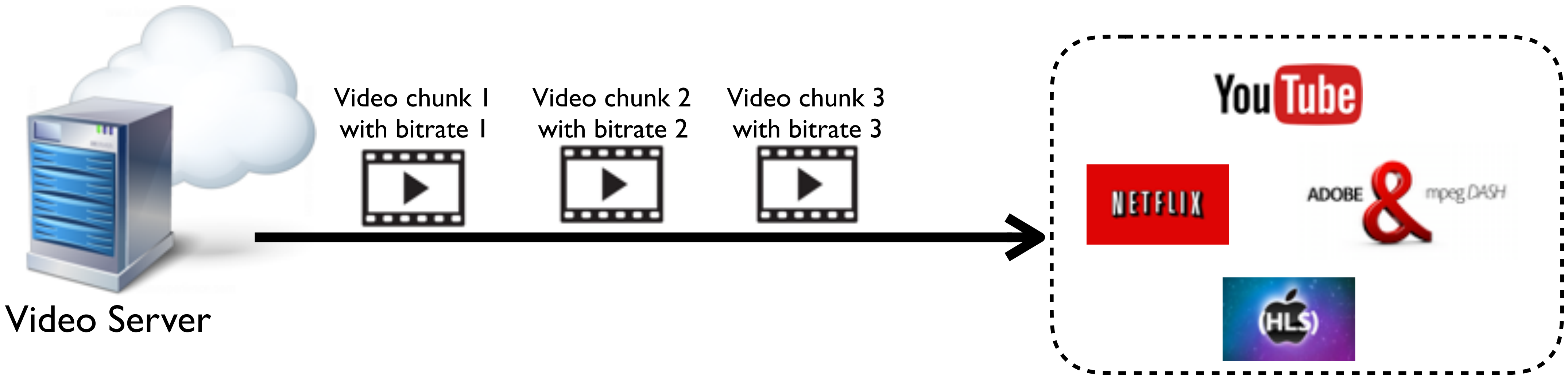
Favor: Fine-Grained Adaptation for Video Streaming

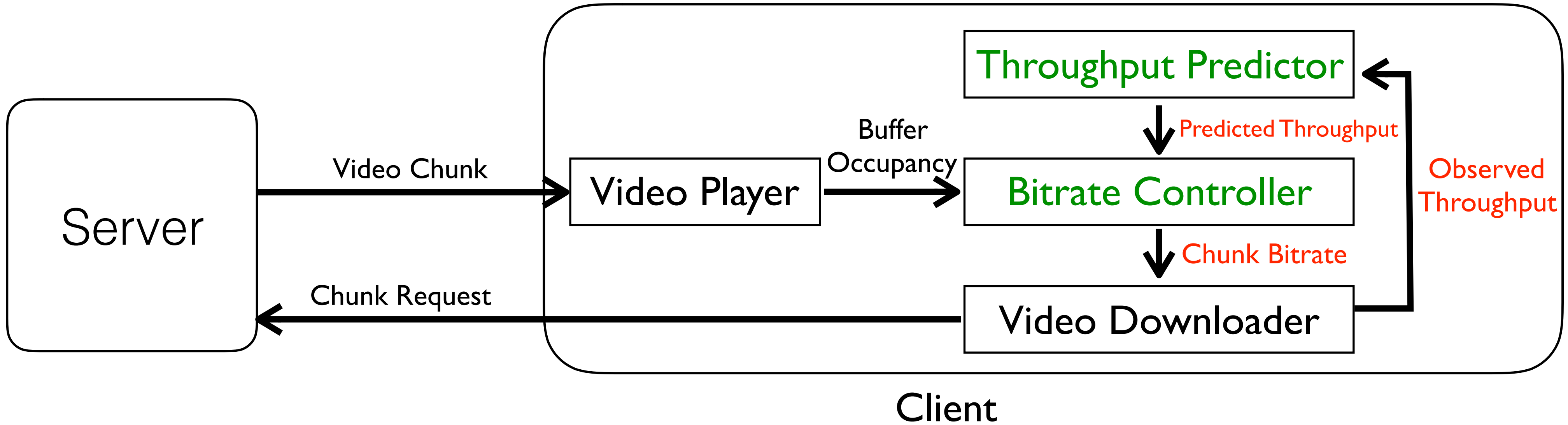
Background

- Dynamic Video Streaming over HTTP(DASH): adapting video chunk bitrates according to dynamic network condition



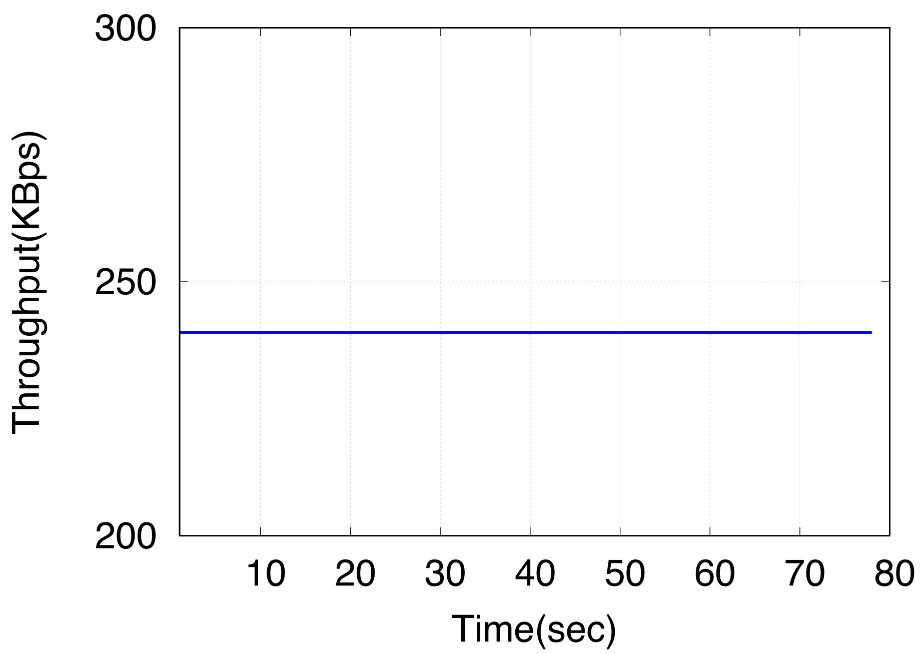
Background

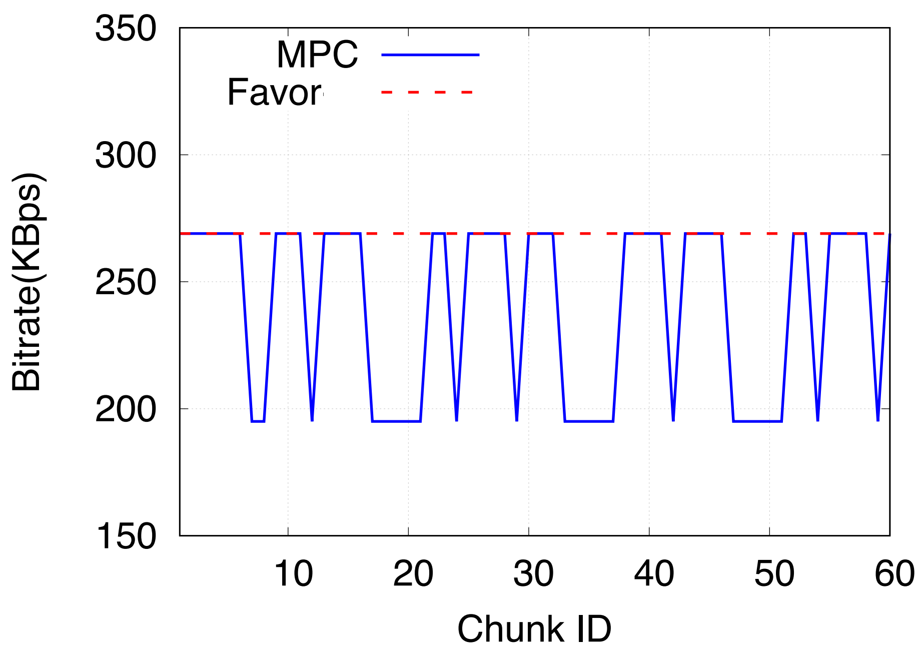
- State-of-art Adaptation Approach: MPC



Bitrate Controller: choosing the bitrate which maximizes the sum of QoE for next K chunks.

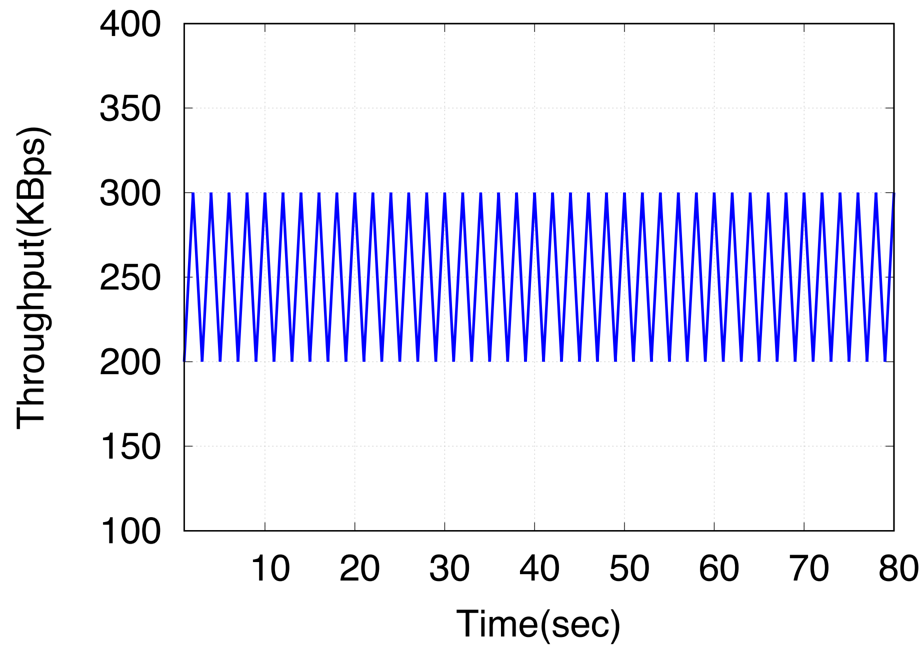
Coarse-Grained Video Adaptation

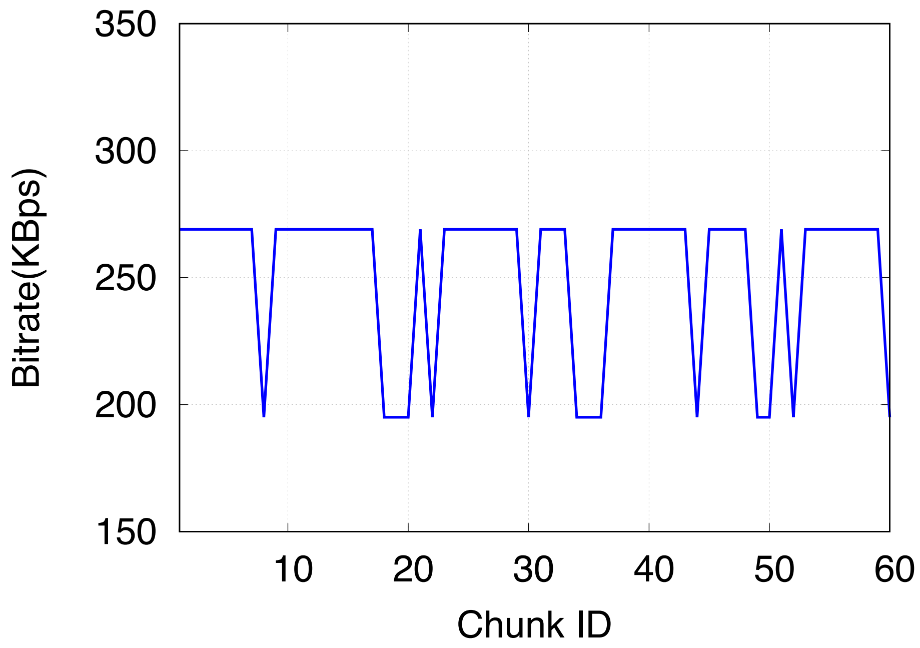




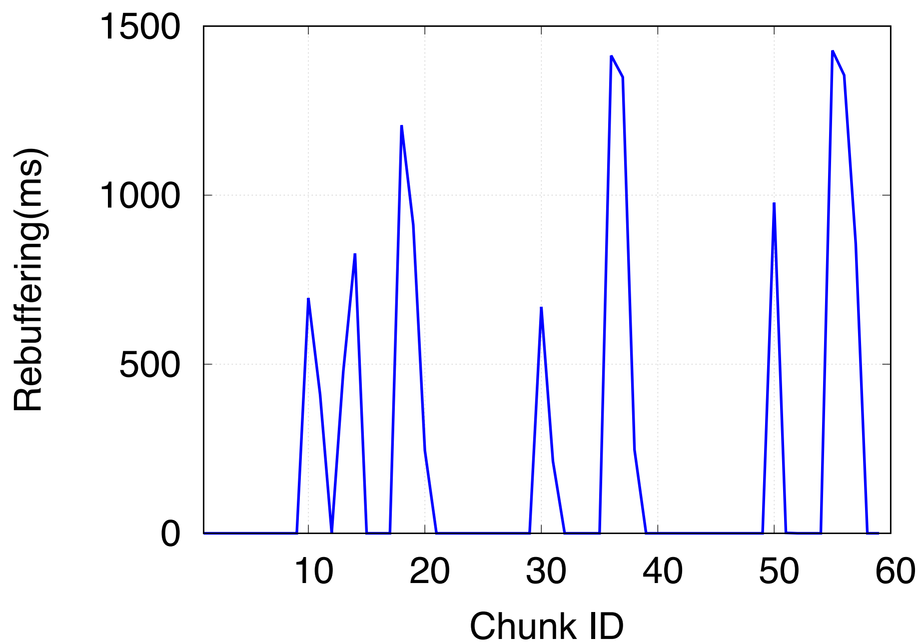
- Under-selecting video rate:
  - select conservative rate when throughput lies between two handful bitrates
  - conservative bitrate under-utilizes throughput and incurs low user QoE

Coarse-Grained Video Adaptation



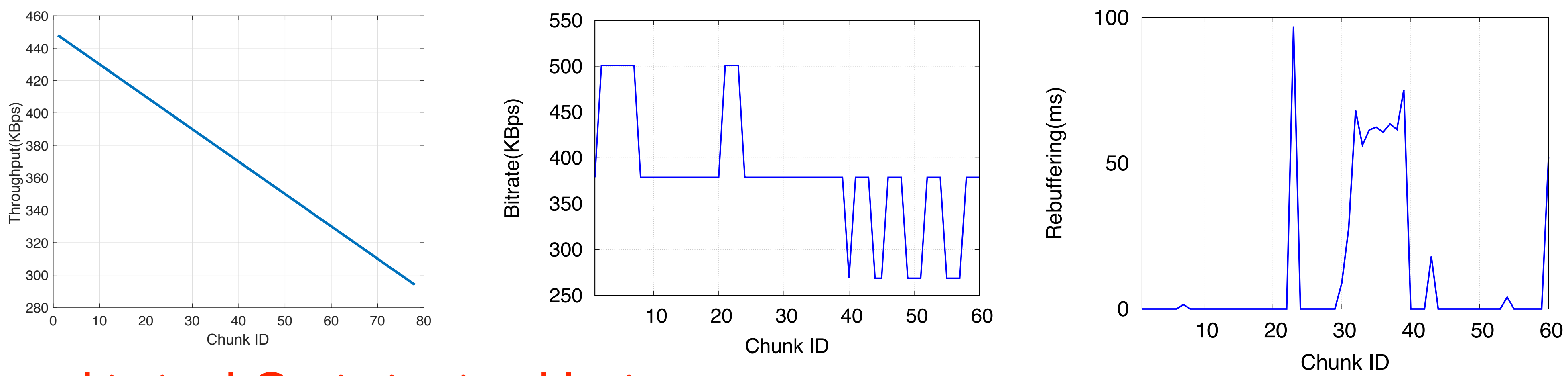


- Fluctuating video bitrate:
  - network condition variation results in large bitrate fluctuation

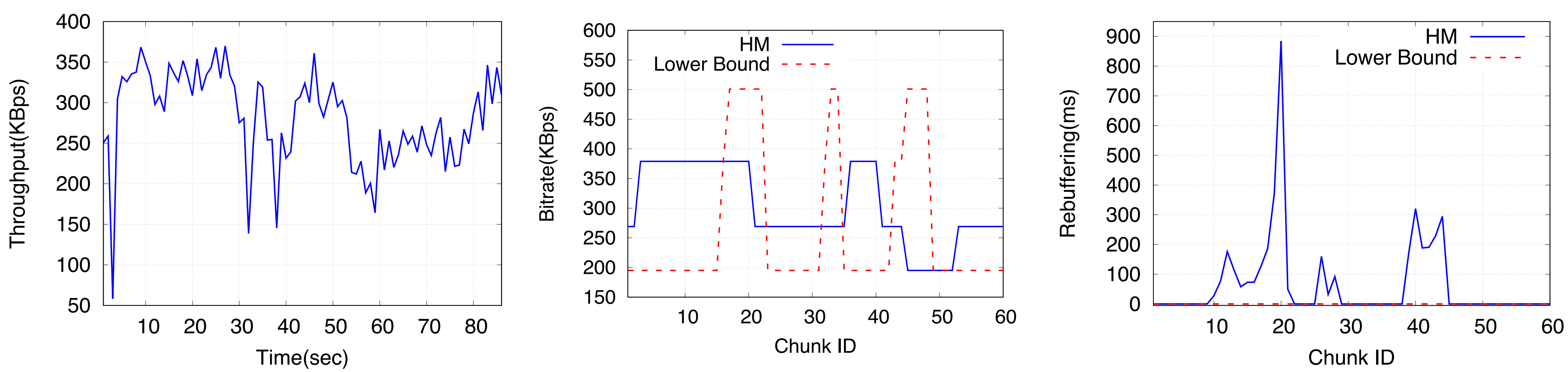


- Frequent video rebuffering:
  - network throughput is below the lowest available video bitrate
  - large rebuffering time

Limitations of Adaptation Algorithms



- Limited Optimization Horizon
  - MPC only optimizes QoE for the next K(e.g. K=3) chunks.
  - QoE beyond K+1 chunks is not protected.
  - Rebuffering happens beyond the optimization horizon.



- Throughput Prediction Error
  - Lower-bound based optimization selects too conservative bitrate.

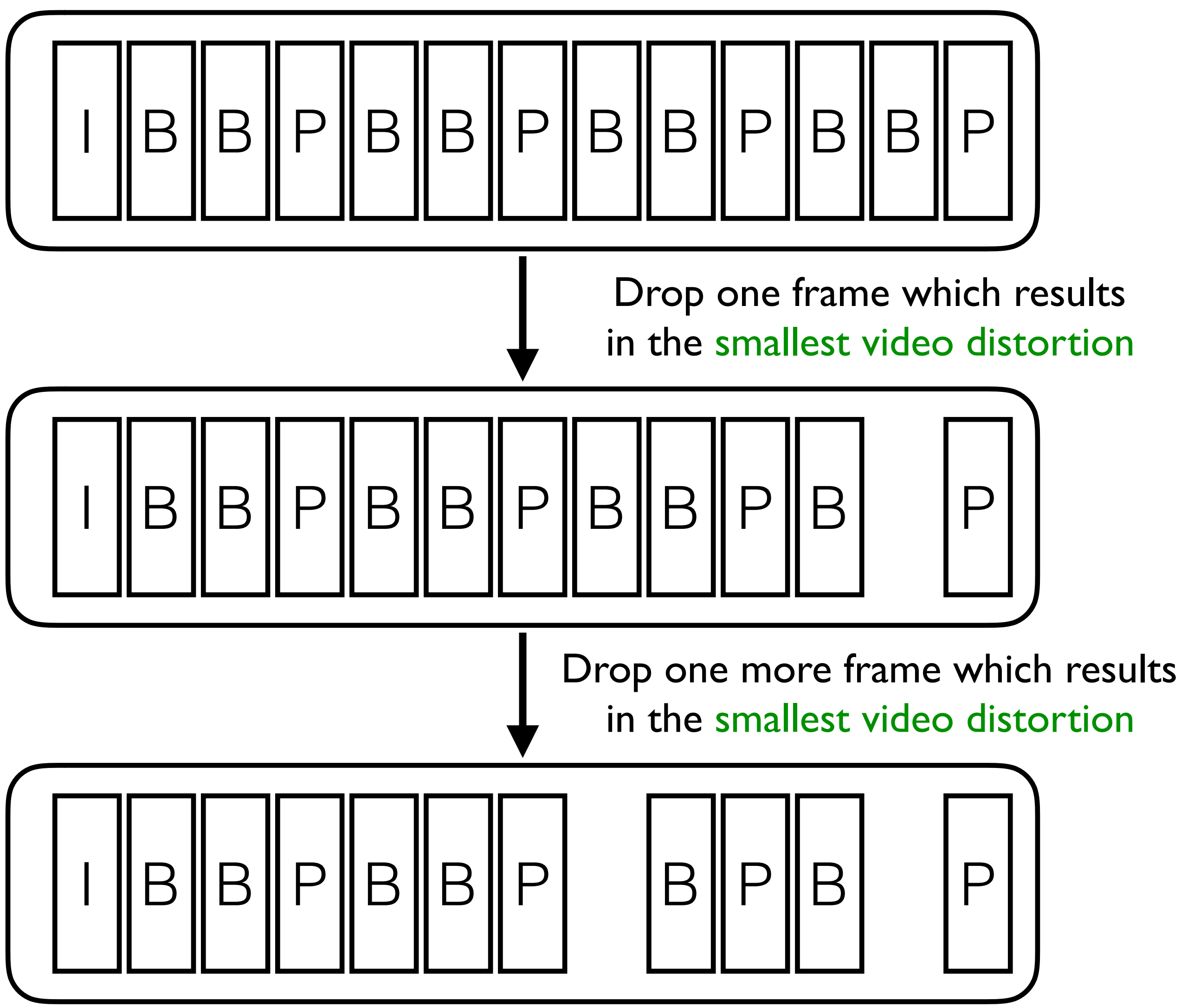
Note: HM is Harmonic-mean based throughput predictor.
Lower bound predictor uses the lowest throughput seen before.

Our Approach

- Fine-grained Adaptation

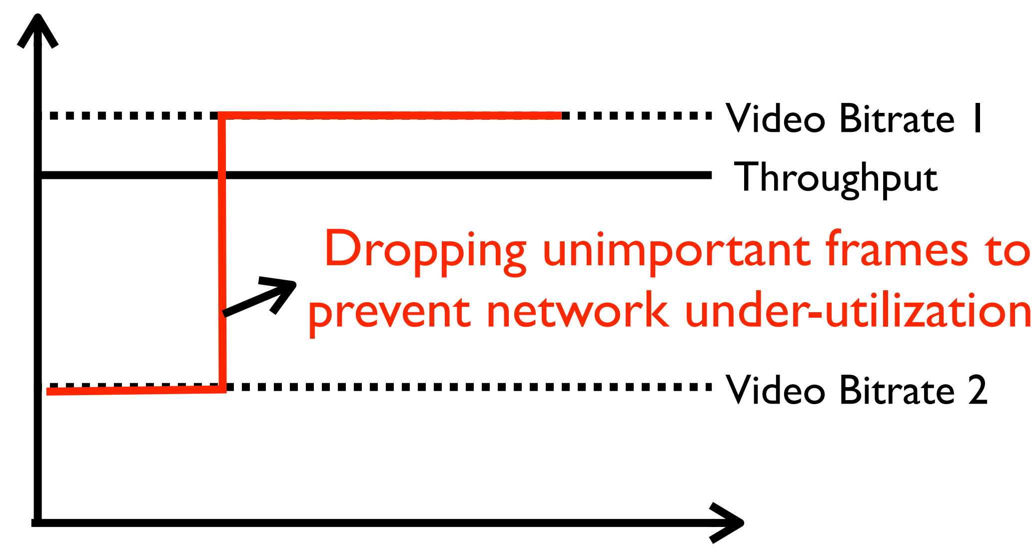
  (1)Frame dropping

  - Video chunk consists of I, B, and P frames
  - Dropping unimportant frames which incur unnoticeable video distortion.



Greedy Frame dropping

Intuition:

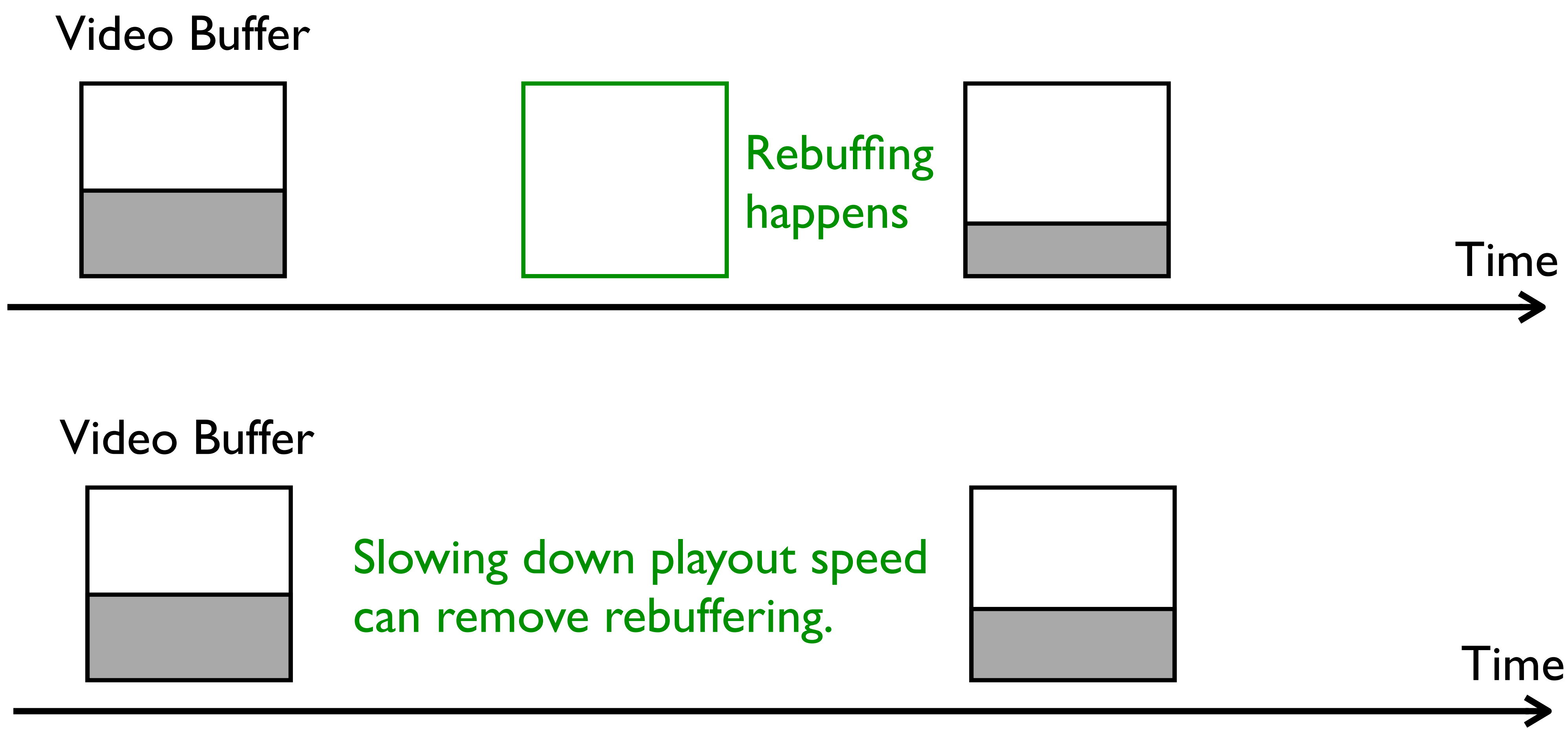


Our Approach

- Fine-grained adaptation

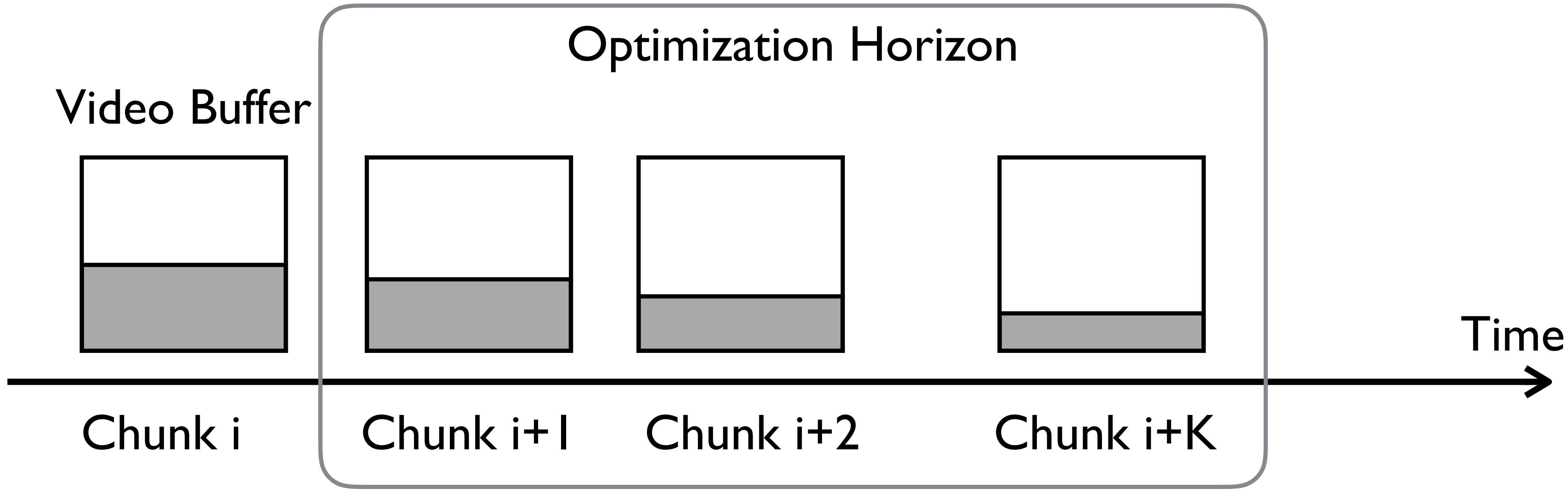
  (2)Playout control

  - Playout speed defines the time duration that player can keep playing before finishing downloading the next chunk.
  - Small playout speed changes are unnoticeable to users.



Our Approach

- Buffer Reservation: mitigate limited optimization horizon



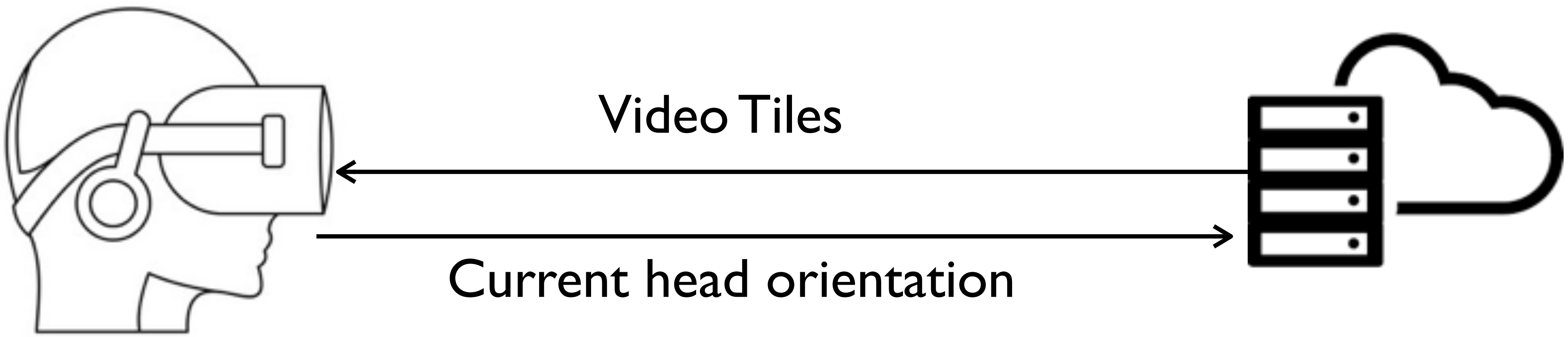
- The estimated buffer occupancy at the end of optimization horizon is not less than a threshold.
- Buffer reservation threshold is dynamically learned based on observed buffer occupancy changes.
- Intuition: reserved buffer can protect QoE against network variations beyond optimization horizon.

Our Approach

- User QoE Model
  - Chunk QoE is defined as linear combination of following factors
    *Bitrate: chunk bitrate, bitrate variation
    *Rebuffering: rebuffering time when downloading that chunk
    *Frame dropping: video distortion due to frame dropping from that chunk
    *Playout Control: playout rate when downloading that chunk
    playout rate variation when downloading that chunk
- Joint Optimization framework
  - decide bitrate, number of frames to be dropped and playout rate for the next K chunks

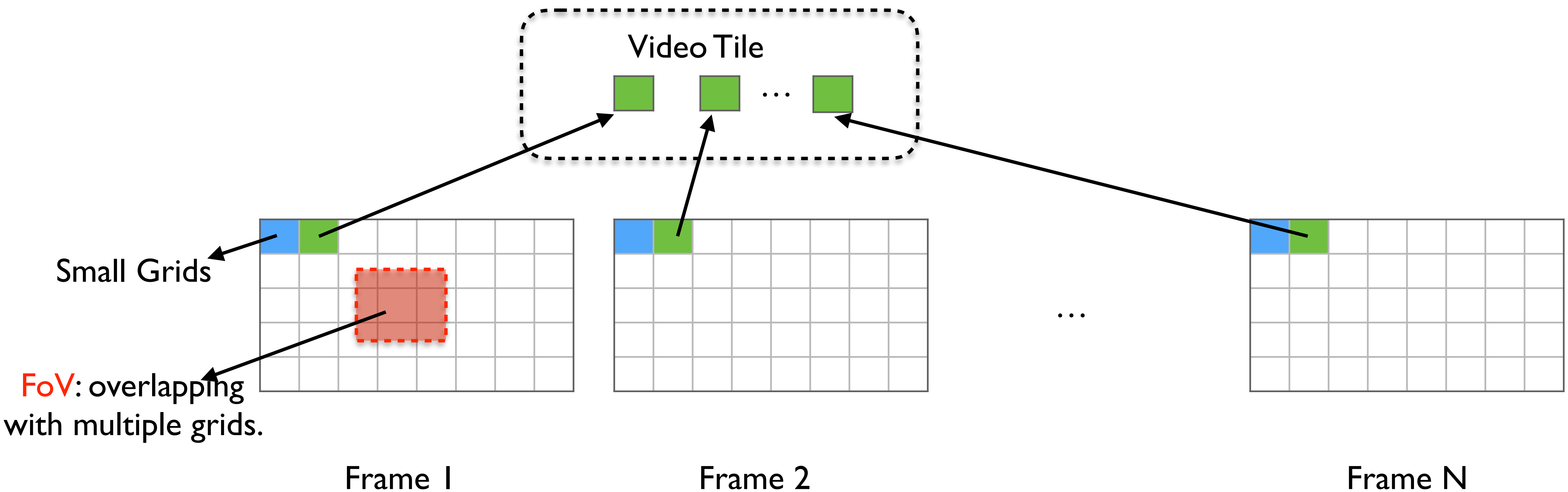
Extension to 360-degree Videos

- Challenges of streaming 360-degree videos
  - much higher bandwidth requirements than normal videos
  - difficult to accurately predict user Field-of-View
- Tile-based Streaming



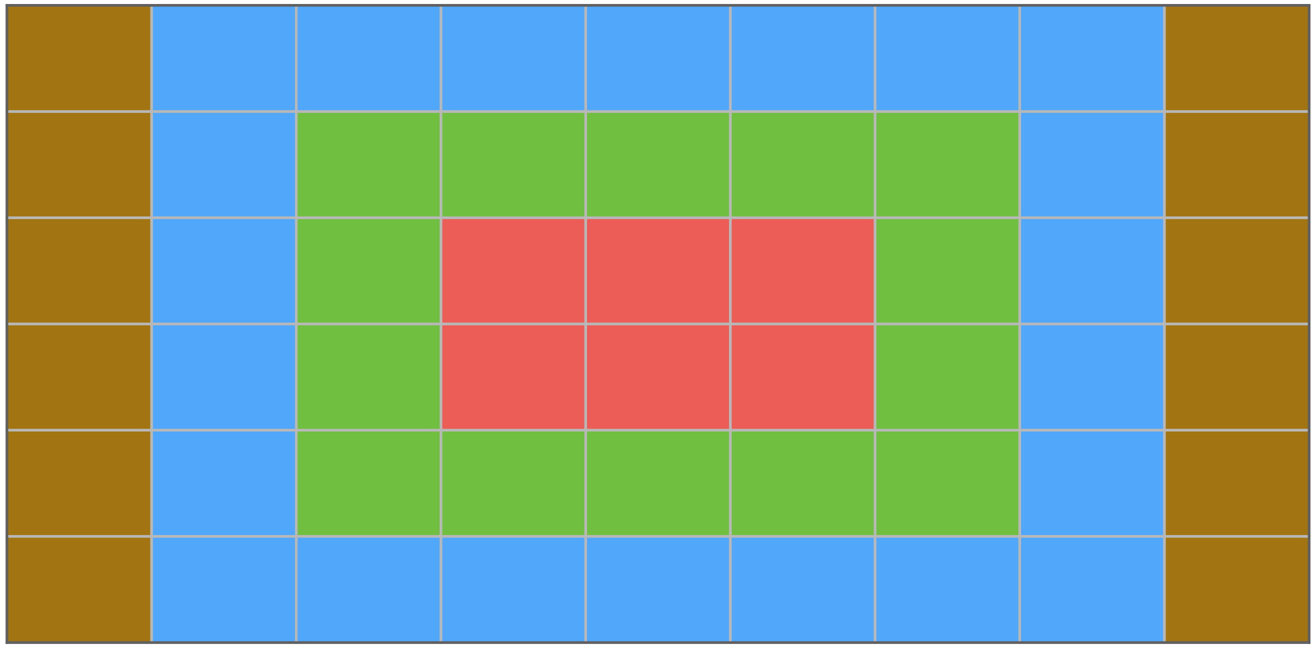
Extension to 360-degree Videos

- Video Tiles
  - A 360-degree frame is projected into a 2D plane. (Projected frame is called Raw frame)
  - Raw frame is divided into equal-size grids.
  - Grids overlapping with FoV are visible to user.
  - Grids at the same location of multiple temporal raw frames form a tile.
  - Each video chunk has many tiles(determined by the number of grids in a raw frame).



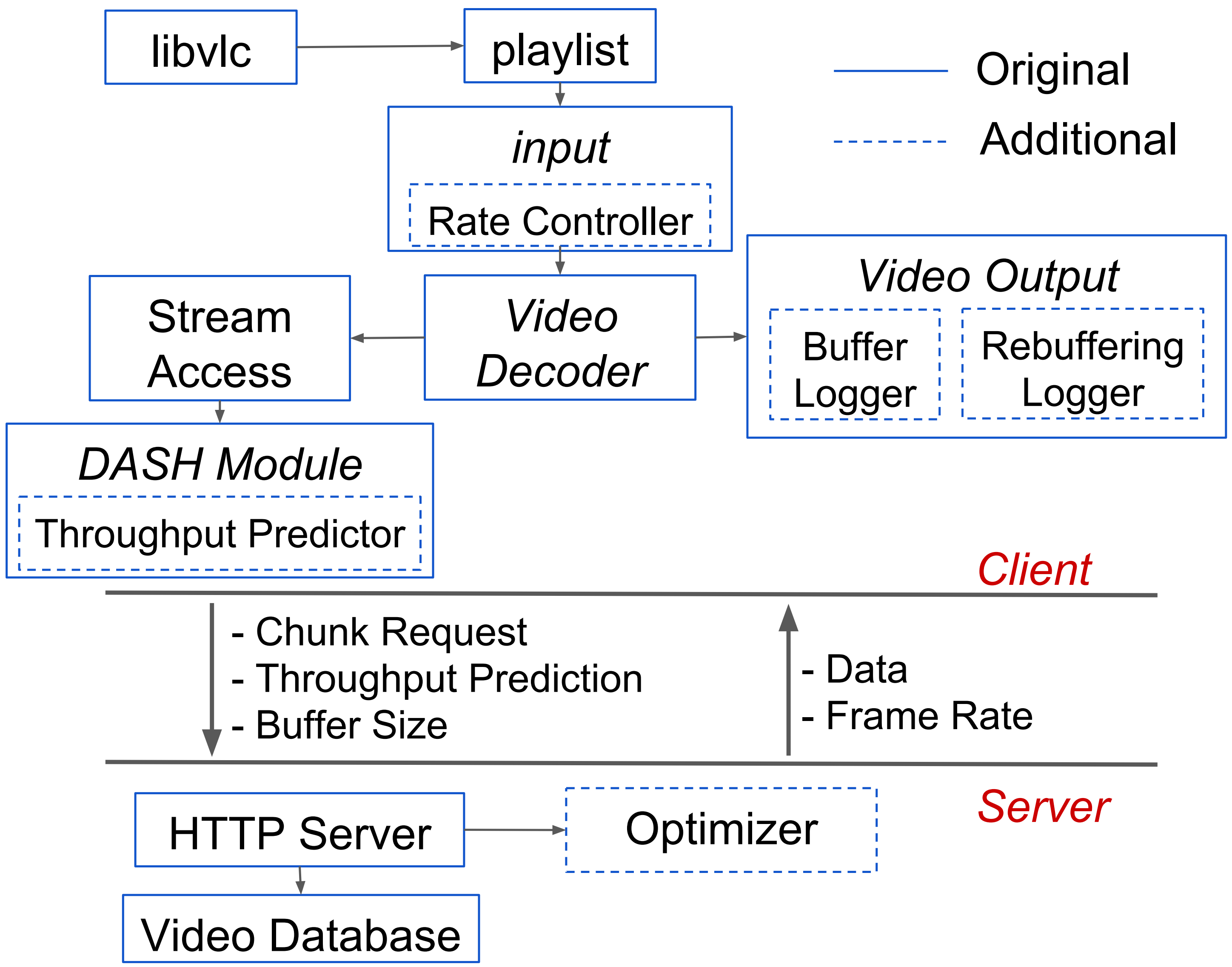
Extension to 360-degree Videos

- Rate adaptation for video tiles
  - Video tiles in a chunk are encoded independently with possibly different bitrates.
  - Group tiles into small number of clusters to reduce complexity.
  - QoE is defined by the quality of visible tiles.



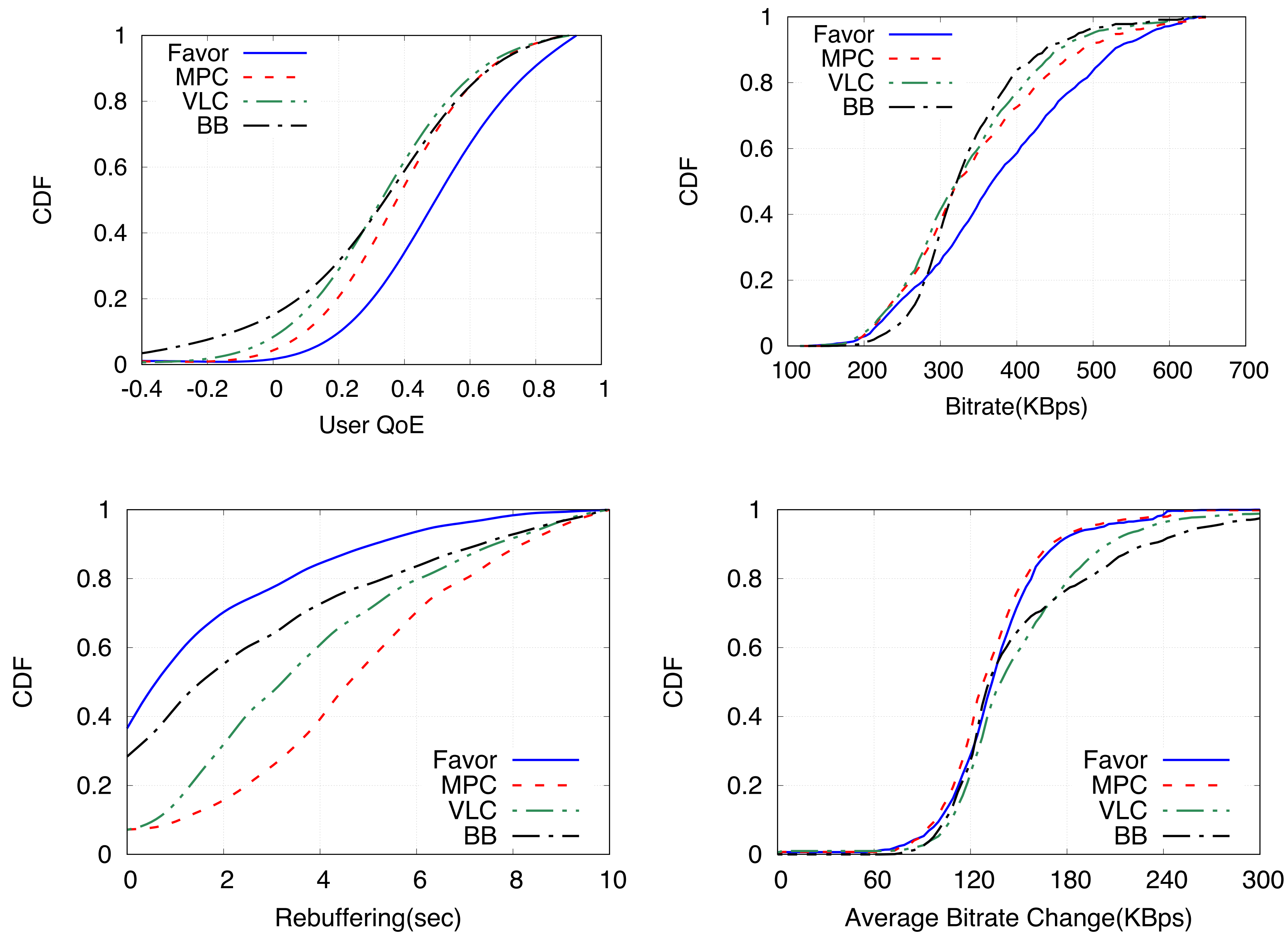
-Tiles are clustered according to the distance to FoV.
-FoV is estimated based on historical head orientation.

System Implementation



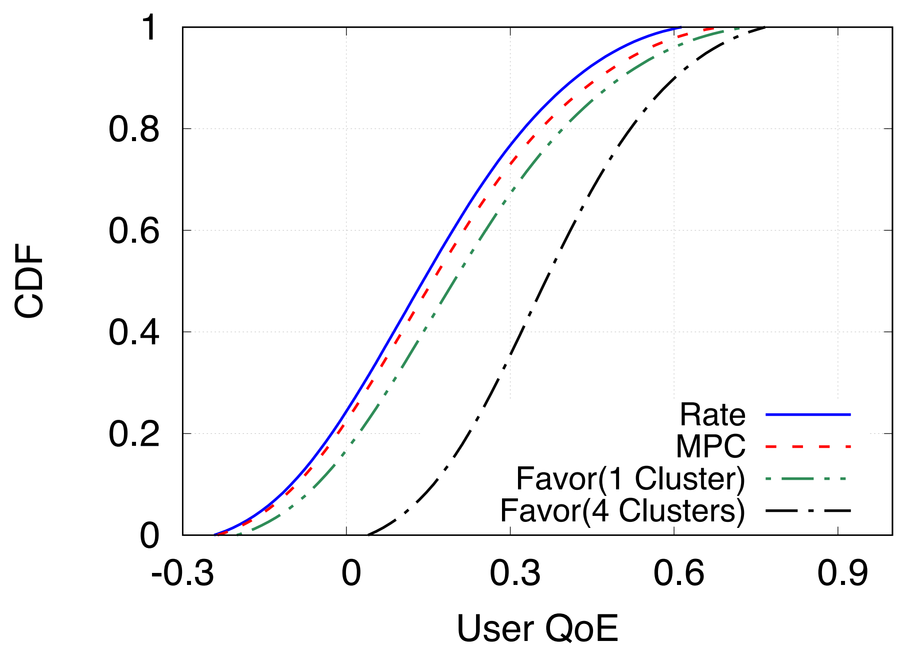
Implementing Favor on top of an open-source video player VLC and a customized HTTP server.

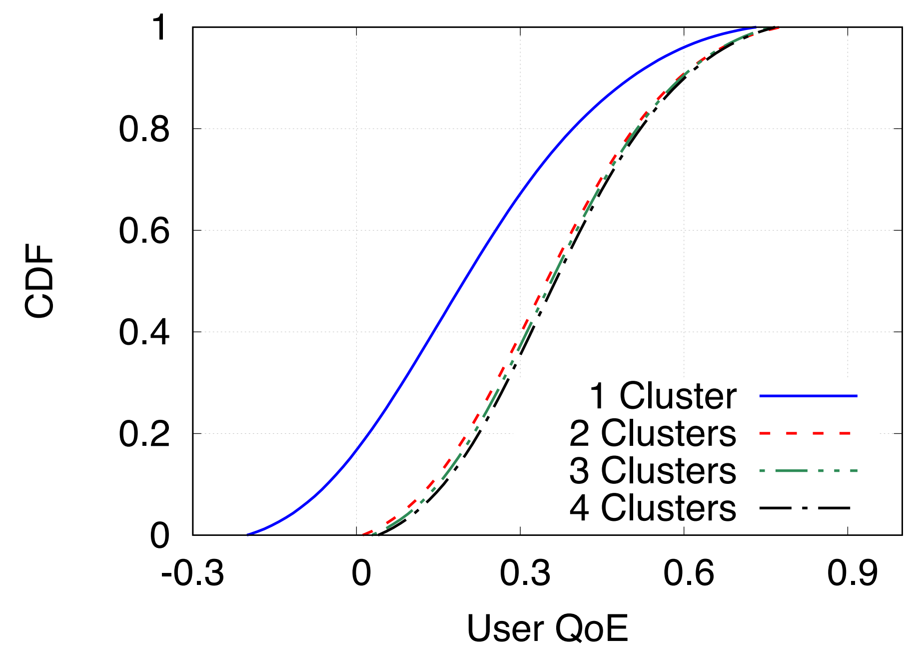
Evaluation Results



-Experiment settings: 300 real throughput traces, 10 videos.
-Comparison: MPC, VLC(rate-based adaptation), BB(buffer-based adaptation)
-Improvements: 24% over MPC, 34% over VLC, 41% over BB.

360-degree Video Results





-Comparison: Rate and MPC select same bitrates for all tiles

-Improvements:

 * Single cluster, 40% over Rate, 23% over MPC

 * 4 clusters: 100% over MPC

Thanks!