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STORM: a Multipath QUIC Scheduler for Quick Streaming Media Transport under Unstable Mobile Networks

Liekun Hu, Changlong Li

Contents

Emerging Mobile Scenarios

- Emerging scenarios that demand high network bandwidth have motivated the development of multipath transport techniques
  - ➢ video conference, VR/MR, teleoperated driving, and cloud gaming
- These scenarios also pose a higher demand for low latency.

Mobile Devices

bandwidth-intensive apps in mobile scenarios

Enhanced Mobility and Reliability Differentiated Transmission

- The enhanced mobilityintroduces more frequent and sudden signal fluctuates
  - cellular network handover, WiFi roaming
- Multipath transport enables reliable transmission of critical data, while relaxing reliability for non-critical traffic

Effect of MPQUIC on QoE

- The evaluations are performed on Xiaomi 12S Pro under LTE, 5G, and WiFi networks
- Multipath transmission leads to a degradation in user experience
  - Typical metrics studied: **FPS (frame-per-second)**, **per-frame end-to-end (E2E) latency**

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- The evaluations are performed on Xiaomi 12S Pro under LTE, 5G, and WiFi networks
- Multipath transmission leads to a degradation in user experience
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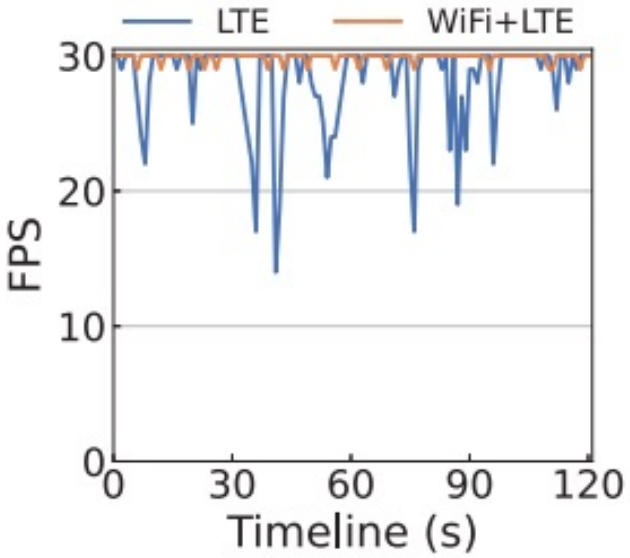
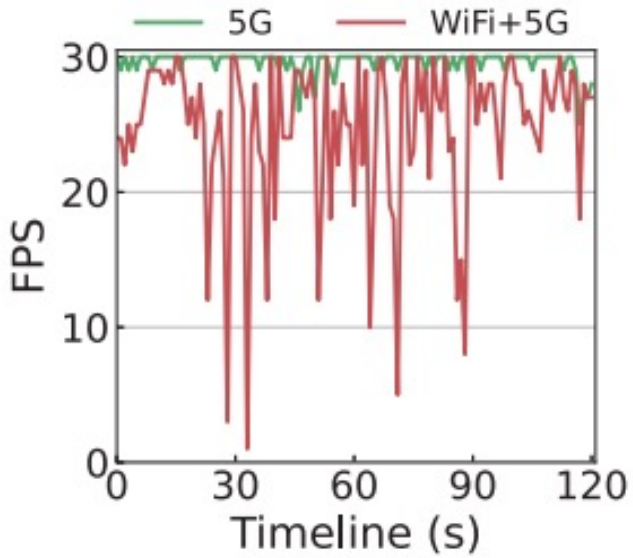
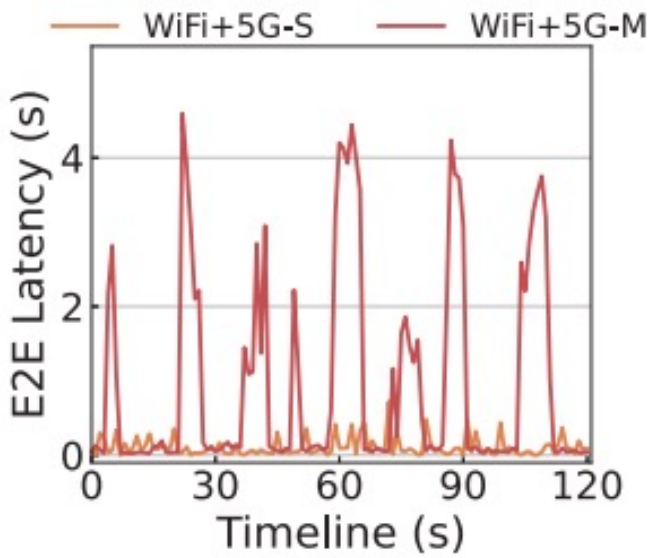


(a) Stationary Case



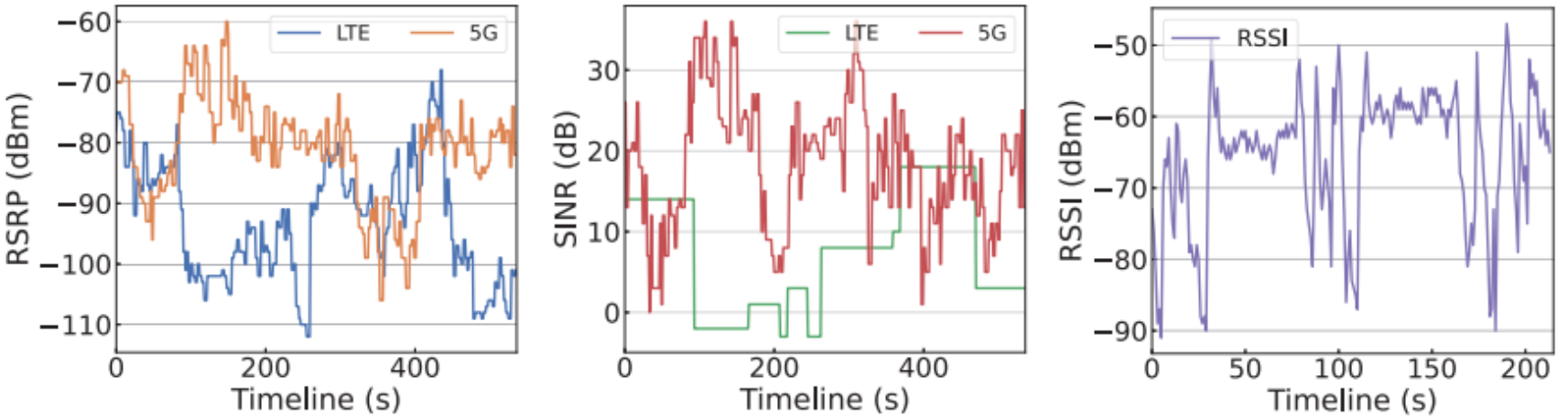
(b) Moving Case



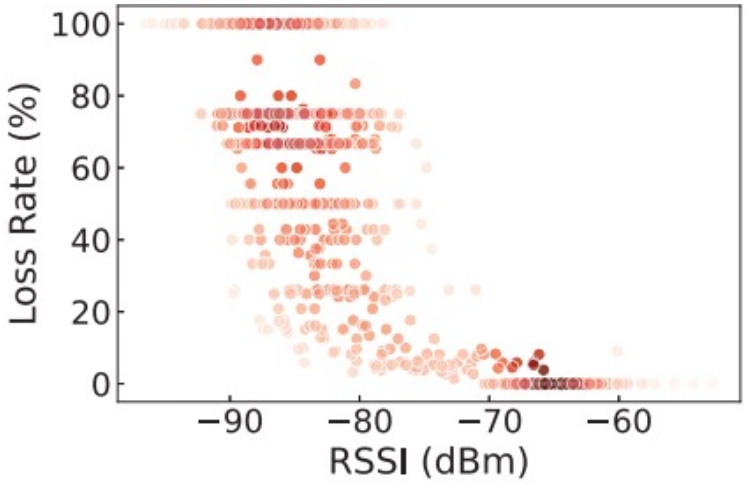
(c) E2E latency

Root Cause Analysis

■ Mobility-induced Signal Changes



(a) LTE and 5G fluctuation (RSRP + SINR) (b) WIFI RSSI fluctuation

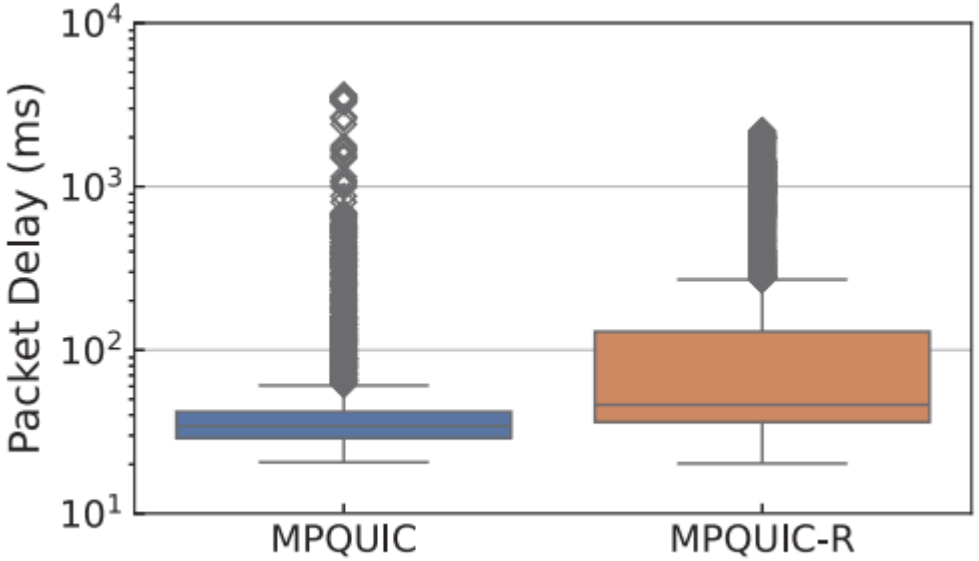


Impact of signal strength on loss rate

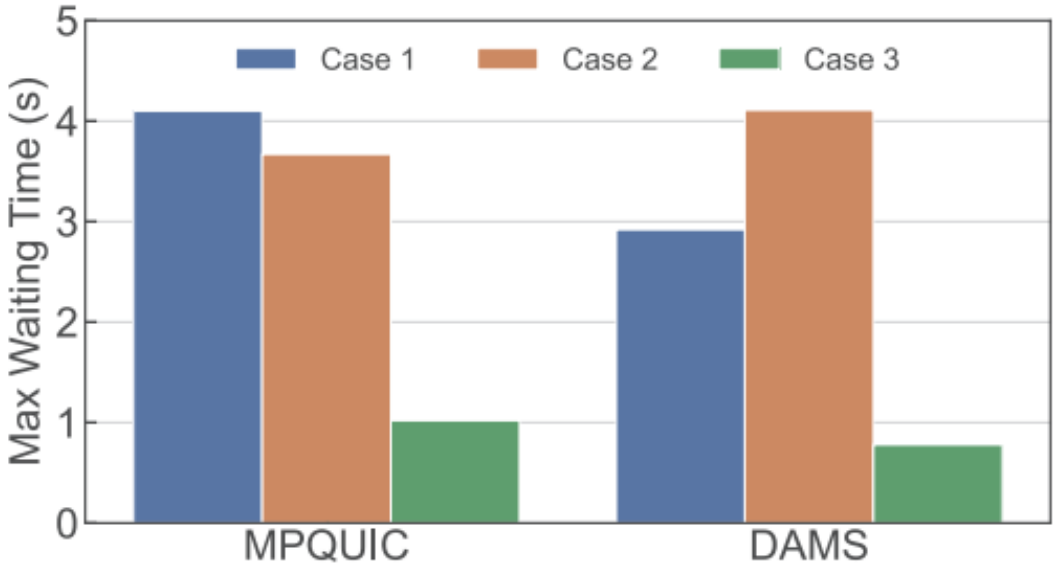
- Mobility causes frequent and significant signal fluctuations
- Signal fluctuations lead to increased packet loss and retransmissions
- the multipath scheduler cannot respond to these rapid changes

Root Cause Analysis

- Scheduling without Reliability Differentiation



Packet delay in MPQUIC (Reliable & Unreliable) and MPQUIC-R (Fully reliable)



Maximum waiting time of critical data in different cases

- MPQUIC exhibits large packet delay outliers in practice, revealing limitations in its reliability design.
- Unreliable data blocks reliable traffic in MPQUIC, raising tail latency

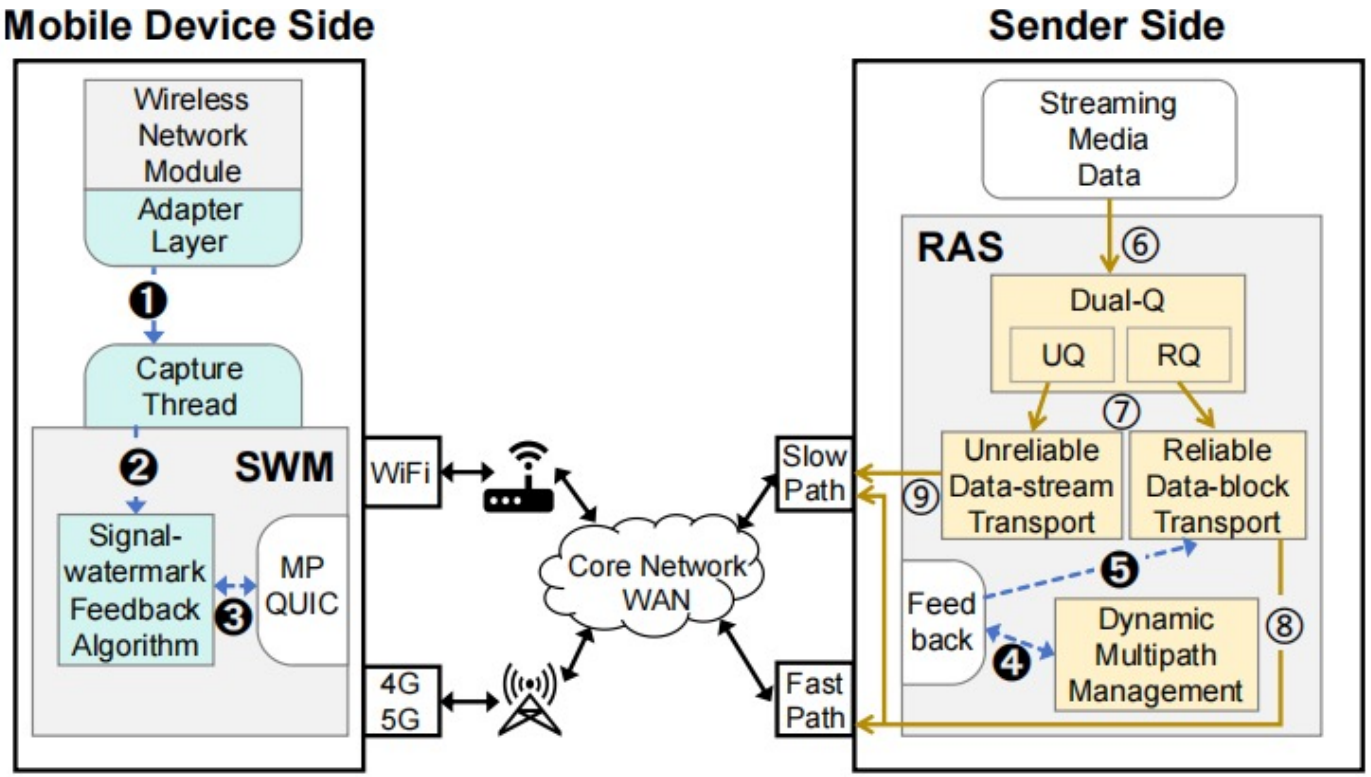
Contents

Overview

- **STORM:** a **M**ultipath QUIC **S**cheduler for quick st**r**eaming media **T**ransport under m**o**bile networks

Overview

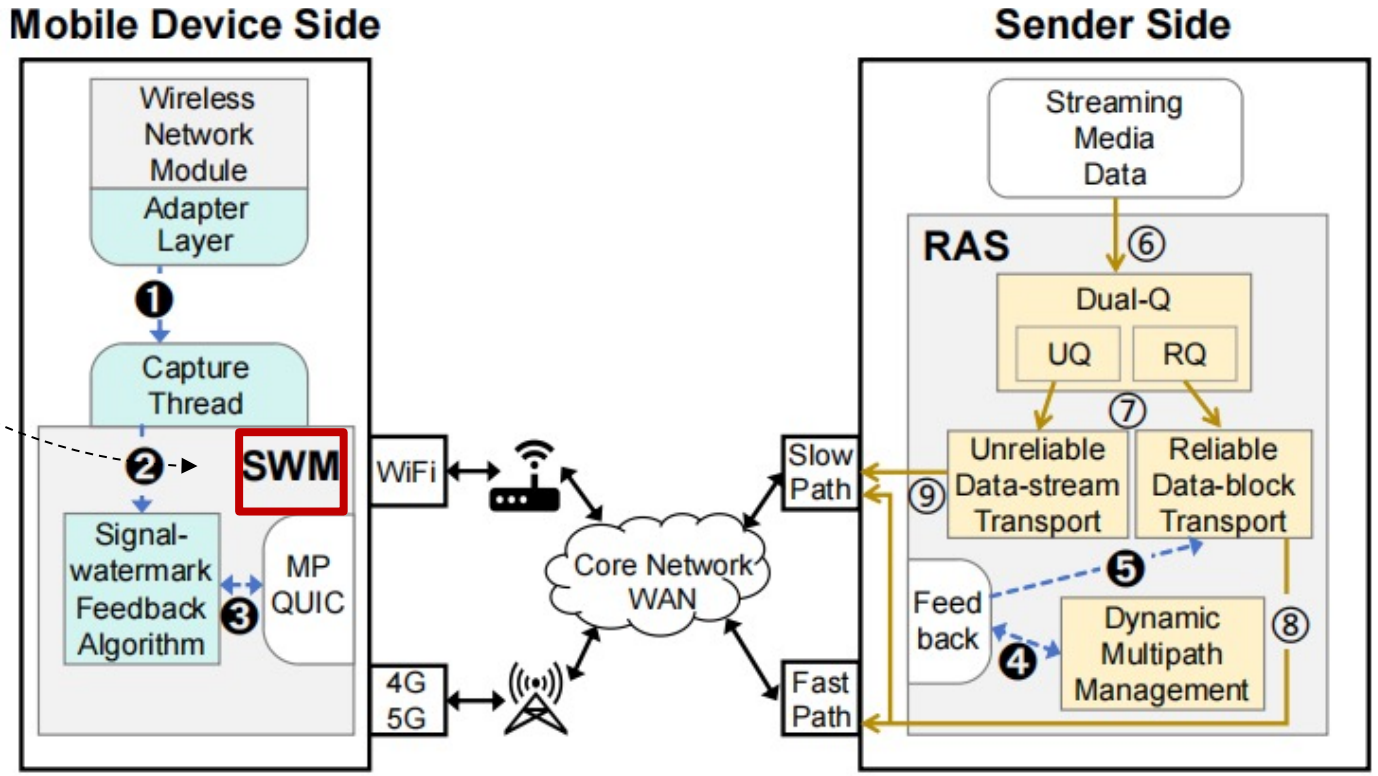
- **STORM:** a **M**ultipath QUIC **S**cheduler for quick st**r**eaming media **T**ransport under m**o**bile networks
  - **SWM**: Signal-watermark Mechanism
  - **RAS**: Reliability-aware Scheduling



Overview

- **STORM:** a Multipath QUIC Scheduler for quick streaming media Transport under mobile networks
  - **SWM**: Signal-watermark Mechanism
  - **RAS**: Reliability-aware Scheduling

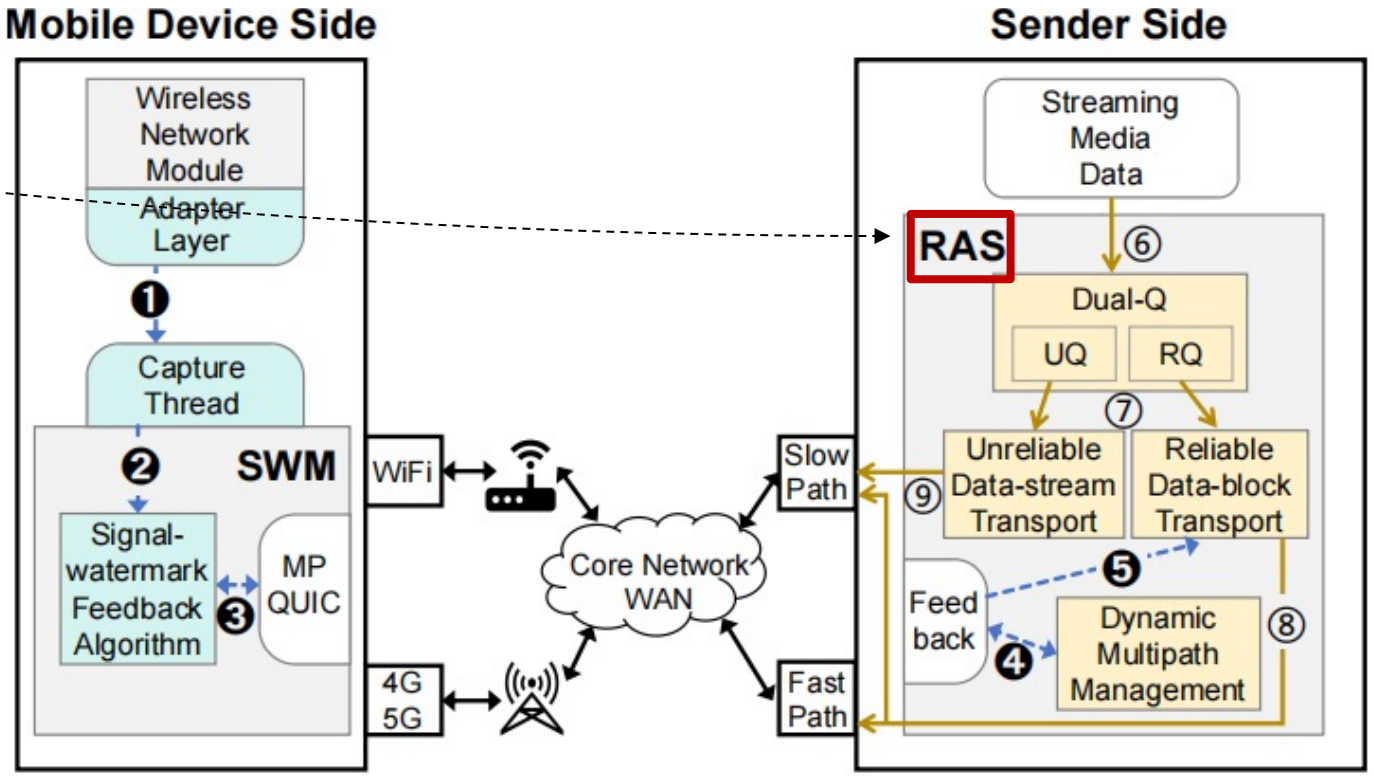
- SWM quantifies path's signal strength, compares it against predefined watermark, then sends differentiated feedback based on the result.



Overview

- **STORM:** a Multipath QUIC Scheduler for quick streaming media Transport under mobile networks
  - **SWM**: Signal-watermark Mechanism
  - **RAS**: Reliability-aware Scheduling

- Driven by SWM feedback, RAS distinguishes the two traffic classes: it organizes reliable data as blocks, streams unreliable data, and manages the deactivation and reactivation of paths as signals fluctuate.



Contents

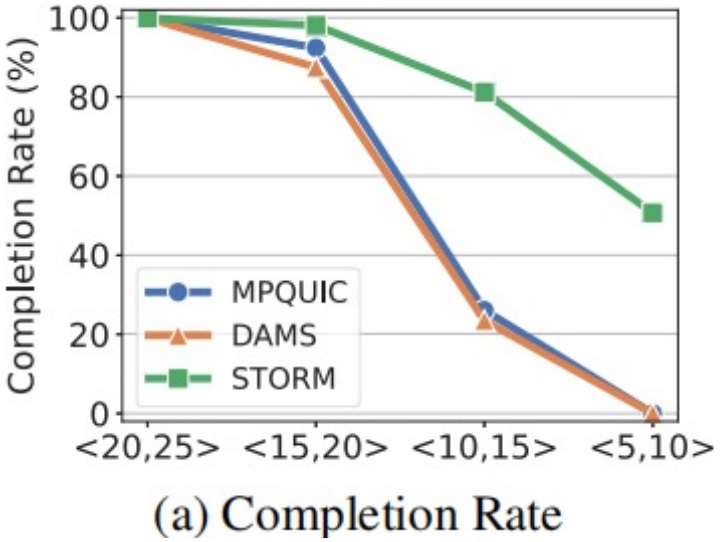
Evaluation

- The evaluations are performed from two aspects.
  - Control Network Environment
  - Applications in the Wild

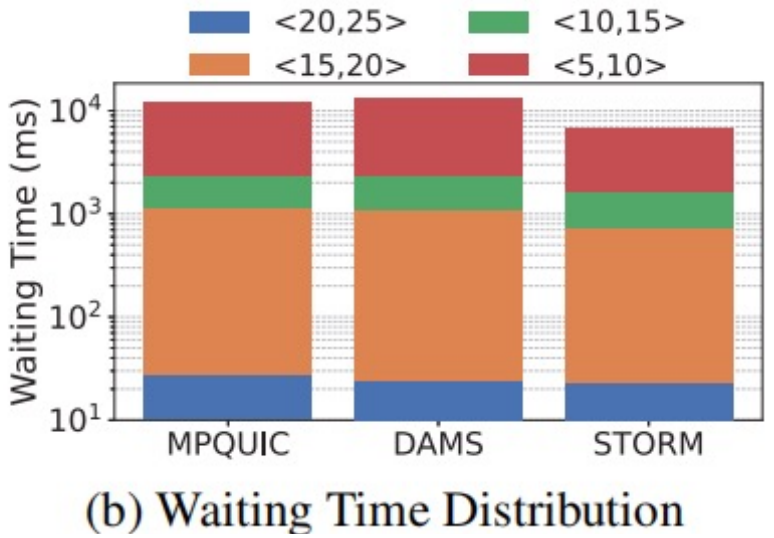
Evl. Type		Dev.	Equipment		
			NET	MEM	OS
Control Lab		PCs	Ethernet	94GB	Ubuntu 20.04
APP	**Video Conf.**	Phone	WiFi-6, LTE/5G	12GB	Android 14
	Live Stream.	Phone	WiFi-6, LTE/5G	12GB	Android 14
	360° Video	Laptop	WiFi-6	16GB	Ubuntu 18.04

Evaluation

- Microbenchmark

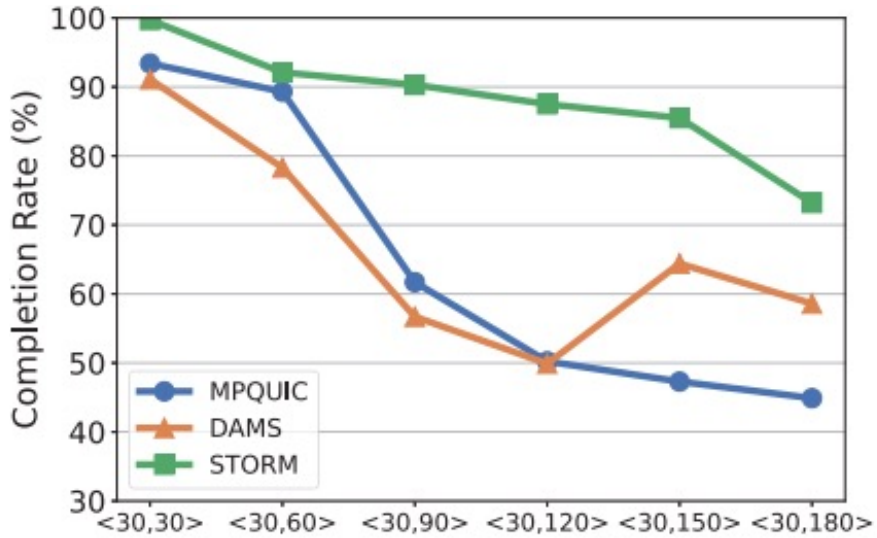


(a) Completion Rate



(b) Waiting Time Distribution

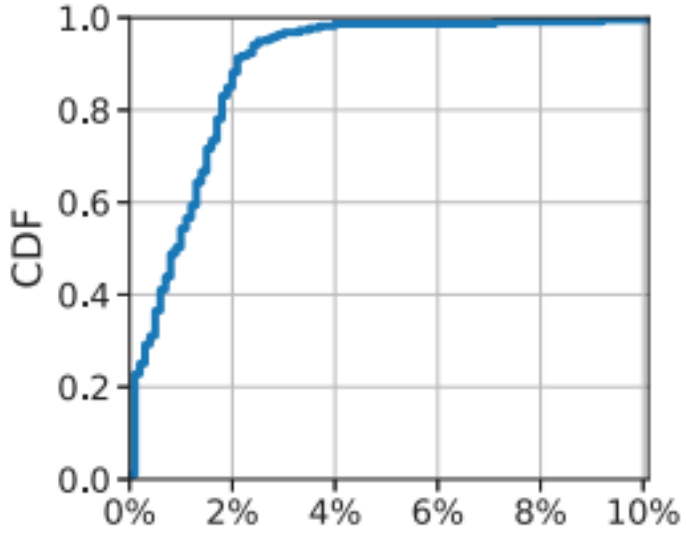
Block completion rate and waiting time distribution under various bandwidth combinations



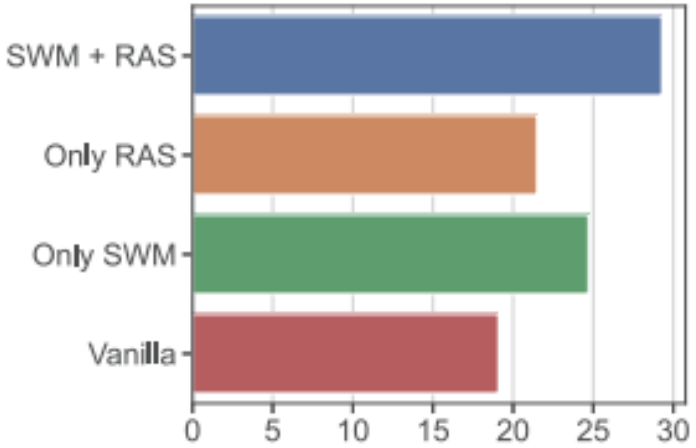
Block completion rate under various RTT combinations

Evaluation

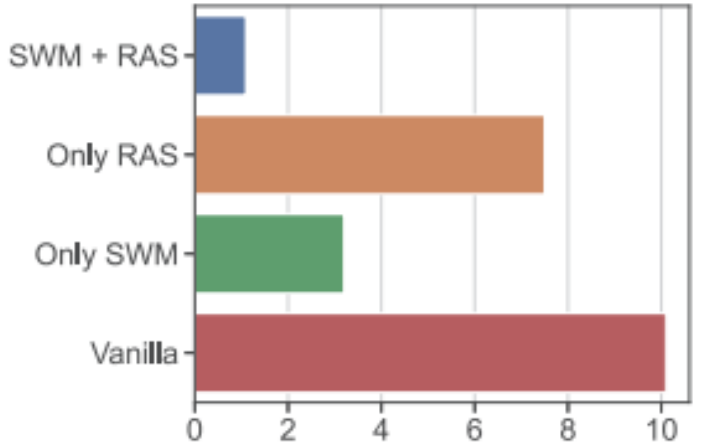
- Signal State Sync Bias



- Ablation Study



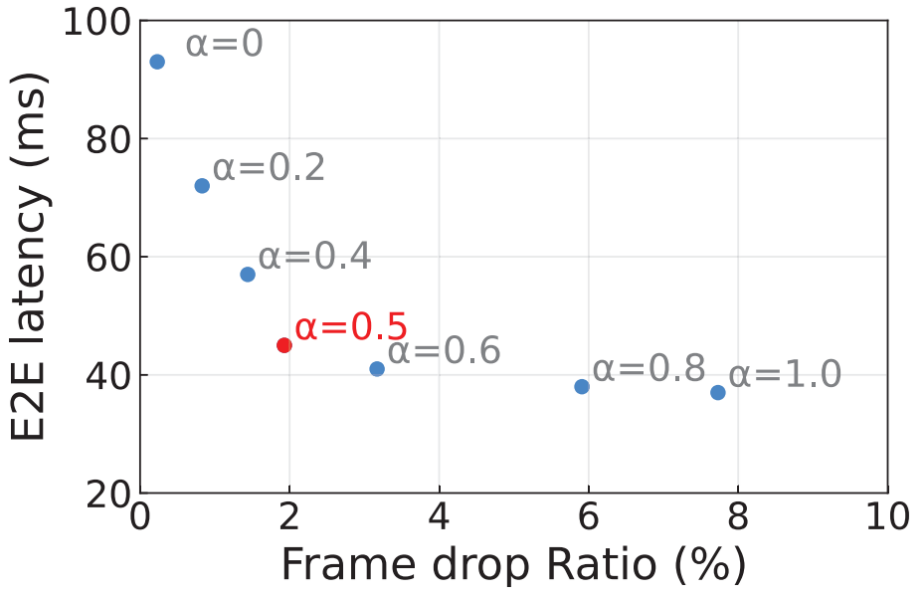
(a) Goodput (Mbps)



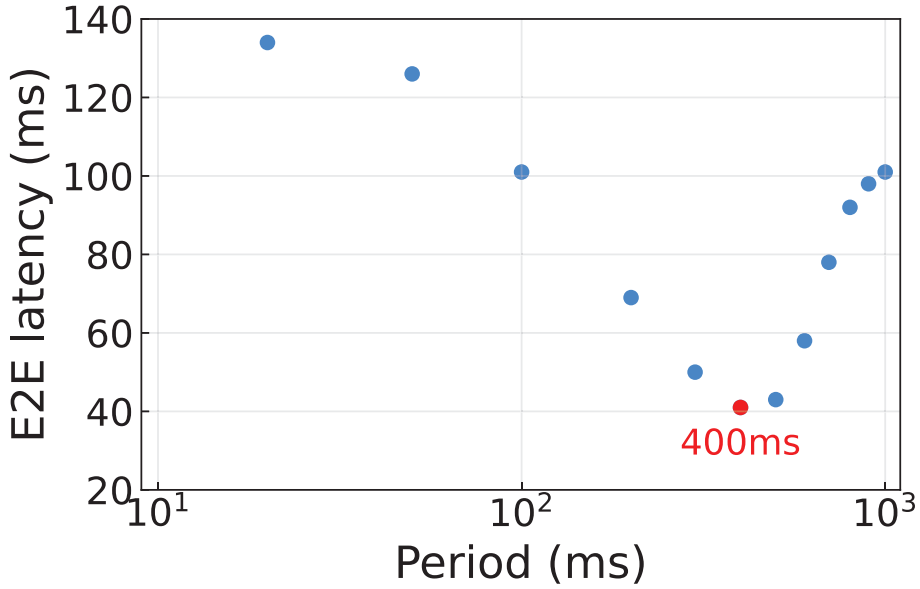
(b) Rebuffering Time (s)

Evaluation

- Parameter α Tuning

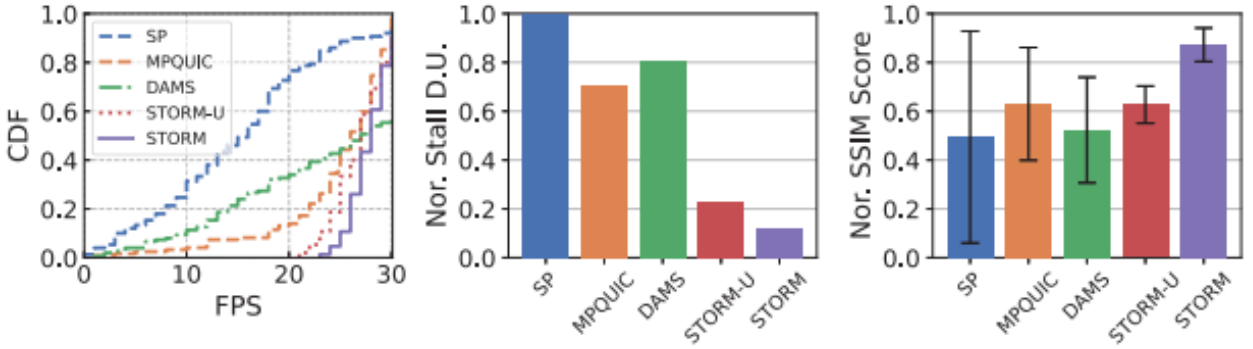


- Recovery Feedback Period

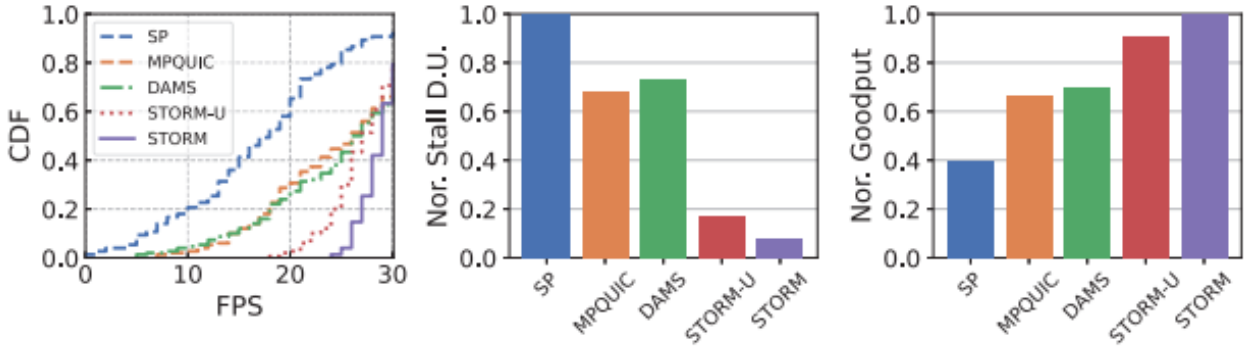


Evaluation

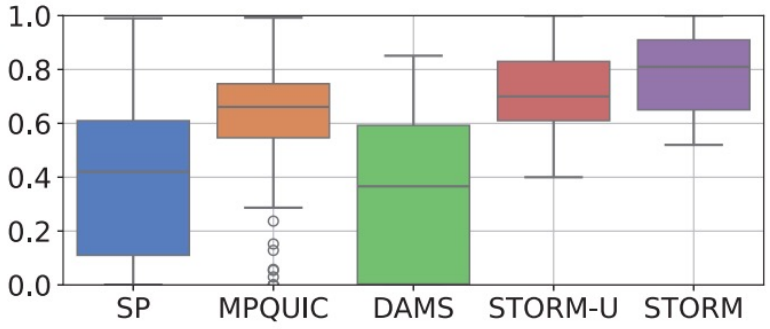
- Benefit on QoE



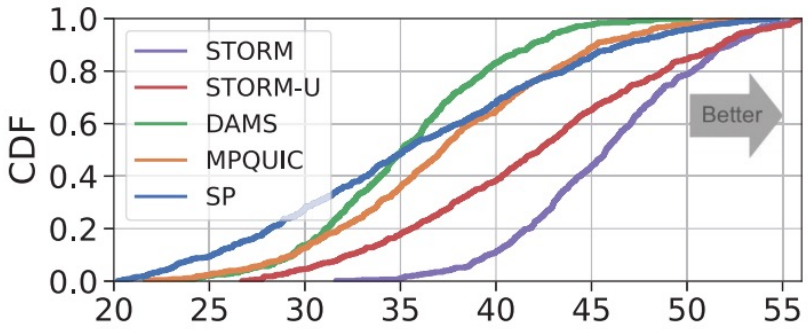
(a) Video conference's QoE



(b) Low-latency live streaming's QoE



(a) User perceived ratio

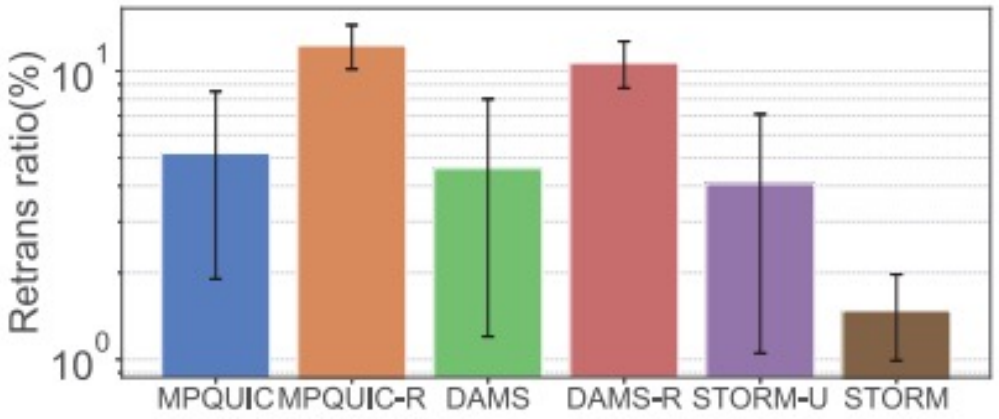


(b) PSNR (dB) distribution

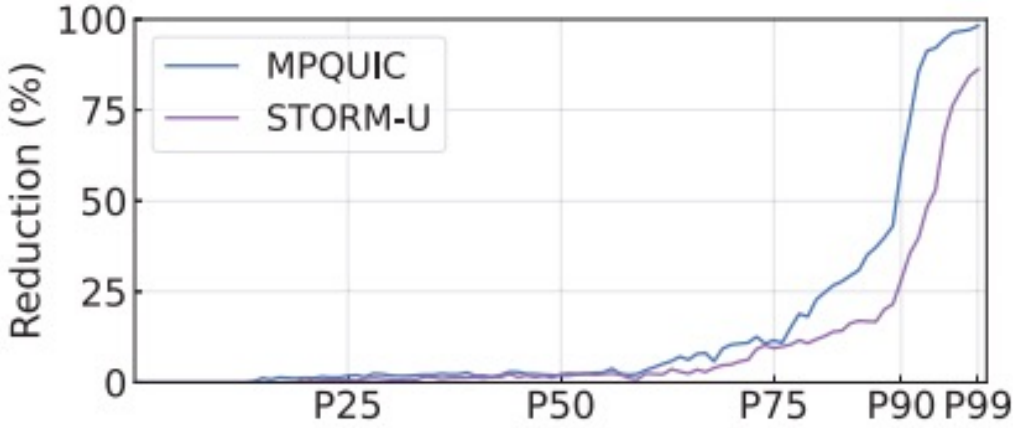
The 360° video's QoE

Evaluation

- Transport Improvement



(a) Retransmission ratio



(b) Packet delay reduction

Contents

Conclusion

Problem: Failure to sense sudden signal changes, combined with the mutual blockage introduced by reliability-agnostic scheduling, increases latency

The user experience degraded when suffering ustable network

Key insight: Leveraging signal-quality feedback, it schedules traffic with differentiated reliability to achieve lower latency.

STORM: a Multipath QUIC Scheduler for Quick Streaming Media Transport under Unstable Mobile Networks

STORM can reduce tail packet delay by 98.2% and improve the frame rate of streaming media data by 1.95x when under unstable networks, compared to the state-of-the-art solutions.

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THANK YOU!

Liekun Hu, Changlong Li

Author info: *https://faculty.ecnu.edu.cn/_s16/lcl1/main.psp*