Joint Rate and FoV adaptation in immersive video streaming

Dongbiao He, Cedric Westphal, J.J. Garcia-Luna-Aceves

360 video costs more network resources than regular video

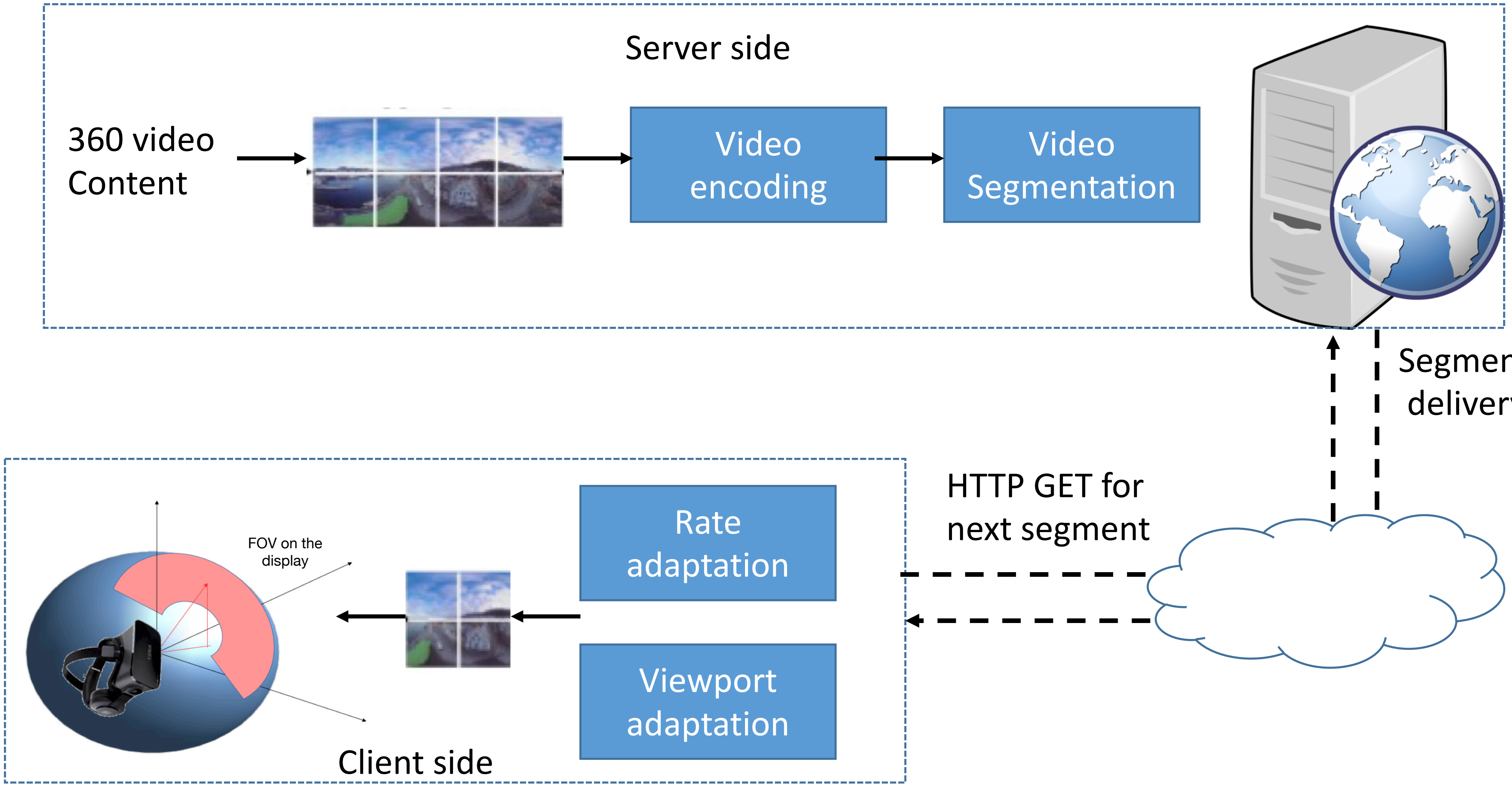
- The file size are typically larger

-lots of viewing angles

-require up to 6 times more bandwidth

- Require a higher resolution for high viewing experience

Viewport based strategy is used for improving the network utilization

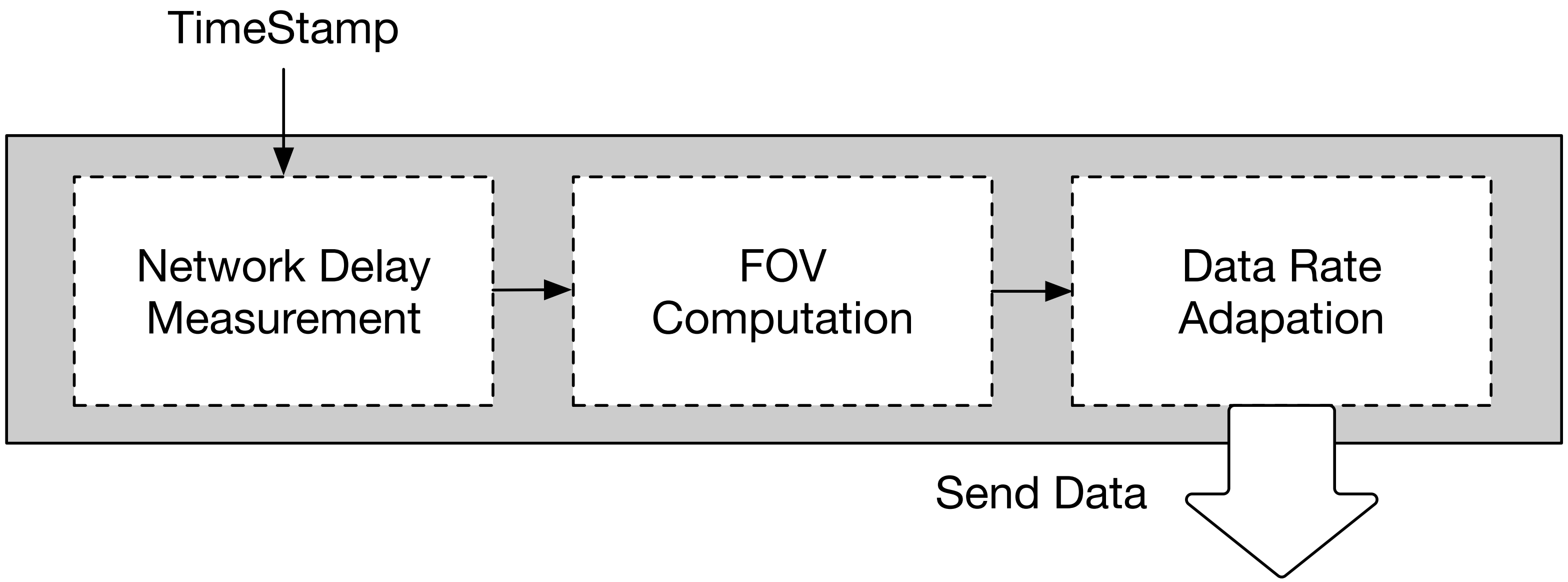


The FoV prediction algorithm is important, but it

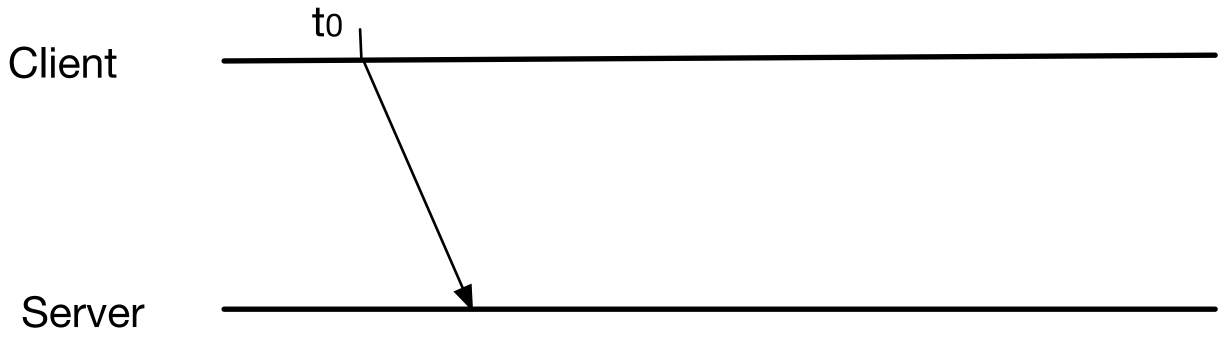
- Requires large datasets for training with AI technologies
- Costs more computation overhead in clients
- Different video content might has different distribution of user behaviors
- Prediction may be inaccurate which will lead to viewport deviation

Approach: Joint rate and FoV adaptation

- Important steps:

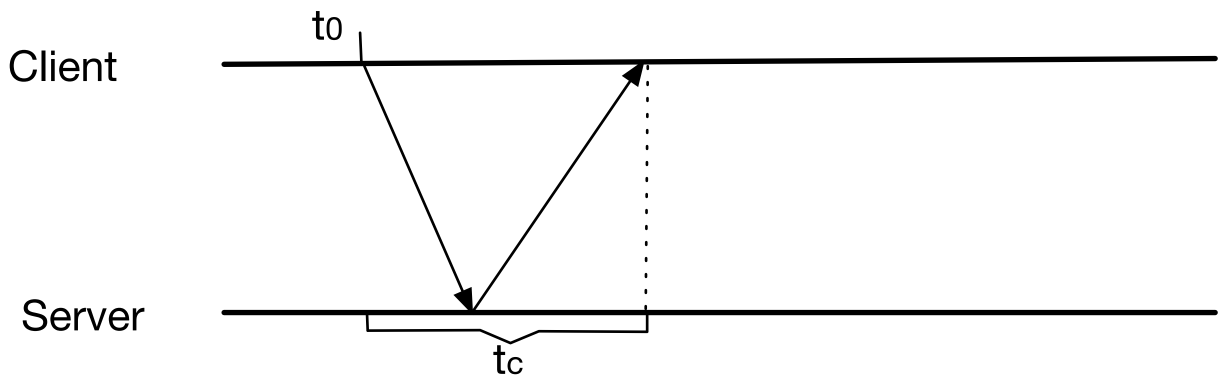


Delay Measurement



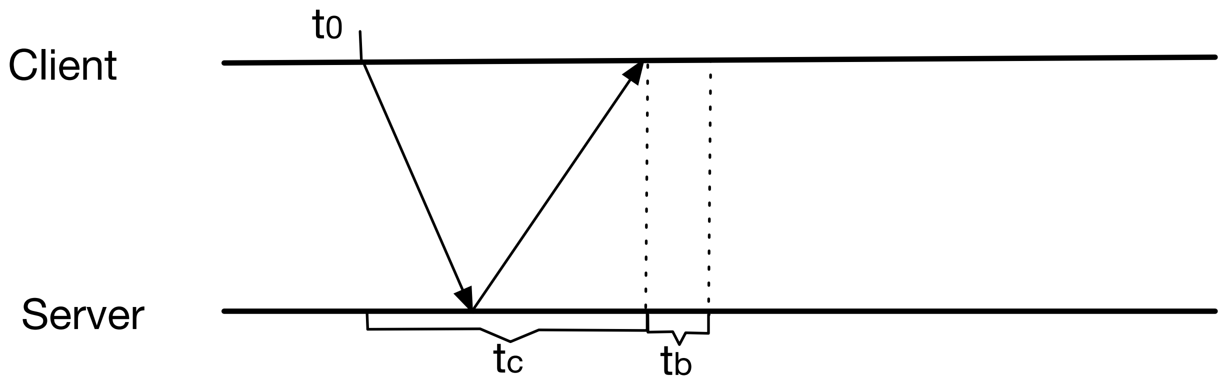
- The user will request at time t_0 a segment that will lasts t_{s1} seconds of playback time;

Delay Measurement



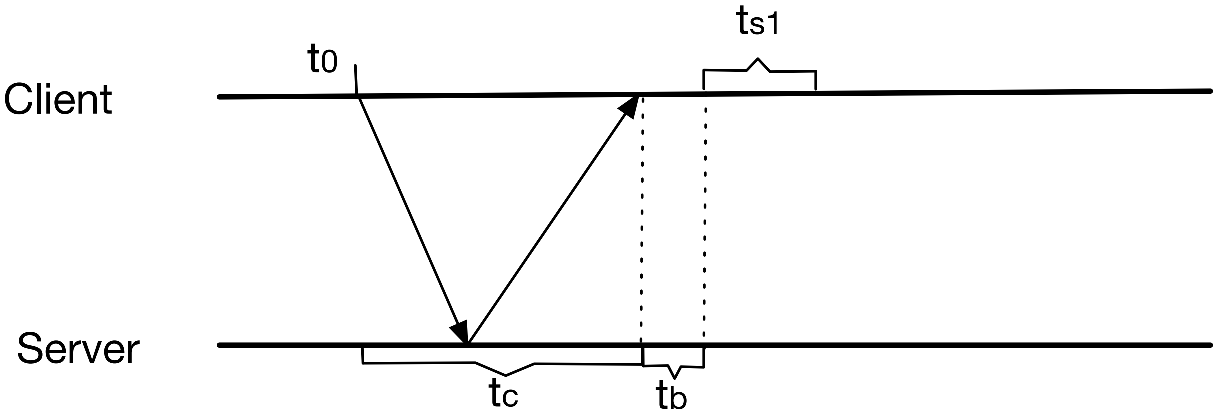
- This segment will be retrieved from the server after **a network transmission completion time** t_c at $t_0 + t_c$.

Delay Measurement



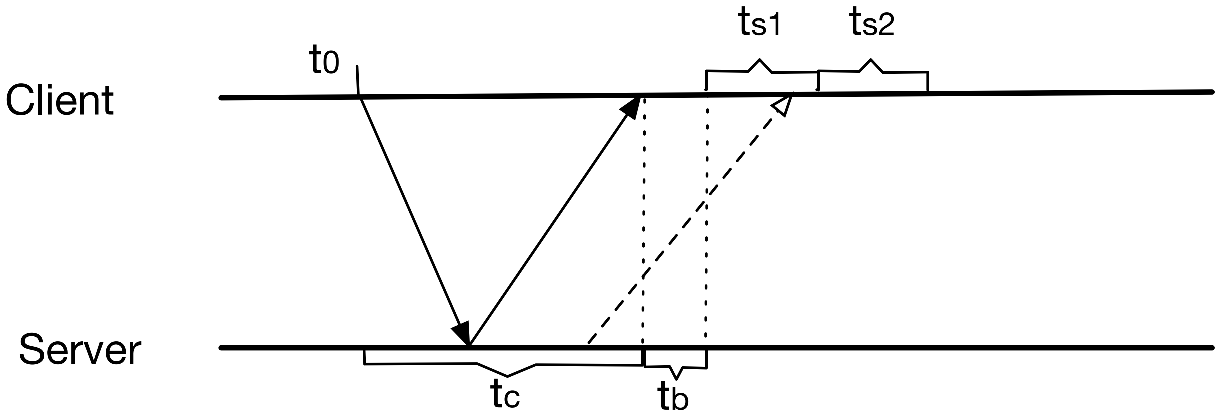
- This segment will then be buffered into a playback buffer, and played back after **a buffer delay** t_b

Delay Measurement



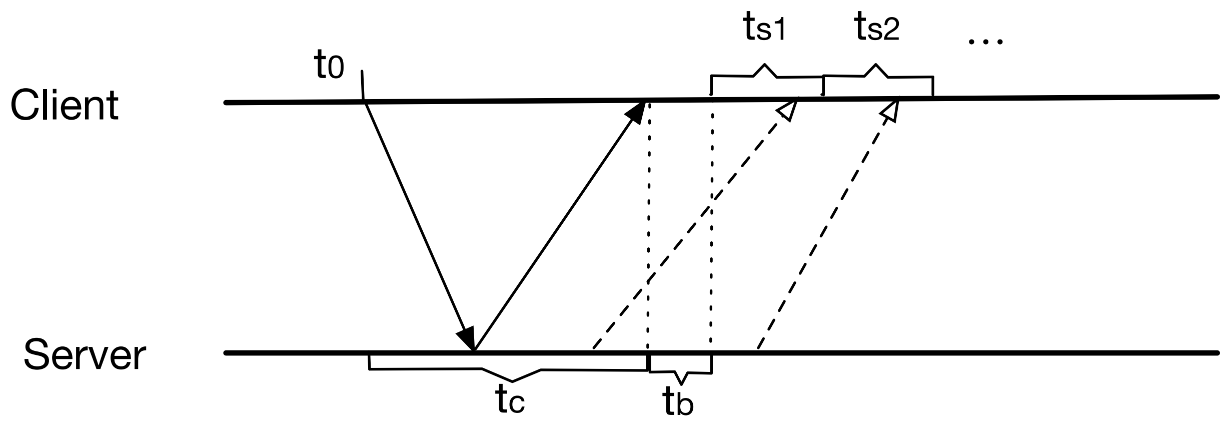
- Finally, the segment will start playing at time $t_0 + t_c + t_b$ and conclude at time $t_0 + t_c + t_b + t_{s1}$

Delay Measurement



- ❑ Then we need to prepare the next segment within the play time of the previous one

Delay Measurement



❑ Then we need to prepare the next segment within the play time of the previous one

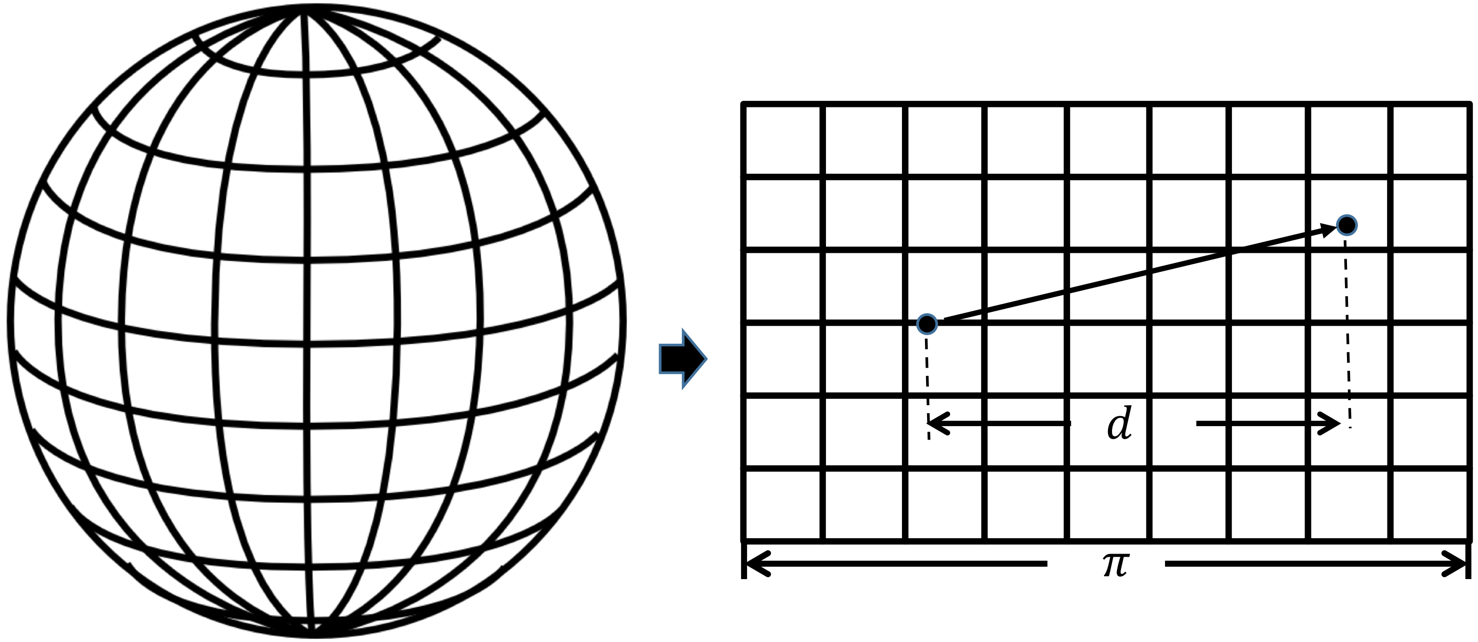
① inter-segment: No video freeze between segments

② intra-segment: No viewport deviation in each segment

Delay Measurement ⇨ FoV Computation

Question 1: How do we use the delay model for FoV computation?

FoV Computation



- Define ***d*** as the FoV distance with a given time interval

FoV Computation

(1)User moves shortly during a given time interval
-e.g., 85% of users moves 0.956 unit within 1000ms
(2)Only part of the view needed to be transmitted to the client side
-*e.g.,* uses less than 30.4% of the view in the sphere

	100ms	250ms	500ms	750ms	1000ms
95%	0.147	0.433	3.012	3.093	3.107
90%	0.096	0.255	0.567	1.11	2.983
85%	0.073	0.19	0.401	0.645	0.956

[1] Xavier Corbillon, Francesca De Simone, and Gwendal Simon. 360-Degree Video Head Movement Dataset. In Proceedings of ACM Multimedia System (MMSys) 2017

FoV Computation

Question 2: How to use the relationship between the distance and delay?

FoV Computation

-Define τ(d) as the choice of FoV: $\lim_{d \to \pi} \tau(d) = \infty$

- Case 1: a small *d*

- Case 2: a large *d*

FoV Computation

① inter-segment: No video freeze between two sequent segment

② intra-segment: No viewport deviation

- Segment S in size s
- Estimated network delay t_n
- The link capacity C

No video freeze

$$t_c(S) = t_n + \frac{s}{C} \leq \tau$$

No Viewport deviation

$$s \leq C \times (\tau - t_n)$$

Key findings with $s \leq C \times (\tau - t_n)$

- The choosing FoV τ should satisfy: $\tau \geq t_n$

Recall the head movement table and time interval table:

Network delay →

Accuracy ↑

	100ms	250ms	500ms	750ms	1000ms
95%	0.147	0.433	3.012	3.093	3.107
90%	0.096	0.255	0.567	1.11	2.983
85%	0.073	0.19	0.401	0.645	0.956

FoV Distance →

A mapping: Network delay → FoV distance

FoV Computation ⇨ Rate Measurement

- Basic strategy:

- The network is responsive: Less tiles of FoV with high resolution
- The response of network is low: longer distance of FoV covers more tiles with relative low resolution

- Enhanced strategy:

- Upon the basic strategy
- Allocate the bitrate of tiles with different weight

➢ Based on the study of Navigation likelihood [ICC 2018]

Rate Measurement

- When the network state changes greatly with the fluctuation of the sending rate? [The available link capacity varies]

--Goal：Control the sending data rate in a steady mode

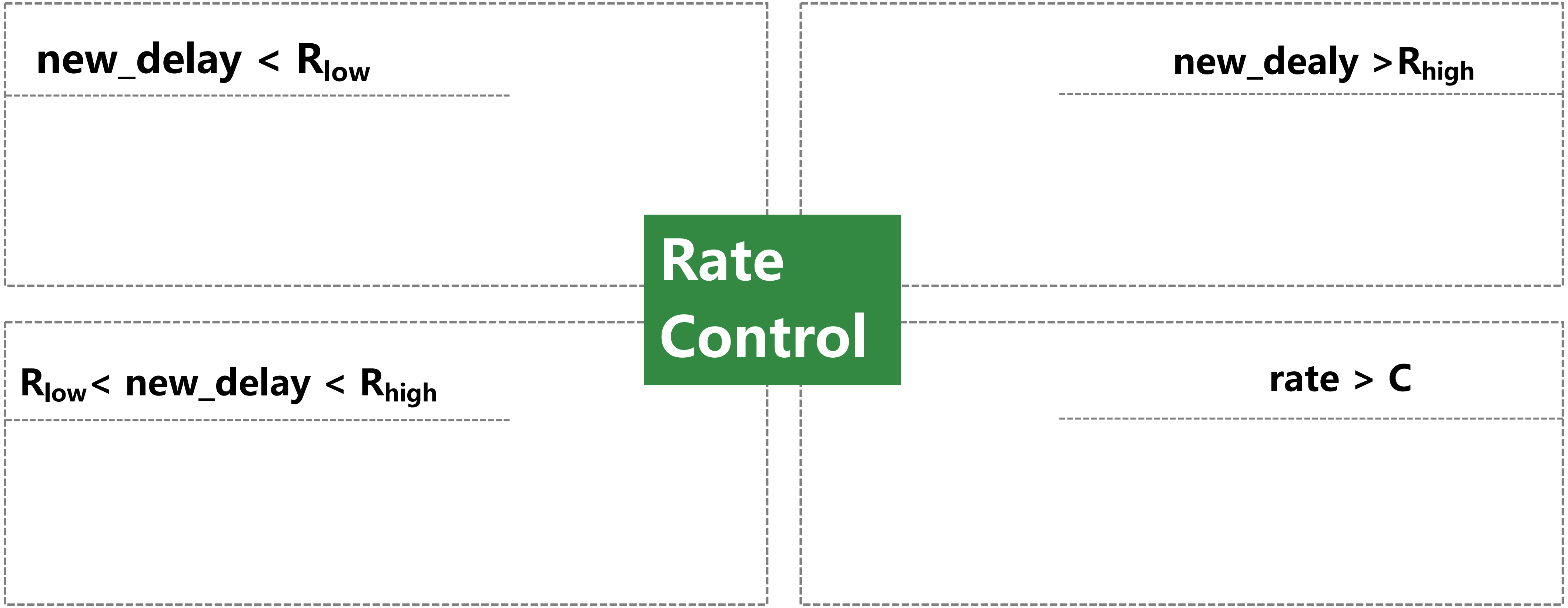
o Steady increase, Steady decrease or remain static

--Setting two threshold for control the rate: R_{low} and R_{high}

o Adjust the sending rate with new_delay

Rate Measurement

- Solution:



Rate Measurement

- Solution:

new_delay < R_{low}

$rate = Max\ rate$

new_dealy > R_{high}

Rate Control

R_{low} < new_delay < R_{high}

rate > C

Rate Measurement

- Solution:

new_delay < R_{low}

$rate = Max\ rate$

new_dealy > R_{high}

$rate = rate_{pre} \times (1 - \alpha \cdot \frac{R_{high}}{new\ dealy})$

Smooth decrease

Rate Control

R_{low} < new_delay < R_{high}

rate > C

Rate Measurement

- Solution:

Rate Control

new_delay < R_{low}

$$rate = Max\ rate$$

new_dealy > R_{high}

$$rate = rate_{pre} \times (1 - \alpha \cdot \frac{R_{high}}{new\ dealy})$$

R_{low} < new_delay < R_{high}

$$rate = rate_{pre} + \beta$$

Additive increase

rate > C

Rate Measurement

- Solution:

Rate Control

new_delay < R_{low}

$$rate = Max\ rate$$

new_dealy > R_{high}

$$rate = rate_{pre} \times (1 - \alpha \cdot \frac{R_{high}}{new\ dealy})$$

R_{low} < new_delay < R_{high}

$$rate = rate_{pre} + \beta$$

rate > C

$$rate = C$$

Evaluation

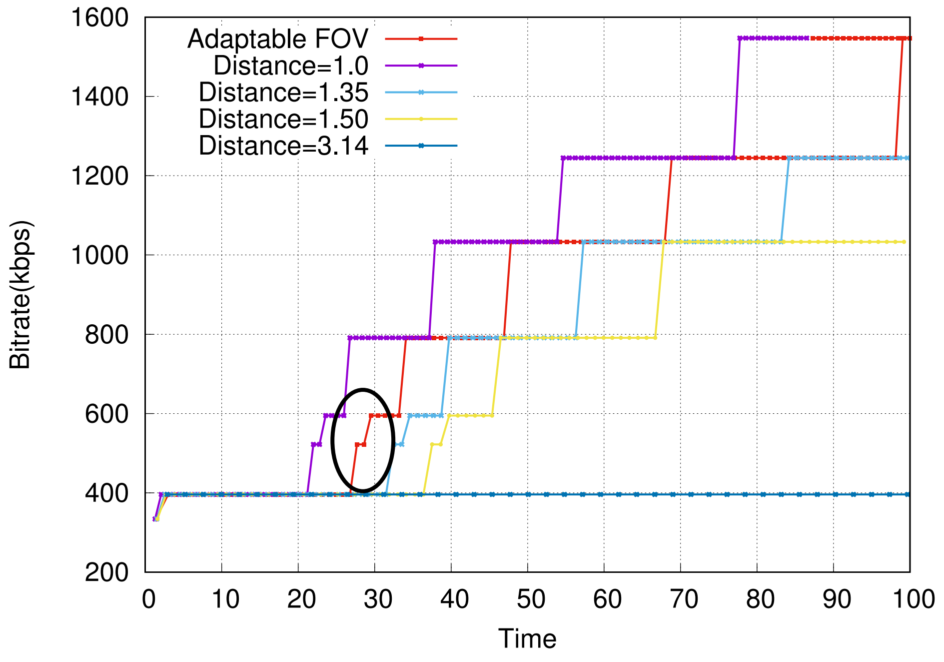
Set up

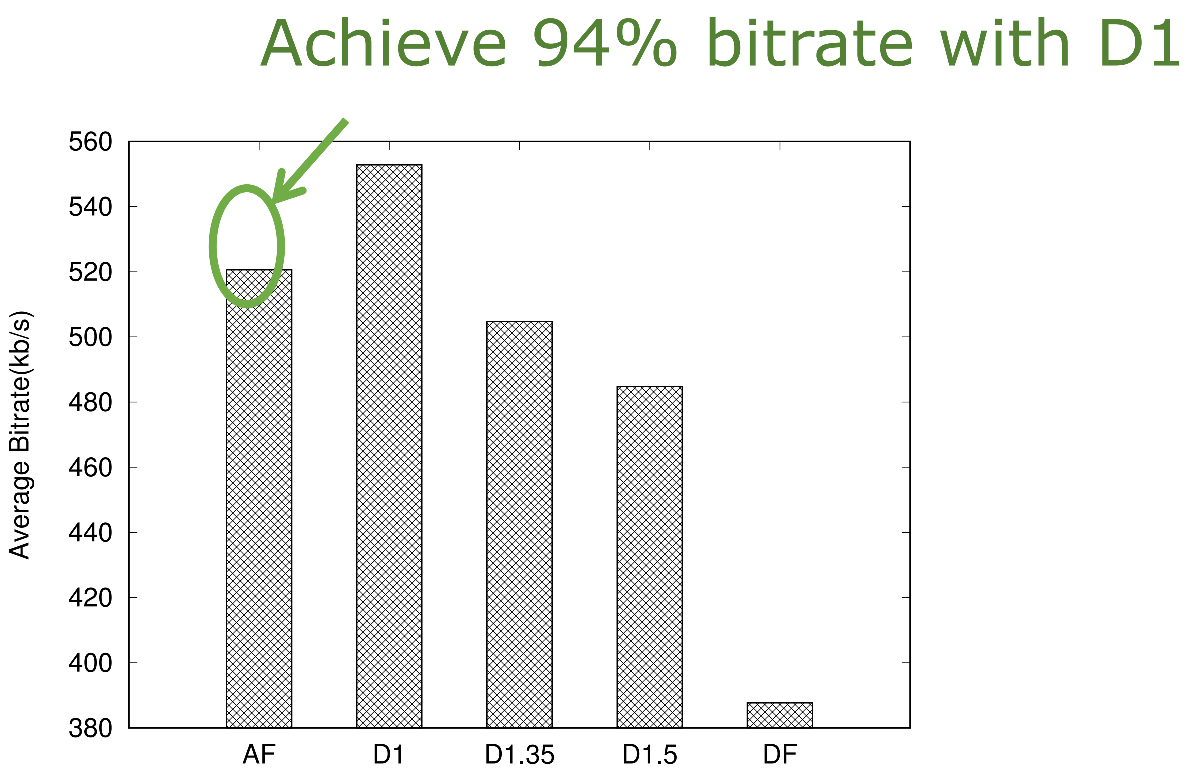
- Trace data: head movement dataset [MMSys 2017]
- Simulated HAS algorithms
- Link Capacity: 0.5 Mbps and 1.0 Mbps (low and high)
- Comparisons: AF, D1.0, D1.35, D1.5 and DF

QoE metric

- Average bitrate
- FoV mismatching frequency
- Network delay

Performance of bitrates

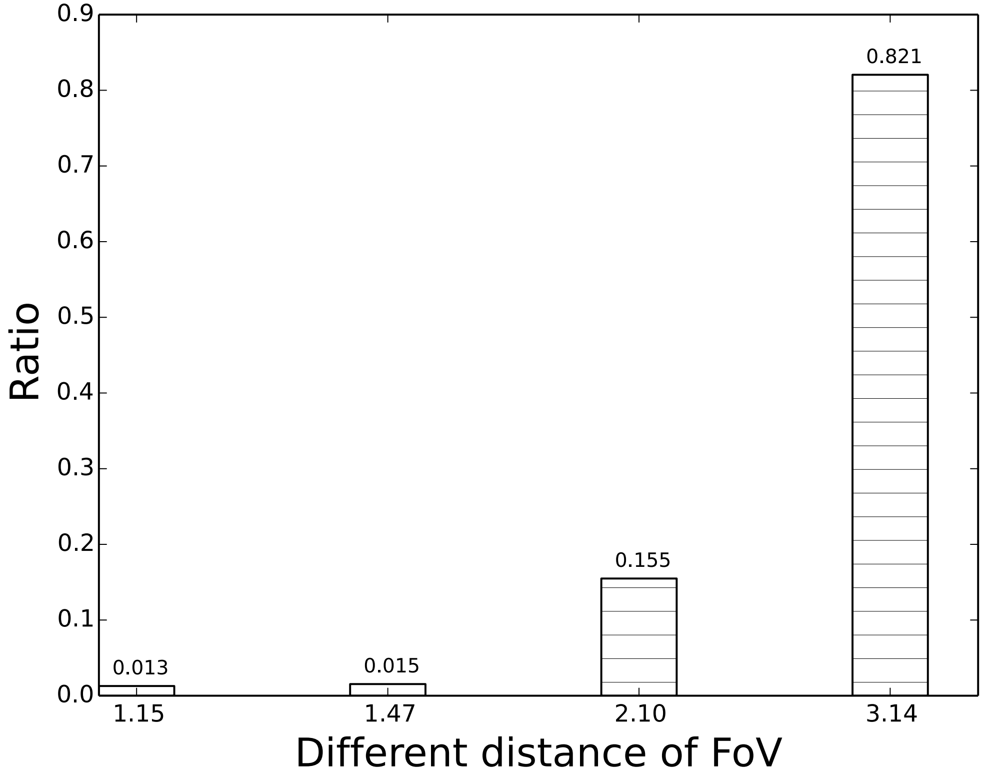




➢ High link capacity:

Our solution achieves the average bitrate between sending distance 1.0 and 1.35

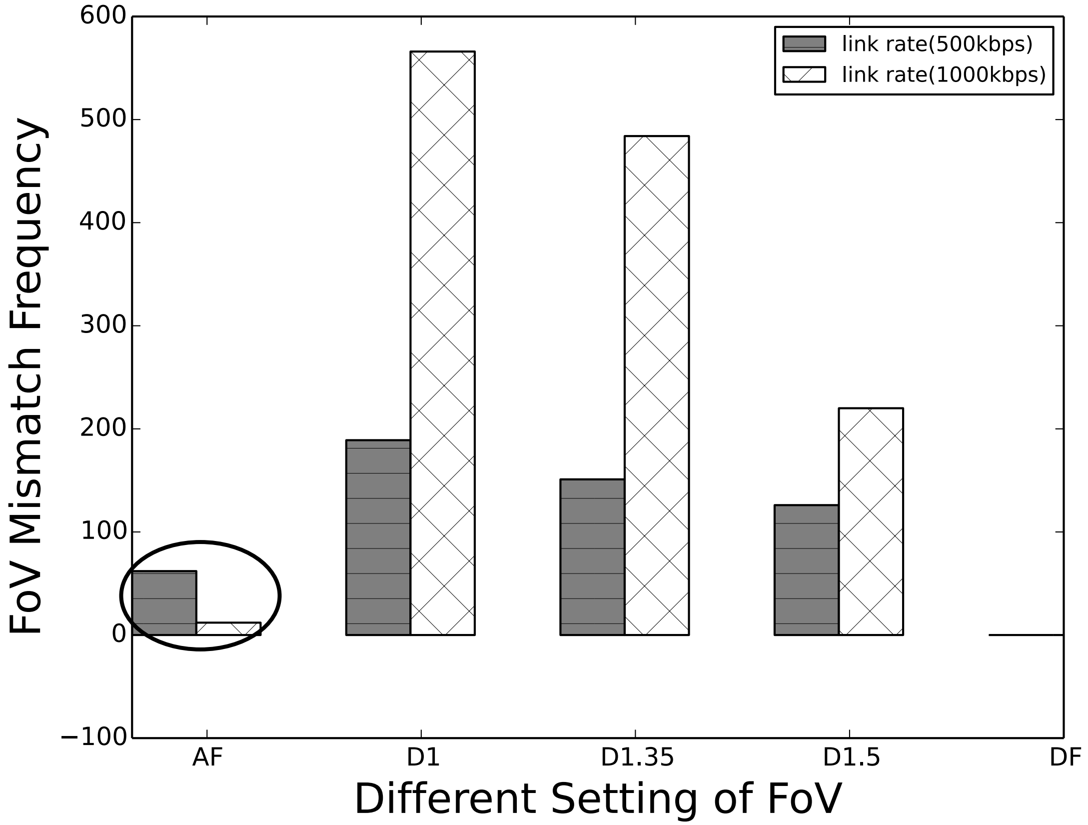
Ratio of Different sending FoV distance



- Low link capacity:

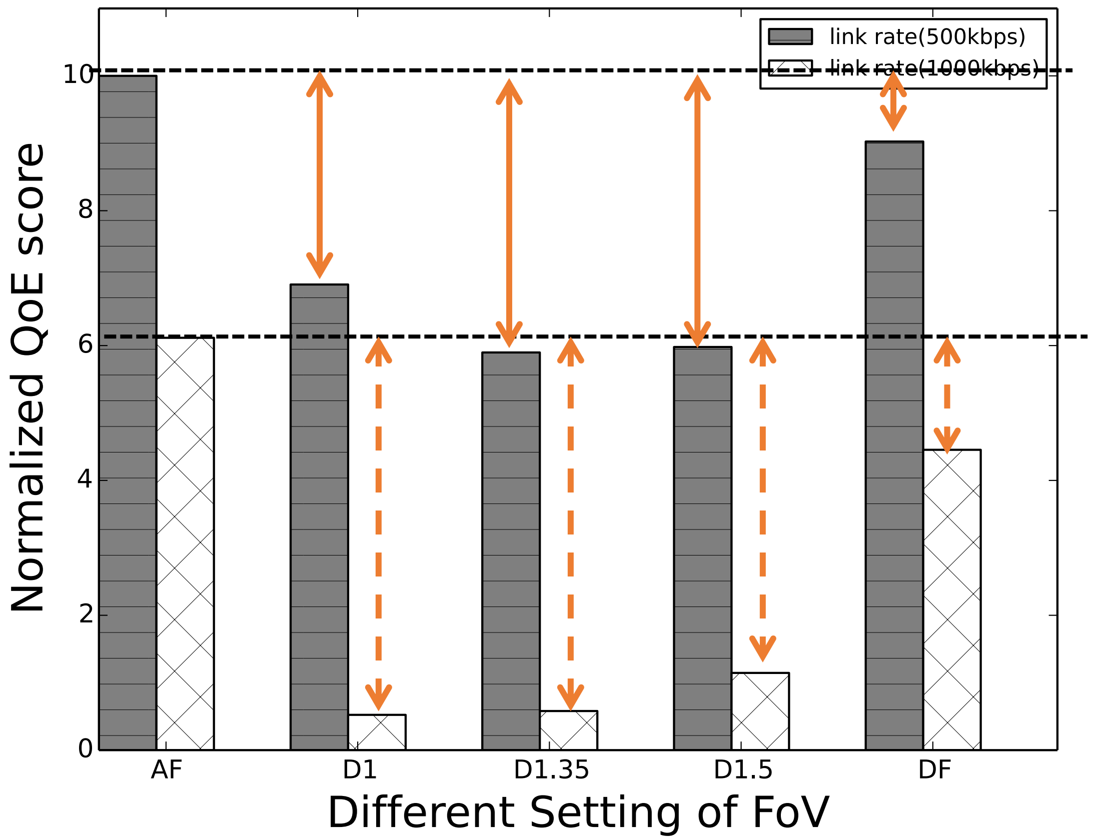
AF tends to sent full sphere to avoid viewport deviation

FoV deviation



- ➢ High bandwidth will lead to less FoV deviation
- ➢ Our solution could adjust to the different bandwidth for reducing the Fov deviation

QoE score



$$QoE\_score \propto \frac{Bitrate}{freq_{miss} \times Delay}$$

Our solution have best performance in the tradeoff between Bitrate and FoV deviation

Conclusion

- FoV adaptation – construct delay measurement model to cope with the viewport prediction
- Rate adaptation – target-buffer-based control algorithm to ensure continuous playback with network latency

➢ Advantage:

- Pre-fetch FoV with simple network delay estimation

➢ Disadvantage:

- More segments with different length for various network conditions

Thanks