ARBITER: Adaptive Rate-Based InTElligent HTTP StReaming Algorithm

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Packet Video Workshop 2016

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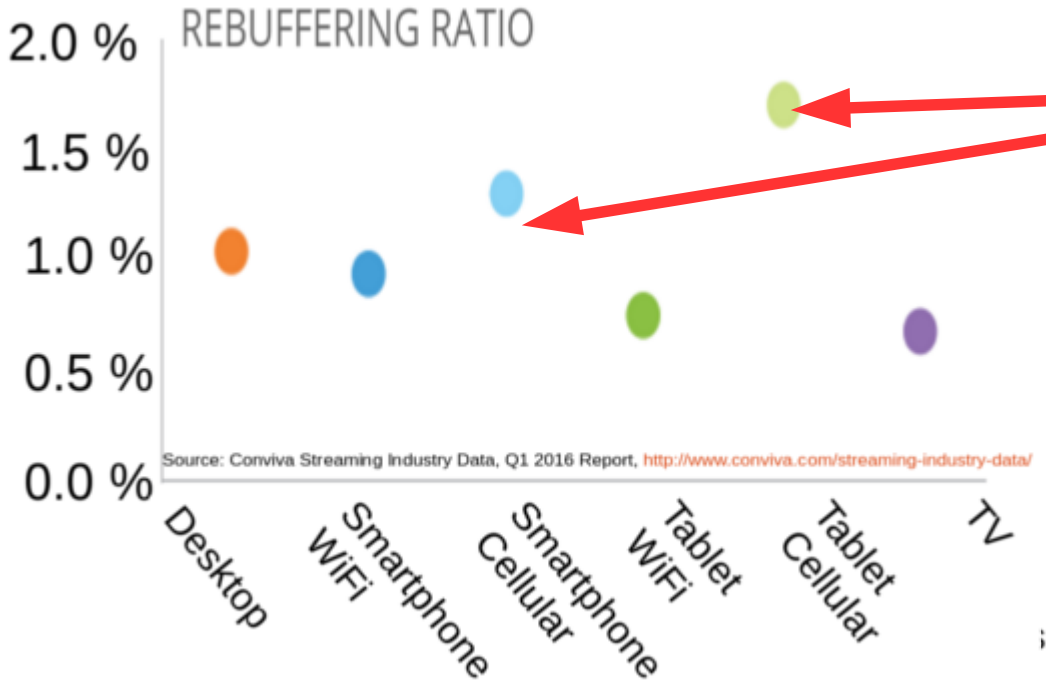
Global Mobile Video Traffic

Mobile video traffic increases by 50% every year

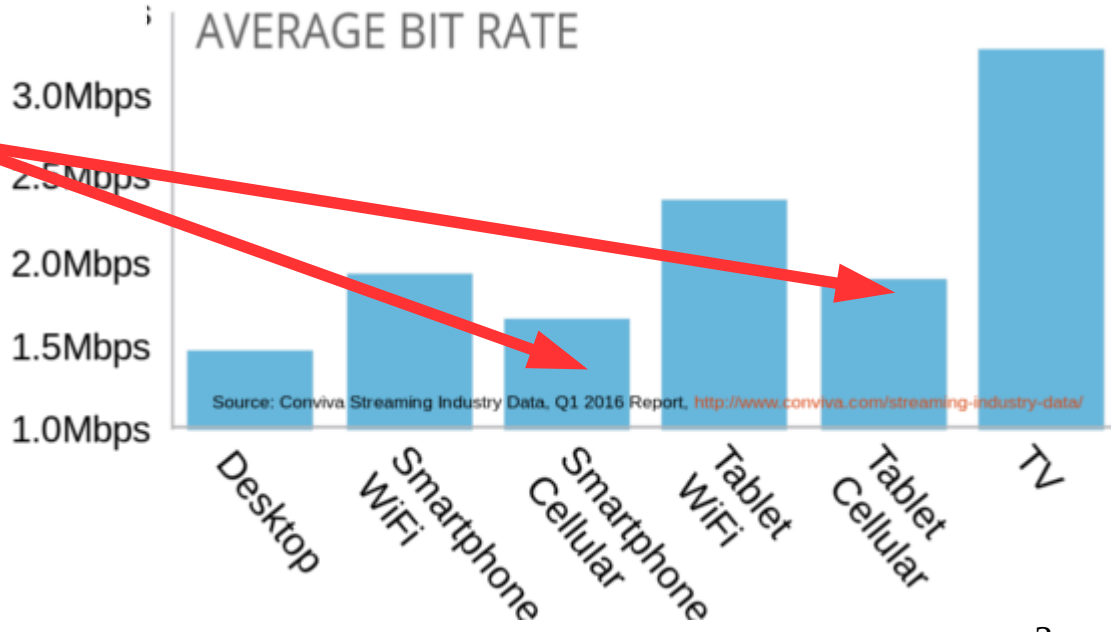
http://www.statista.com/statistics/252853/global-mobile-video-traffic-forecast/

Mobile Video Streaming Issues

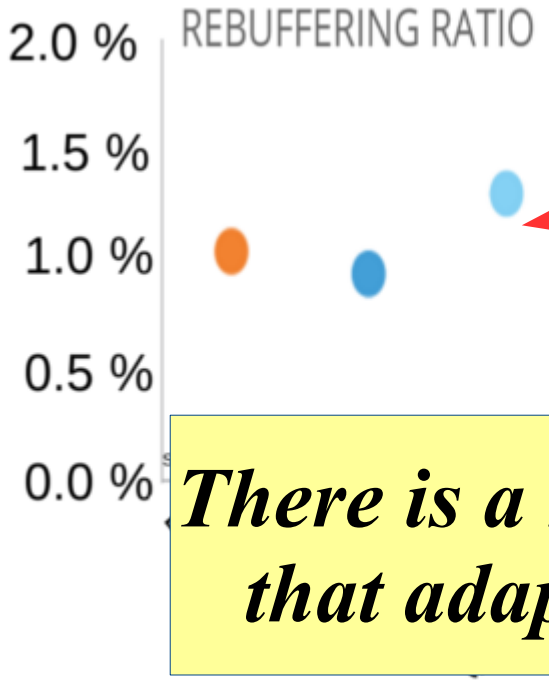


Video clients stall more in mobile networks

Video clients stream lower quality in mobile networks



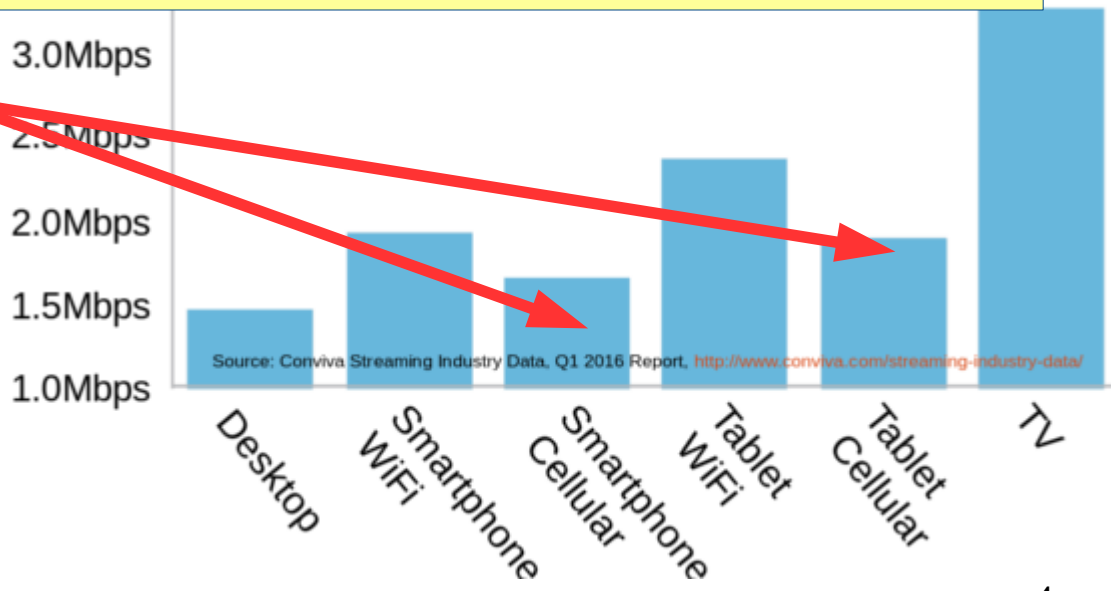
Mobile Video Streaming Issues



Video clients stall more in mobile networks

There is a need for advanced mobile video clients that adapt to underlying operating conditions

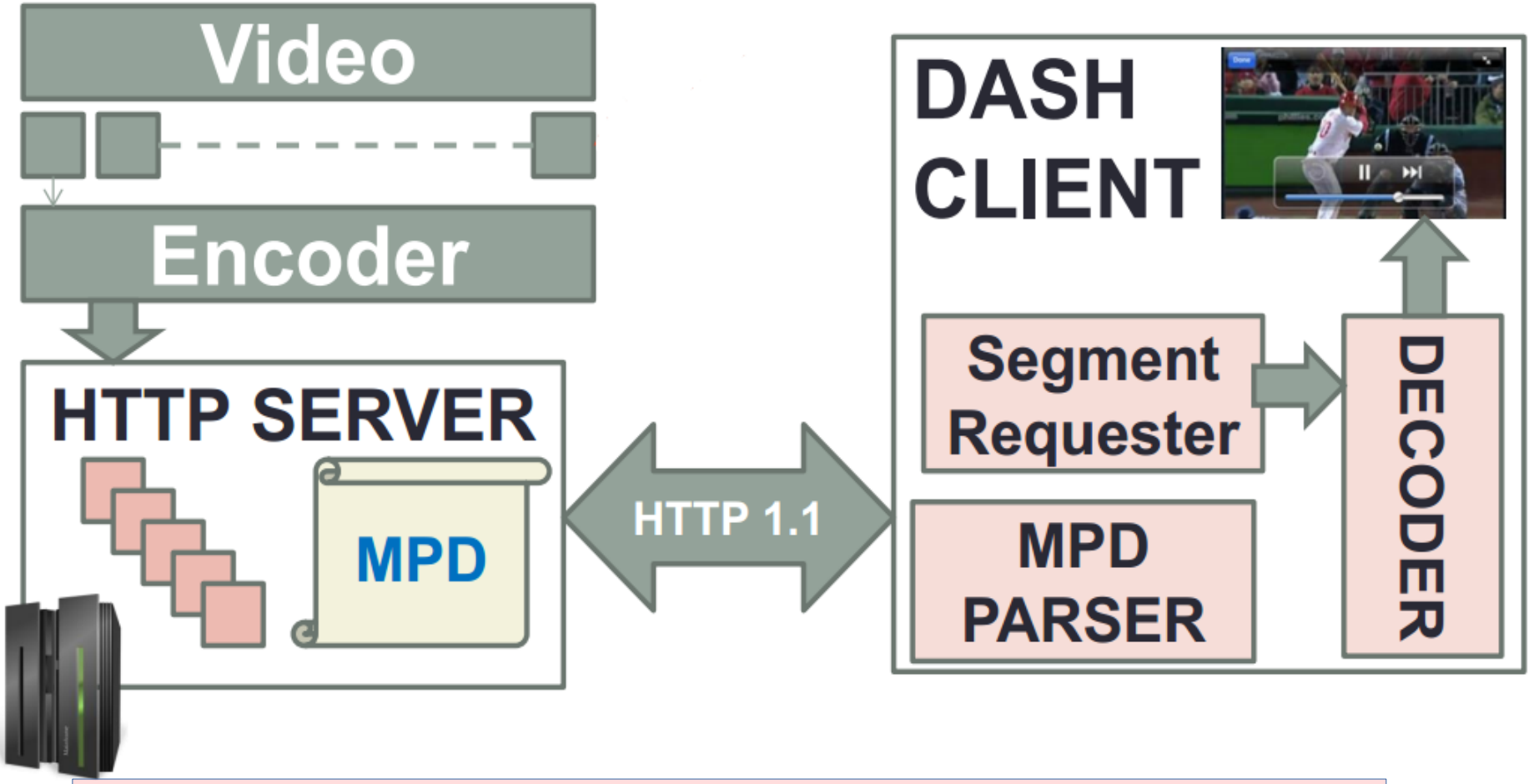
Video clients stream lower quality in mobile networks



Outline

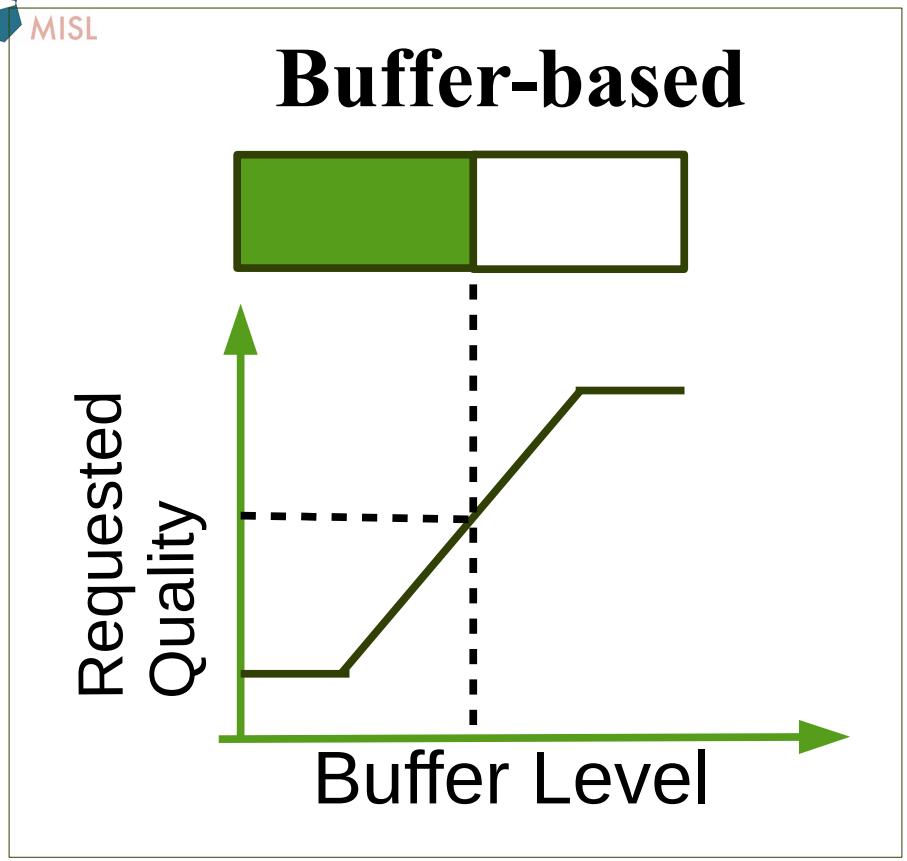
- DASH adaptation Approaches
- ARBITER Design
- Performance Evaluation
- Conclusions

DASH Architecture



DASH client changes the video quality at segment border to adapt to changes in the operating conditions

DASH Adaptation Strategies(1/2)

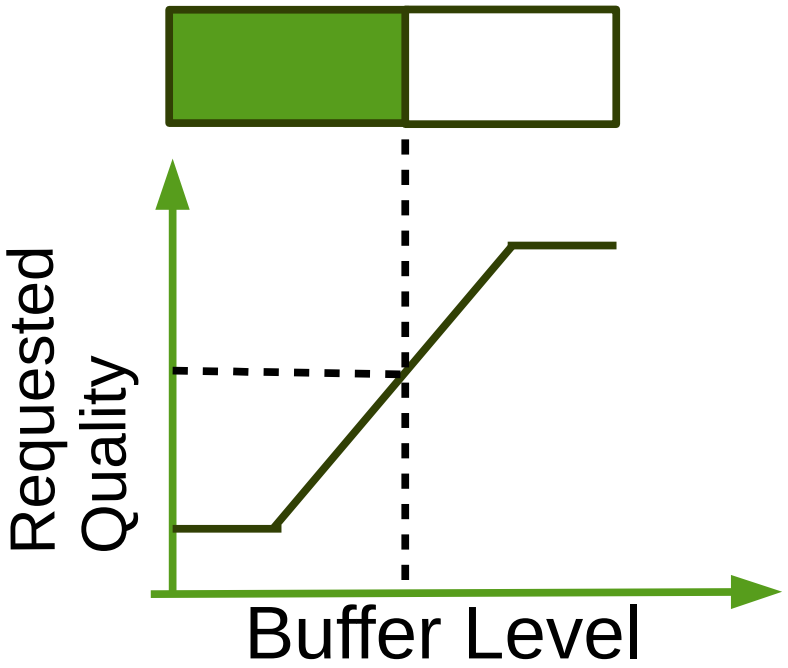


Example: BBA [9], Sigcomm 2014

DASH Adaptation Strategies(1/2)

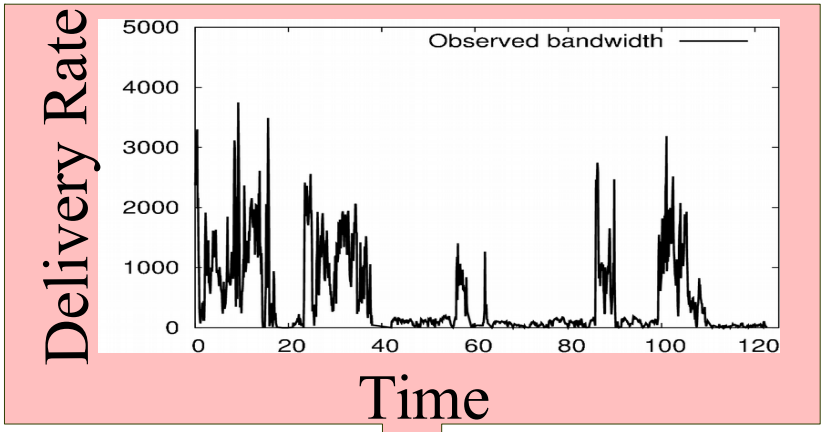
MISL

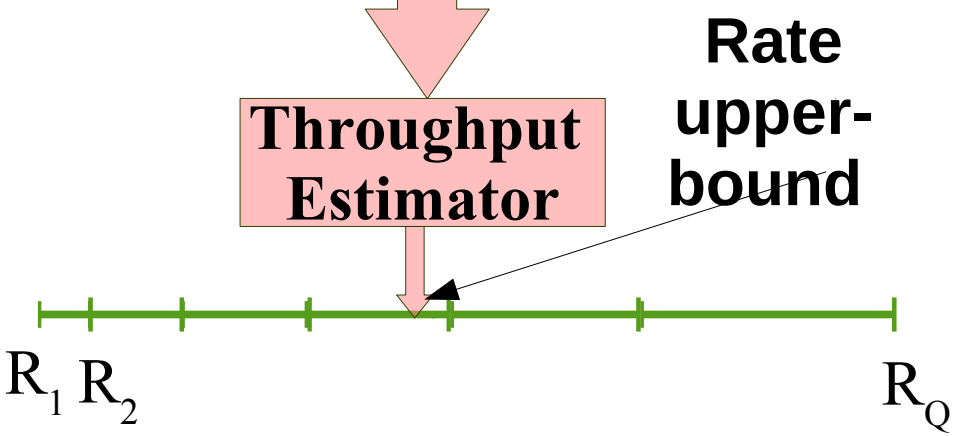
Buffer-based



Example: BBA [9], Sigcomm 2014

Rate-based



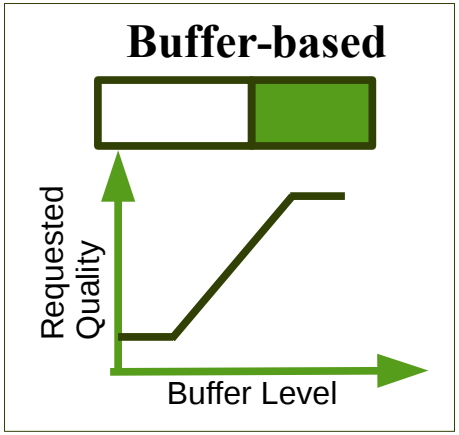


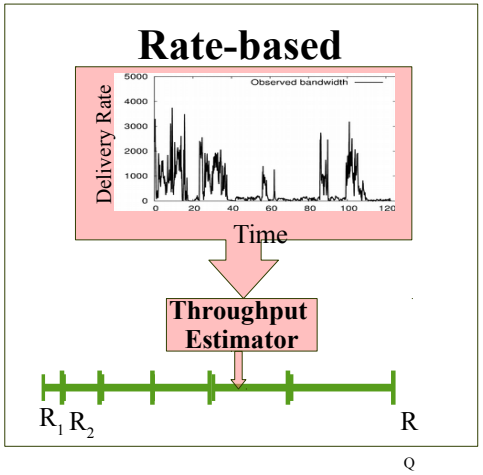
Example: FESTIVE [9], CoNext'12

DASH Adaptation Strategies(2/2)

Hybrid Algorithms

- Integrates application and network states in their decision using different approaches
  - [5] uses Markov decision process for adaptation decision with the bandwidth modeled using a normal distribution whose parameters are estimated using Q-learning
  - [17] (Sigcomm 2015) formulates an optimization framework to maximise a QoE objective





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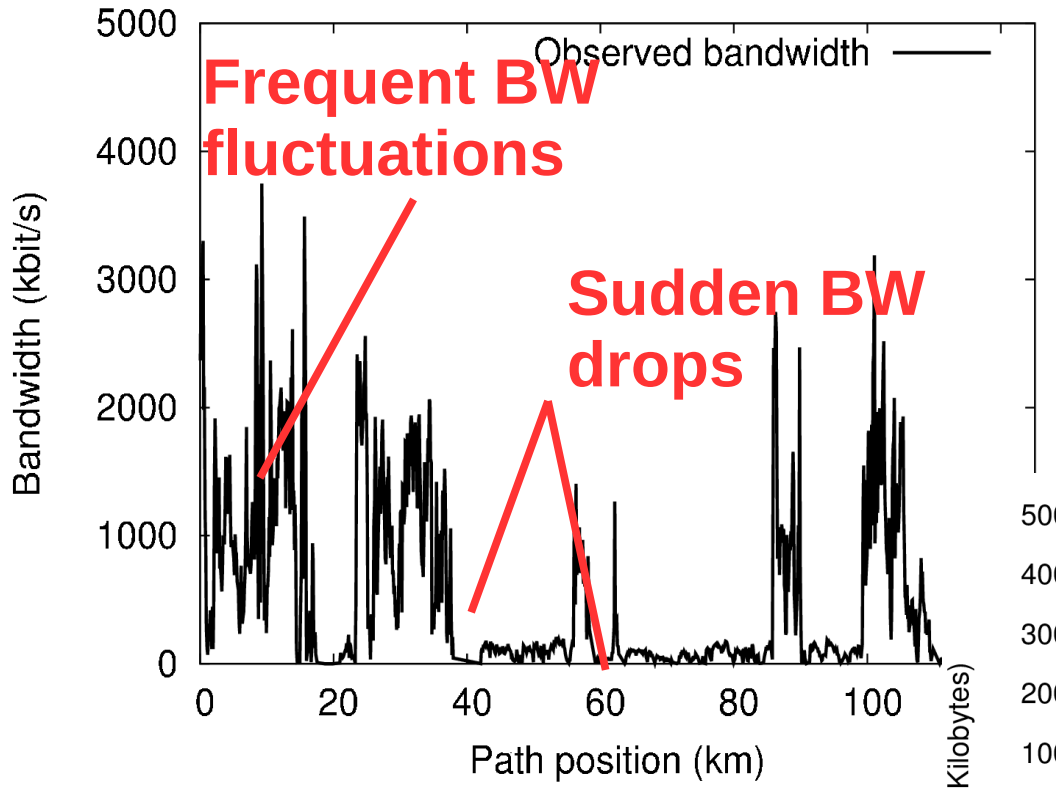
Challenge: Variable Operating Conditions

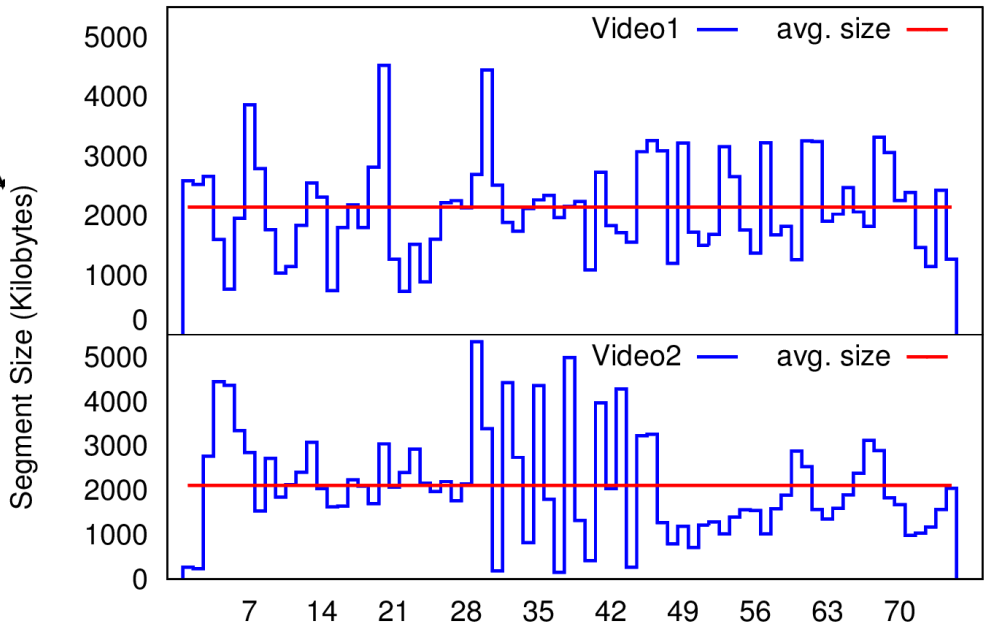
Highly Variable Bandwidth



http://home.ifi.uio.no/paalh/dataset/hsdpa-tcp-logs/

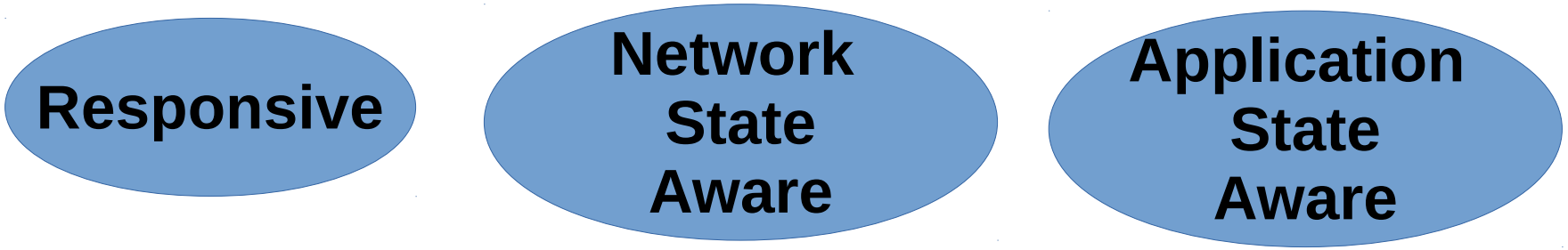
High Variability is an inherent feature

High Variable bitrate



ARBITER Design Overview

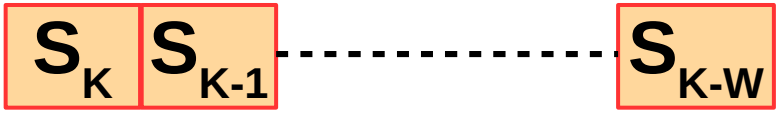
- ***Objective: handling inherent system variability using an intelligent light-weight adaptation algorithm***
- *ARBITER accommodates throughput variability by employing an* ***adaptive throughput estimation****.*



- *ARBITER accommodates video rate variability by adapting to* ***short-term average video rate***

ARBITER: Adaptive Throughput Estimation

Segment throughput samples



Segment Exponential Weights

Responsive weighted Average Throughput $\mu_s = \sum_{i=1}^{W} w_i b_{k-i},$

Adaptive Throughput Estimate

$$r_t = \mu_s * \rho_v * \rho_b$$

Network Awareness Scaling Factor

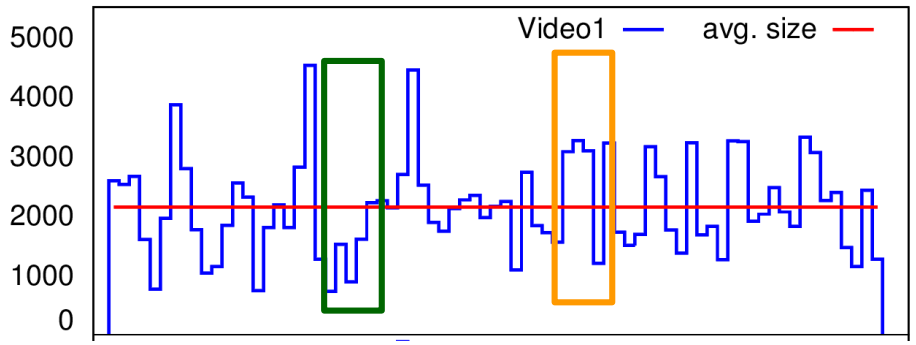
Highly variable S_K → smaller scale factor

Application Awareness Scaling Factor

- Low buffer level → smaller scale factor

- High buffer level → large scale factor (>1)

Video Aware Quality Selection

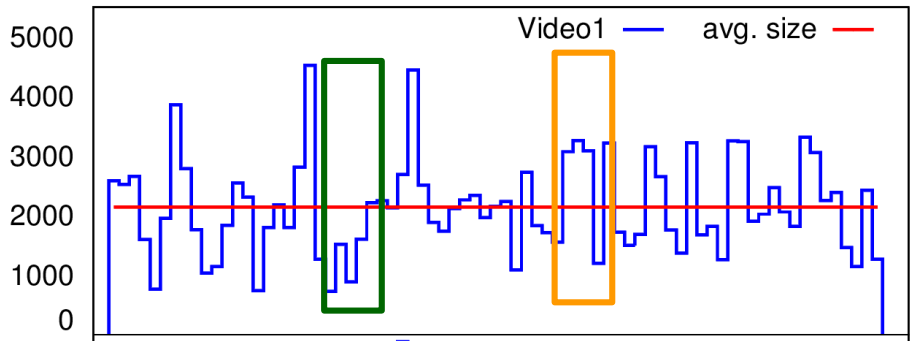


Video rate vary over time
- **Green** window has low a video rate
- **Orange** window has a high video rate

ARBITER adaptation decisions are based on short-term average video rate.

$$r_a(q) = \frac{\sum_{i=1}^{W_v} S_{k+i}(q)}{W_v * T}$$

Video Aware Quality Selection



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ARBITER adaptation decisions are based on short-term average video rate.

$$r_a(q) = \frac{\sum_{i=1}^{W_v} S_{k+i}(q)}{W_v * T}$$

ARBITER selects the representation whose short term average rate is below the estimated throughput

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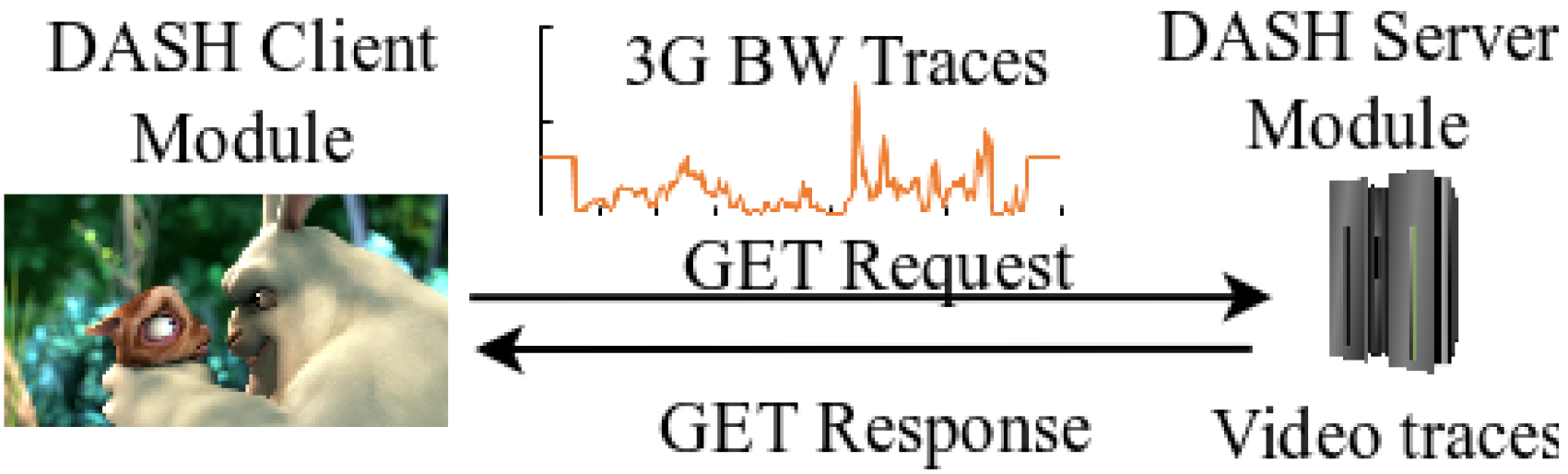
Evaluation Setup

- Performance evaluation is performed using NS3
- A client connects to the server using a single TCP [new Reno] connection



- 60 and 120 Sec buffer
- 8 sec initial buffering
- 4 sec rebuffering

- 54 3G traces [15]

- data set [14]
- 6 movies
- 4- and 10- sec segments

Performance Evaluation

ARBITER performance is compared against

BBA [8]	**ELASTIC** [6]
buffer-based algorithm	PI controller with a harmonic mean throughput estimator.

- **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 total stall duration per session
  - n_{sw} The average number of switches per session
  - l_{sw}: The average switching level
  - χ : The user quality of experience based on DASH-UE model (IEEE Trans. Broadcasting 2015)

60sec Buffer and 4-Sec Segment

- **ARBITER achieves the highest QoE score with aprox. 25% improvement.**
  - In comparison to BBA: ARBITER attains similar average rate, with 33% drop in the number of stalls and 35% drop in the average stall duration, and improved switching performance.
  - In comparison to ELASTIC: ARBITER attains 60% improvement in rate but worse stall performance and more switches.
    - Additional stalls are concentrated in 3% sessions.

Algorithm	n_{st}	t_{st}	r_{av}	n_{sw}	l_{sw}	χ
ARBITER	0.34	2.81	1055.9	26.33	1.12	48.7
BBA	0.44	4.34	1158.2	25.27	1.673	38.5
ELASTIC	0.24	1.74	662.69	13.33	1.23	37.3

120sec Buffer and 4-Sec Segment

- **ARBITER achieves the highest QoE score with a noticeable margin**
- Larger buffer helps all algorithms to improve their stall performance
- Larger buffer additionally helps BBA to improve its switching performance
- Larger buffer harms ELASTIC due to its tendency to fill in the buffer (usually with a low quality video)

Algorithm	n_{st}	t_{st}	r_{av}	n_{sw}	l_{sw}	χ
ARBITER	0.08	0.75	935.34	22.75	1.09	47.8
BBA	0.10	0.85	983.92	15.23	1.30	40.8
ELASTIC	0.08	0.74	495.56	10.42	1.23	30.5

120sec Buffer and 10-Sec Segment

- **ARBITER maintains its QoE superiority**
- **Larger segments reduce the QoE attained by all algorithms.**
- Larger segments reduce the stall count but increases the stall duration
- Larger segments reduce the number of switches of all algorithms
- Larger segments negatively impact BBA switching level

Algorithm	n_{st}	t_{st}	r_{av}	n_{sw}	l_{sw}	χ
ARBITER	0.06	1.03	928.1	11.63	1.2	40.3
BBA2	0.09	1.51	986.89	10.75	1.7	30.3
ELASTIC	0.03	0.82	474.78	5.51	1.5	27.9

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Conclusions

- The design of advanced adaptation algorithms is crucial for the success of mobile video
- ARBITER represents an intelligent adaptation algorithm that integrates application state, network state, and video specifics in its decision.
- Extensive performance evaluation shows that ARBITER attains a balanced visual and temporal quality performance leading to a superior user QoE.
- As future work, we consider comparing ARBITER to
  - other algorithms using different operating conditions
  - An offline QoE optimized benchmark

ARBITER: Adaptive Rate-Based InTElligent HTTP StReaming Algorithm

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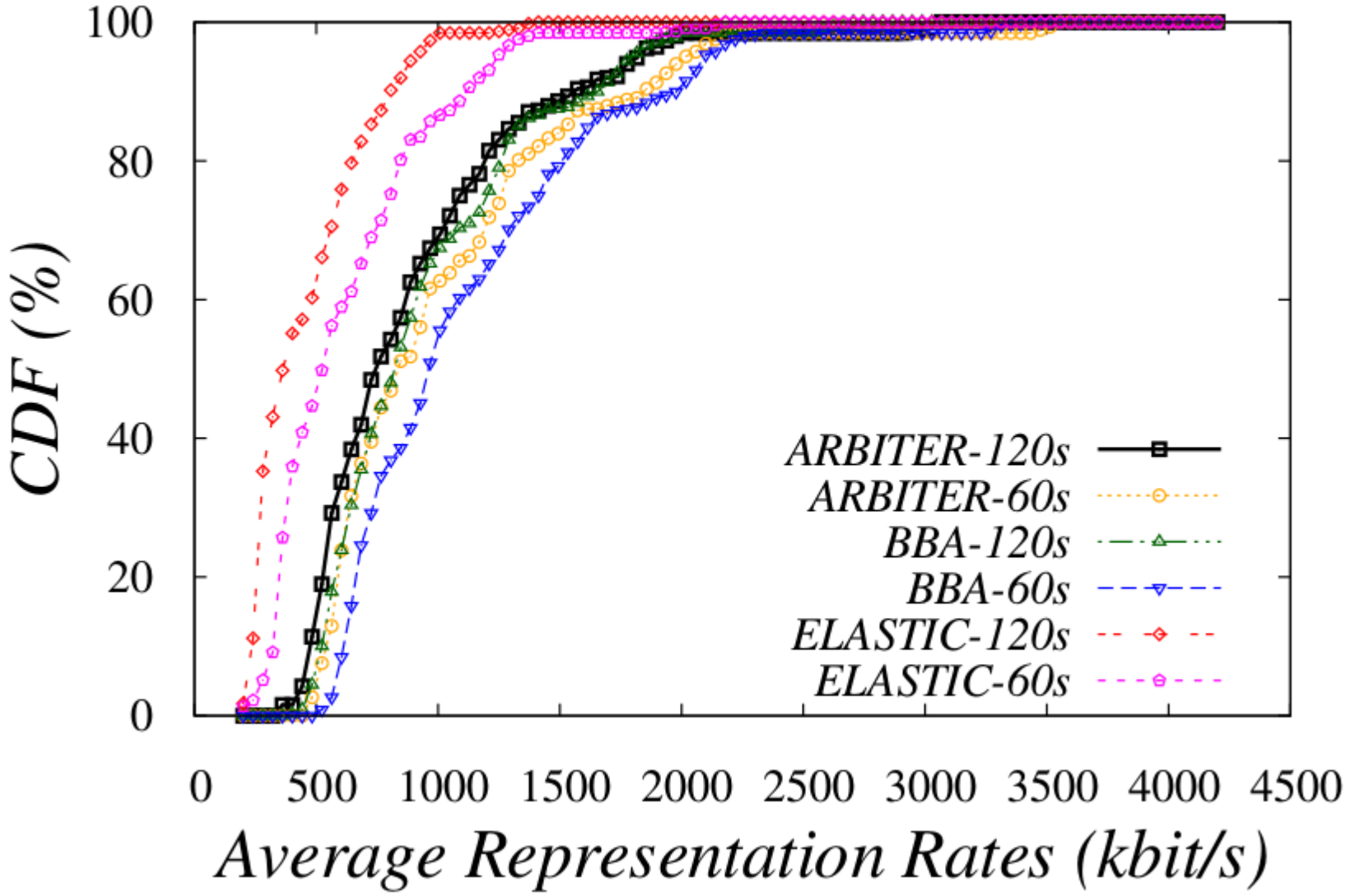
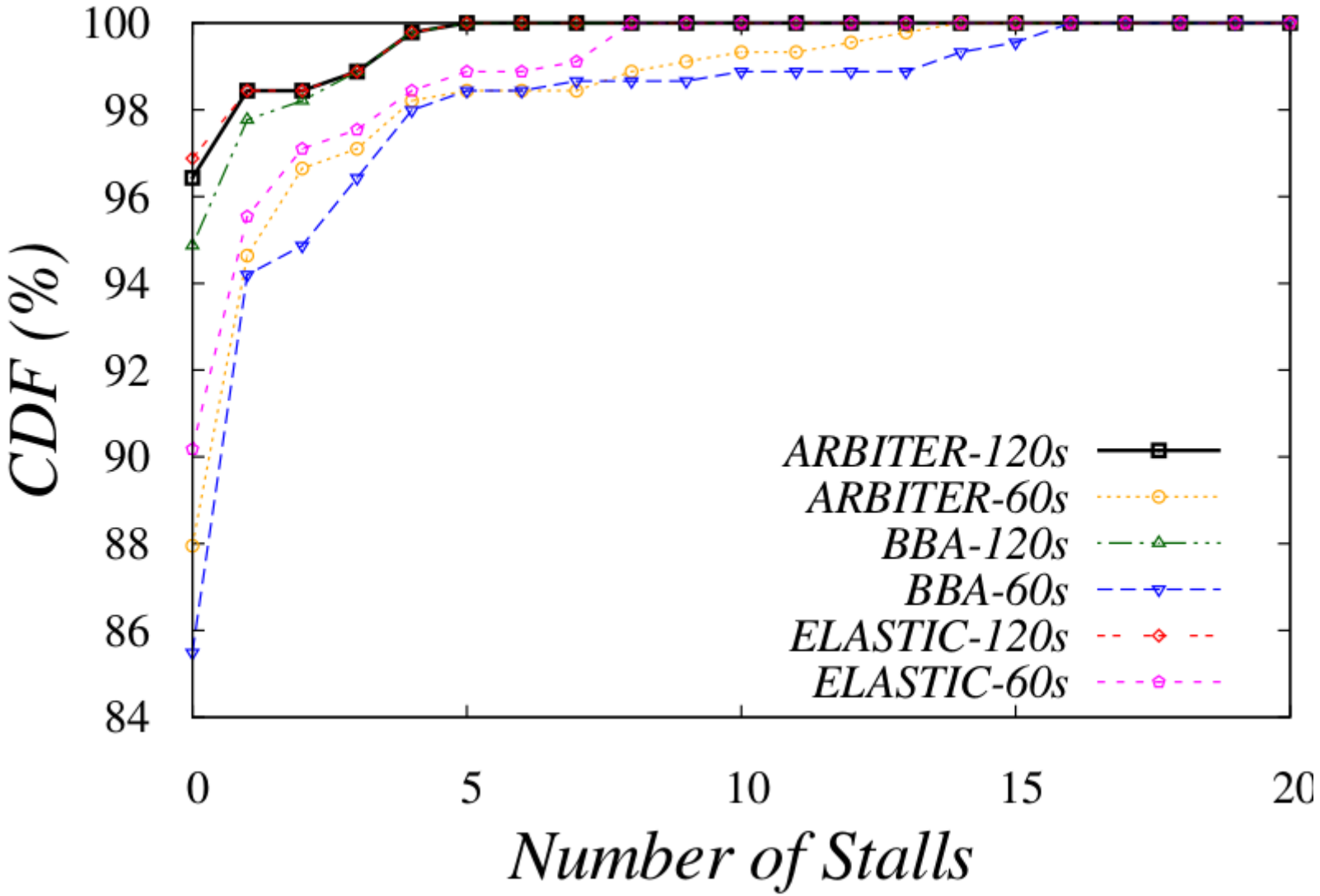
DASH-UE QoE Model

- Max score is 100
- Reduced scores are due to
  - Start-up delay penalty (temporal quality)
  - Stall count and duration penalty (temporal quality)
  - Persisting on a low quality penalty (visual quality)
  - Switching down penalty (visual quality)
- Visual quality penalties are based on video quality metric (VQM) for individual segments

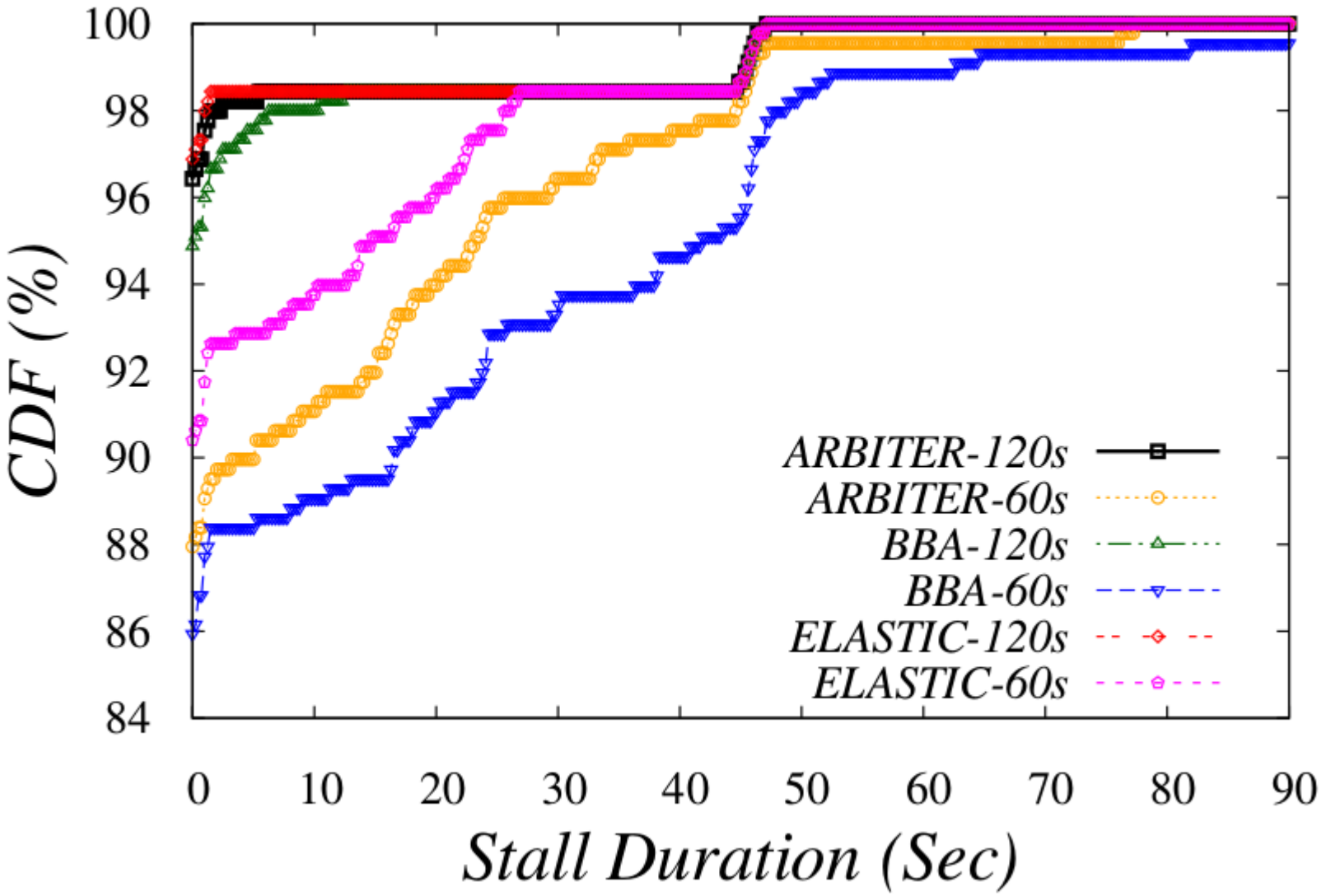
Average Representation Rate



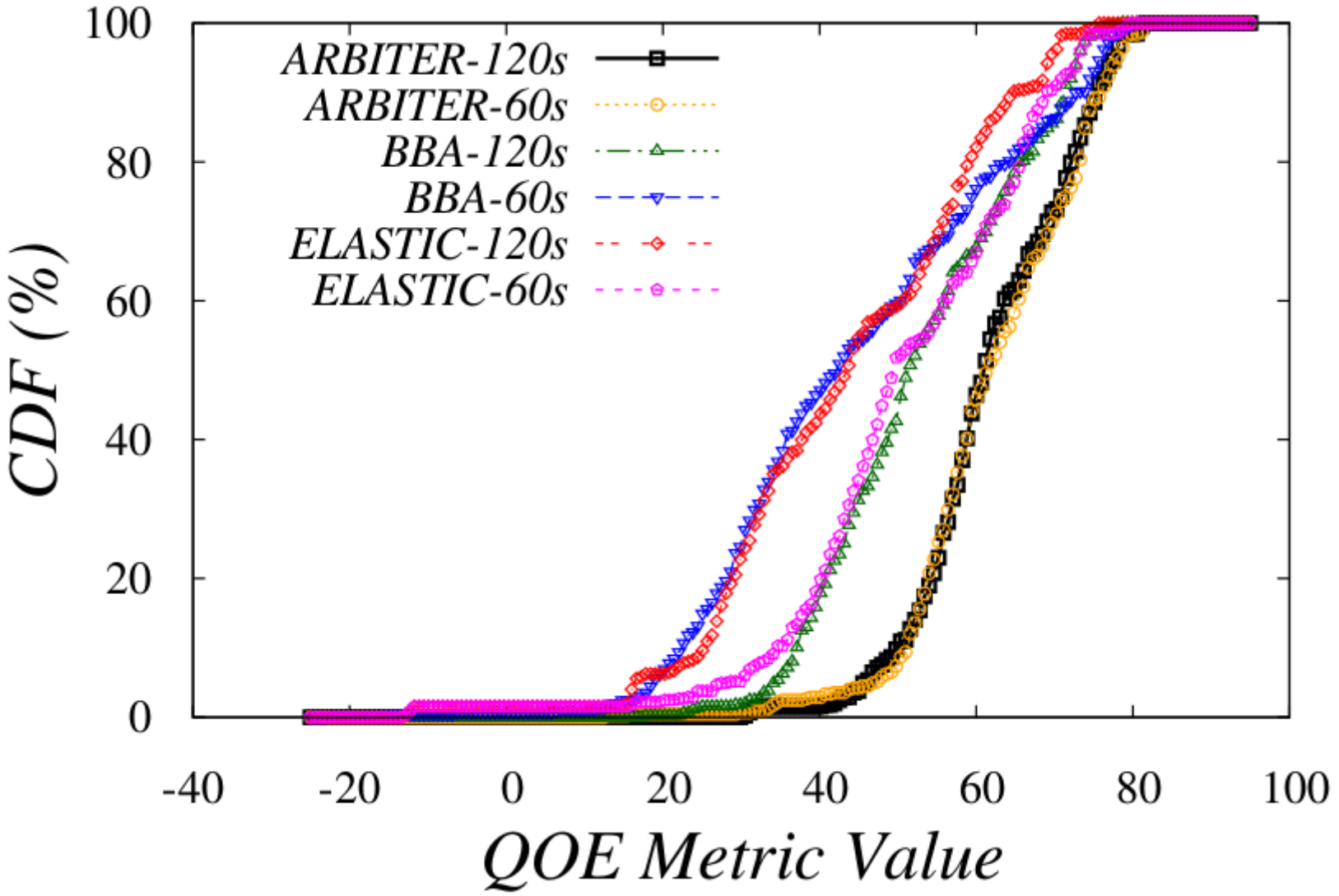
Number of Stalls



Stall Duration



QoE Metric


ARBITER-120s
ARBITER-60s
BBA-120s
BBA-60s
ELASTIC-120s
ELASTIC-60s
CDF (%)
100
80
60
40
20
0
-40
-20
0
20
40
60
80
100
QOE Metric Value