

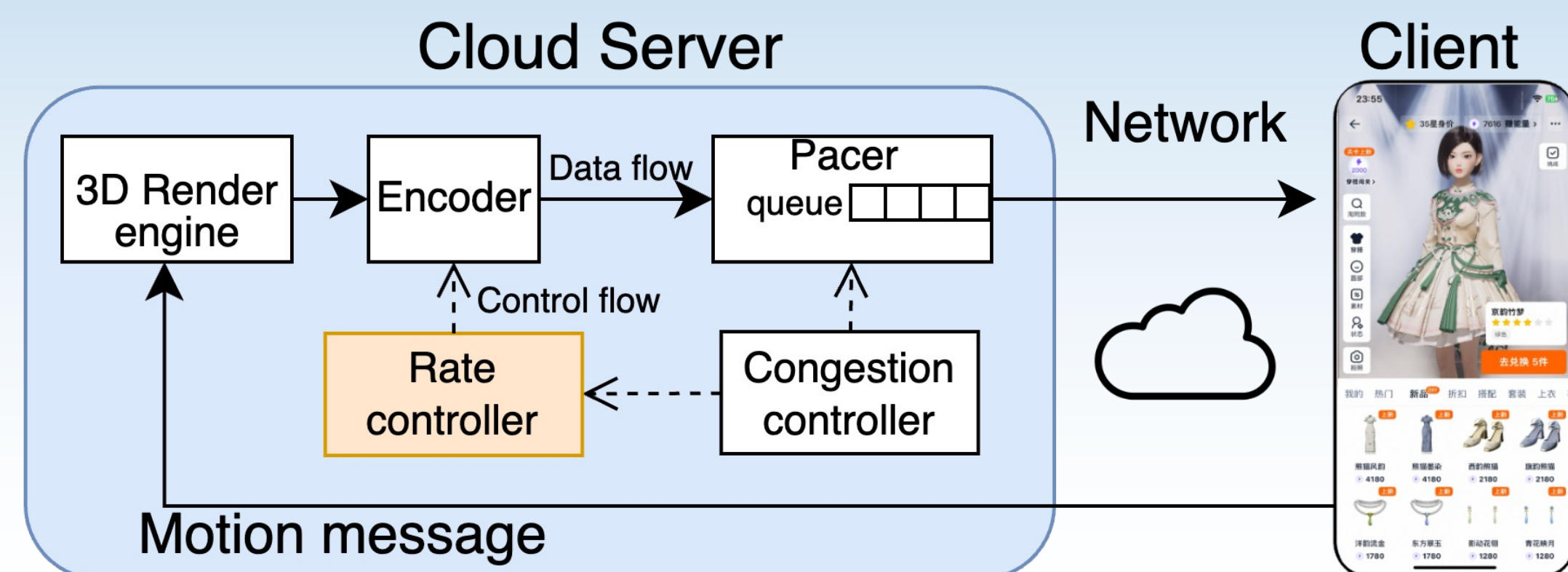
# MARC: Motion-Aware Rate Control for Mobile E-commerce Cloud Rendering

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## Mobile cloud rendering: A key technology for immersive 3D experiences

## QoE (Quality of Experience) requirements

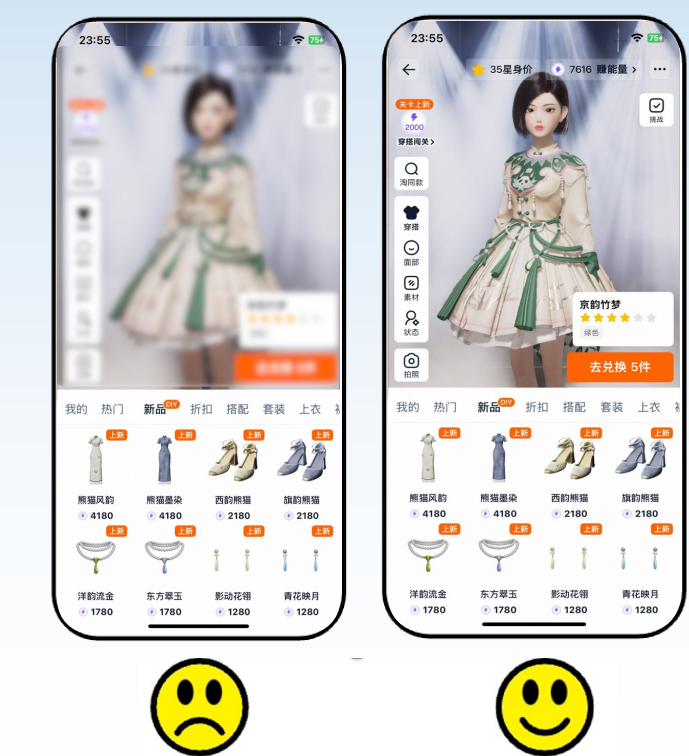
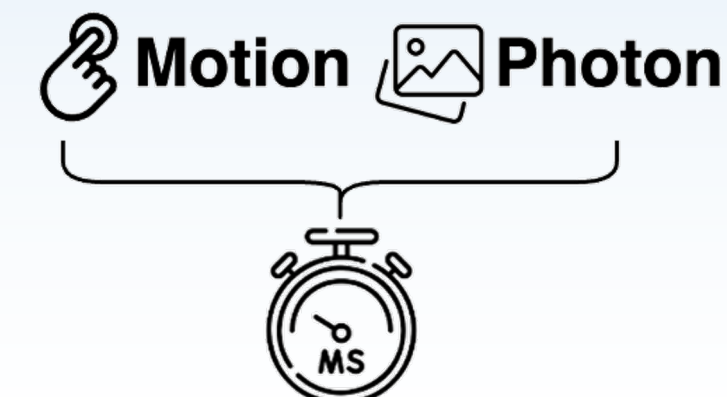
Background



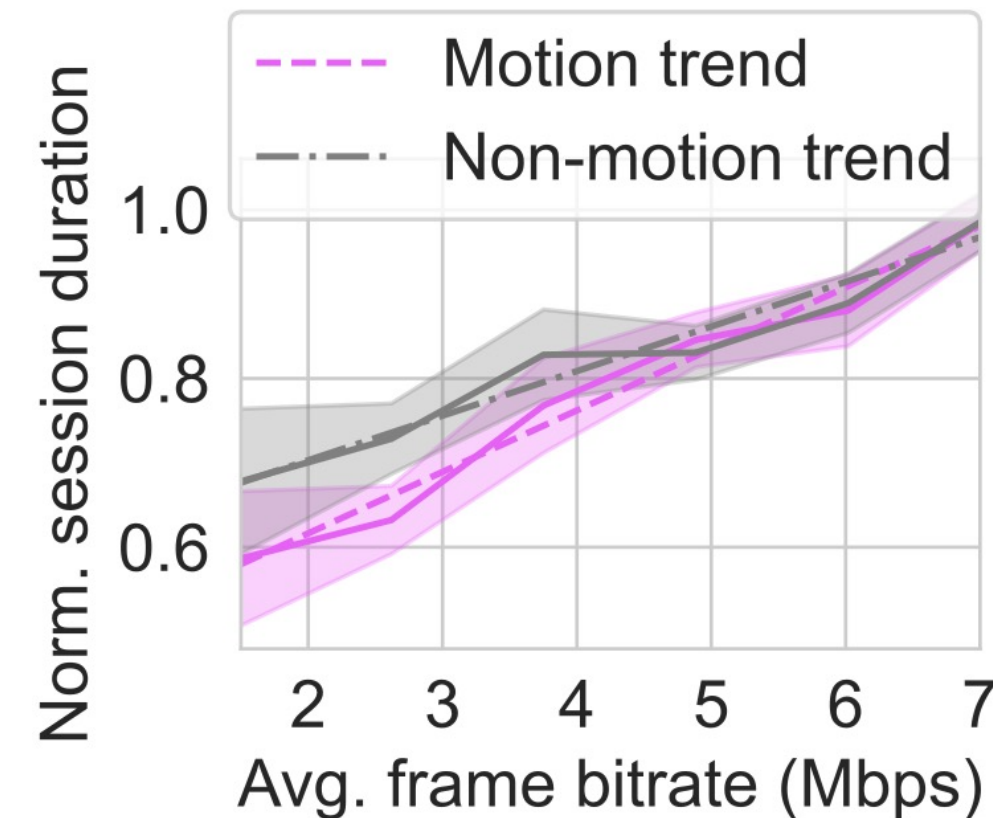
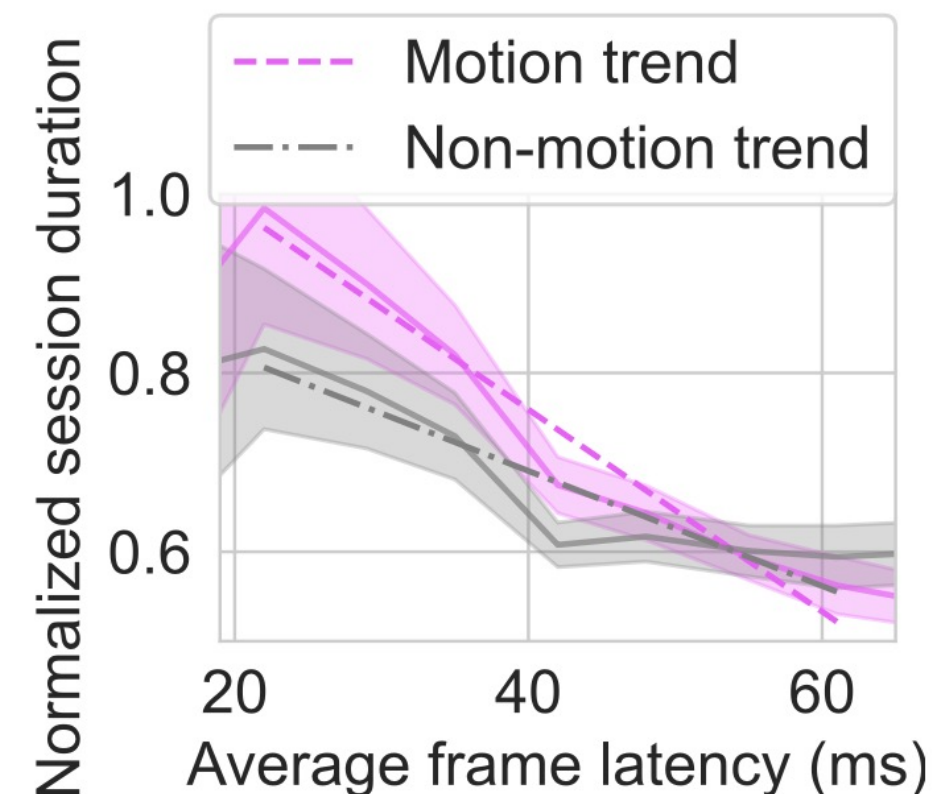
Inspect  
(Non-motion)

Engage  
(Motion)

**Low Latency** vs. **High Visual Quality**  
Motion-to-photon (MTP) latency < 150ms  
Higher video bitrate yields clearer frames

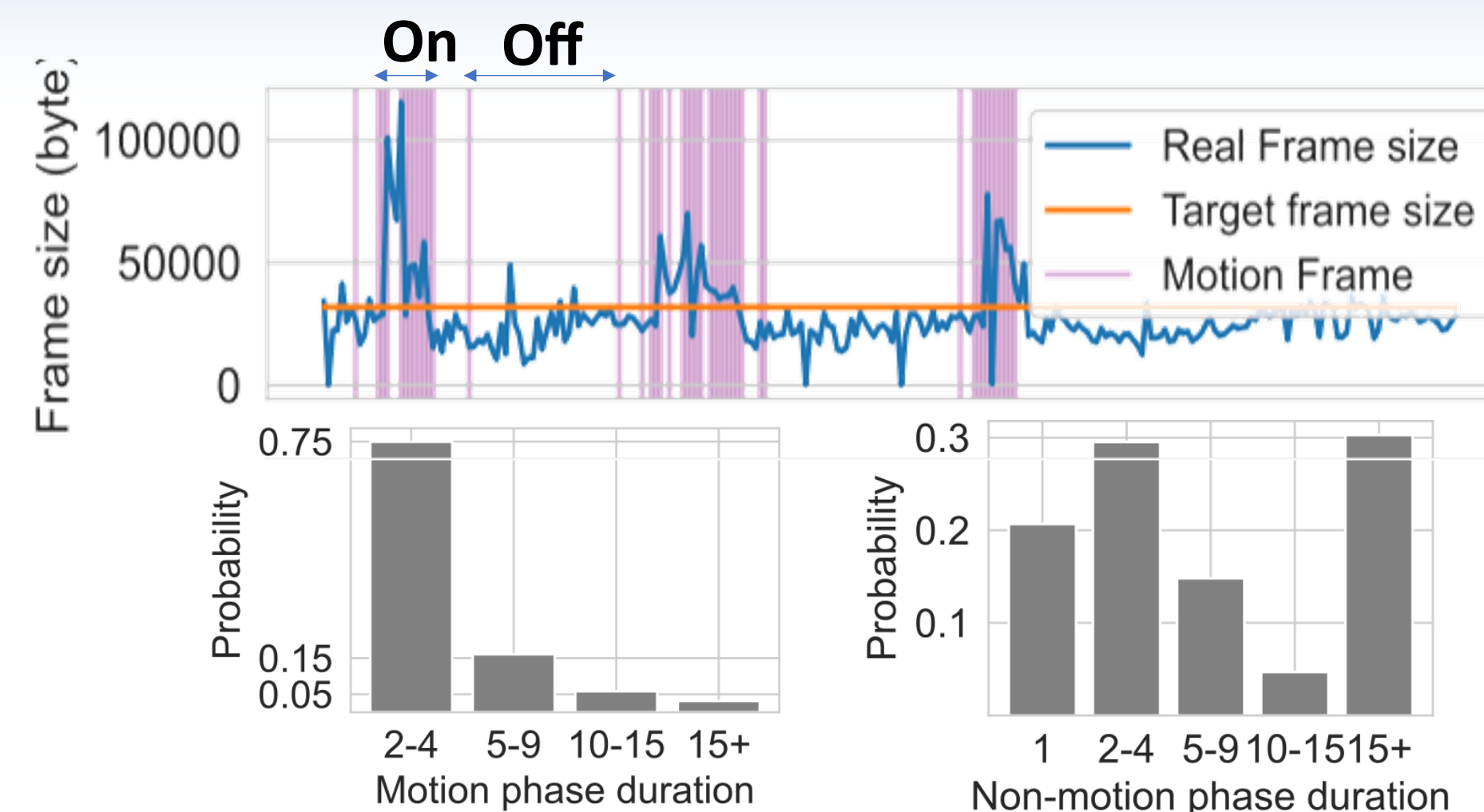


**O1:** In motion phases, frame latency has a greater impact on user engagement than bitrate



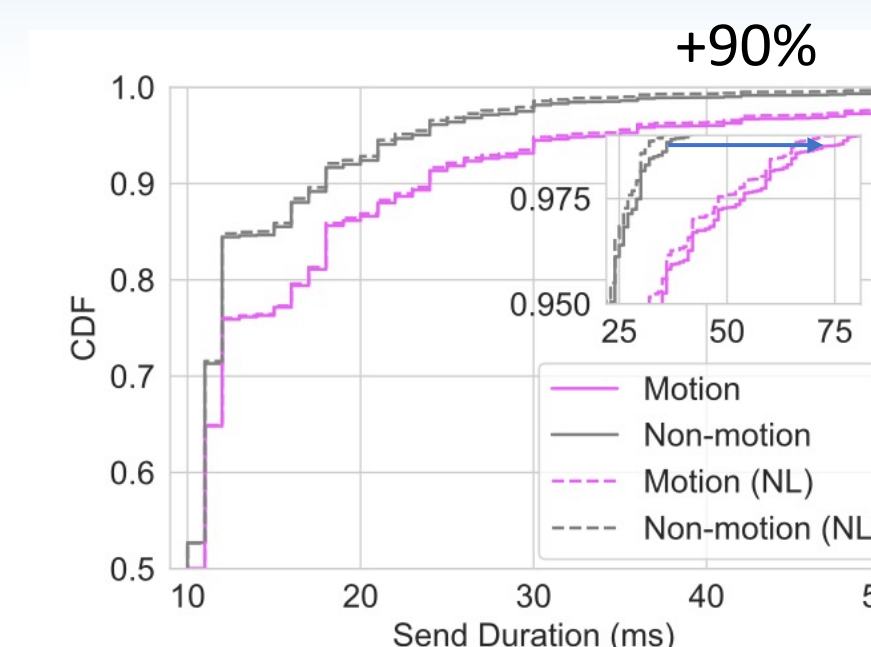
During user interaction, **latency sensitivity is 75.7 % higher** than in non-motion periods.

**O2:** User interactions exhibit an **On-Off pattern**

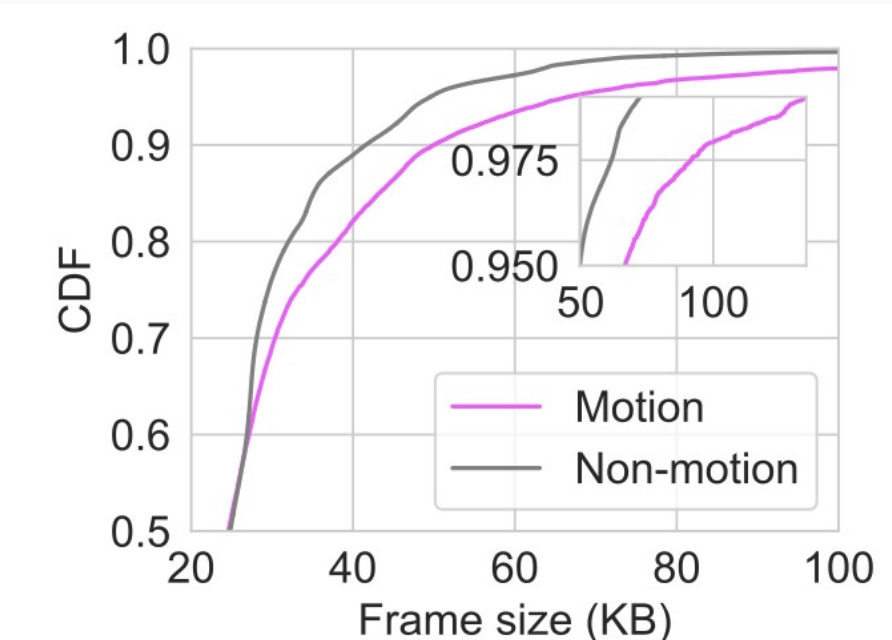


Length distribution of consecutive **motion or non-motion** frames

**O3:** Motion frames are larger & incur higher latency



(a) CDF of send duration.



(b) CDF of frame size.

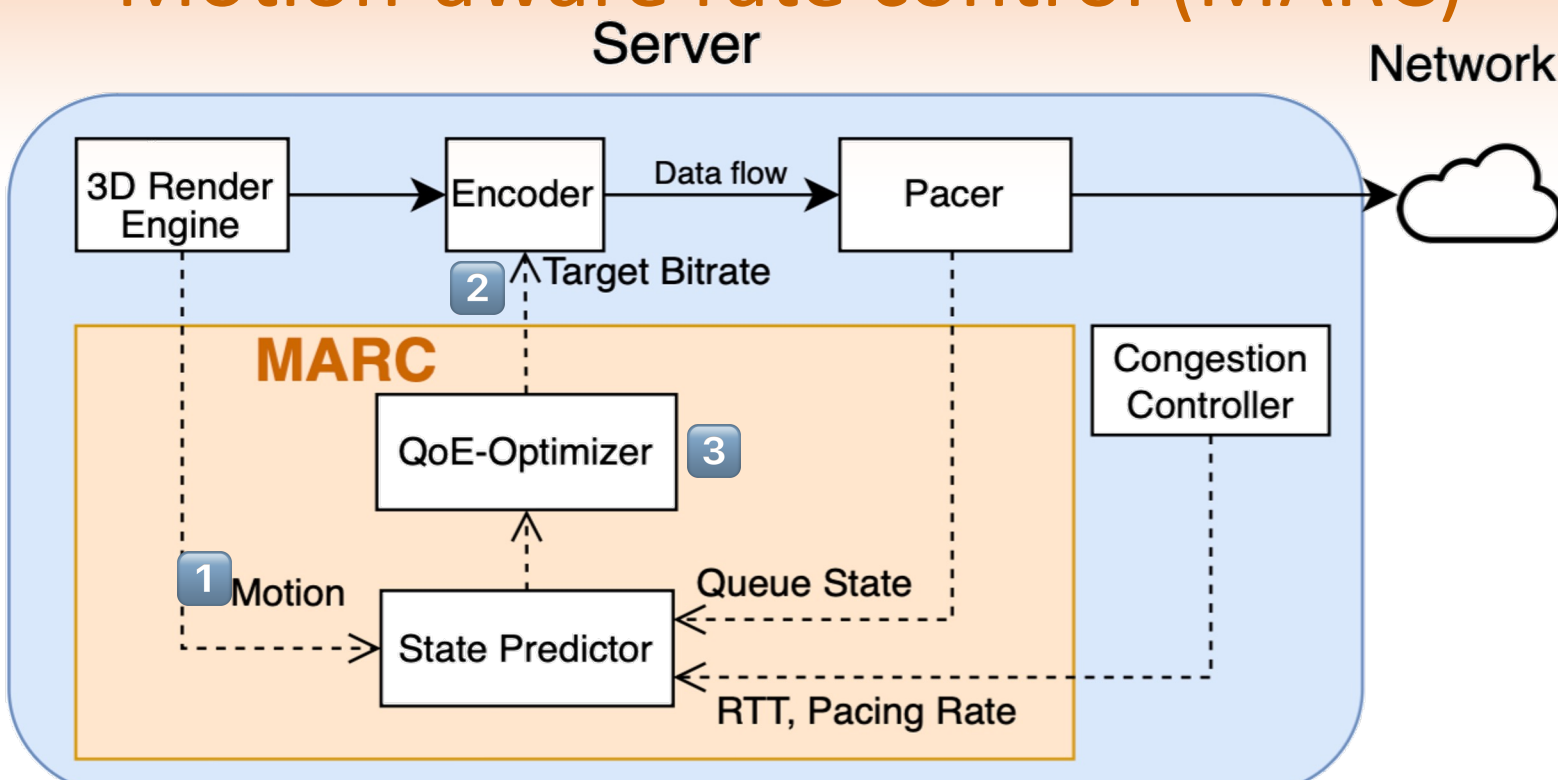
Latency spikes often occur when users are most sensitive to interaction delays

**R1:** Motion-aware rate control for dynamic user preferences

**R2:** Frame-level decisions are required to keep up with rapid state changes

**R3:** Differentiate bitrate assignment for motion/non-motion frames

## Motion-aware rate control (MARC)



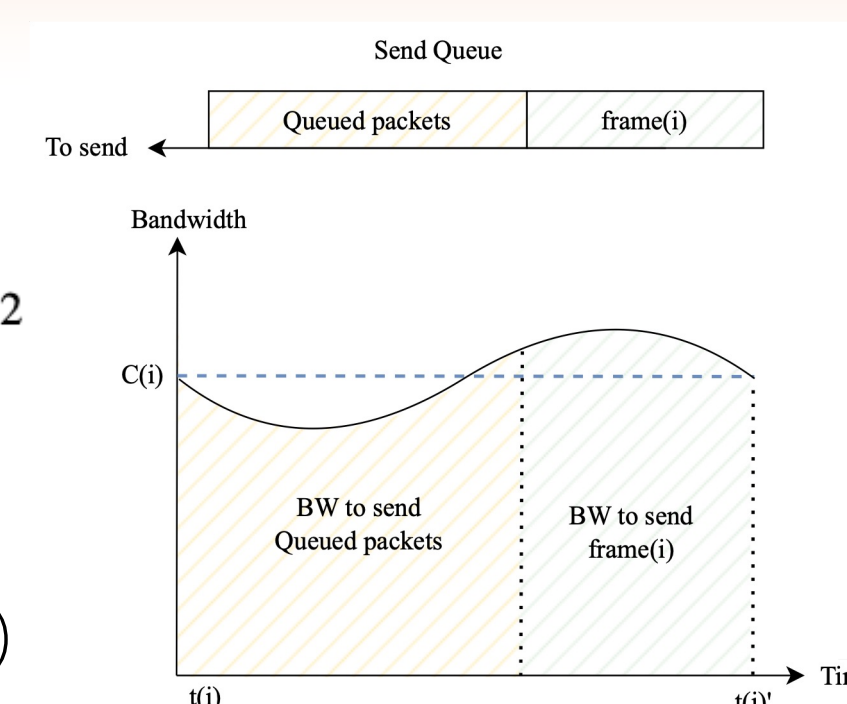
N step QoE optimization

$$QoE_1^N = \sum_{i=1}^N q_R(R_i) - \sum_{i=1}^N (\lambda_s + M(i) \times \lambda_m) \times q_L(L(i))$$

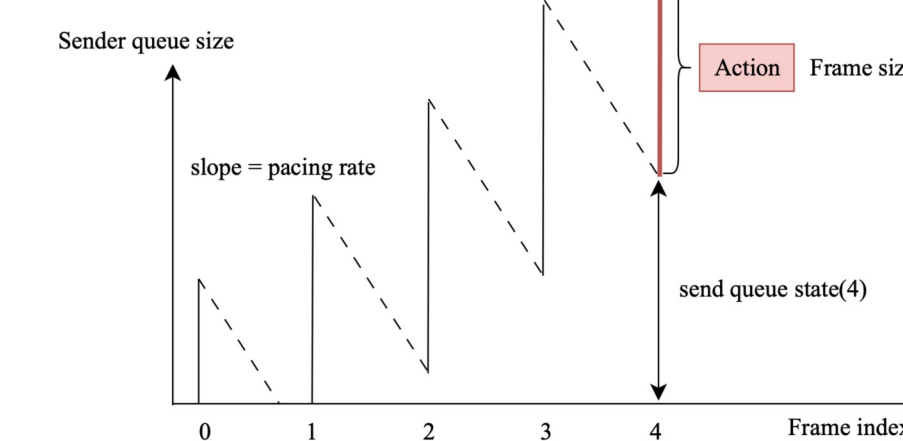
$$q_R(R) = \left(1 - \frac{1}{R/a + 1}\right) \times \frac{R_{Max} + a}{R_{Max}} \quad q_L(L) = \left(\frac{L}{L_{max}}\right)^2$$

Motion prediction  
Markovian model  
Observation (state length=5) Prediction (0/1)

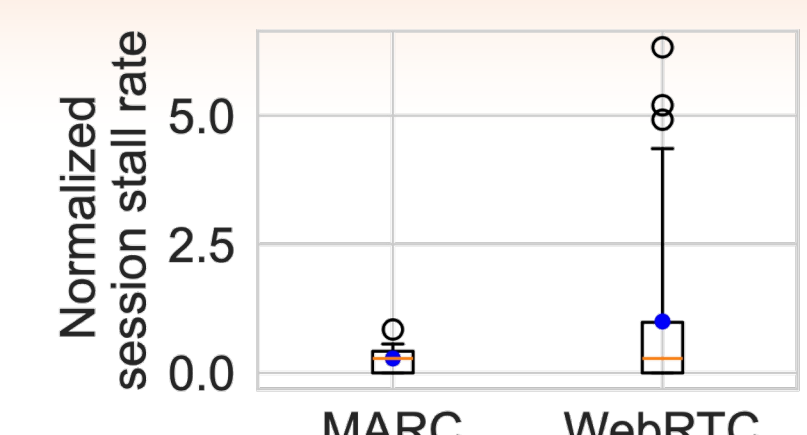
Queueing and sending of a frame



Modeling the cascading effects of queueing



Online A/B test (1 Million sessions)



|        | Session Duration | Interaction Ratio |
|--------|------------------|-------------------|
| WebRTC | 1                | 1                 |
| MARC   | 1.09             | 1.20              |

Observation &amp; Requirement

Design &amp; Evaluation