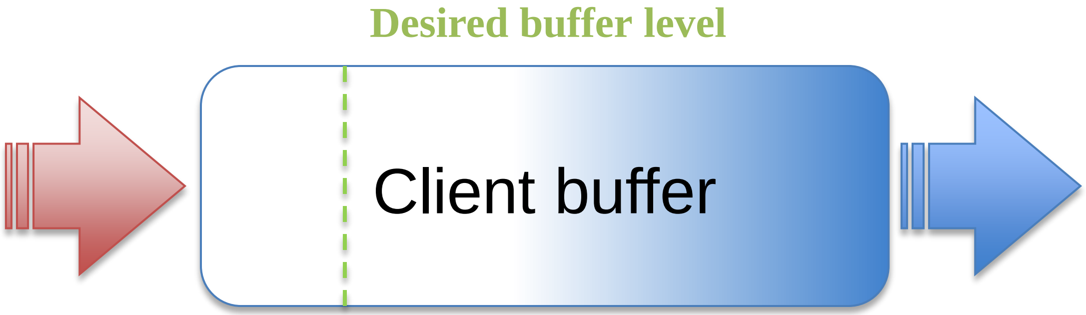
Drain-rate

$$1 \cdot t[i]$$

Compute the buffer level **every discrete chunk**.

$a[i]$	:	the throughput rate achieved during the reception of chunk *i*	$r[i]$	:	the selected video bit rate of chunk *i*
			$t[i]$	:	the reception duration of chunk *i*

A Model of Buffer Dynamics



Fill-rate

$$\frac{a[i]}{r[i]} \cdot T_c \cdot \frac{r[i]}{a[i]}$$

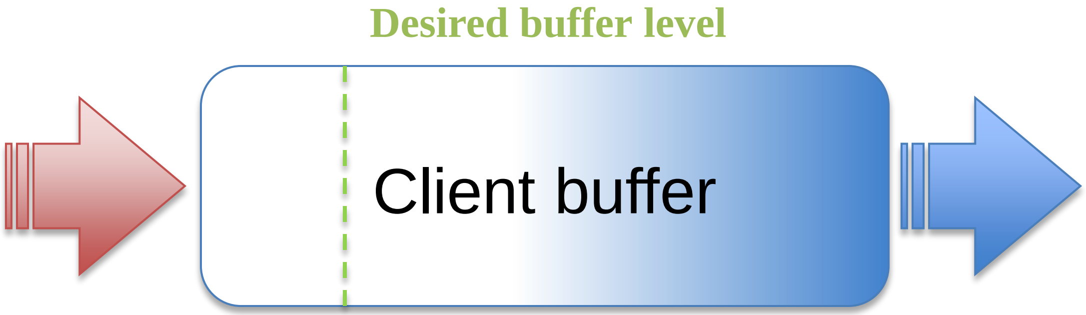
Drain-rate

$$T_c \cdot \frac{r[i]}{a[i]}$$

Compute the buffer level **every discrete chunk**.

$a[i]$	:	the throughput rate achieved during the reception of chunk i
$r[i]$	:	the selected video bit rate of chunk i
T_c	:	the chunk duration

A Model of Buffer Dynamics



Fill-rate

$$T_c$$

Drain-rate

$$T_c \cdot \frac{r[i]}{a[i]}$$

Current buffer level

$$b[i] = b[i-1] + T_c - T_c \cdot \frac{r[i]}{a[i]}$$

$b[i]$: the buffer level (in seconds) when the client finishes the reception of chunk i

Rate Selection

Buffer dynamics

$$b_R[i] = b[i-1] + T_c - T_c \cdot \frac{r_R[i]}{a[i]}$$

Rate selection

$$\hat{R}[i] = \underset{R \in \mathcal{R}}{\operatorname{argmin}} \left| b_R[i] - \beta_{ref} \right|$$

$b[i]$	:	the buffer level (in seconds) when the client finishes the reception of chunk i	$\hat{R}[i]$	:	the selected quality level (the nominal bit rate) of the video for chunk i
T_c	:	the chunk duration (each chunk containing a fixed duration of video)	R	:	the quality level (the nominal bit rate) of the video
$r_R[i]$	:	the selected video bit rate for chunk i with the nominal bit rate R	$\mathcal{R}$	:	the set of quality levels (nominal bit rates) of the video
$a[i]$	:	the throughput rate achieved for chunk i	β_{ref}	:	the desired buffer level (in seconds)

Outline

✓ **Motivation**

✓ **Rate control for buffer stabilization**

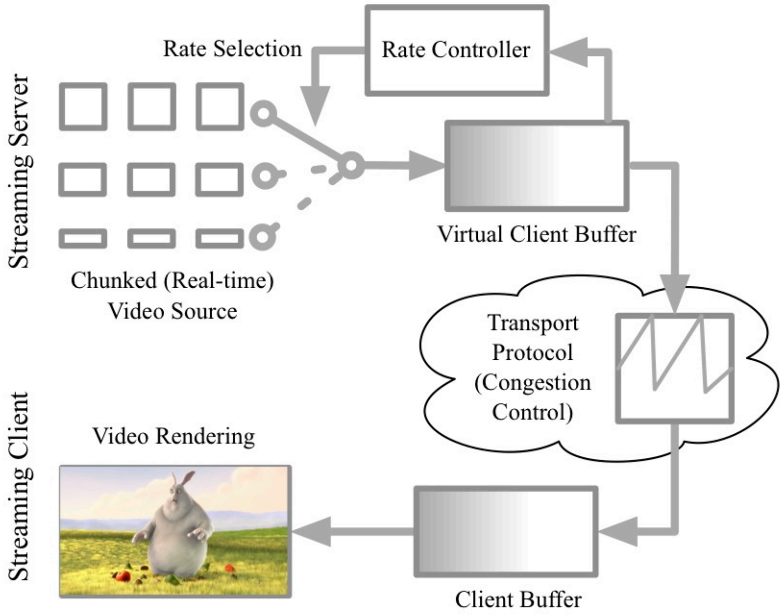
- **Buffering delay**
- **Modeling buffer dynamics**
- **Rate selection**

❑ **Prototype implementation**

- **Server-based streaming architecture (Open-Loop rAte Control, OLAC)**
- **Transport protocol configuration**

❑ **Results**

Open-Loop rAte Control (OLAC) [3]



- **Virtual client buffer** simulates client buffer on the server.
- A rate control on the server offers **immediate feedback** from clients.
- **Hybrid** throughput- and buffer-based adaptation **balances efficiency and stability**.

[3] Y. Shuai, G. Petrovic, and T. Herfet. OLAC: an Open-Loop Controller for Low-Latency Adaptive Video Streaming. In *Proceedings of the IEEE International Conference on Communications* (ICC), London, UK, 2015.

Transport Protocol Configurations

Our streaming prototype implementation is evaluated with two transport protocol configurations: standard **TCP-Cubic** and Predictably Reliable Real-time Transport (**PRRT**).

PRRT [4] provides

- error control under a specific delay constraint (***Predictable Reliability***),
- adaptive proactive and reactive error control (***capacity-approaching***),
- **opportunistic TCP-friendliness** by delay and equation-based congestion control,
- and **accurate throughput estimate** for applications.

[4] M. Gorius, Y. Shuai, and T. Herfet. Dynamic Media Streaming with Predictable Reliability and Opportunistic TCP-Friendliness. In *Proceedings of the IEEE Consumer Communications and Networking Conference* (CCNC), Las Vegas, USA, 2013.

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Performance Comparison

Our benchmark rate controls are

- **DASH** VLC plugin [5] and
- Quality Adaptation Controller (**QAC**) for adaptive video streaming [6].

We deploy the buffer stabilizer within OLAC streaming architecture on top of

- TCP, referring to Dynamic Adaptive Streaming over TCP (**DAST**), and
- PRRT, referring to Dynamic Adaptive Streaming over PRRT (**DASP**).

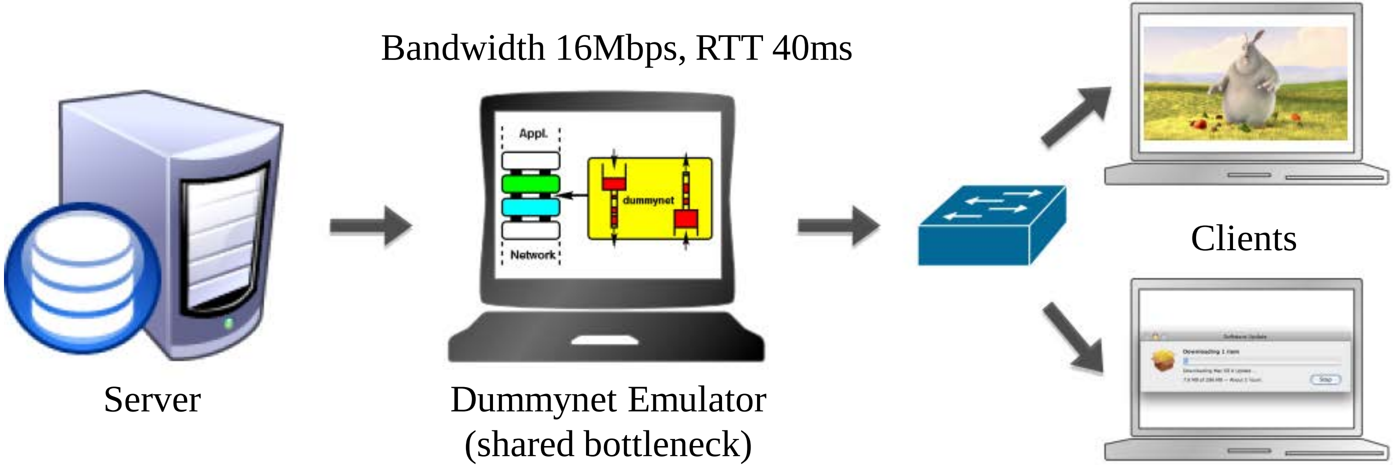
Therefore, our performance comparison contains four sets of performance results: DASH, QAC, DAST (OLAC over TCP), and DASP (OLAC over PRRT).

[5] C. Müller and C. Timmerer. A VLC media player plugin enabling dynamic adaptive streaming over HTTP. In *Proceedings of the 19th ACM international conference on Multimedia* (MM), Scottsdale, USA, 2011.

[6] L. Cicco, S. Mascolo, and V. Palmisano. Feedback control for adaptive live video streaming. In *Proceedings of the second annual ACM conference on Multimedia systems* (MMSys), San Jose, USA, 2011.

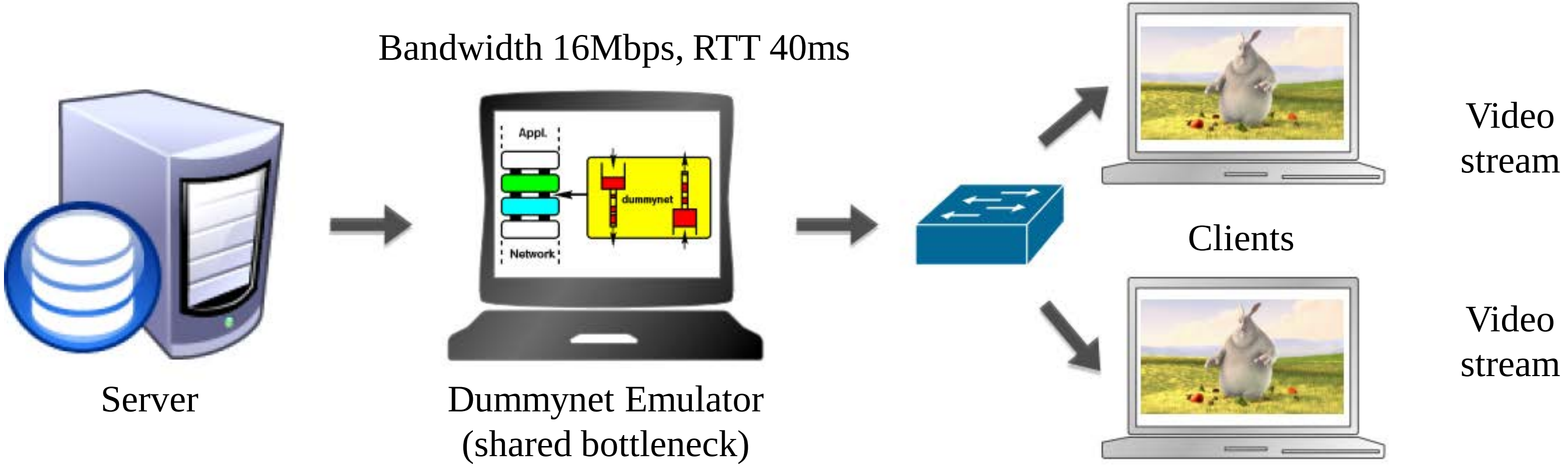
Experimental Setup

- Wide area network
- Dynamic video bit rate 1-16 Mbps, chunk duration of 2s, 4s, 6s, and 8s
- Maximum client buffer size is set to the same size of chunk duration
- Entire streaming sessions lasts 180s, competing session appears from 60-120s

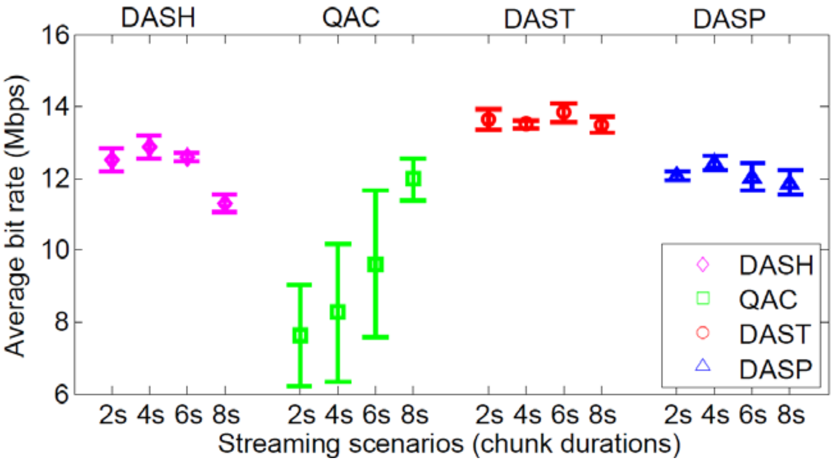


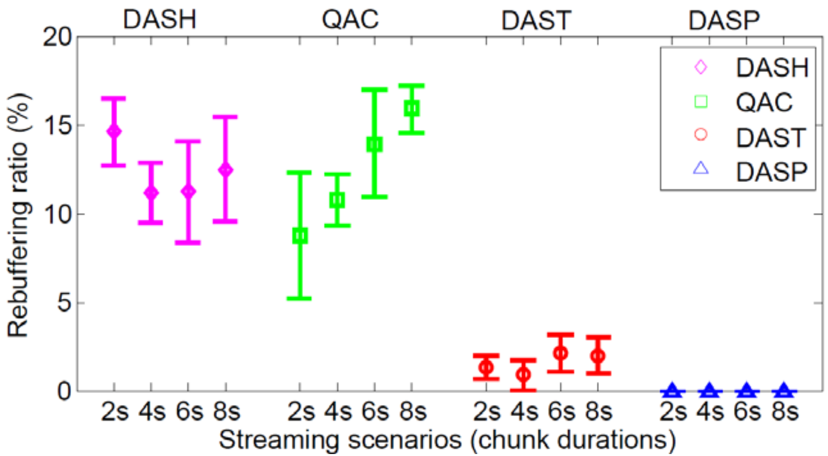
Experimental Setup

- Wide area network
- Dynamic video bit rate 1-16 Mbps, chunk duration of 2s, 4s, 6s, and 8s
- Maximum client buffer size is set to the same size of chunk duration
- Three concurrenct streaming sessions simultaneously run for 120s



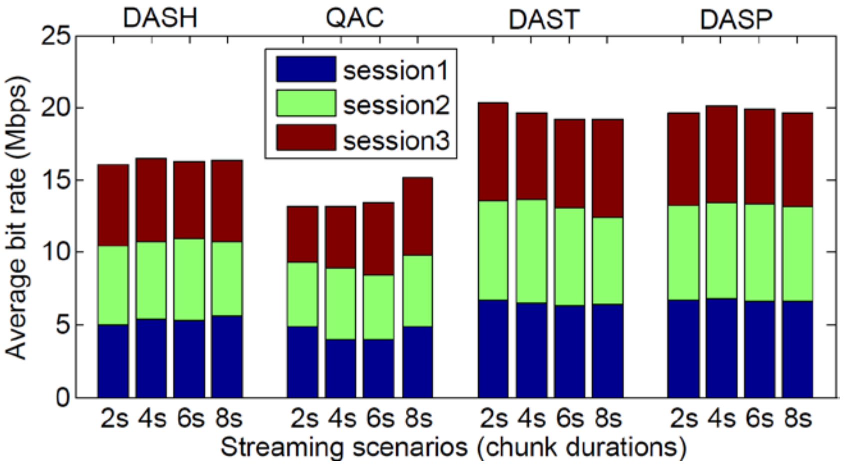
Experimental Results

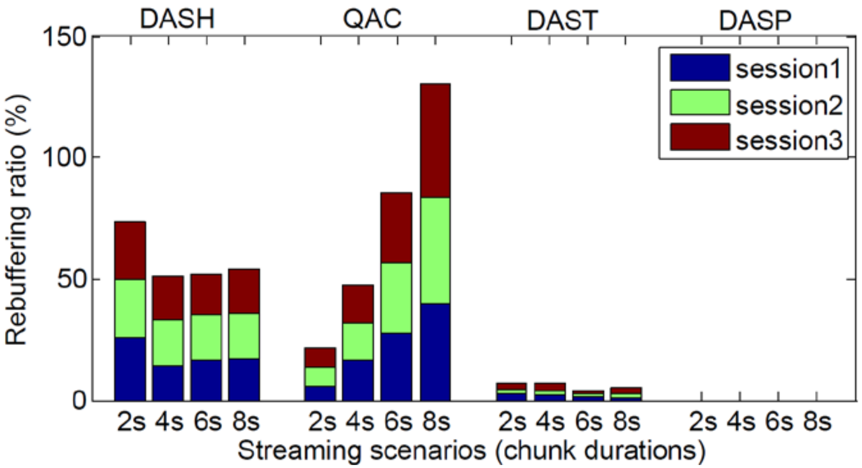




- DASP had zero rebuffering events. DAST reduces the rebuffering ratio by at least 81% and 85%, compared to DASH and QAC, respectively.
- The average bit rate achieved with DAST is increased by 5-19% and 13-78% compared to DASH and QAC, respectively.

Experimental Results





- The average bit rates achieved with DAST and DASP are 17-26% and 27-54% higher compared to DASH and QAC, respectively.
- DASP had zero rebuffering events. DAST achieves with a 68-96% lower rebuffering ratio compared to QAC.

Conclusion

A solution for ***low-latency*** dynamic video streaming

- effectively stabilizes the buffer at a level **as short as a chunk-duration**,
- significantly **improves user experience** in low-latency dynamic streaming.

Thank you for your attention!