Bandwidth-aware Prefetching for Proactive Multi-video Preloading and Improved HAS Performance

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- Dissatisfaction with the service and service providers
- Terminated sessions

→ Lost revenue!!

Users of the on-demand video streaming services ...

watch the beginning of several videos (~5 seconds)

before actually watching a video until the end[1].

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before actually watching a video until the end[1].

- Knowing these patterns, popular streaming services offer several related videos to chose from, based on
  - current video choice
  - user viewing history
  - popular videos in the geographical area
  - many other information sources ...

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- Alternate videos must be readily available for playback and played instantaneously
- Prefetching must be quality-adaptive and have no negative effects on the current video's playback
- These goals need to be achieved with the current state-of-the-art

Contributions

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  - enables quality adaptive prefetching and instantaneous playback of alternative videos

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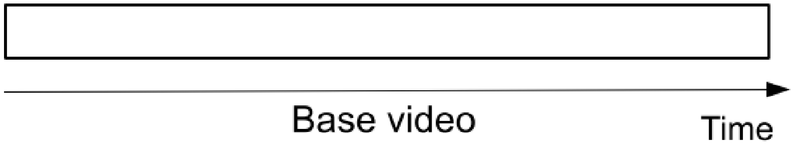
    - improves the playback quality of the current video, by addressing the well known on-off problem in HAS
    - ensures stall free playback of the current video with improved playback experience
- Our policy classes captures a diverse set of use cases
- We characterize and show the benefits of our prefetching policies through our proof-of-concept implementation

HTTP-based Adaptive Streaming (HAS)



- HTTP-based streaming

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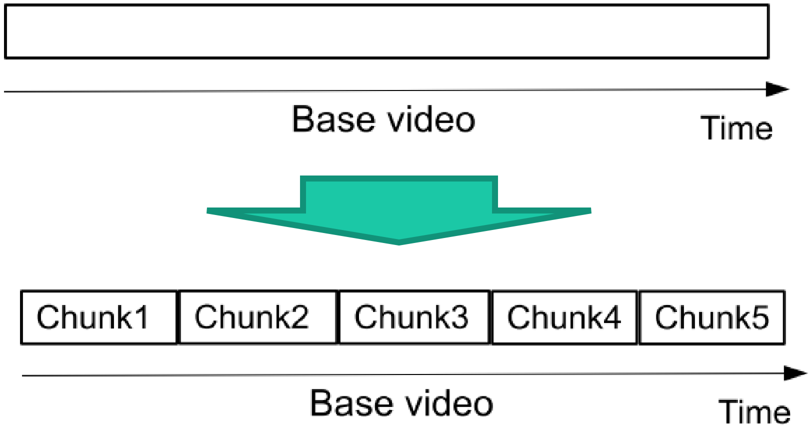

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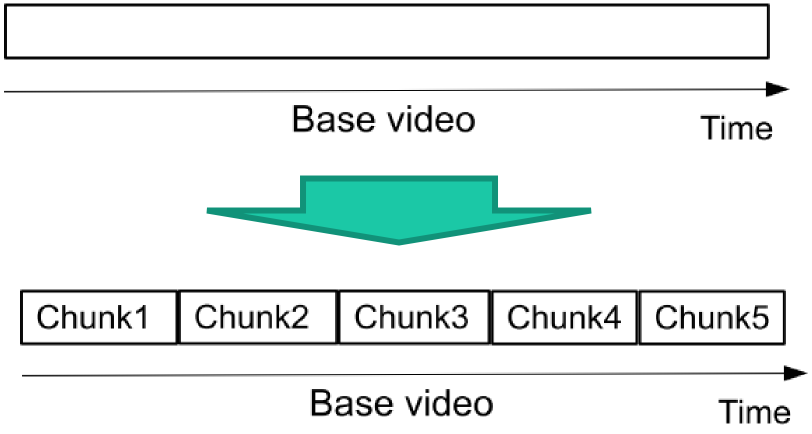

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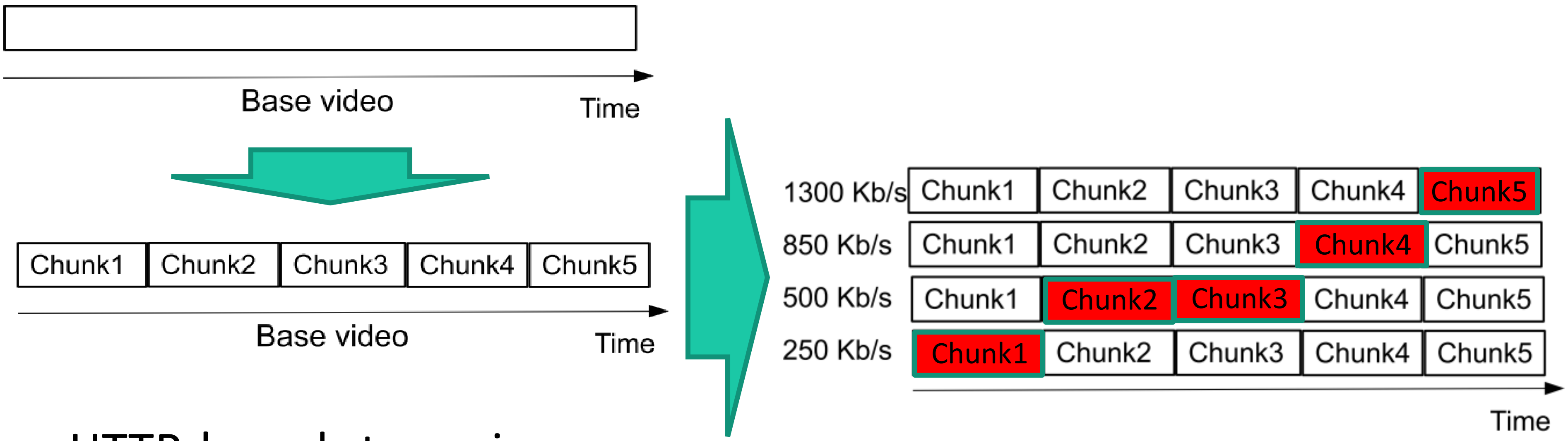

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  - Clients adapt quality encoding based on buffer/network conditions

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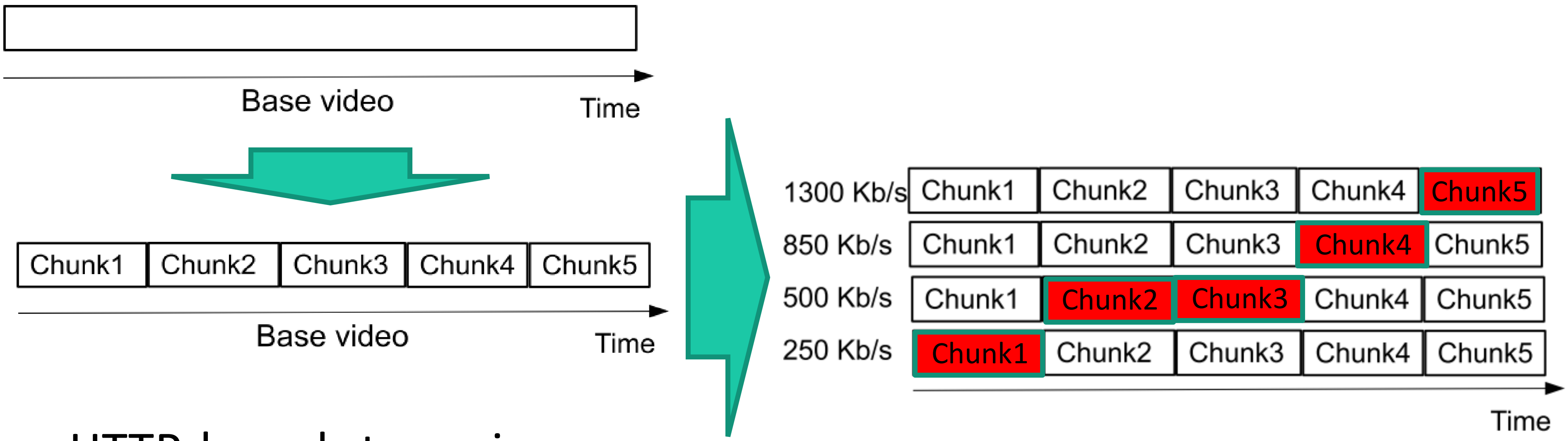

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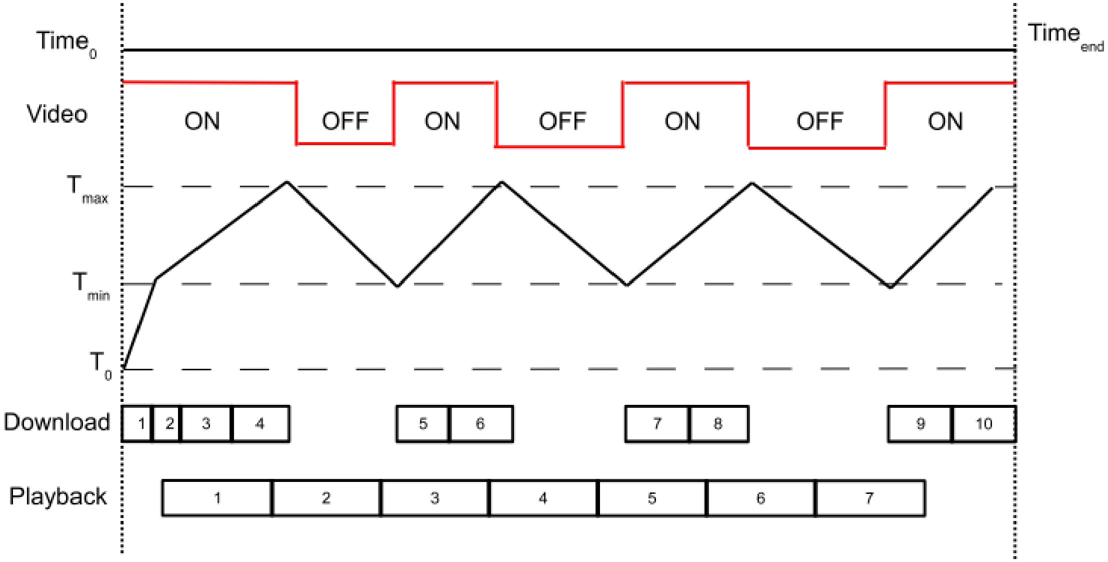
- HTTP-based adaptive streaming
  - Clients adapt quality encoding based on buffer/network conditions
  - Support for interactive VoD

On-off switching in HAS

- Most HAS players perform ON-OFF switching based on two buffer thresholds: T_{min} and T_{max}



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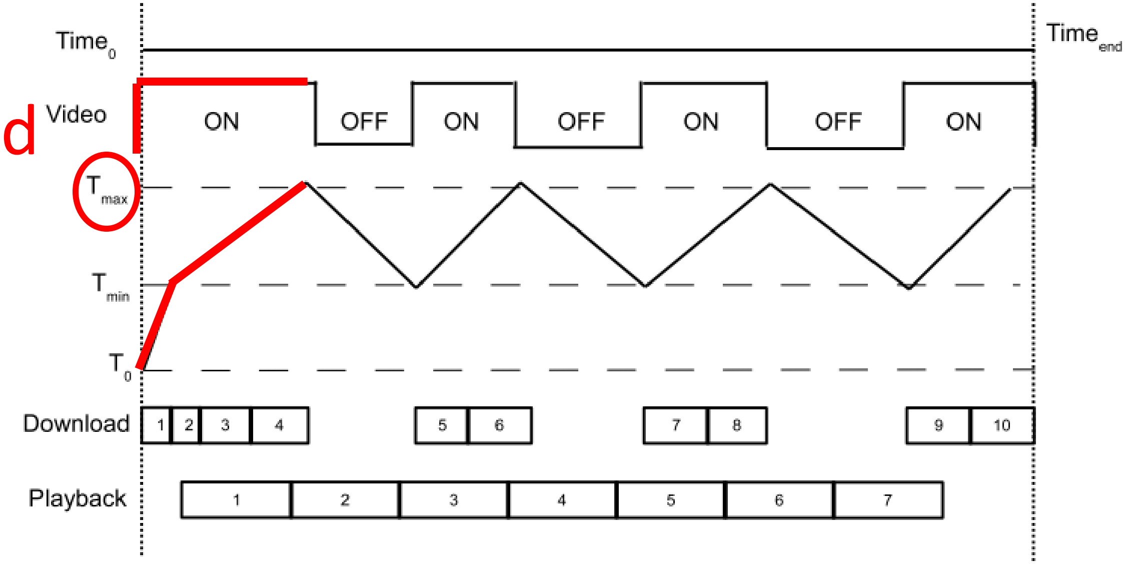

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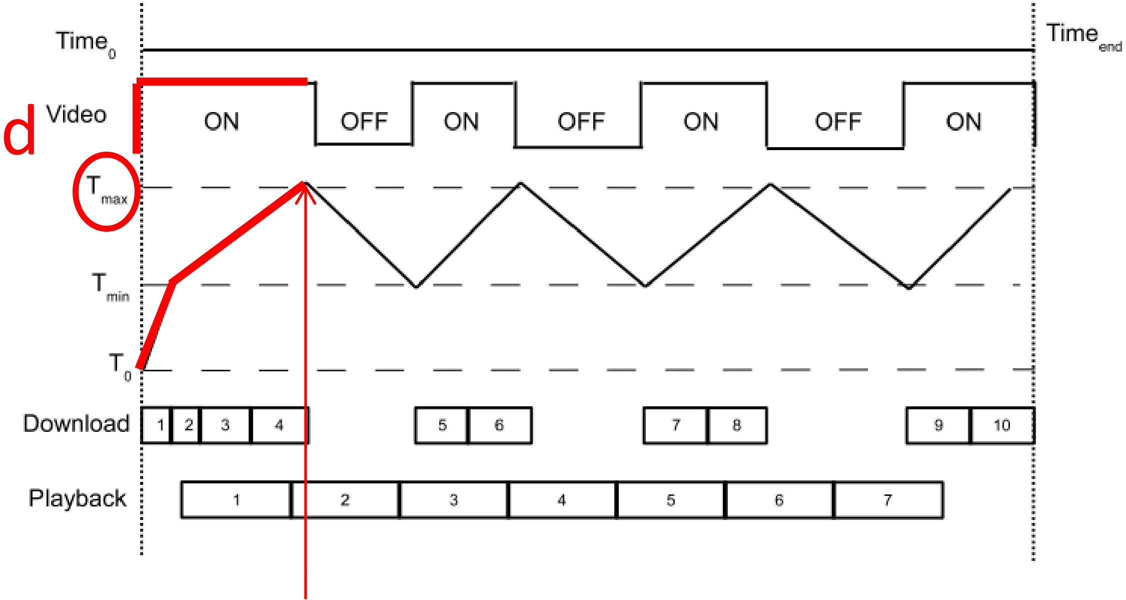

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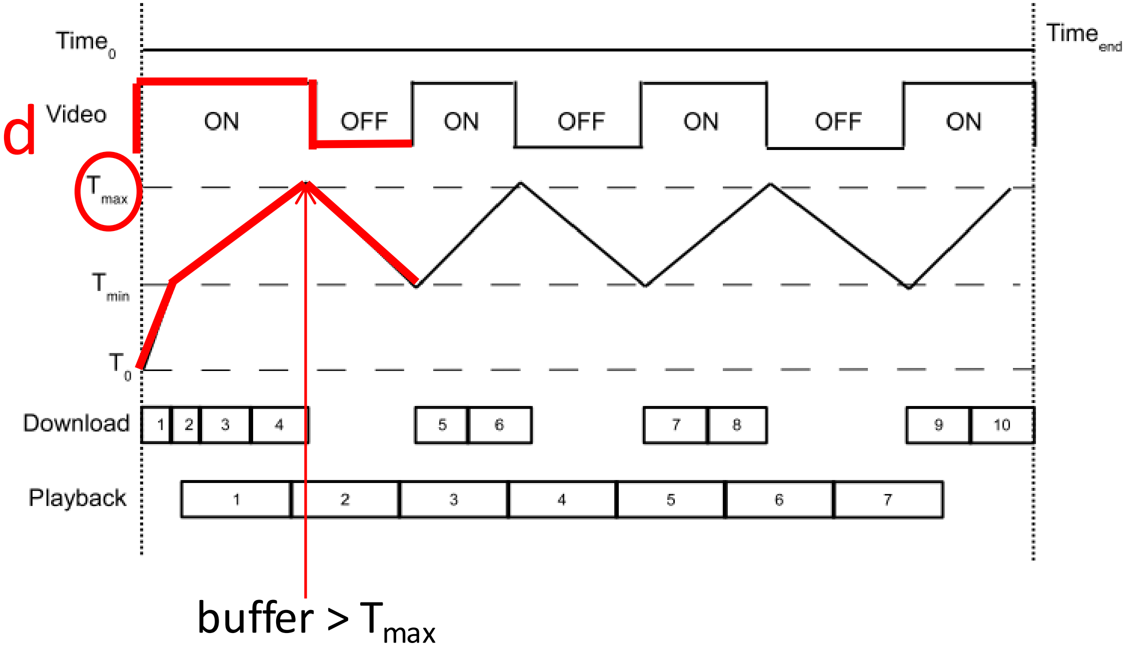

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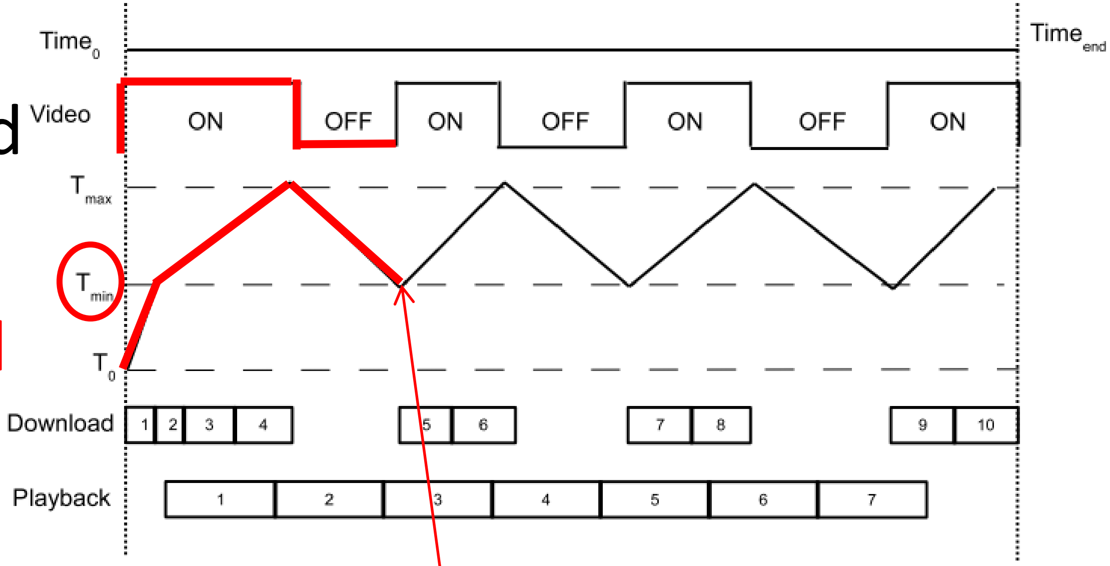

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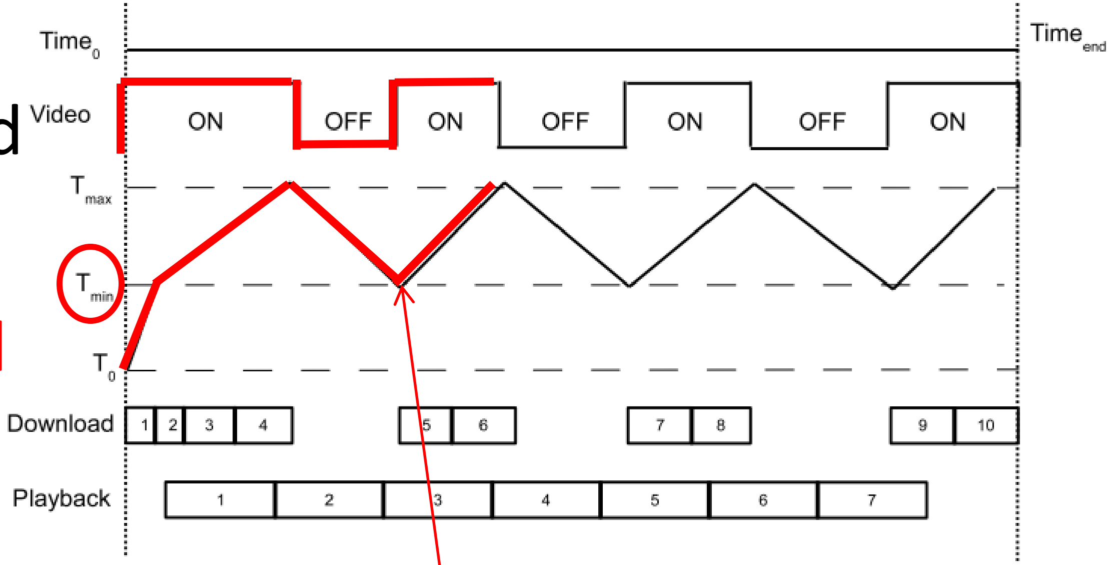

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Issues with on-off switching in HAS

- Although thresholds on the buffer is beneficial, on-off switching has been shown to lead to:

Issues with on-off switching in HAS

- Although thresholds on the buffer is beneficial, on-off switching has been shown to lead to:
  - Unfair bandwidth allocation
  - Under utilization of bandwidth
  - Unnecessary fluctuations in quality adaptation

Prefetch alternative videos during off periods

- Allow instantaneous playback of alternative videos
- In addition, prefetching during off periods:

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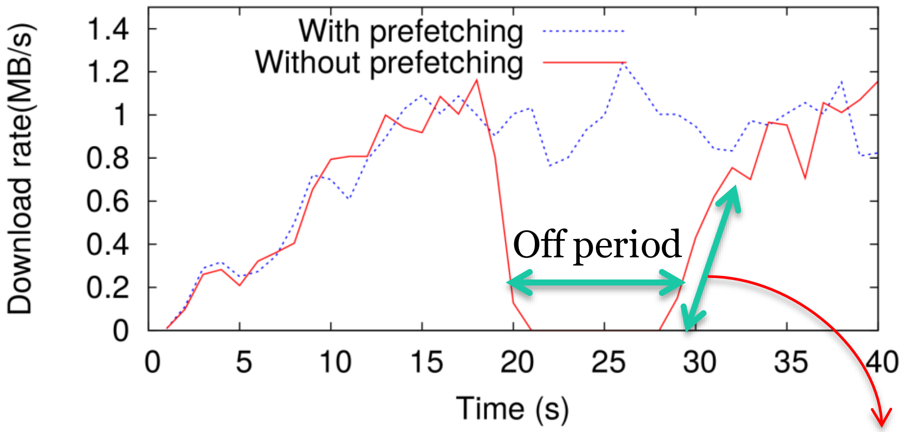
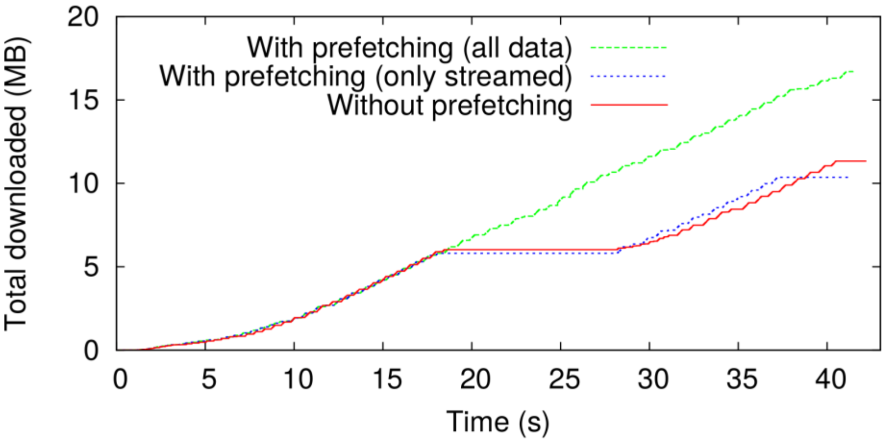
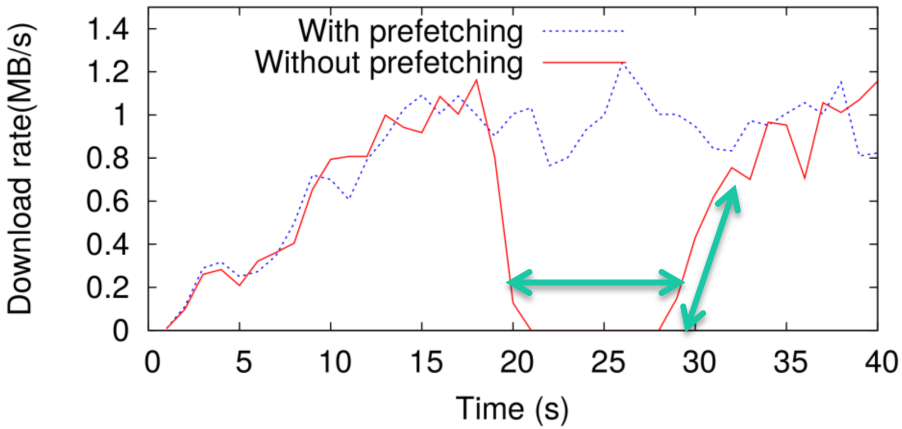


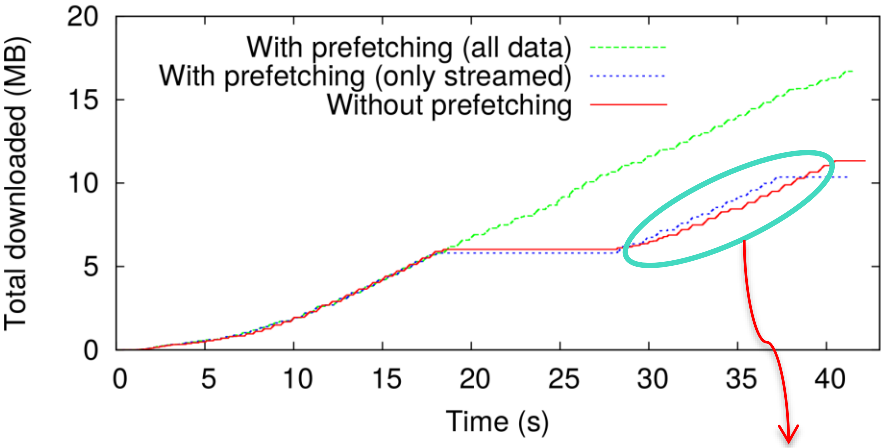


Slow-start and ramp up

Prefetch alternative videos during off periods

- Allow instantaneous playback of alternative videos
- In addition, prefetching during off periods:
  - Avoids the need to ramp-up from slow-start
  - Client remains active throughout the duration





With prefetching, data is downloaded faster and the next off period is reached sooner

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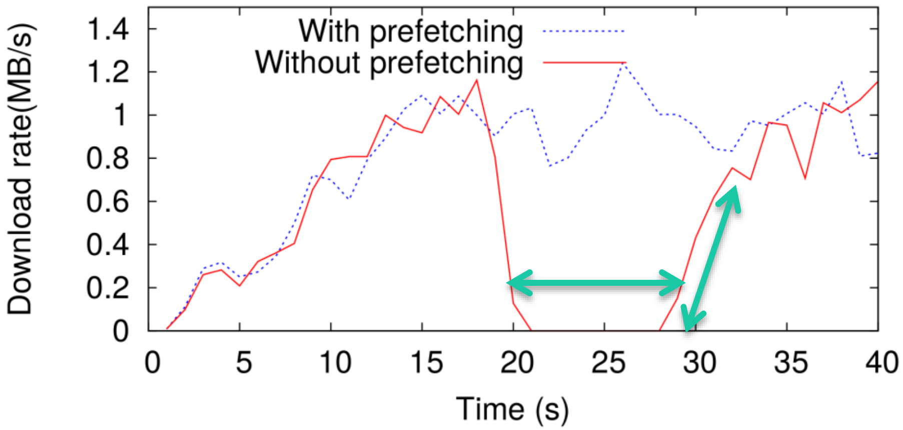
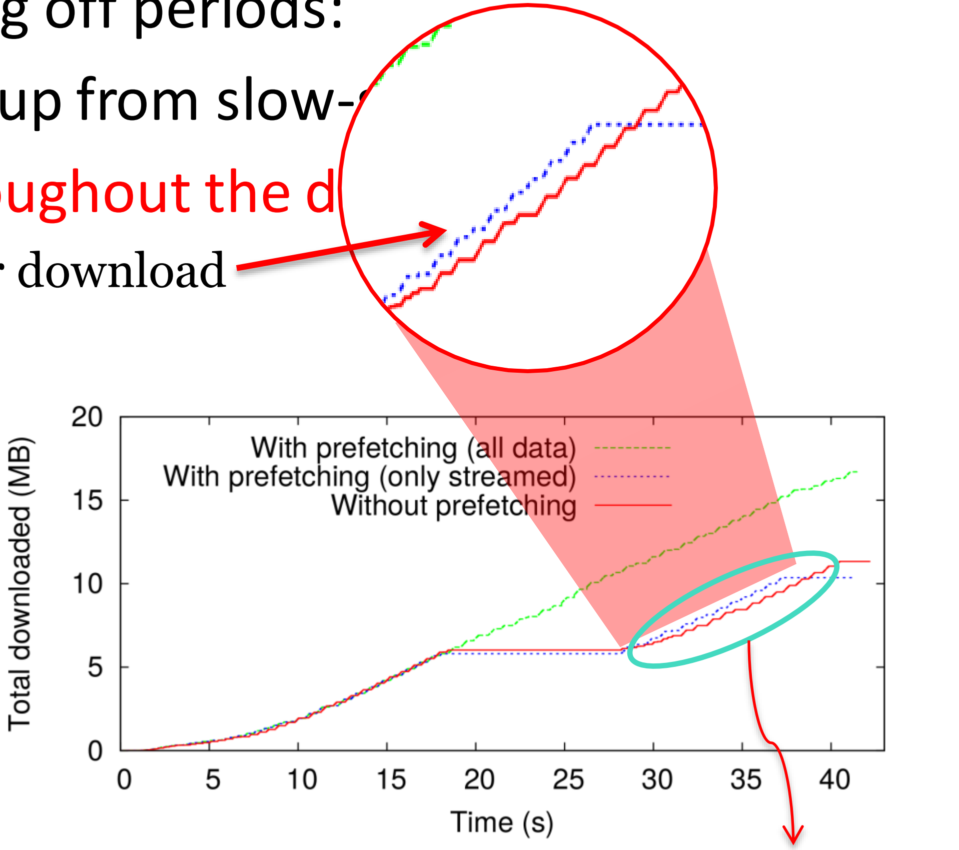
Greater slope → faster download





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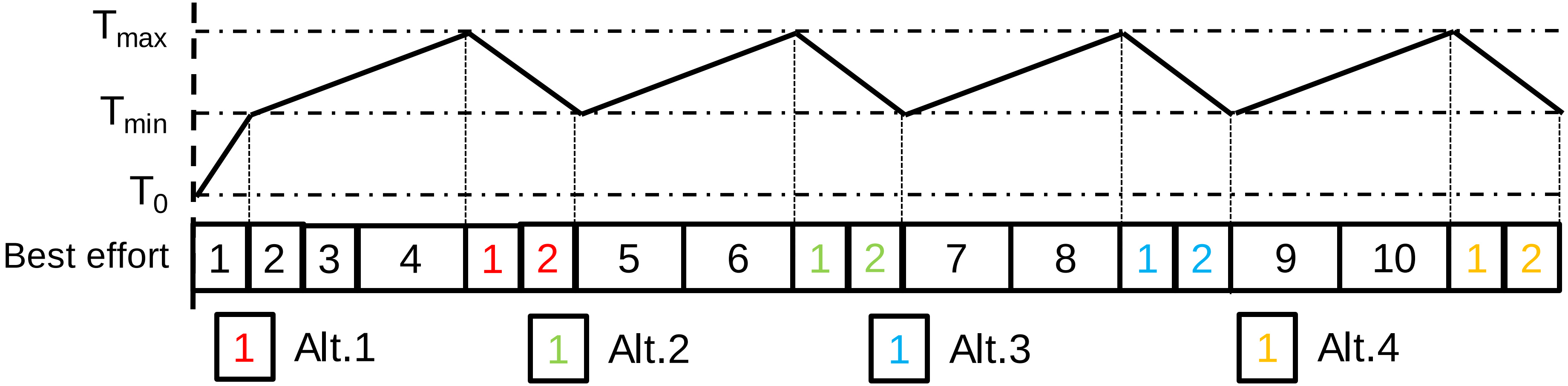
Prefetching policies

- In order to control the number of prefetched chunks and the time at which alternate videos will be available for playback, we consider three broad classes of prefetching policies:
  - Best-effort
  - Token-based
  - Deadline-based

Prefetching policy: Best-effort

- Prefetching rules:
  - Prefetch alternative chunks when $T \geq T_{max}$ and $r(T - T_{min})$ > prefetched chunk size



Prefetching policy: Best-effort

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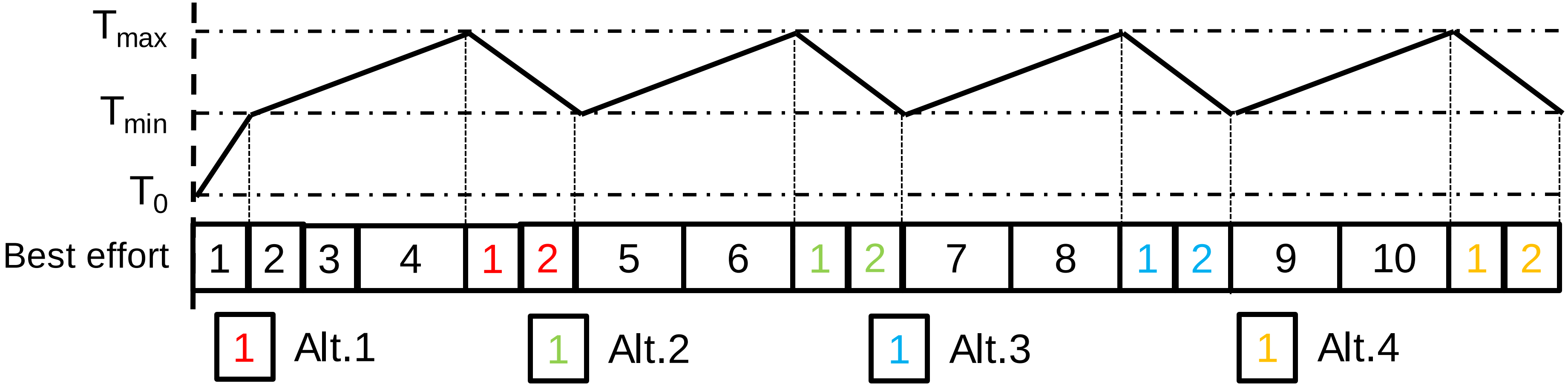
  - Number of chunks per alternate video is controlled by parameter ‘*n*’



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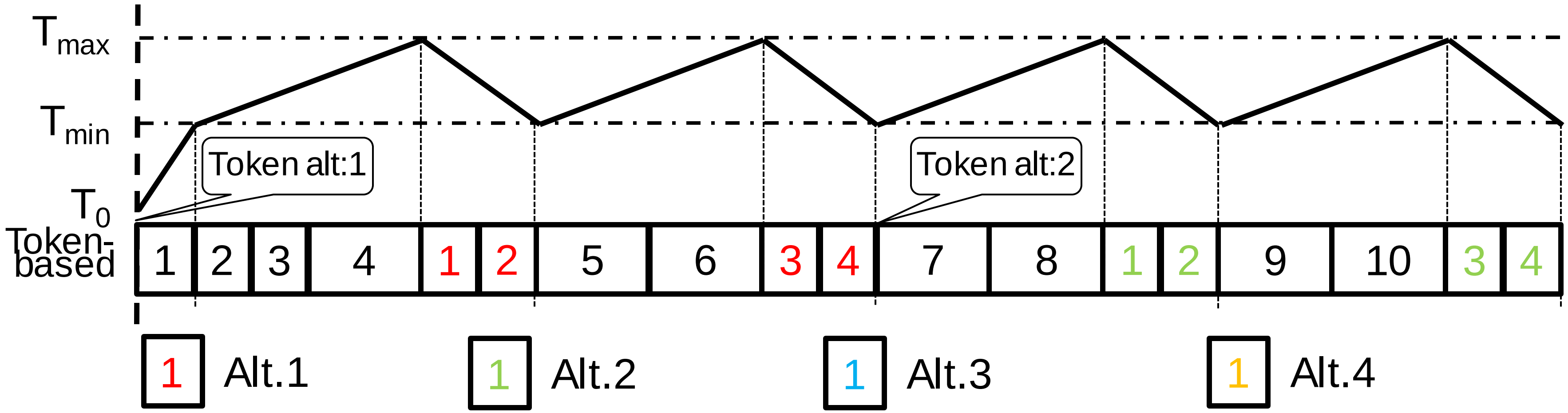

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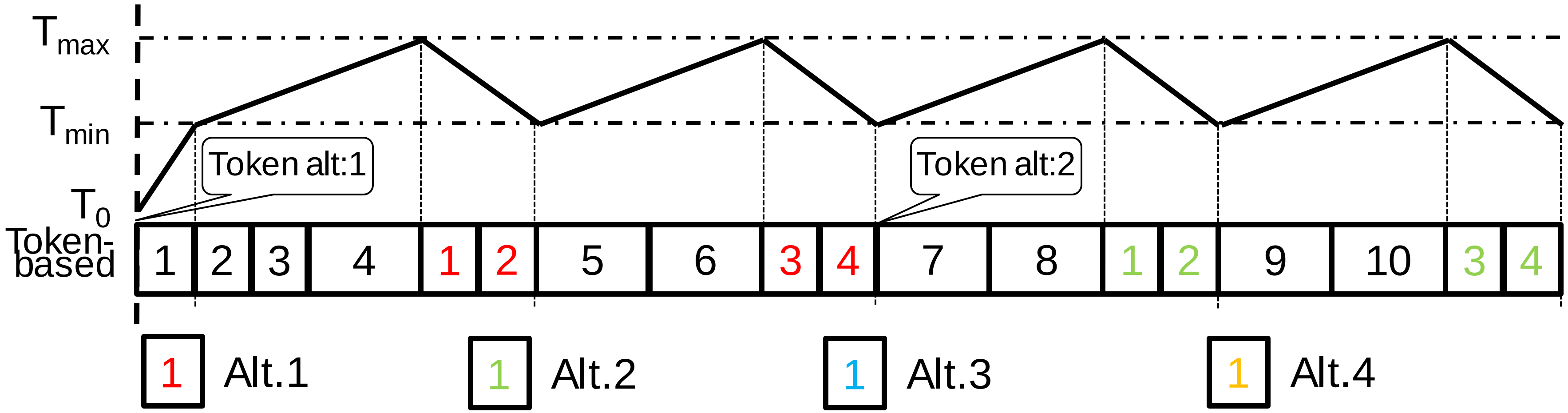

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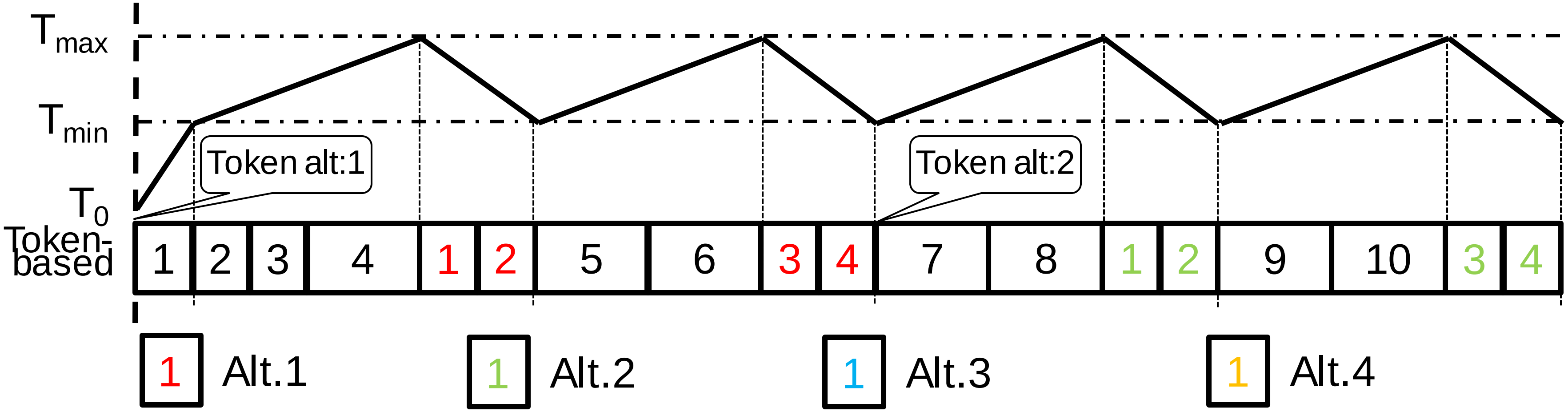
  - Time Δ determines time between prefetching of alternative videos



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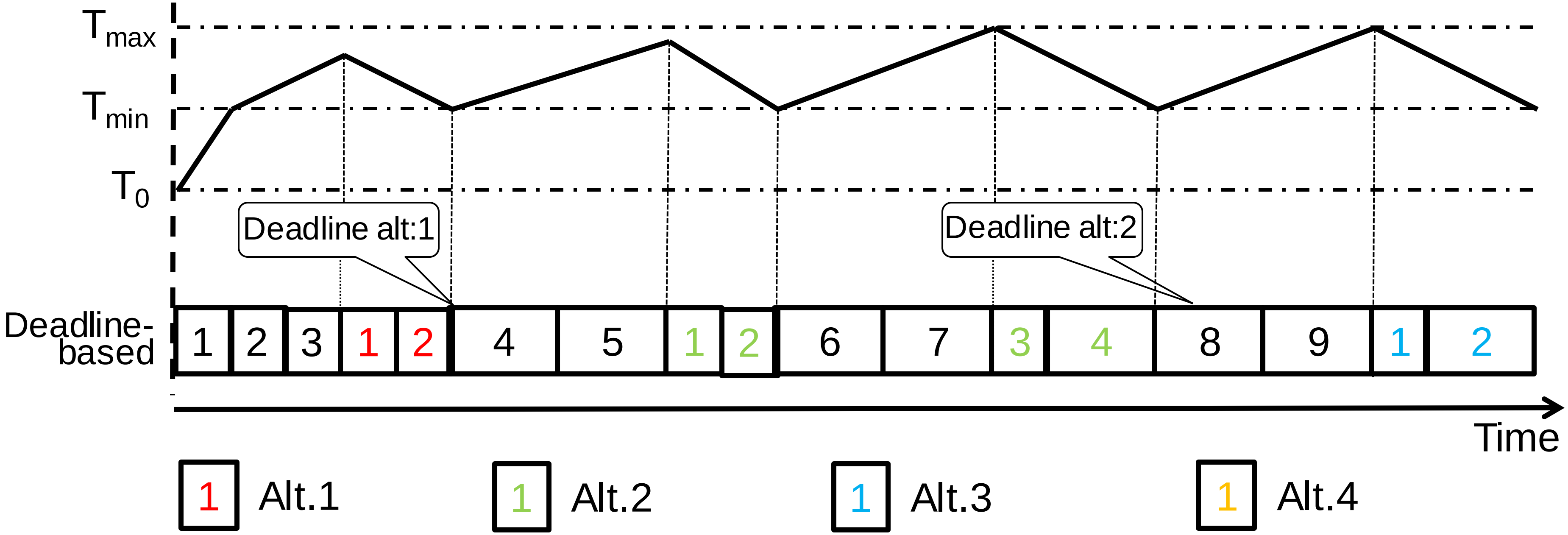
- Prefetching rules:
  - Strict deadlines by which ‘*n*’ chunks of alternative videos (and ‘*m*’ chunks of current video) must be downloaded



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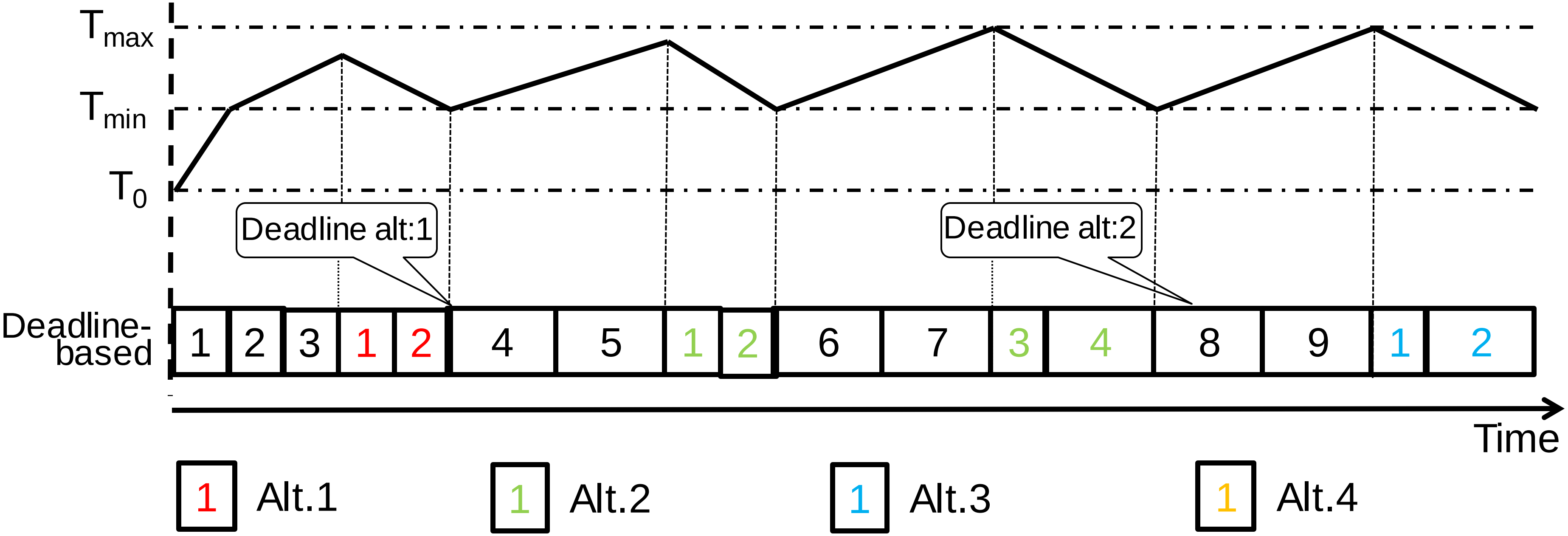

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$$\text{maximize} \sum_{i=1}^{m_a+1} q_i^s l_i^s + \sum_{j=1}^{n} q_j^a l_j^a$$

Playback quality of streamed video

Playback quality alternative video chunks

The optimization formulation above originally appeared in our ACM MM 2014 paper.

Quality-adaptive Prefetching for Interactive Branched Video using HTTP-based Adaptive Streaming

In Proceedings of the ACM International Conference on Multimedia (ACM Multimedia), Orlando, FL, Nov. 2014.

Policy characterization

- All experiments performed with at least one competing flow
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- Example results
  - 4 Mbps (shared) link
  - 1 competing flow
  - 150ms RTT
  - $T_{min}/T_{max} = 8/12$
  - *n* (chunks to prefetch per alternative video) = 2

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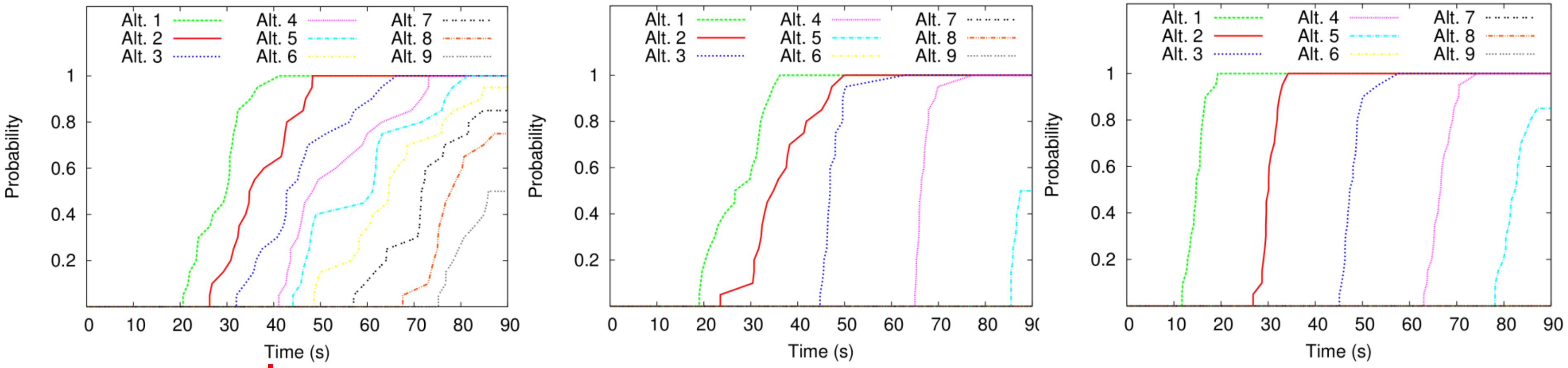
Policy characterization: Number of alternative videos



- Best-effort policy
  - Moves to the next alternative video after 2 chunks of the previous alternative video is completed

Figures: Download completion time of the *n*=2 chunks of each alternative video

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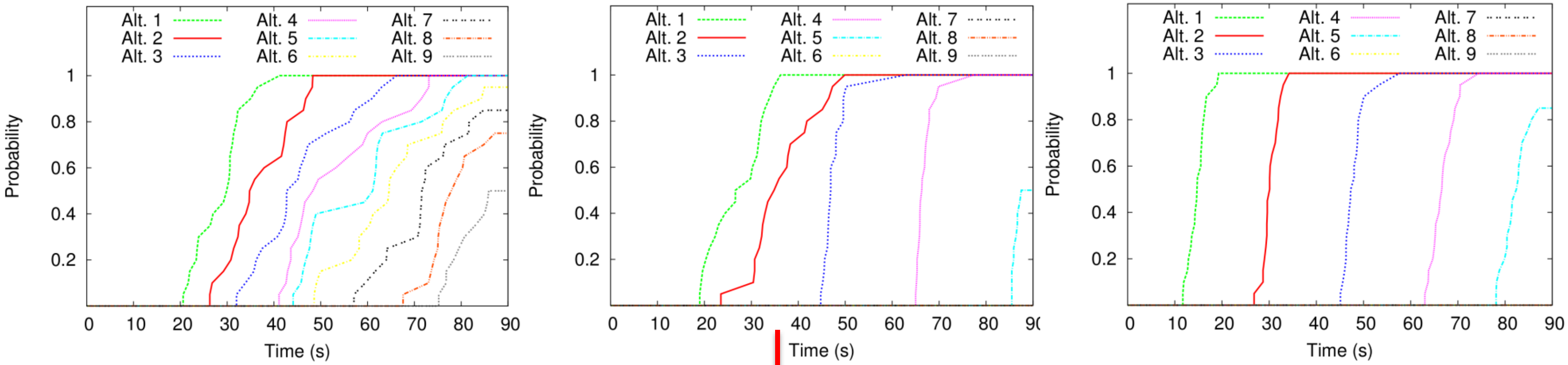
Policy characterization: Number of alternative videos



- Token-based policy
  - Moves to the next alternative video only when the next token is released

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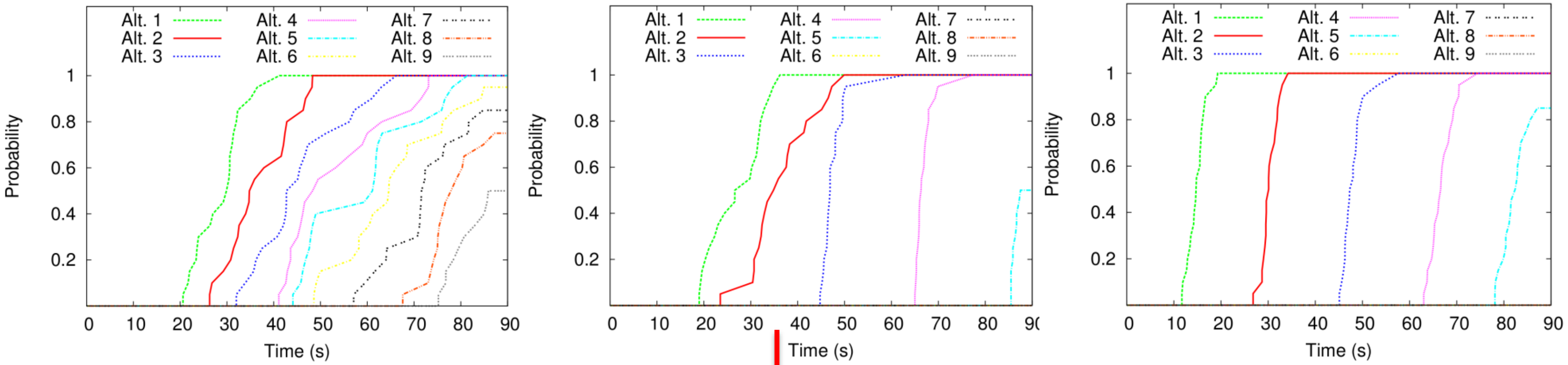
Policy characterization: Number of alternative videos



- Token-based policy
  - Moves to the next alternative video only when the next token is released
  - Prefetches more chunks of alternative videos in the absence of new tokens

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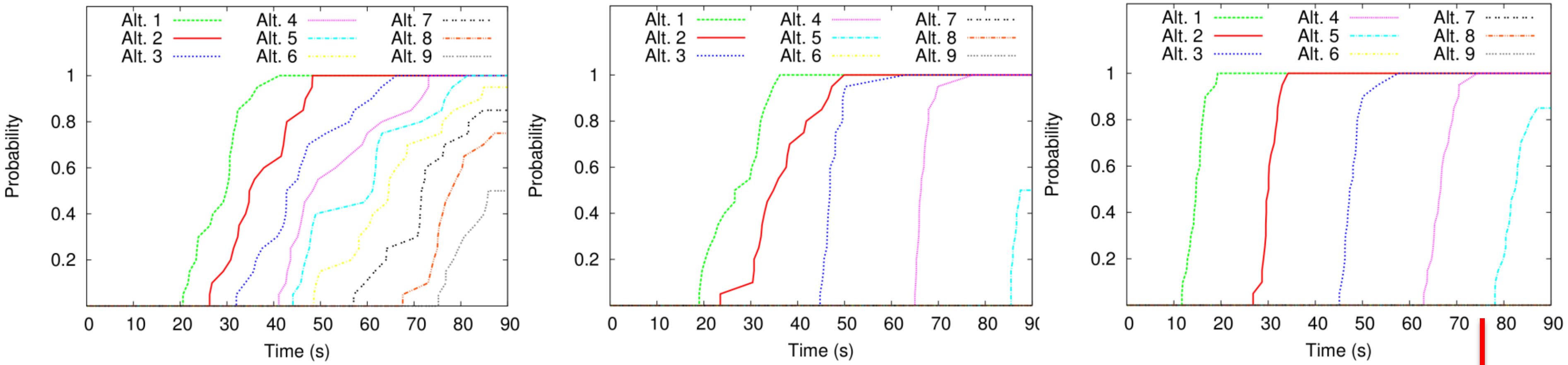

- Deadline-based policy
  - Deadlines every 20s

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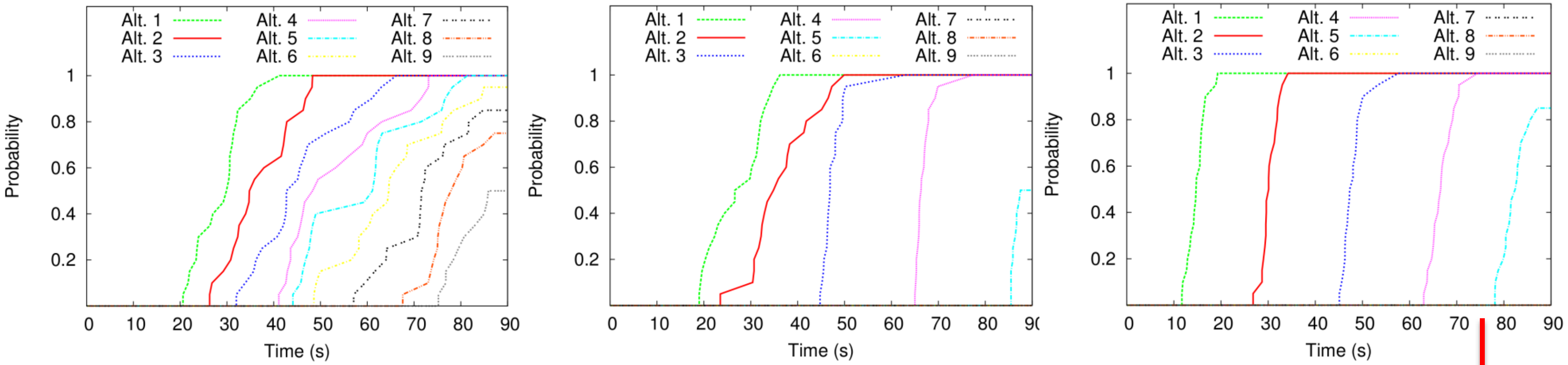

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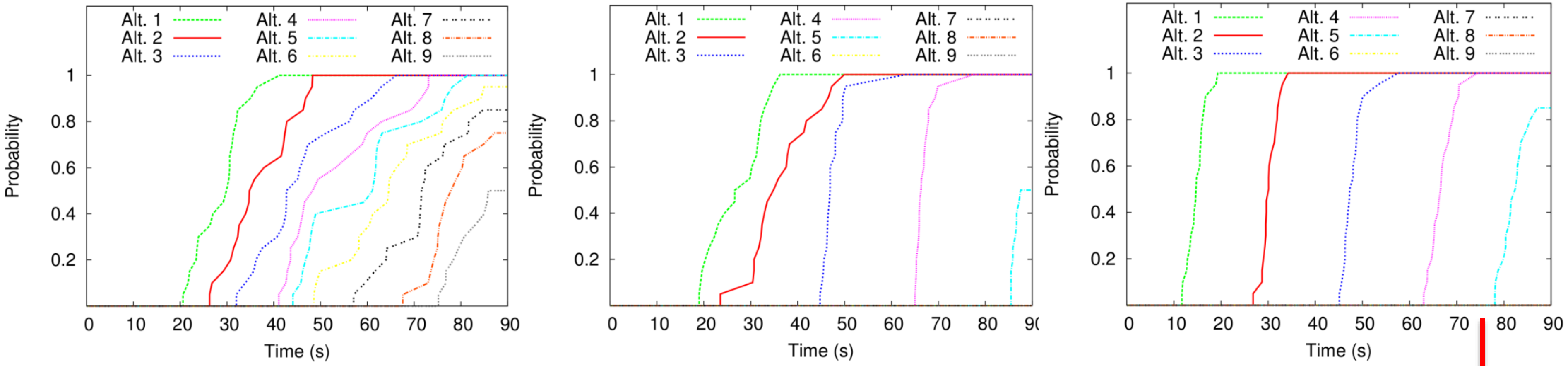
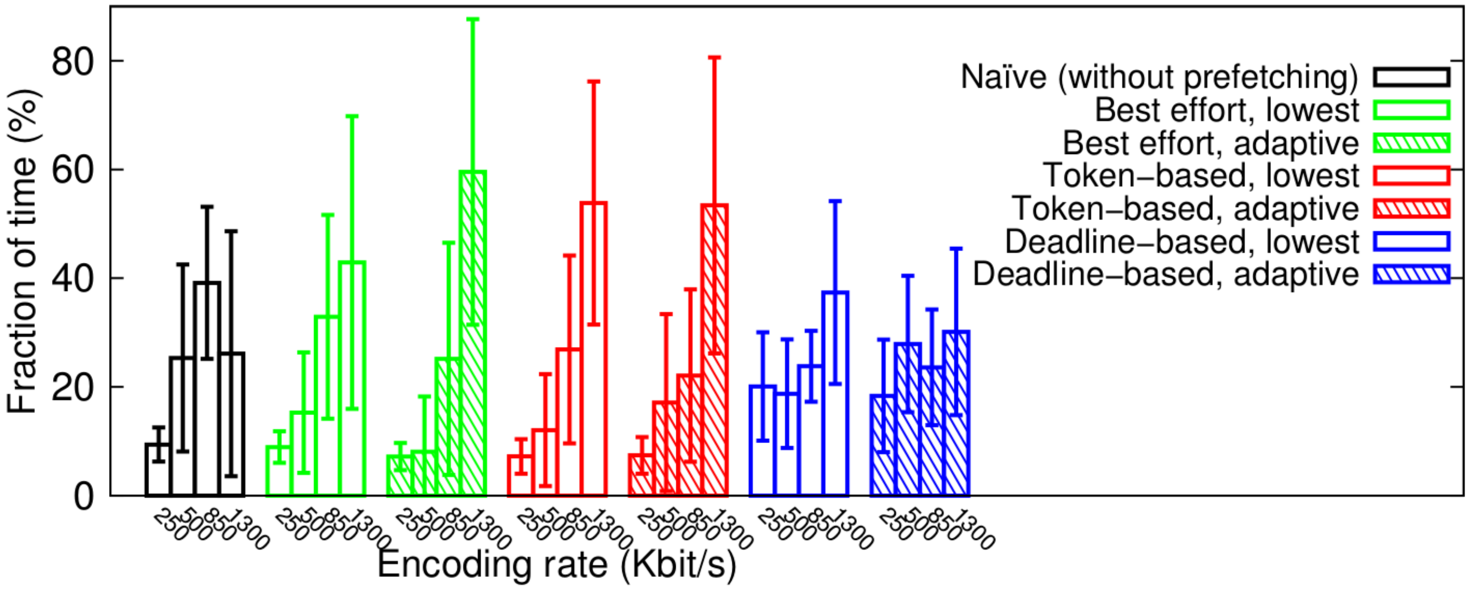


- Deadline-based policy
  - Deadlines every 20s
  - Evenly spaced download completions, respecting their download deadlines
  - When the deadline is satisfied, the player moves ahead with the next deadline

Figures: Download completion time of the *n*=2 chunks of each alternative video

Policy characterization: Playback quality of streamed video chunks



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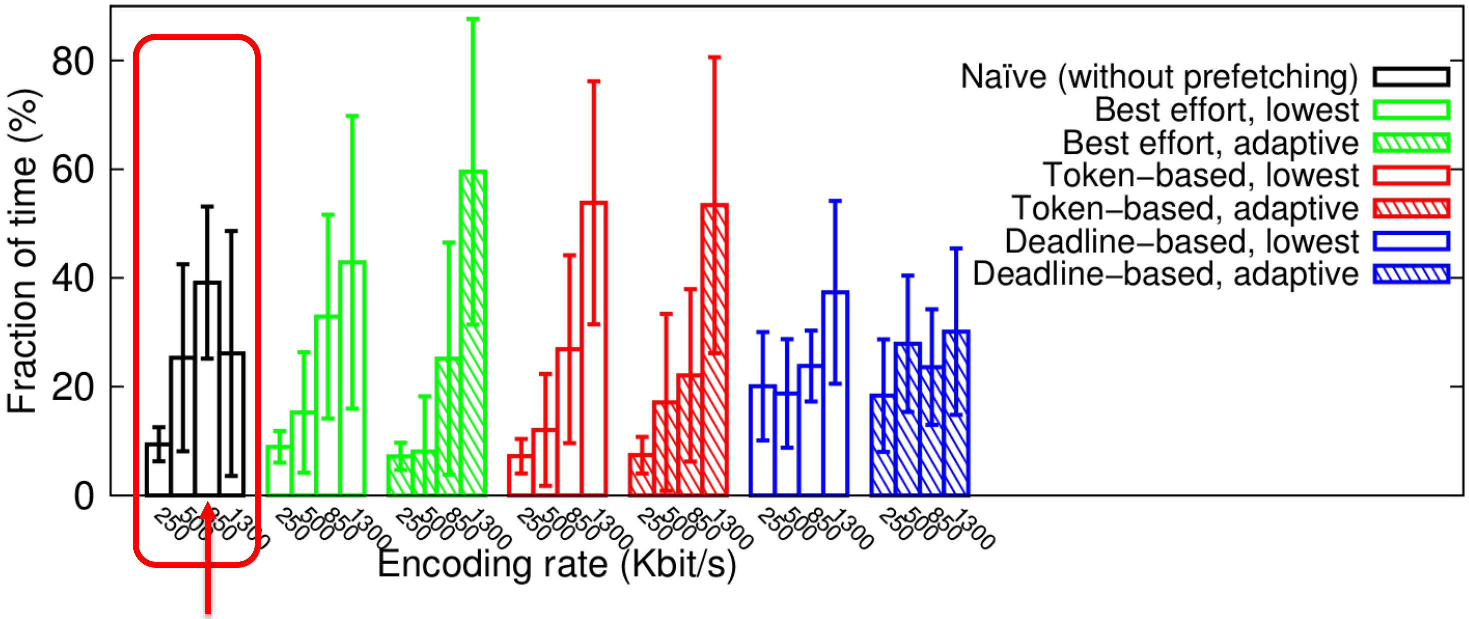
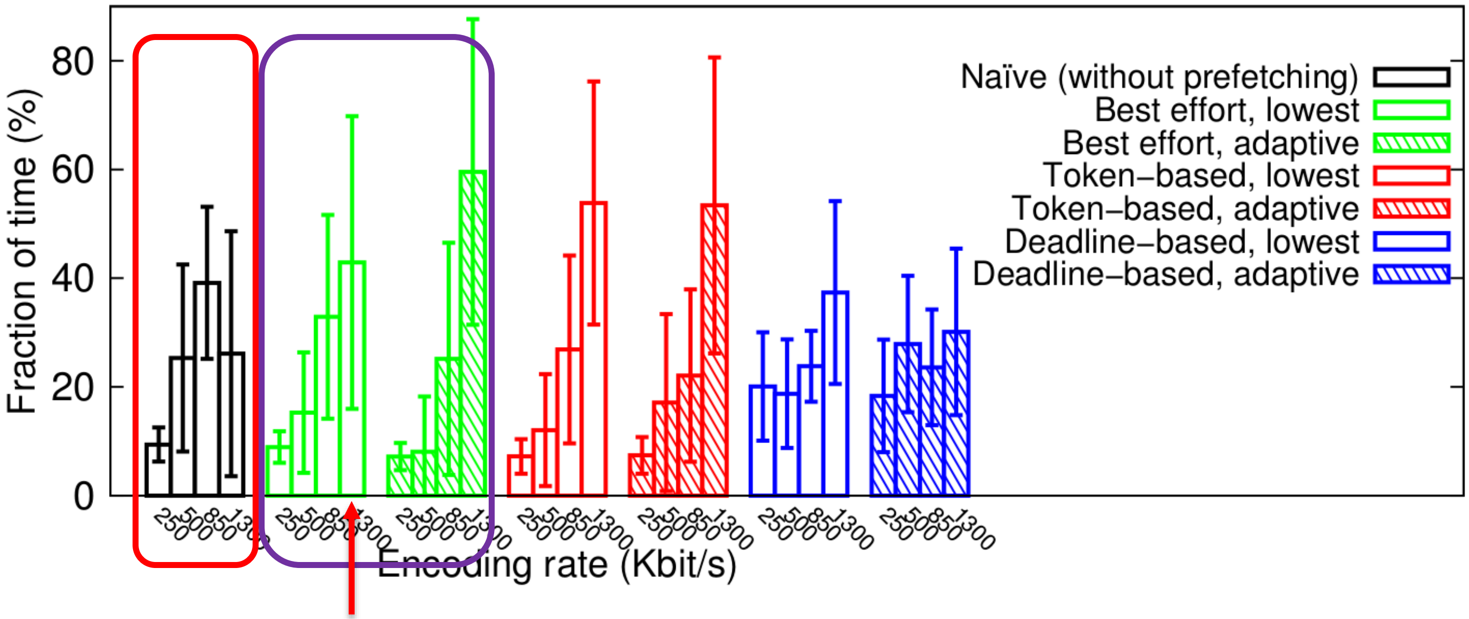


Medium quality

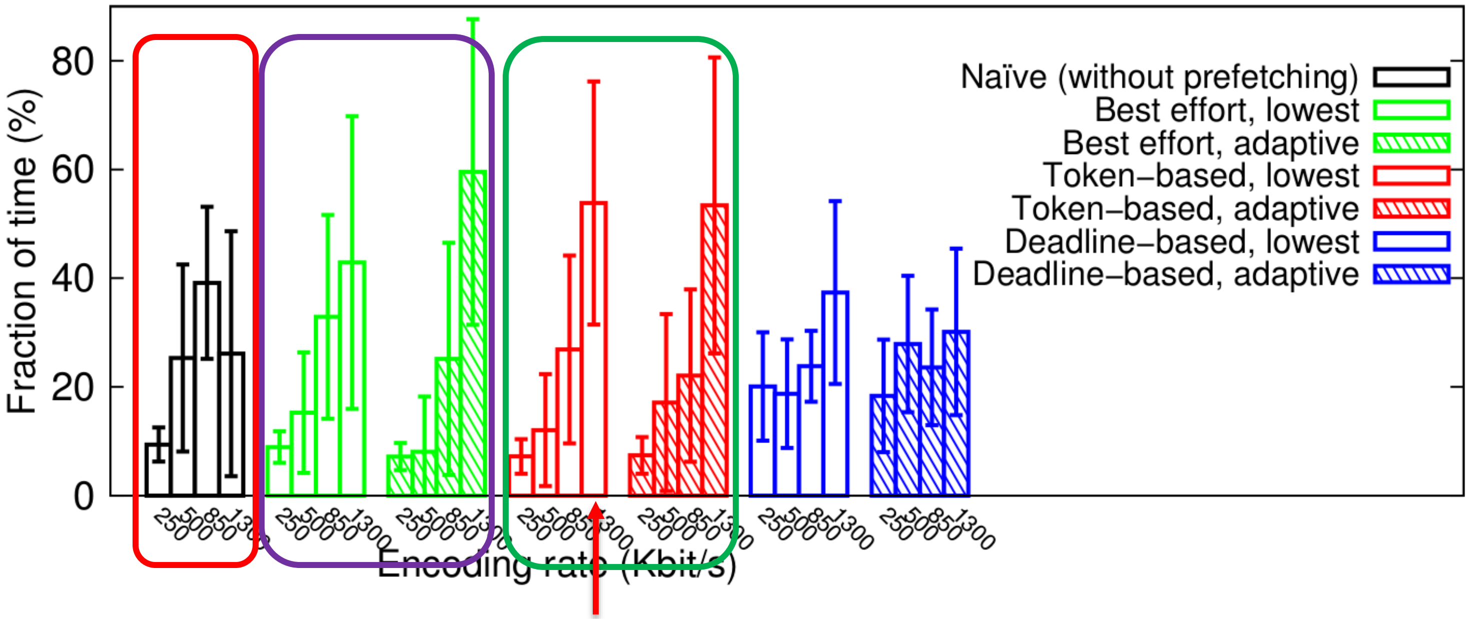
Policy characterization: Playback quality of streamed video chunks



High quality

- Best-effort policy achieves better playback rates than the naïve player

Policy characterization: Playback quality of streamed video chunks



High quality

- Best-effort policy achieves better playback rates than the naïve player
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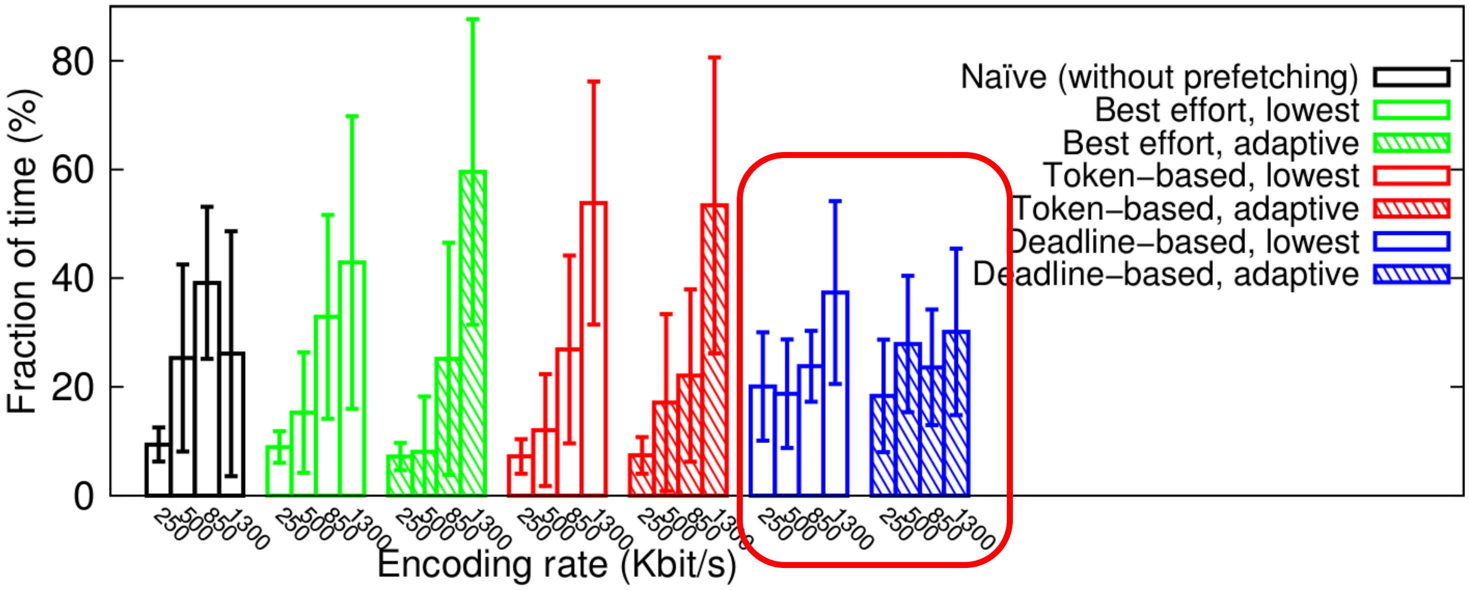
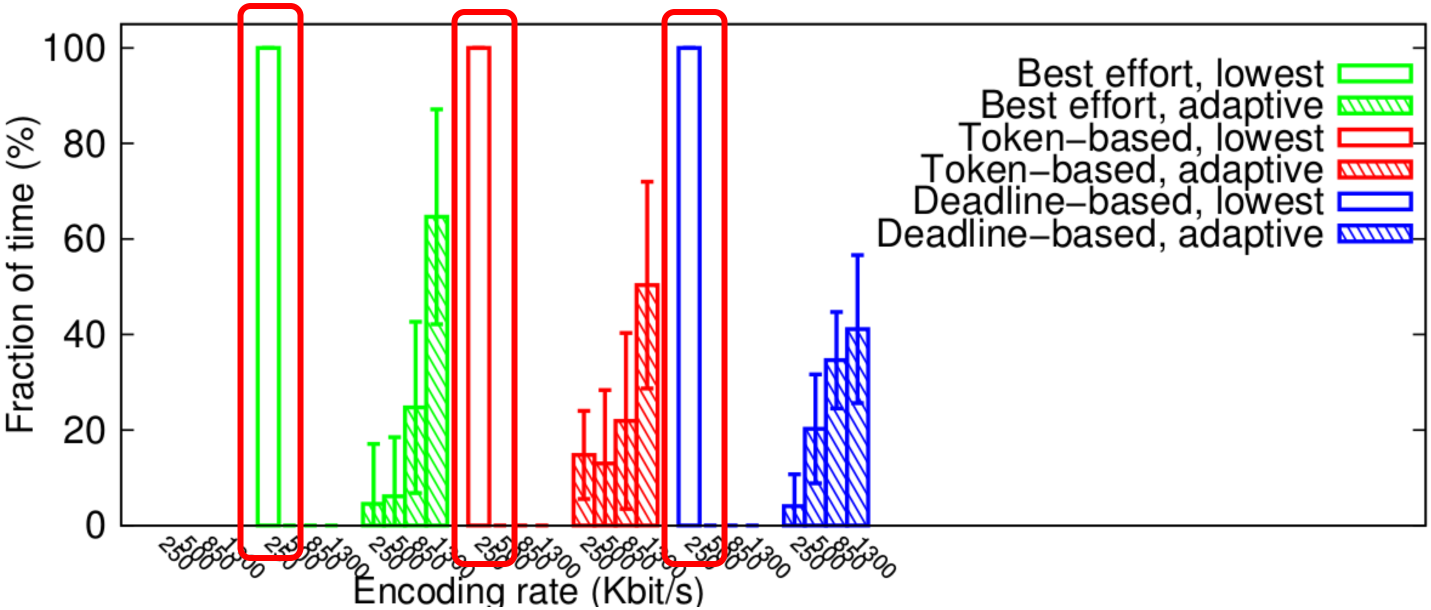


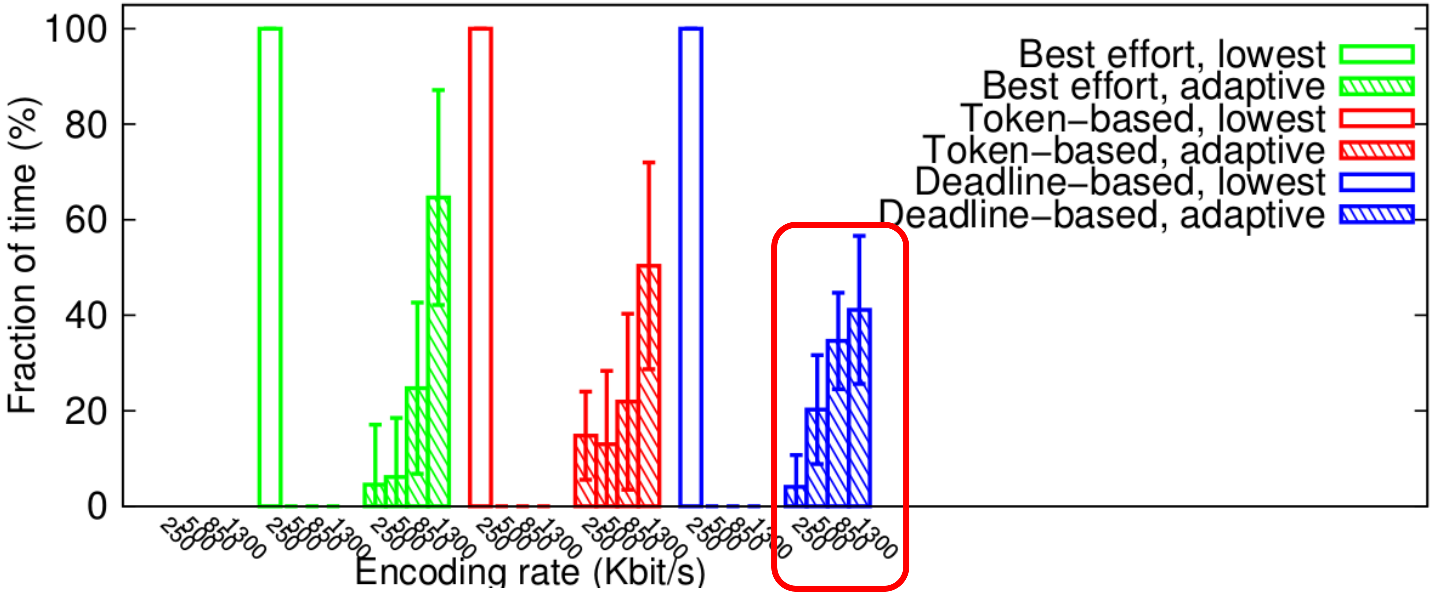
- Best-effort policy achieves better playback rates than the naïve player
- Token-based policy also achieves better playback rates than the naïve player
- Comparatively, deadline-based policies achieve lower playback qualities due to deadline constraints

Policy characterization: Playback quality of alternate video chunks



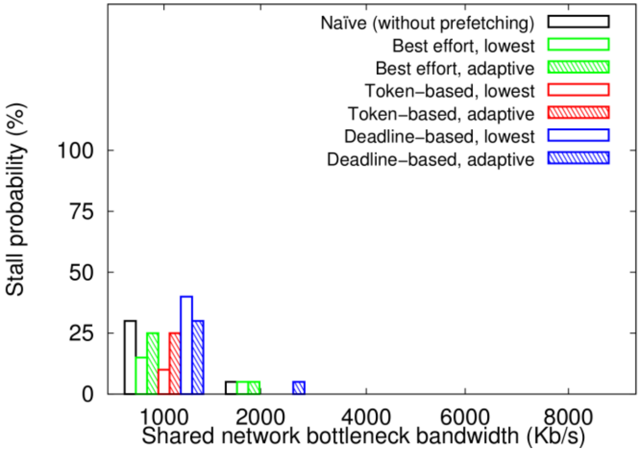
- Lowest-quality prefetching always chooses the lowest encoding available

Policy characterization: Playback quality of alternate video chunks

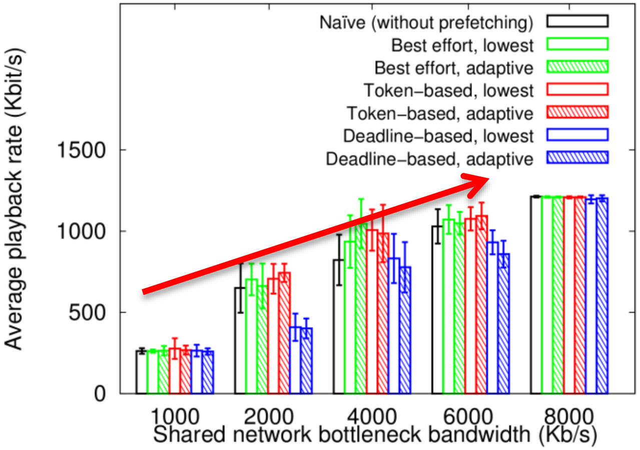


- Lowest-quality prefetching always chooses the lowest encoding available
- Deadline-based policy trades-off quality of both streamed and alternate videos to achieve the deadlines

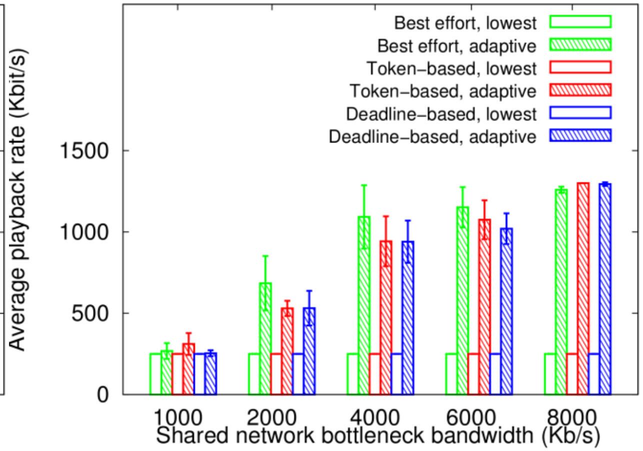
Impact of network conditions: Bandwidth



Stall probabilities



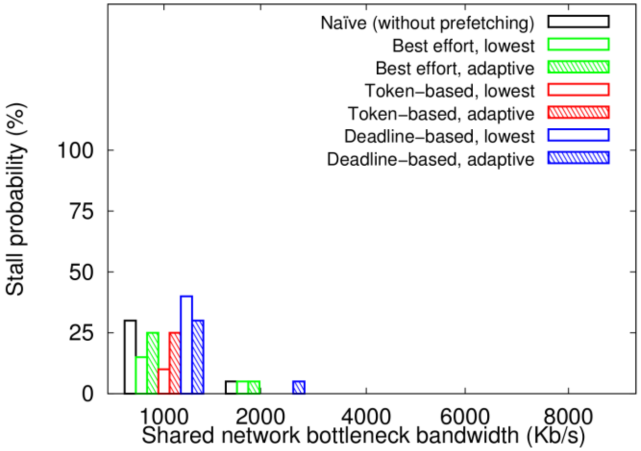
Quality of streamed video



Quality of alternate video

- All policies adapt playback quality based on bandwidth

Impact of network conditions: Bandwidth



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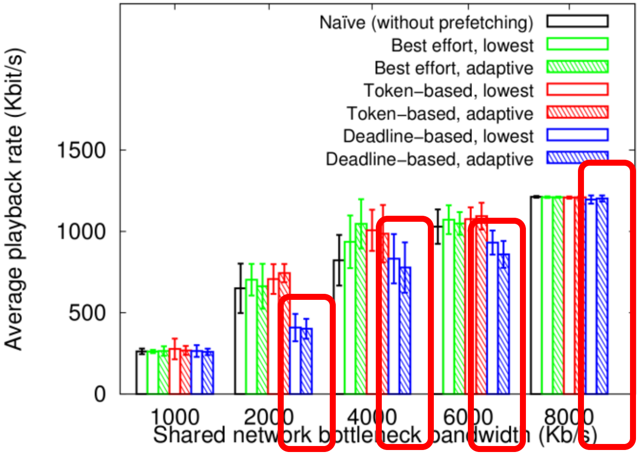
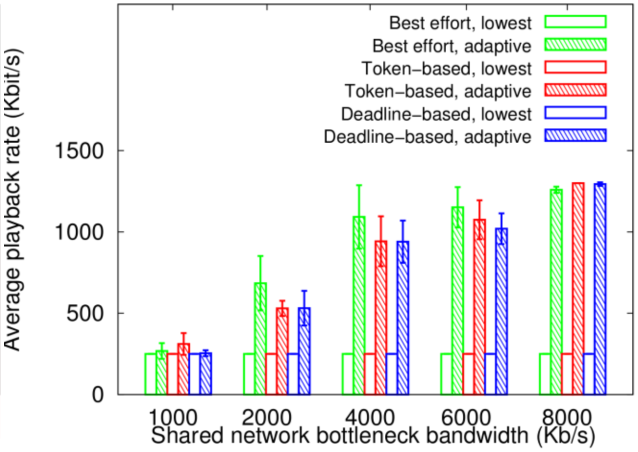


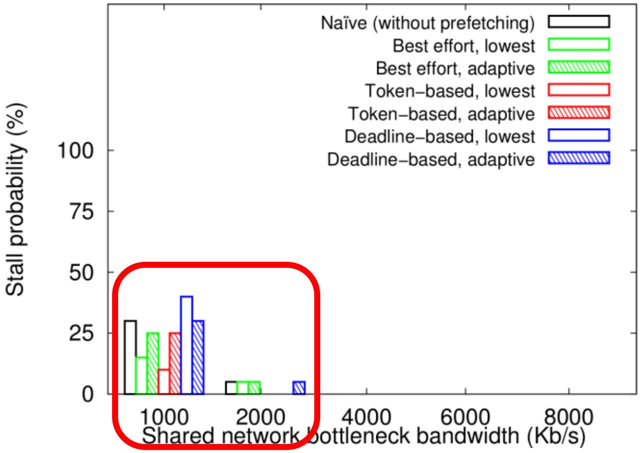
Quality of streamed video



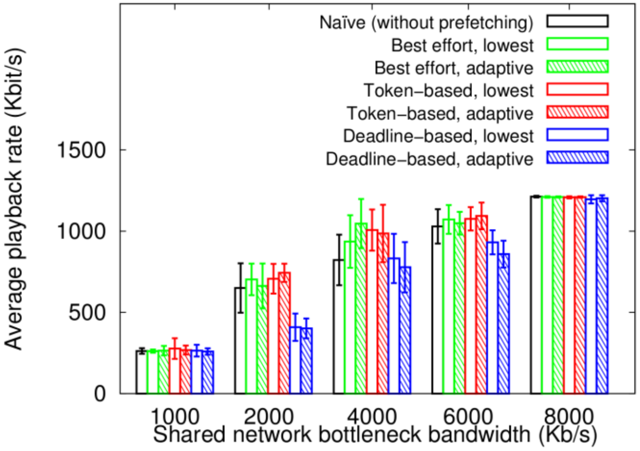
Quality of alternate video

- All policies adapt playback quality based on bandwidth
- Deadline-based policy consistently trades-off playback quality in order to meet deadlines

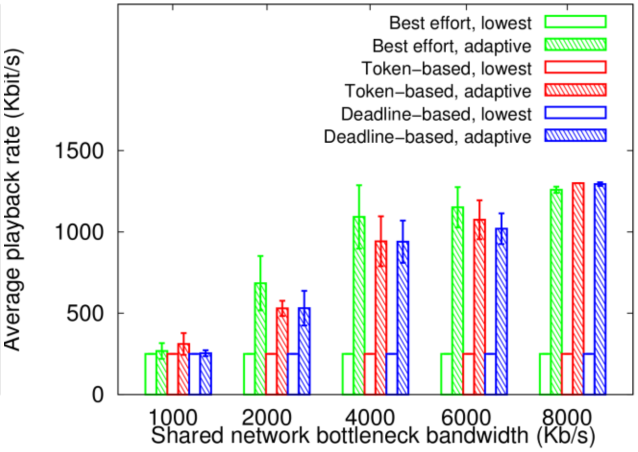
Impact of network conditions: Bandwidth



Stall probabilities



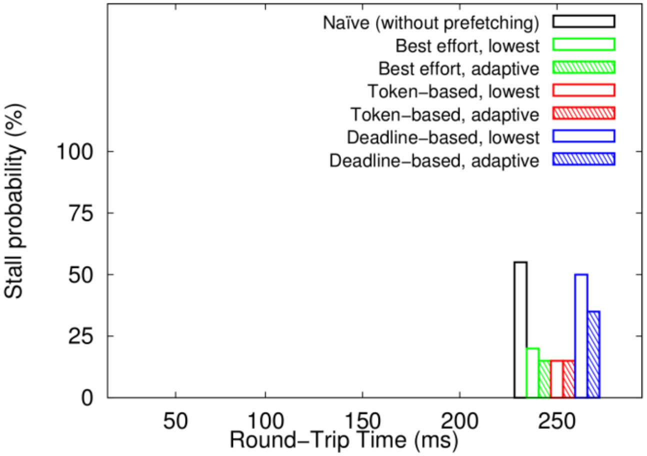
Quality of streamed video



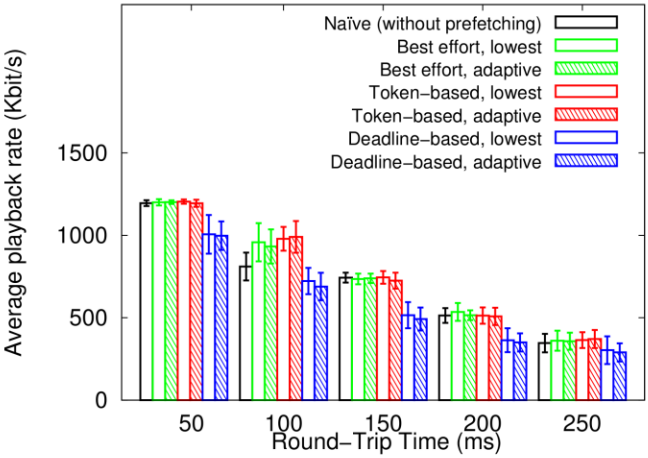
Quality of alternate video

- All policies adapt playback quality based on bandwidth
- Deadline-based policy consistently trades-off playback quality in order to meet deadlines
- Best-effort and token-based policies perform slightly better than the naïve player at low bandwidths

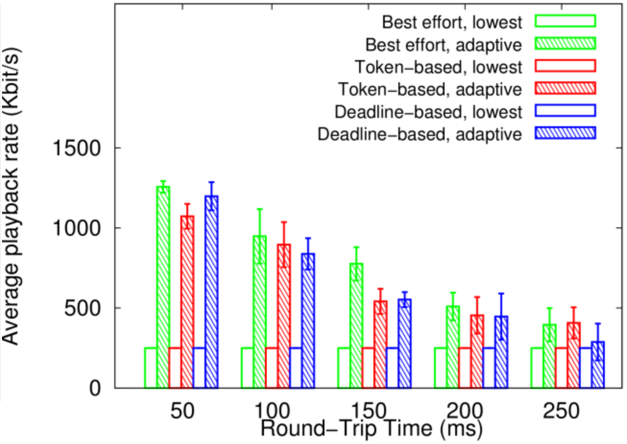
Impact of network conditions: RTT



Stall probabilities



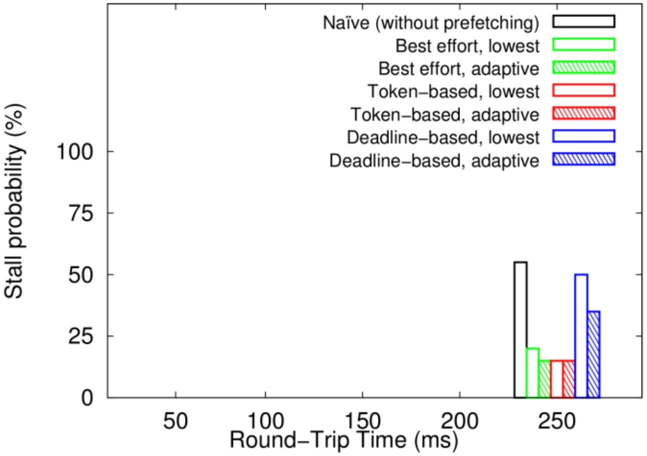
Quality of streamed video



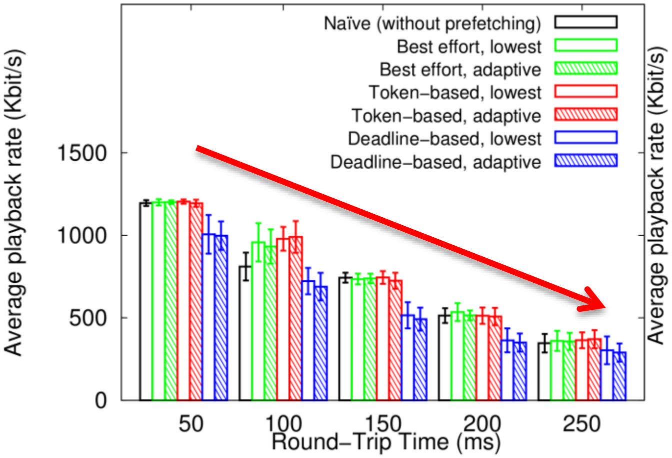
Quality of alternate video

- The video flow experiences increasing RTTs while the competing flows RTT remains constant at 50ms

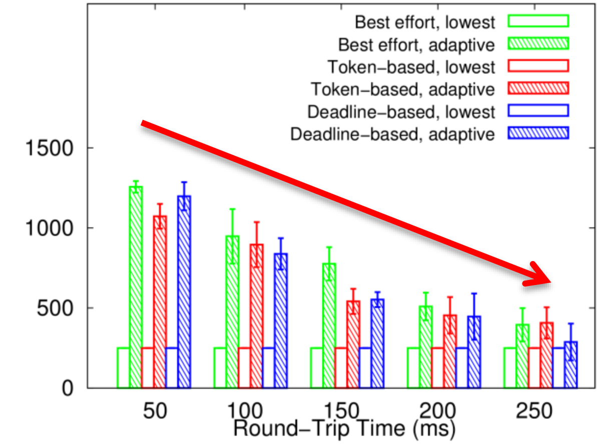
Impact of network conditions: RTT



Stall probabilities



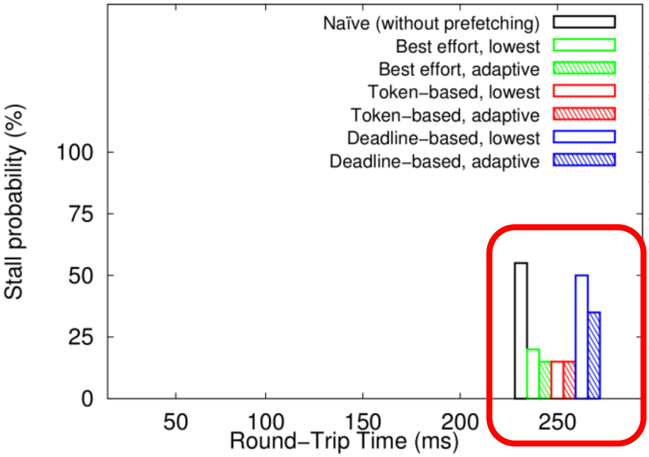
Quality of streamed video



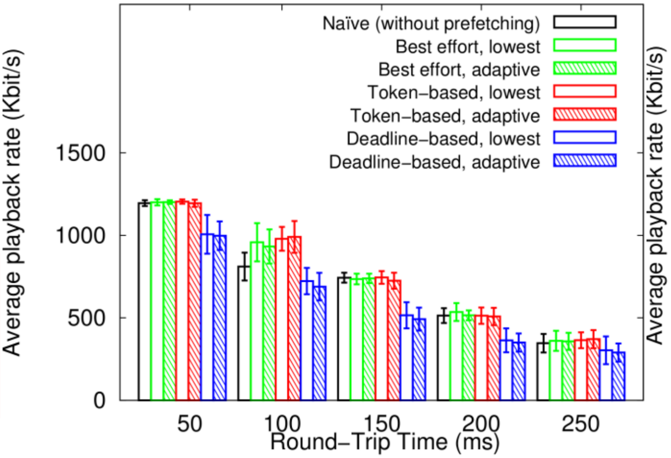
Quality of alternate video

- In general, TCP throughput decreases with increasing RTTs, as shown by playback qualities

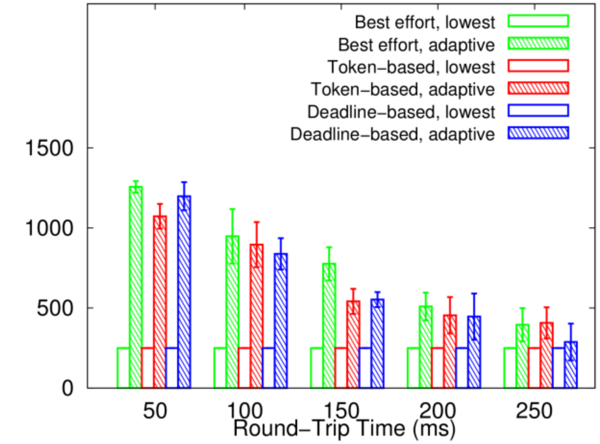
Impact of network conditions: RTT



Stall probabilities



Quality of streamed video



Quality of alternate video

- In general, TCP throughput decreases with increasing RTTs, as shown by playback qualities
- Playback stalls experienced at high RTTs, although all three policies out perform the naïve player

Startup times

	Startup time/SD (seconds)
Prefetched chunk	0.6/0.15
No prefetching, 2000 Kb/s, 150ms RTT	10/4.1
No prefetching, 4000 Kb/s, 150ms RTT	5.8/2.3
No prefetching, 6000 Kb/s, 150ms RTT	4.0/1.2
No prefetching, 8000 Kb/s, 150ms RTT	3.6/1.4

- With prefetching, startup times are low and independent of throughput or RTT
- Fetch time of the chunk from cache ~0.1 second, the additional time is required to change player states

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- With prefetching, startup times are low and independent of throughput or RTT
- Fetch time of the chunk from cache ~0.1 second, the additional time is required to change player states
- Startup times decrease with increasing bandwidth, but are always constrained by the larger RTT and network conditions to reach the server

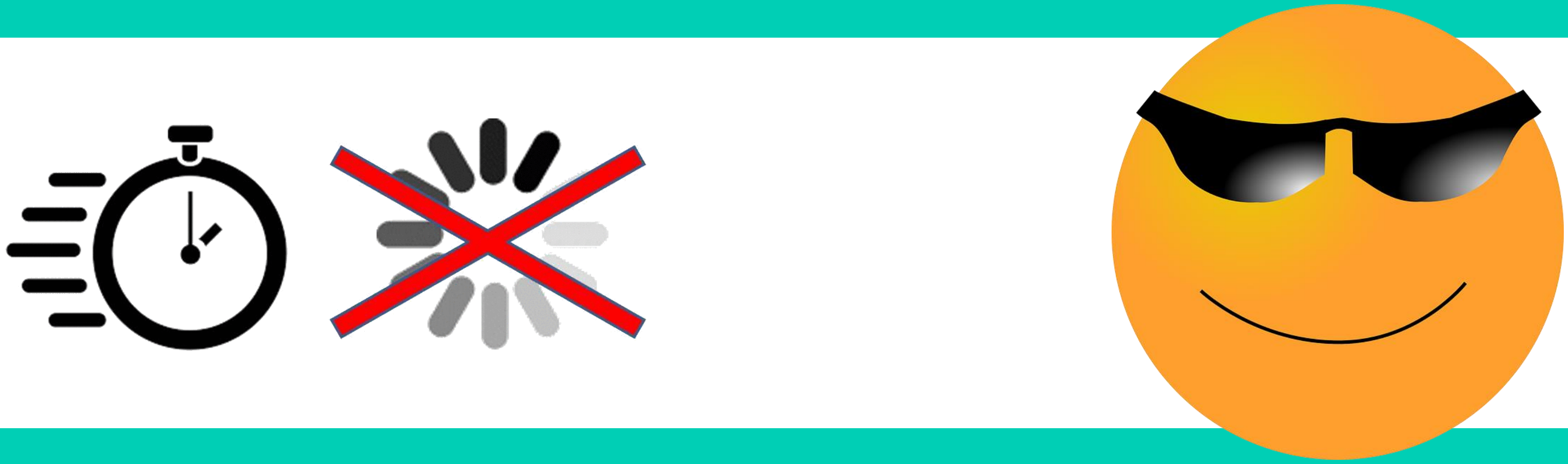
Other experimental results

- Also performed experiments under wide range of other scenarios, including
  - different buffer sizes (*4/6, 8/16, 12/24, 12/30* seconds)
  - different real-world bandwidth traces
  - different number of competing flows
  - different OSes running different TCP versions
- Our conclusions and relative performance across policies remain consistent in all scenarios

Conclusions

- We have designed, implemented and evaluated a HAS-based solution, which:
  - enables quality-adaptive prefetching and instantaneous playback of alternative videos
  - leads to perceptible gains for the streamed video in terms of stall-free playback and better playback quality
- Considered three different policy classes and two quality adaptation methods to cater for different real-world use cases
- Overall, our solutions improve the bandwidth utilization and playback experience by leveraging off periods to download alternative videos that are most likely to be watched

Bandwidth-aware Prefetching for Proactive Multi-video Preloading and Improved HAS Performance



Our source codes are available for download here:
http://www.ida.liu.se/~nikca/papers/mm15.html

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