

# STATE-OF-THE-ART SCHEDULER FOR MULTIPATH QUIC

## Motivation

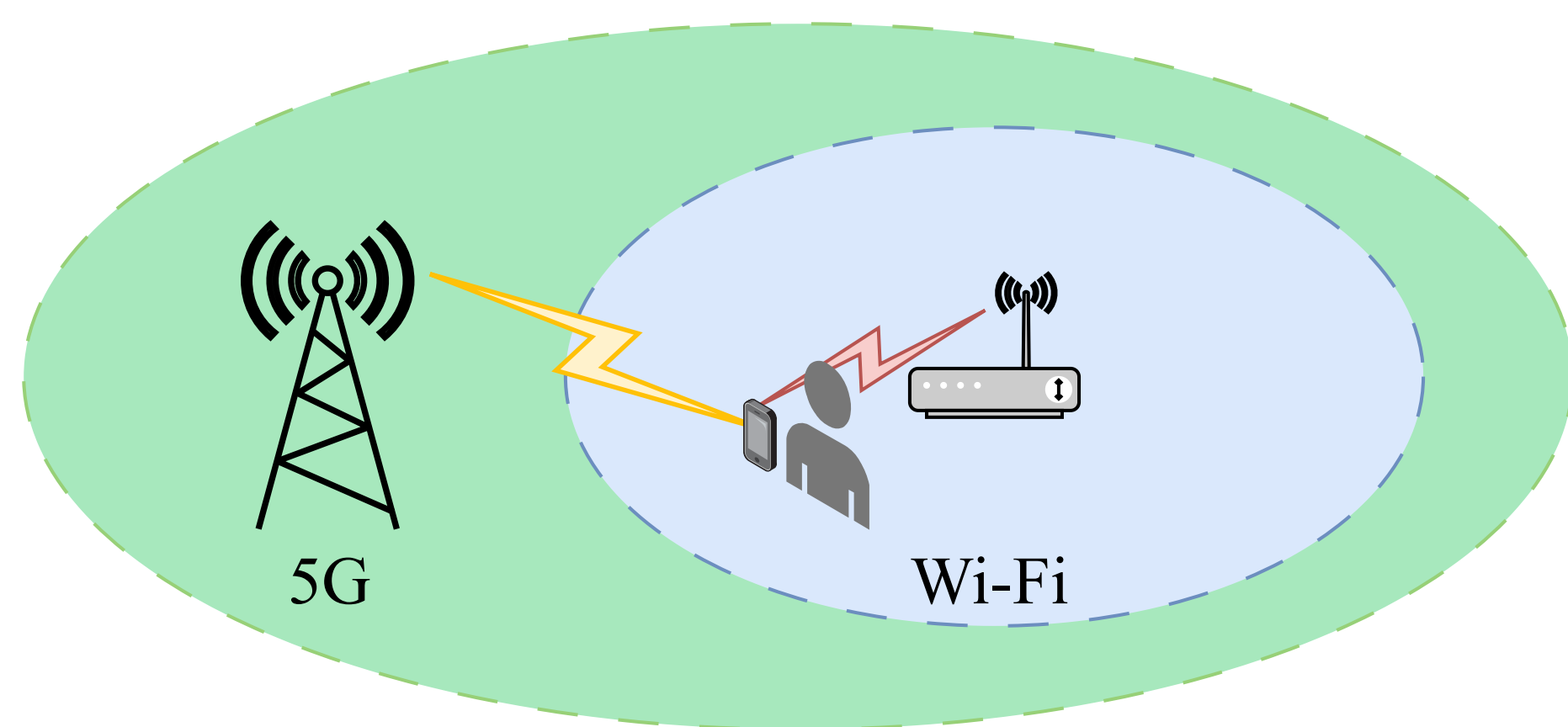
### Multipath QUIC (MPQUIC)

Smartphones often switch networks due to user movement

- ▶ distinct path characteristics

The *path* and *stream* choice affects QUIC's

- ▶ user experience
- ▶ service quality

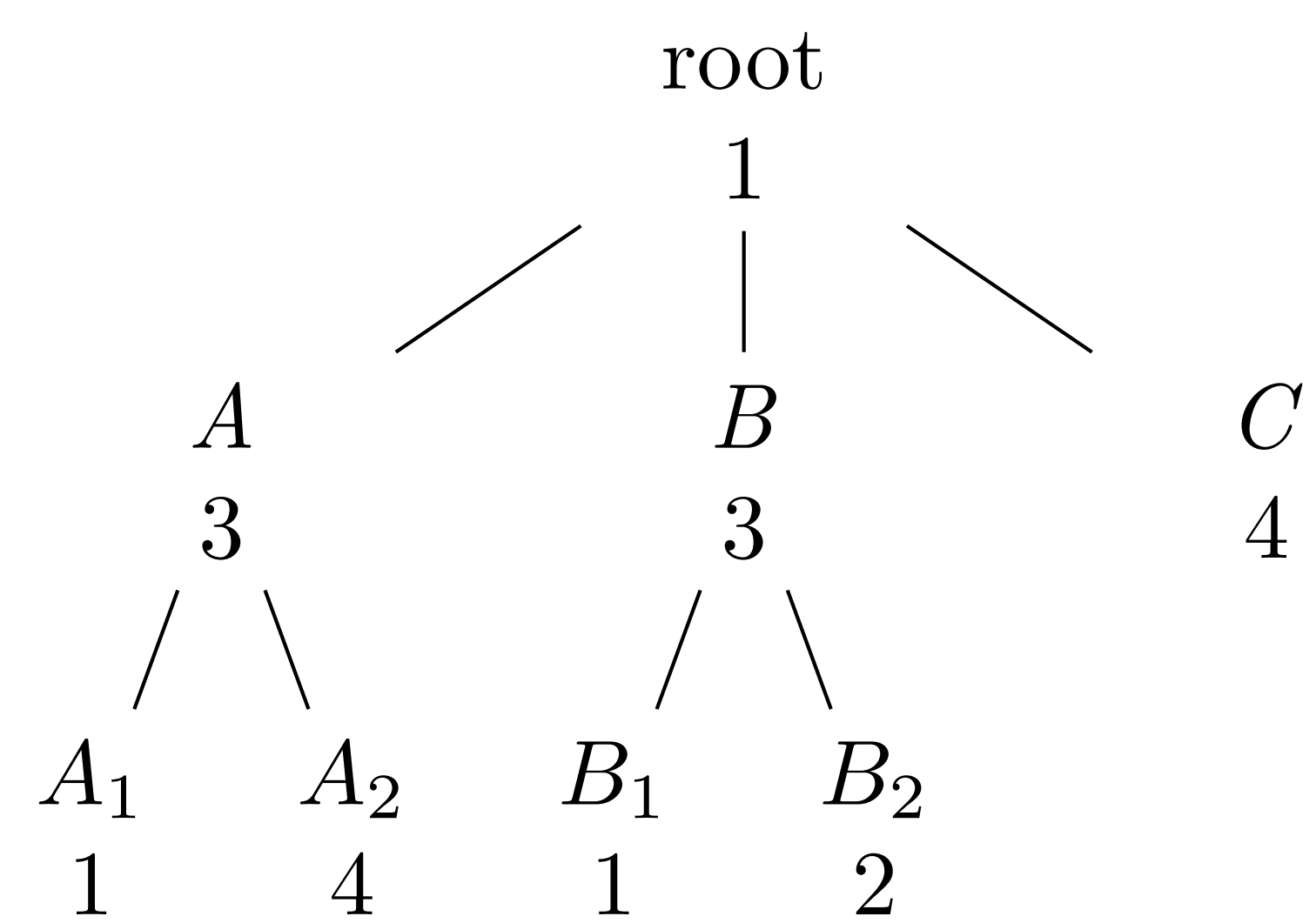


## Goal

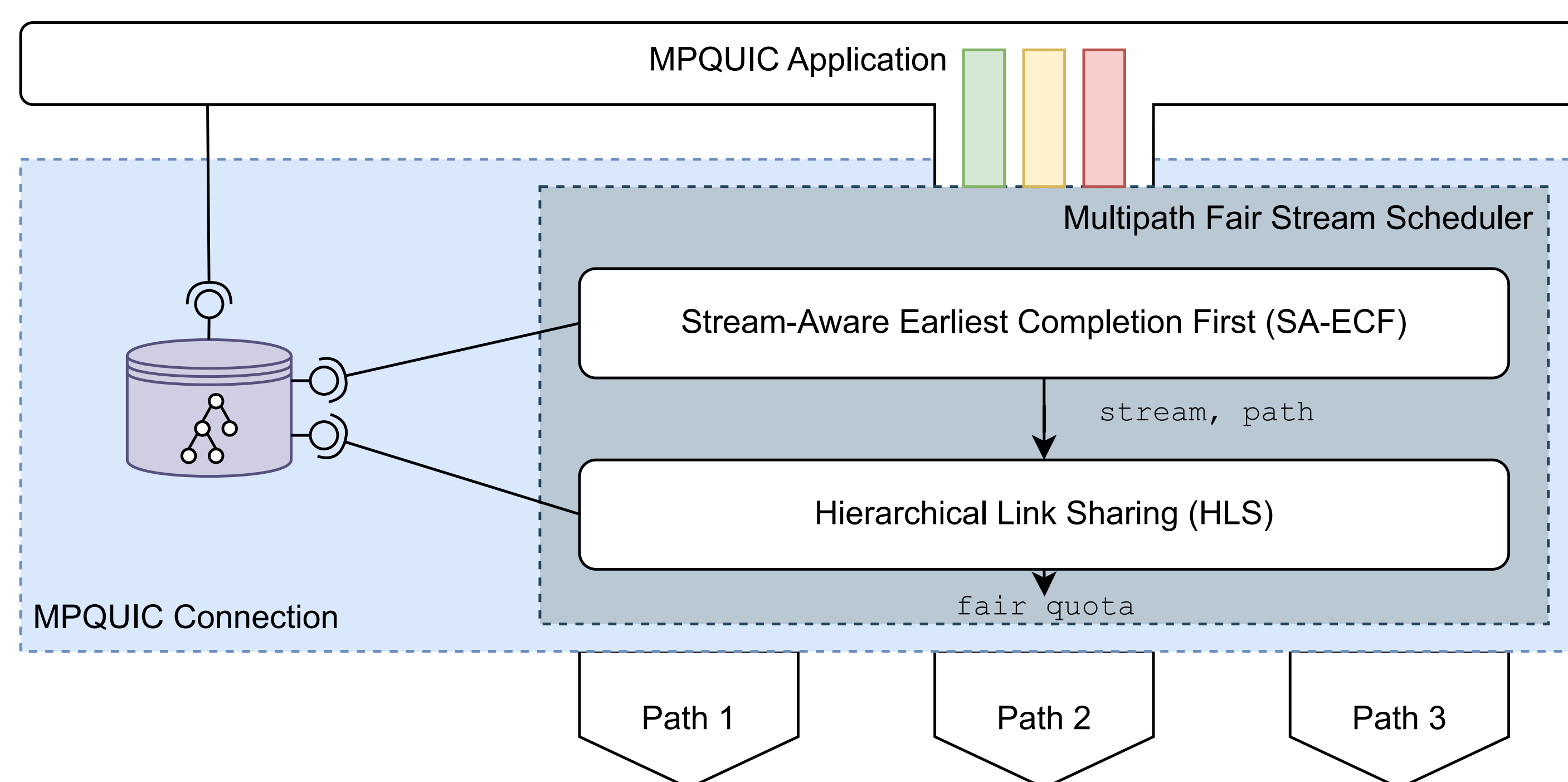
A general-purpose scheduler, enabling

- ▶ strategy-proof minimum rate guarantees
- ▶ fine-grained, provably max-min fair allocations
- ▶ *hierarchical* prioritization mechanisms

to meet modern application demands under path heterogeneity



## Architecture and Implementation



### Stream scheduler: Hierarchical Link Sharing [1]

- ▶ classful qdisc, ported to QUIC
- ▶ application protocol-agnostic
- ▶ unused bandwidth re-distributed to unsatisfied classes

### Path scheduler: Stream-Aware Earliest Completion First [3]

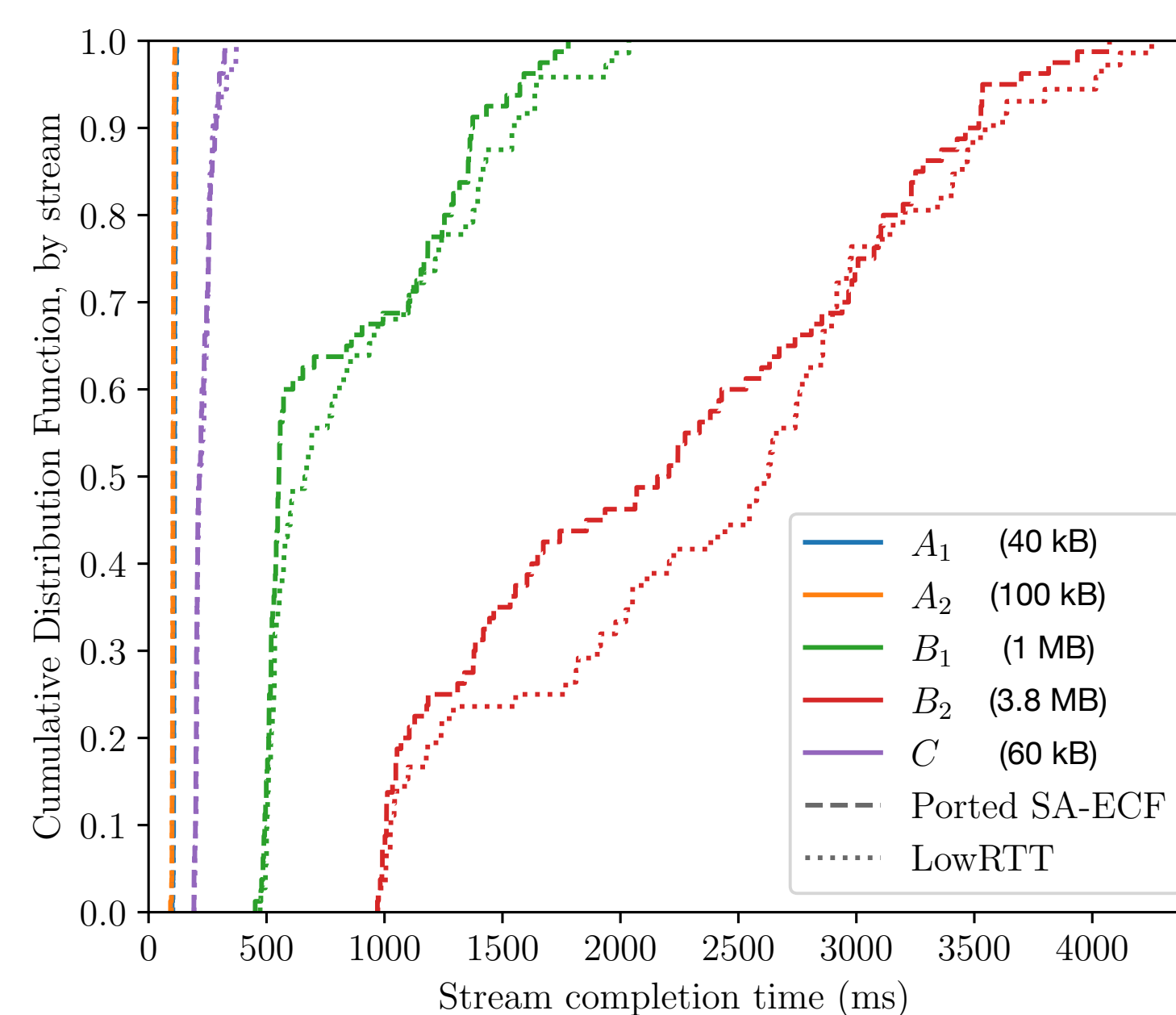
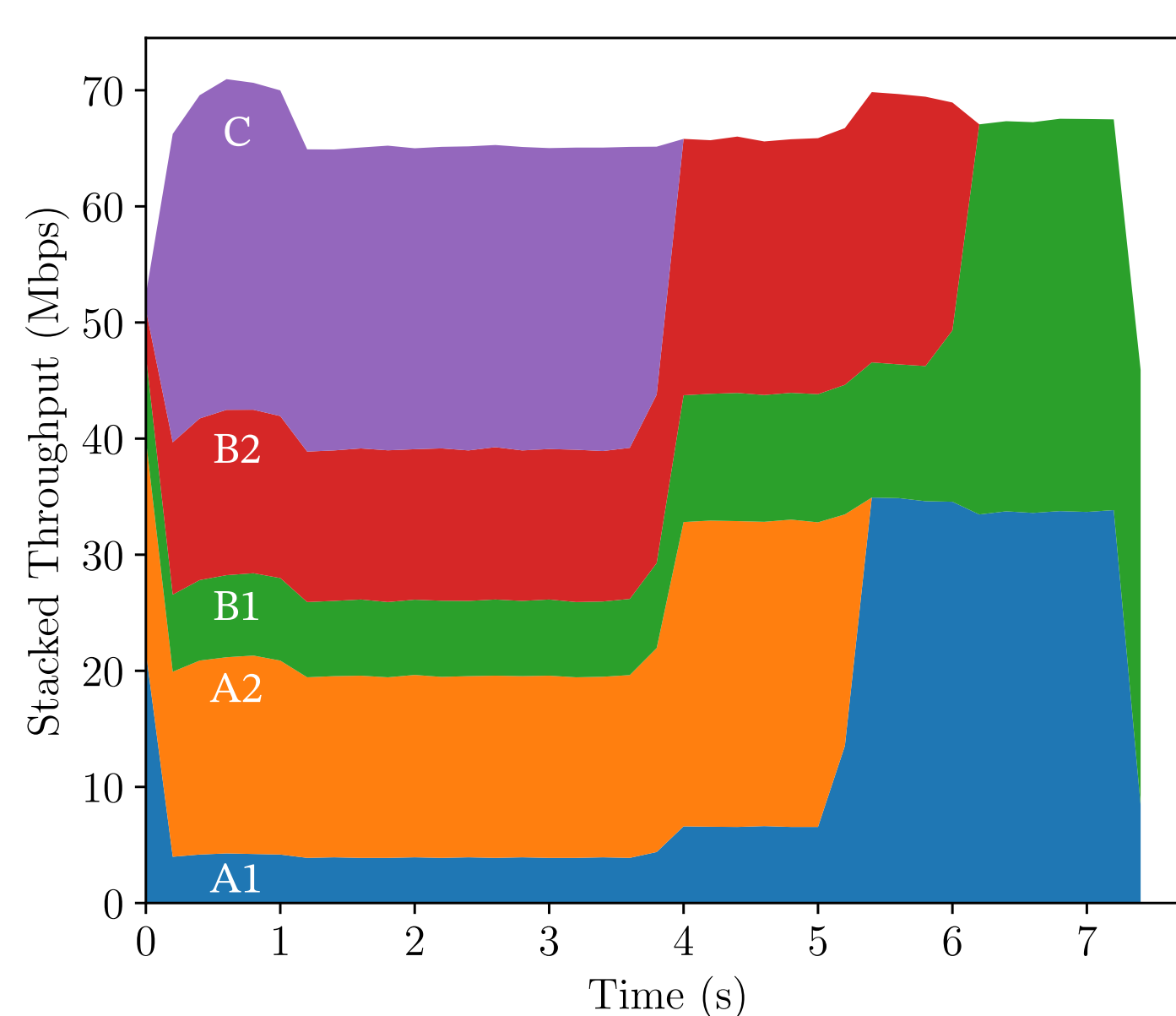
- ▶ per-stream completion time estimates over different paths
- ▶ slower path not used if the stream would be delayed

Integrated into Cloudflare's open-source QUIC library quiche

## Evaluation of HTTP/3 Transmission Scenarios

### Singlepath Bulk Traffic with five 100 Mbit files

- ▶ Isolated traffic classes
- ▶ Byte-granular
- ▶ Runtime-efficient



### Multipath Web Traffic 100 GETs for a 5 MB page

#### Path characteristics:

- ▶ 50 Mbps, 10ms RTT
- ▶ 10 Mbps, 50ms RTT

Improved path handling  
 ⇒ faster response times

## Limitations

The adapted Stream-Aware ECF scheduler

- ▶ risks poor performance with homogeneous paths
- ▶ is inspired by approaches for Multipath TCP

⇒ opportunities for tailor-made MPQUIC schedulers

## Summary

### Takeaway Messages

- ▶ HLS integrable in QUIC at deployable rates
- ▶ SA-ECF handles path heterogeneity well for web-like traffic

### Outlook

- ▶ Support HLS with the Extensible Prioritization Scheme [2]

[1] N. Luangsomborn and J. Liebeherr. HLS: A packet scheduler for hierarchical fairness. In *2021 IEEE 29th International Conference on Network Protocols (ICNP)*, pages 1–11, 2021.  
 [2] K. Oku and L. Pardue. Extensible Prioritization Scheme for HTTP. RFC 9218, June 2022.  
 [3] A. Rabitsch, P. Hurtig, and A. Brunstrom. A Stream-Aware Multipath QUIC Scheduler for Heterogeneous Paths. In *Proceedings of the Workshop on the Evolution, Performance, and Interoperability of QUIC, EPIQ'18*, page 29–35, New York, NY, USA, 2018. Association for Computing Machinery.