Adaptive Streaming of Content-Aware-Encoded Videos in dash.js

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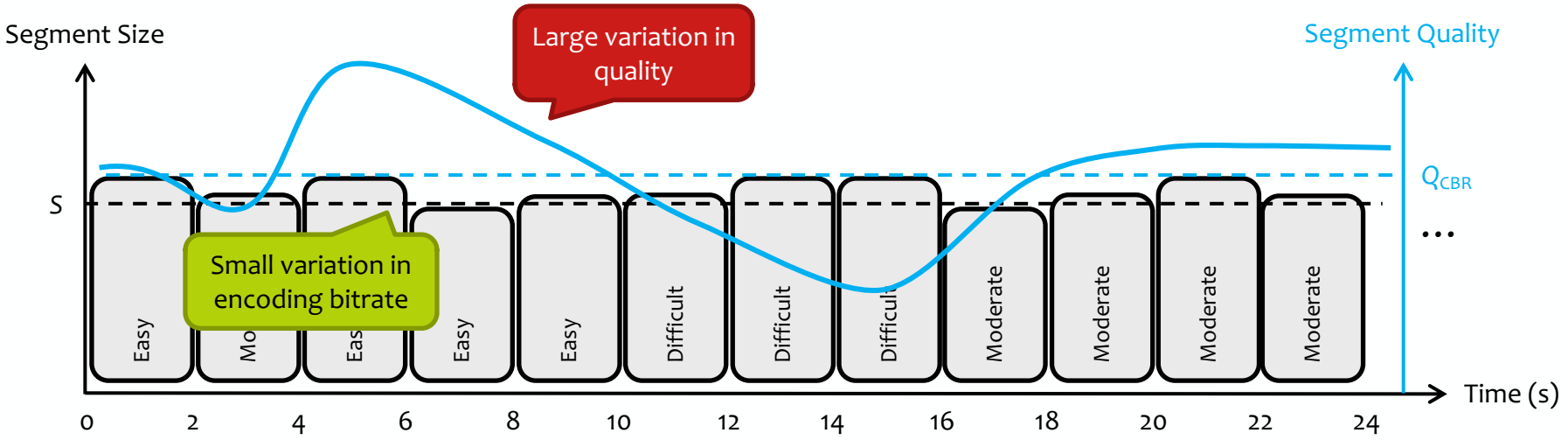
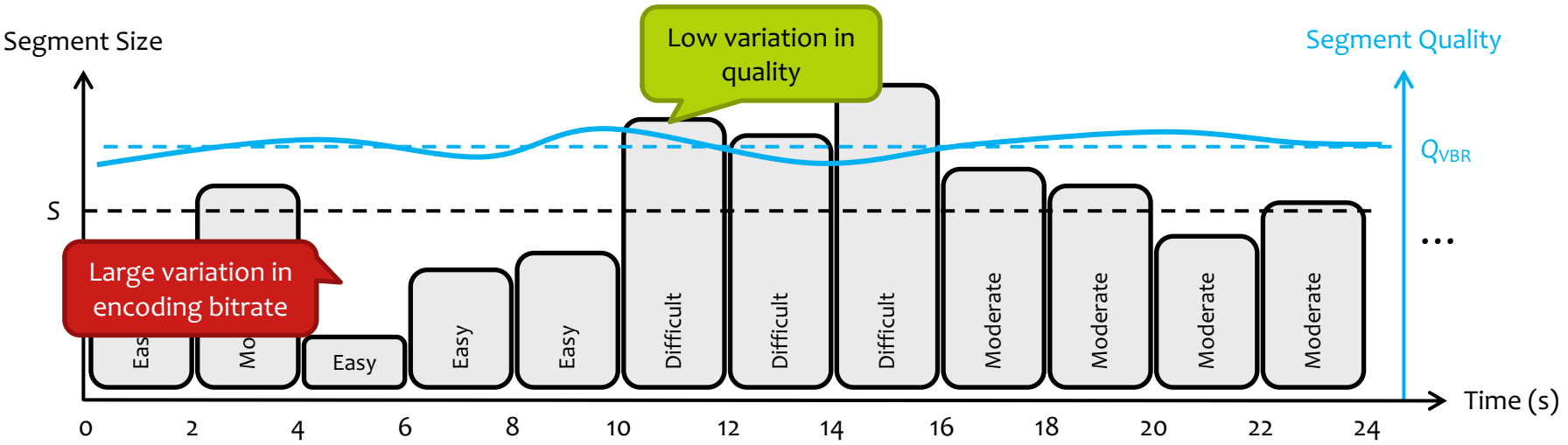
Adaptation Feature Delivers Inconsistent Quality

Guidelines Limited Bitrate Variability to (Mostly) 10% So Far



If there is something worse than having to watch a video at a lousy quality, it is to watch that video with varying quality

What If We Encode in a More Subtle Fashion?

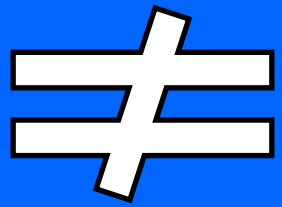


While we spend the same total amount of bits, we not only increase average quality but also reduce quality variation

HLS authoring spec for ATV allows 2x capping rate for VoD. For linear content, variability is limited to 10-25% range.

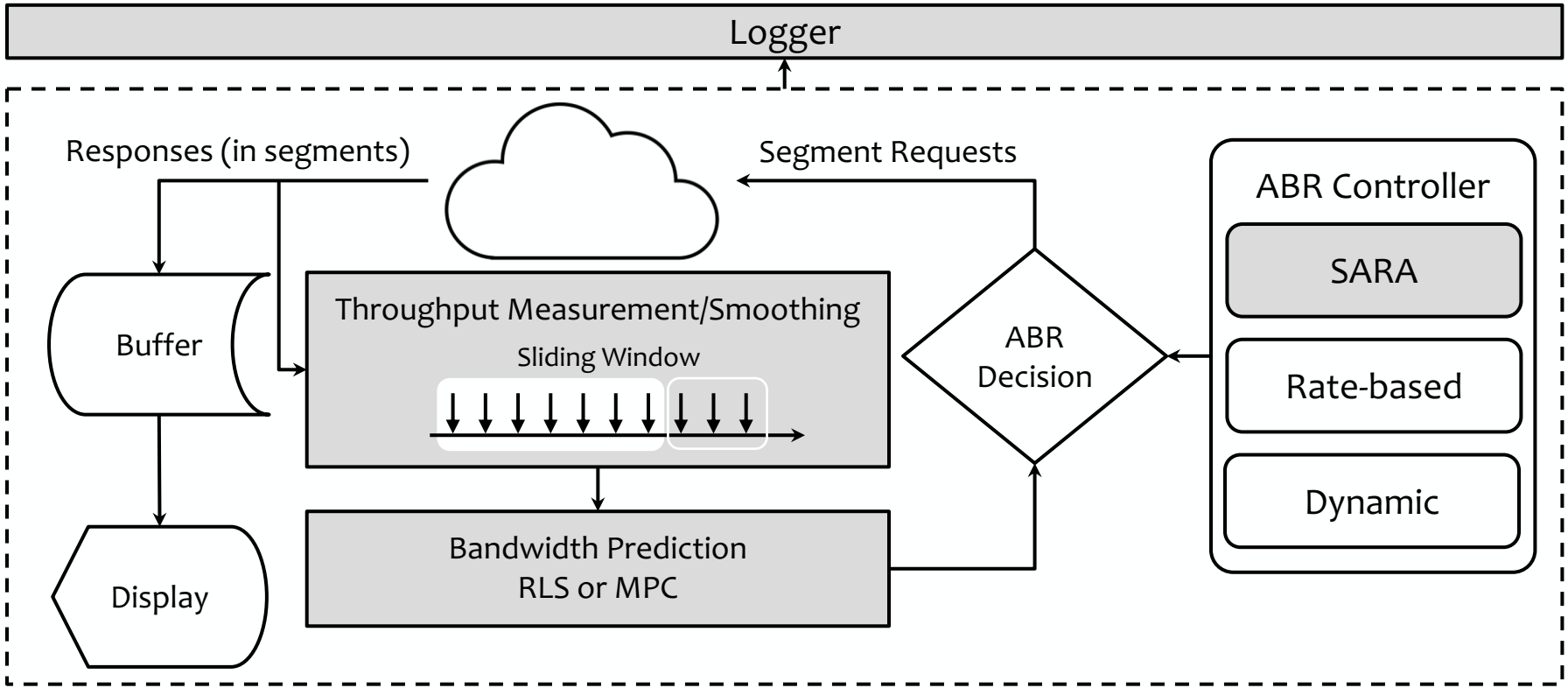
Generating content-aware-encoded segments is easy but streaming them is not!

Content-aware Encoding

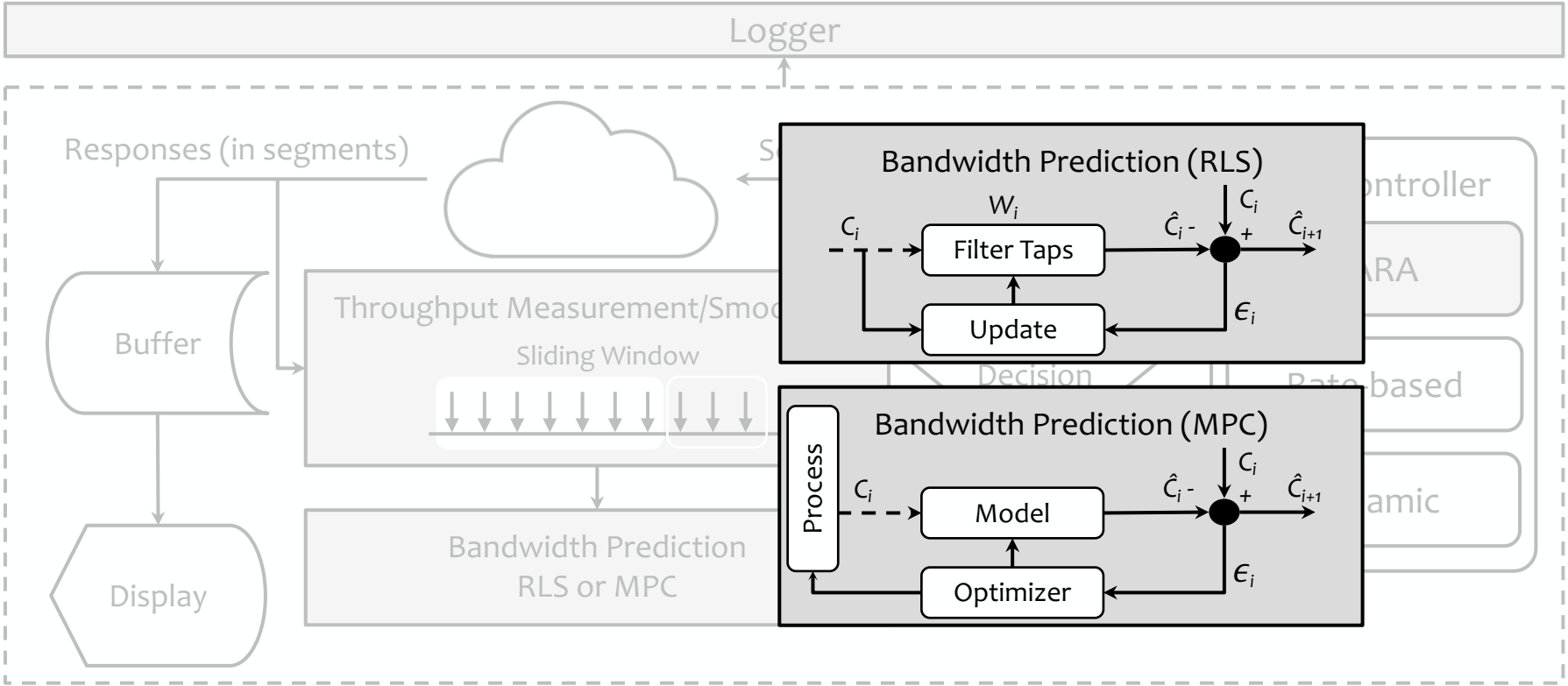


Content-aware Streaming

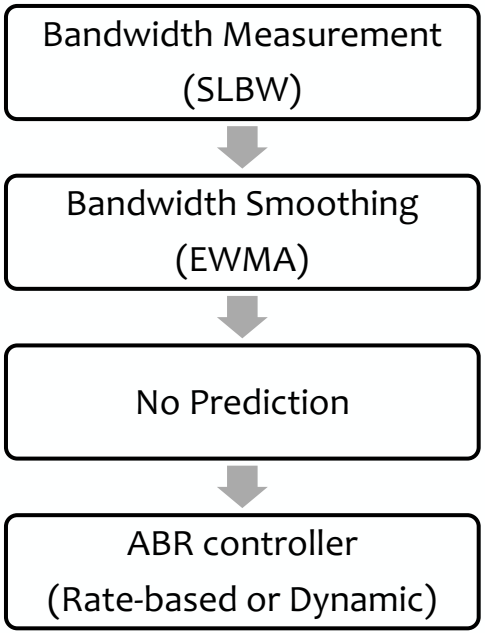
Size-Aware Rate Adaptation (SARA) Components in dash.js



Size-Aware Rate Adaptation (SARA) Components in dash.js

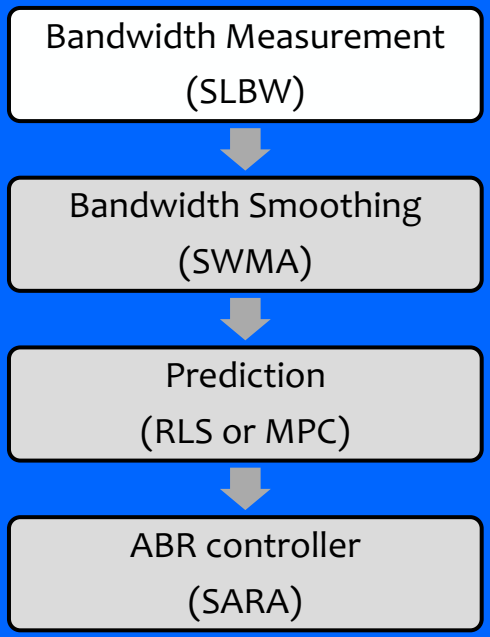


Default dash.js



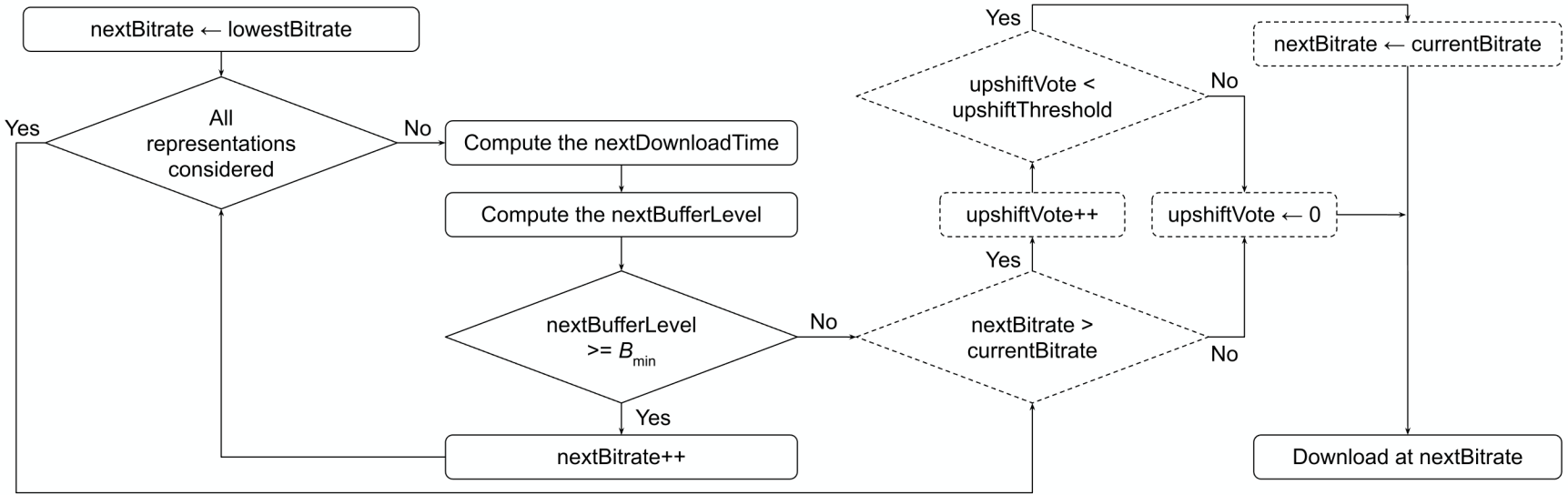
SLBW: Divides the segment size by download time
EWMA: (Exp. weighted) average of the last four segments

SARA



SWMA: Averages the last three segments
RLS: Recursive Least Squares
MPC: Model Predictive Control

Flowchart of the SARA ABR Rule



Example: When the Current Buffer Level is One Second

- Two-second segments
- Four representations advertised at 300, 500, 1000 and 2500 Kbps
- Predicted bandwidth 500 Kbps
- B_{min}: Two seconds

Advertised Encoding Bitrate (Kbps)	Advertised Segment Size (Kbits)	Actual Size (Kbits)	Predicted Bandwidth (Kbps)	Current Buffer Level (s)	Next Download Time (s)	Next Buffer Level (s)
300	600	200	500	1.0	0.4	2.6
500	1000	250	500	1.0	0.5	2.5
1000	2000	500	500	1.0	1.0	2.0
2500	5000	1250	500	1.0	2.5	0.5

Example: When the Current Buffer Level is 10 Seconds

- Two-second segments
- Four representations advertised at 300, 500, 1000 and 2500 Kbps
- Predicted bandwidth 500 Kbps
- B_{min}: Two seconds

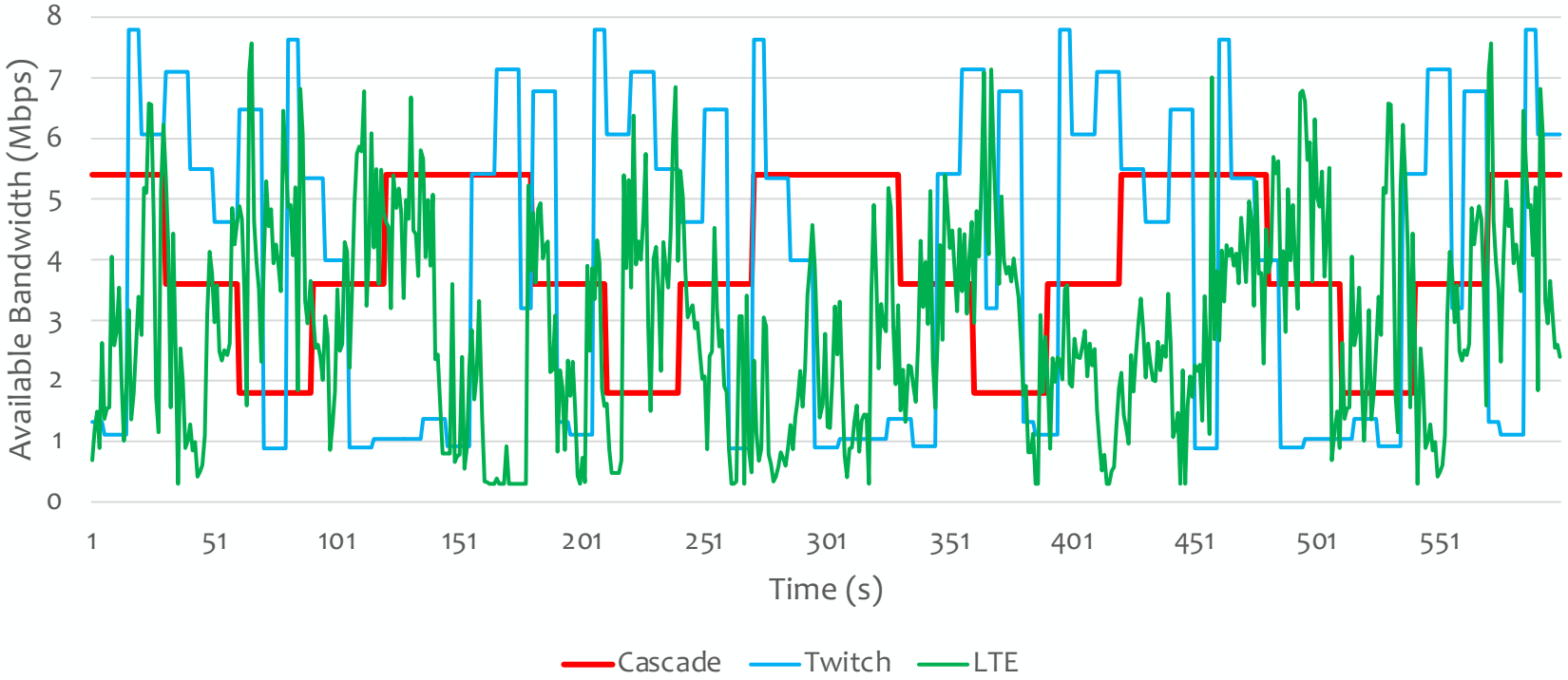
Advertised Encoding Bitrate (Kbps)	Advertised Segment Size (Kbits)	Actual Size (Kbits)	Predicted Bandwidth (Kbps)	Current Buffer Level (s)	Next Download Time (s)	Next Buffer Level (s)
300	600	200	500	10.0	0.4	11.6
500	1000	250	500	10.0	0.5	11.5
1000	2000	500	500	10.0	1.0	11.0
2500	5000	1250	500	10.0	2.5	9.5

Evaluation and Results

Experimental Setup

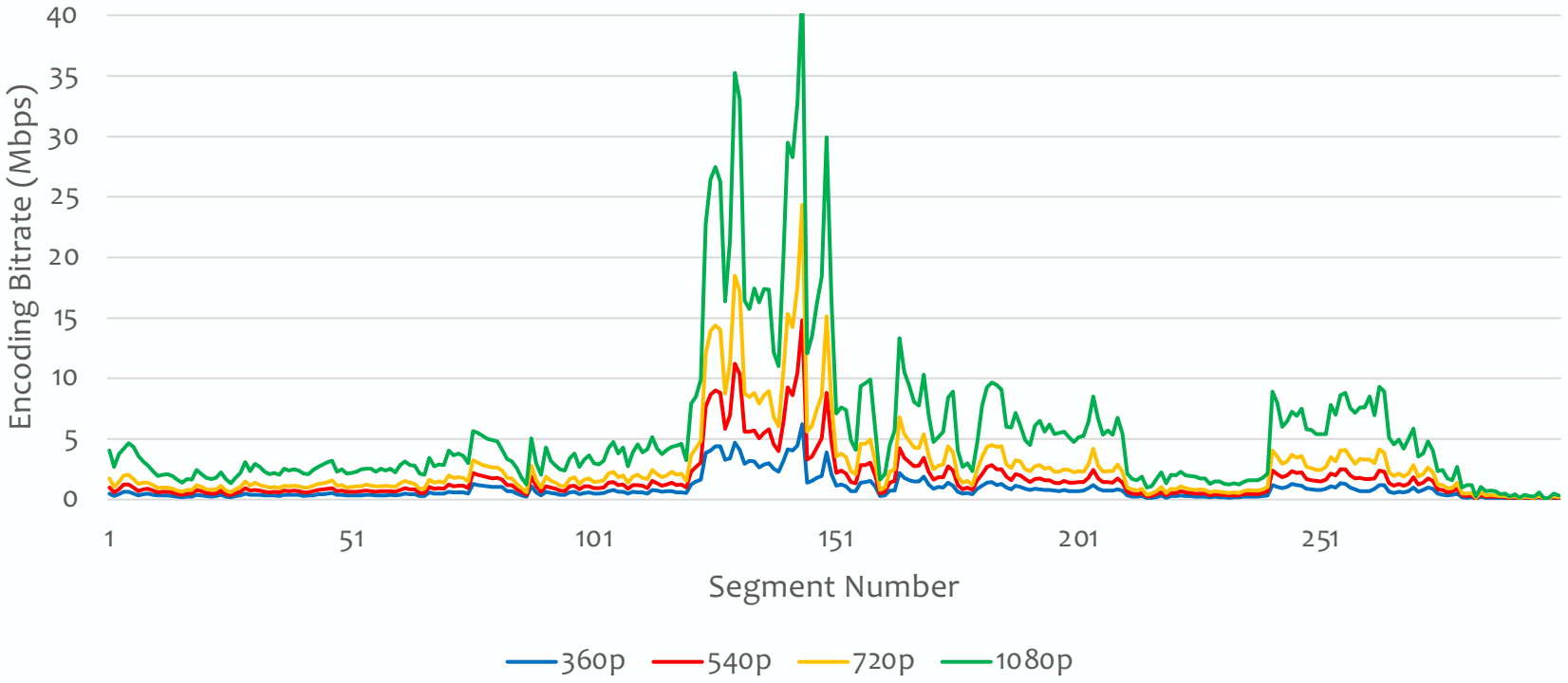
- Bandwidth profiles
  - Cascade
  - Twitch
  - LTE
- Test content
  - 10-minute mixed video encoded by a professional encoder with the CAE mode enabled
  - H.264/AVC, two-second segments, 25 fps
- Four representations with average bitrates of
  - 360p at 850 Kbps
  - 540p at 1690 Kbps
  - 720p at 2720 Kbps
  - 1080p at 5540 Kbps

Bandwidth Profiles



* Repurposed from https://ieeexplore.ieee.org/document/9429986

Segment Encoding Bitrates



Evaluation and Results

Metrics

Metric	Definition
TD	Total downloaded video size (in megabytes)
TRD	Total rebuffering duration (in seconds)
LRC	Long-rebuffering count
SRC	Short-rebuffering count (rebufferings shorter than a frame duration)
HD	Percentage of segments rendered at 720p or higher
Segment Counts	Number of segments fetched at each resolution

Evaluation and Results

ABR Parameters

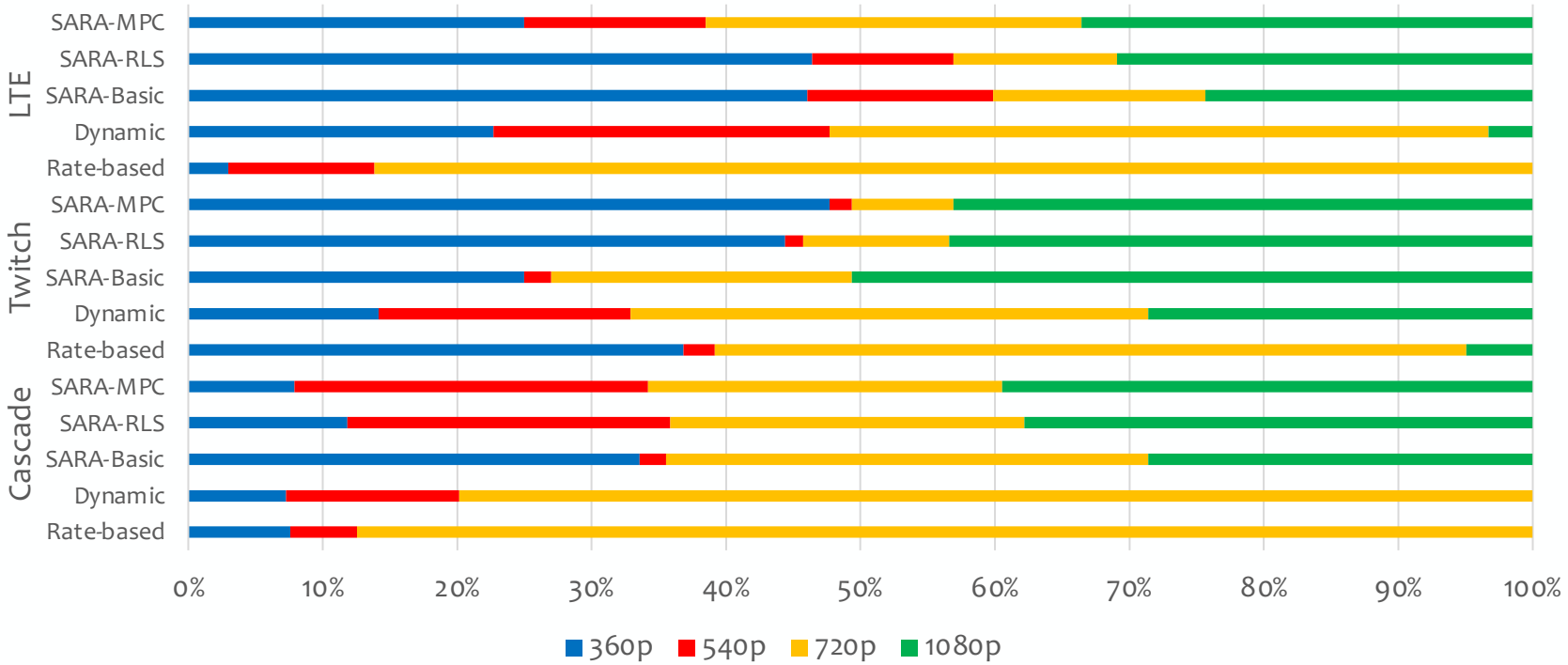
- Five ABR rules
  - Rate based (built-in)
  - Dynamic (built-in)
  - SARA-Basic: Size-aware but has no prediction (uses SWMA output)
  - SARA-RLS: Size-aware and uses RLS
  - SARA-MPC: Size-aware and uses MPC
- B_{min} = 6 seconds and B_{max} = 30 seconds
- Playback starts after six seconds of media is buffered

Results – Rebuffering Performance

Bandwidth Profile	ABR Rule	TD (MB)	RD (s)	LR	SRC	HD (%)
Cascade	Rate-based	184.00	4.92	6	11	88.33
	Dynamic	165.88	3.17	10	8	80.67
	SARA-Basic	178.56	1.26	3	5	65.33
	SARA-RLS	196.10	0.40	1	1	65.00
	SARA-MPC	198.0	0.80	2	1	66.67
Twitch	Rate-based	180.8	2.69	6	8	61.67
	Dynamic	186.5	2.54	10	6	68.00
	SARA-Basic	231.4	1.40	3	7	74.00
	SARA-RLS	199.0	1.00	3	4	55.00
	SARA-MPC	203.6	1.02	4	5	51.33
LTE	Rate-based	188.7	1.90	5	12	87.00
	Dynamic	130.19	1.30	6	7	53.00
	SARA-Basic	140.38	1.27	5	6	40.67
	SARA-RLS	146.10	1.00	3	7	43.67
	SARA-MPC	161.47	0.95	4	5	62.33

Zooming into segments #100-#200: Rate-based and dynamic ABR experience most of their rebufferings during this period and their HD performance drops whereas SARA flavors increase their HD shares

Results – HD Performance



Observations

- Bandwidth prediction accuracy has a direct effect on rebuffering duration and HD performance
- Long-term predictions do help (under investigation)
- SARA-MPC produces better HD performance results than SARA-RLS when the network is more dynamic (RLS makes more conservative predictions and underperforms in upshifting)
- RLS findings
  - RLS is robust against time-varying network conditions through the forgetting factor, but use RLS for one or two-step predictions (performs poorly for longer terms)
  - RLS exhibits extremely fast convergence, does not need a prediction model

Key Takeaways

CAE saves bits or improves quality, clients must support streaming CAE content

SARA is simple; it greatly reduces rebuffering and improves HD performance

Bandwidth prediction is not that difficult and should be used in deployments

Running code is available to let others perform further testing

Thank you

- SARA - IBC'21 Demo Page
  - Download the code, open issues and report bugs
  - Watch the videos through offline demo
- Reach out to any of us for questions
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Further Reading

- Zhi Li, Ali C. Begen, Joshua Gahm, Yufeng Shan, Bruce Osler and David Oran, "Streaming video over HTTP with consistent quality," in Proc. ACM Multimedia Systems Conf. (MMSys), Singapore, Mar. 2014 (DOI=10.1145/2557642.2557658)

- Ali C. Begen, "Quality-aware HTTP adaptive streaming," in Proc. Int. Broadcasting Convention Conf. (IBC), Amsterdam, The Netherlands, Sept. 2015 (DOI=10.1049/ibc.2015.0004)

- Yanyuan Qin, Shuai Hao, Krishna R. Pattipati, Feng Qian, Subhabrata Sen, Bing Wang and Chaoqun Yue, "Quality-aware strategies for optimizing ABR video streaming QoE and reducing data usage," in Proc. ACM Multimedia Systems Conf. (MMSys), 2019

- W. Cooper, S. Farrell and K. Subramanian, "QBR metadata to improve streaming efficiency and quality," SMPTE Annual Technical Conf. and Exh., 2017

- Abdelhak Bentaleb, Mehmet N. Akcay, May Lim, Ali C. Begen and Roger Zimmermann, "Catching the moment with LoL+ in Twitch-like low-latency live streaming platforms," IEEE Trans. Multimedia, to appear (DOI=10.1109/TMM.2021.3079288)

- Abdelhak Bentaleb, Bayan Taani, Ali C. Begen, Christian Timmerer and Roger Zimmermann, "A survey on bitrate adaptation schemes for streaming media over HTTP," IEEE Commun. Surveys Tuts., vol. 21/1, pp. 562-585, Firstquarter 2019 (DOI=10.1109/COMST.2018.2862938)