

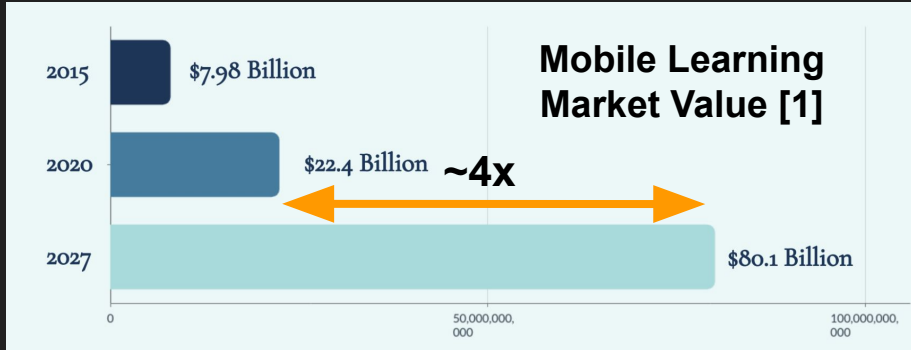


COMPACT: Content-aware Multipath Live Video Streaming for Online Classes using Video Tiles

Shubham Chaudhary, Navneet Mishra, Keshav Gambhir, Tanmay Rajore,
Arani Bhattacharya, Mukulika Maity

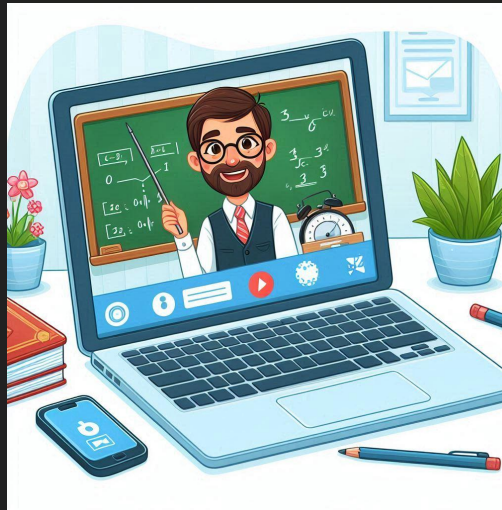
Indraprastha Institute of Information Technology Delhi (IIITD), India

Increasing Popularity Of Online Learning



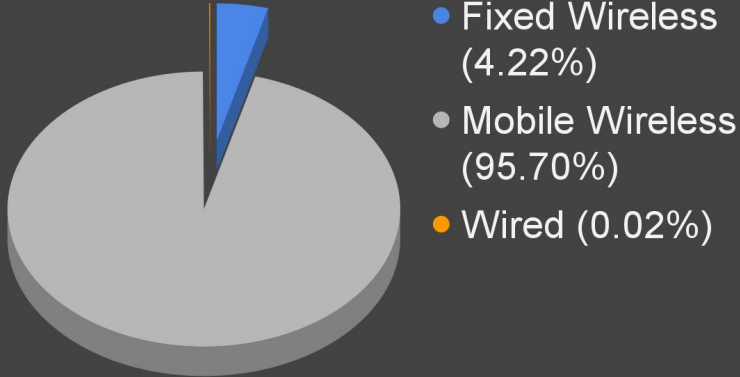
Requires consistently high bandwidth.

Live streaming plays a vital role in online learning.



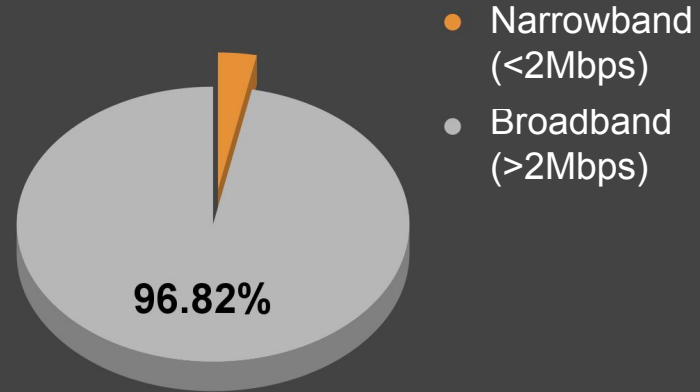
Can Current Cellular Network Serve Live Streaming?

Internet Subscriptions



Approx. 95% internet users in India rely on cellular network [1].

Broadband vs. Narrowband Users



30.34 million users (3.18%) have <2Mbps speed [1].

Zoom recommends having at least 2.6Mbps for group meeting [2].

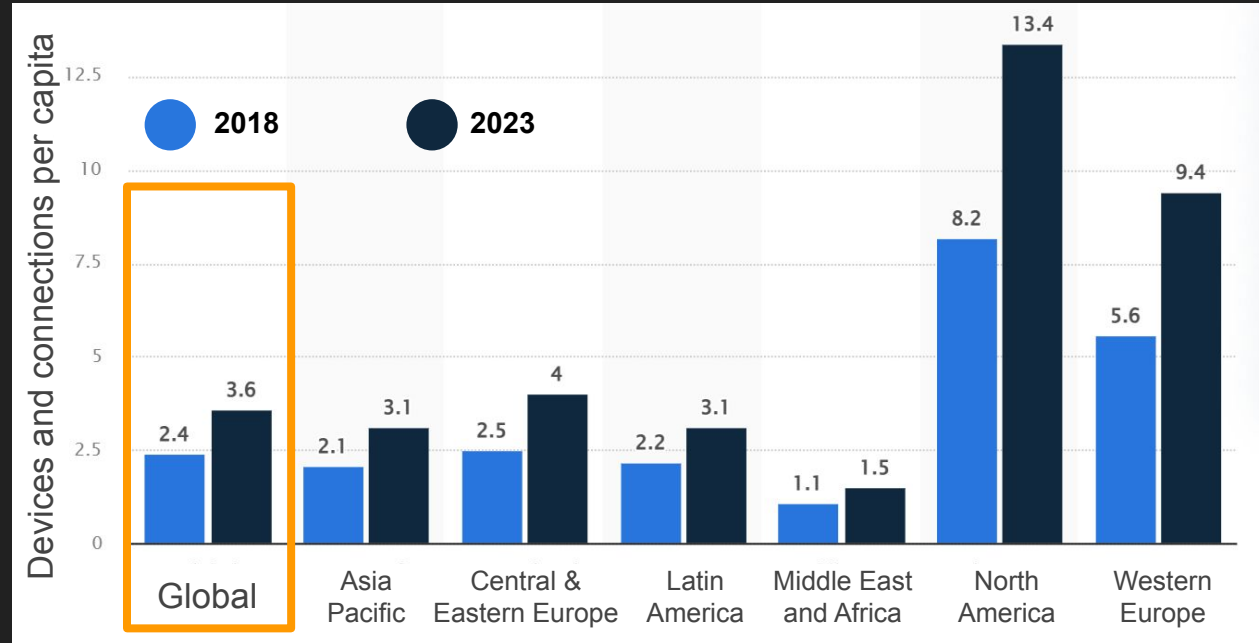
[1] TRAI: Telecom Regulatory Authority of India

[2] Zoom

People Use Multiple Devices



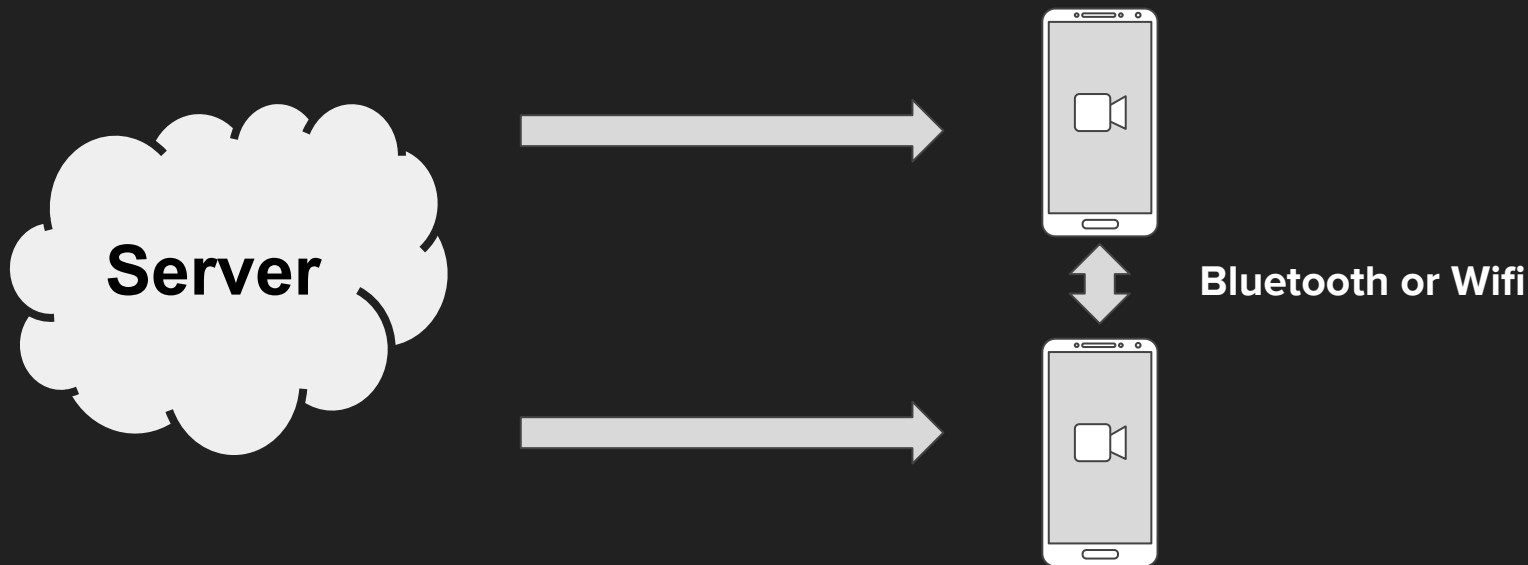
Source: <https://www.quinolanguages.com/knowledgebase/can-install-program-multiple-devices/>



Can we aggregate the bandwidth of multiple devices to improve user QoE (Quality of Experience)?

Collaboration Among Devices

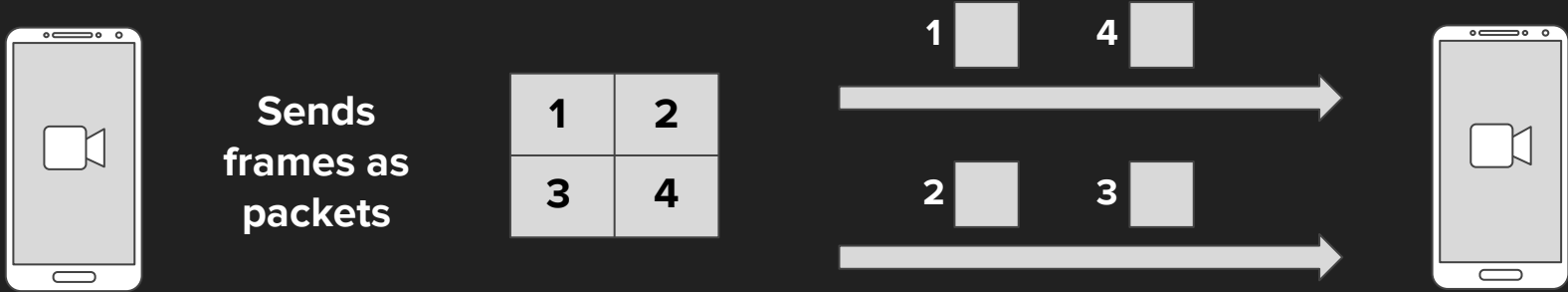
Works like MPBond [1], MicroCast [2], and OASIS [3] use multiple devices at user end to improve file download or video-on-demand streaming.



- [1] MPBond @ MobiSys'20.
- [2] MicroCast @ MobiSys'12.
- [3] OASIS @ MMSys'24

Using Multipath For Real-time Video Streaming

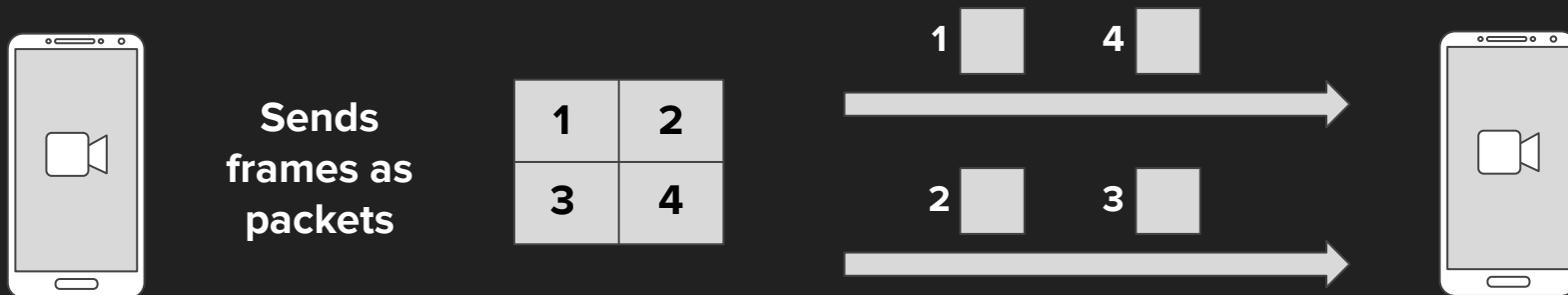
1. Converge [1] uses multipath for video conferencing and uses frame-aware scheduling.



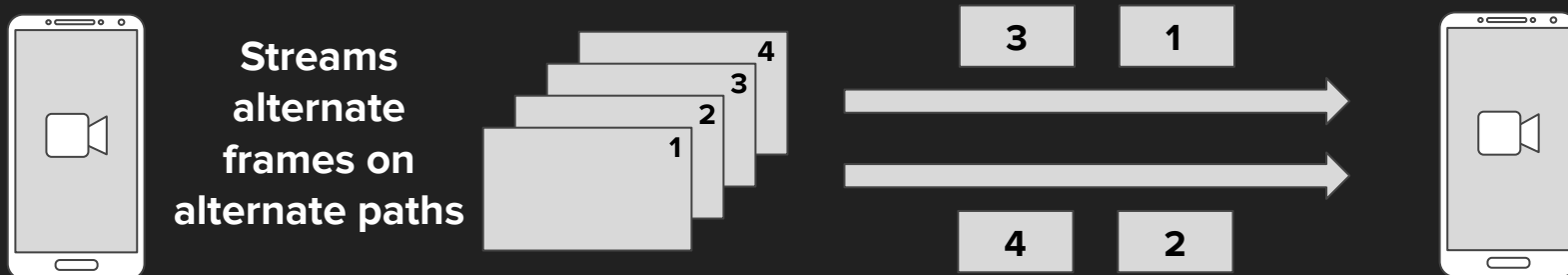
[1] Converge @ SIGCOMM'23

Using Multipath For Real-time Video Streaming

1. Converge [1] uses multipath for video conferencing and uses frame-aware scheduling.



2. TwinStar [2] improves cloud gaming by scheduling consecutive frames on different paths.

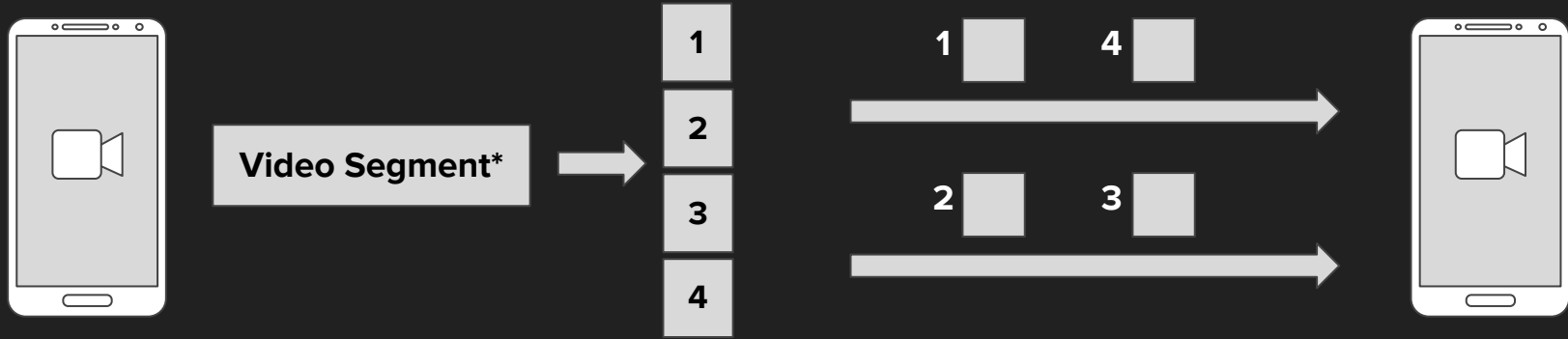


[1] Converge @ SIGCOMM'23

[2] TwinStar @ MM'23

Using Multipath For Real-time Video Streaming

3. AggDeliv [1] and XLINK [2] use multipath for video delivery using Multipath QUIC protocol.



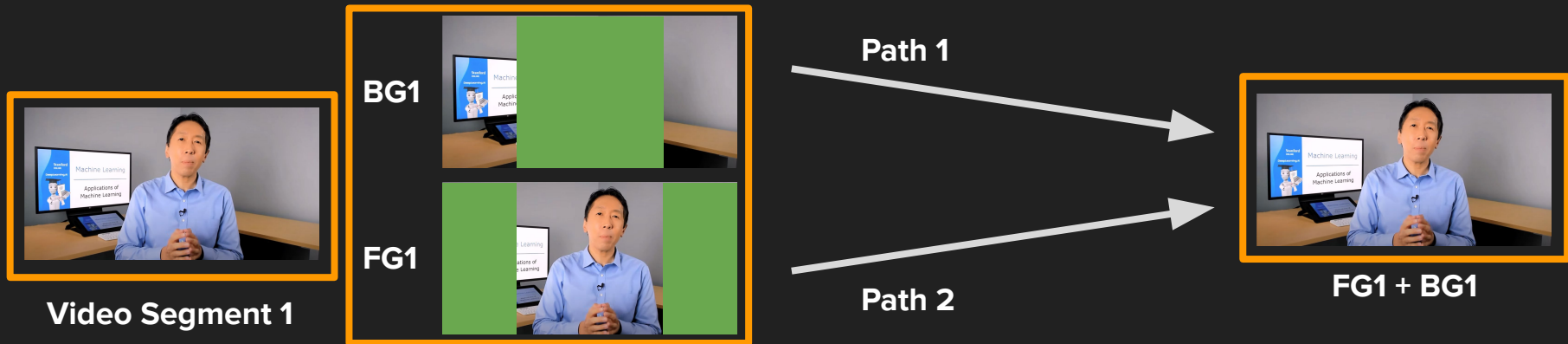
All of these prior works are content oblivious.
Therefore, cannot eliminate Head-of-Line Blocking.

[1] AggDeliv @ INFOCOM'24

[2] XLINK @ SIGCOMM'21

*A bunch of encoded frames are called video segment.

Why Do We Need Content Awareness?

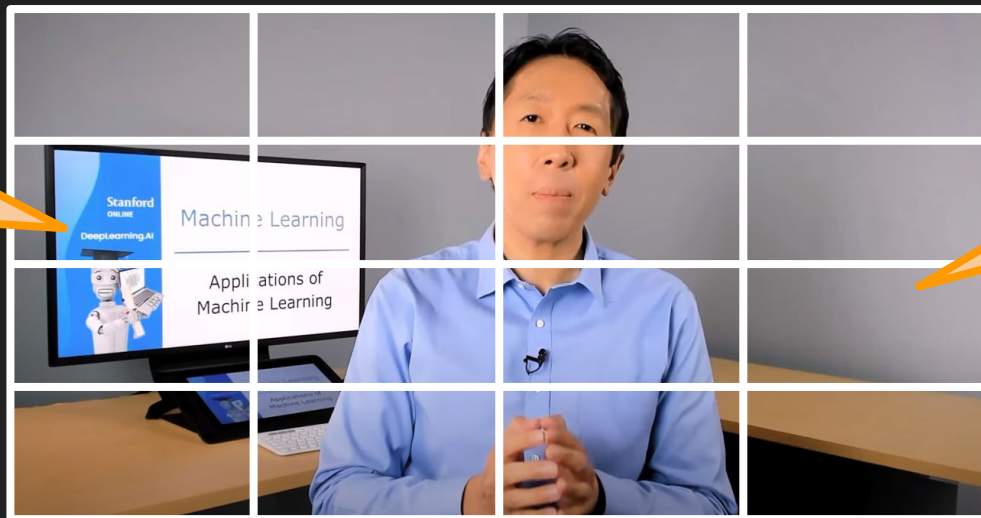


Content-awareness helps in encoding spatial content at different qualities.

We used binary choice as currently smartphones have only two (WiFi & cellular) high bandwidth interface.

Idea 1: Video Tiles Can Help In Spatial Segregation

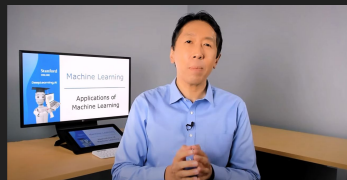
They act as independent video streams



Tiles are spatial rectangular blocks

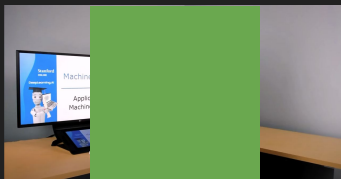
We propose to use content-aware multipath live streaming using video tiles.

How To Schedule Tiles?

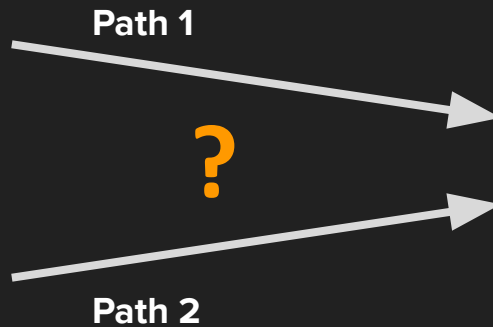
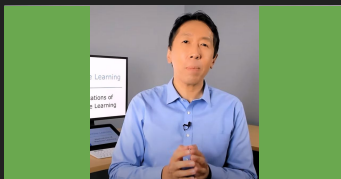


Video Segment 1

BG1

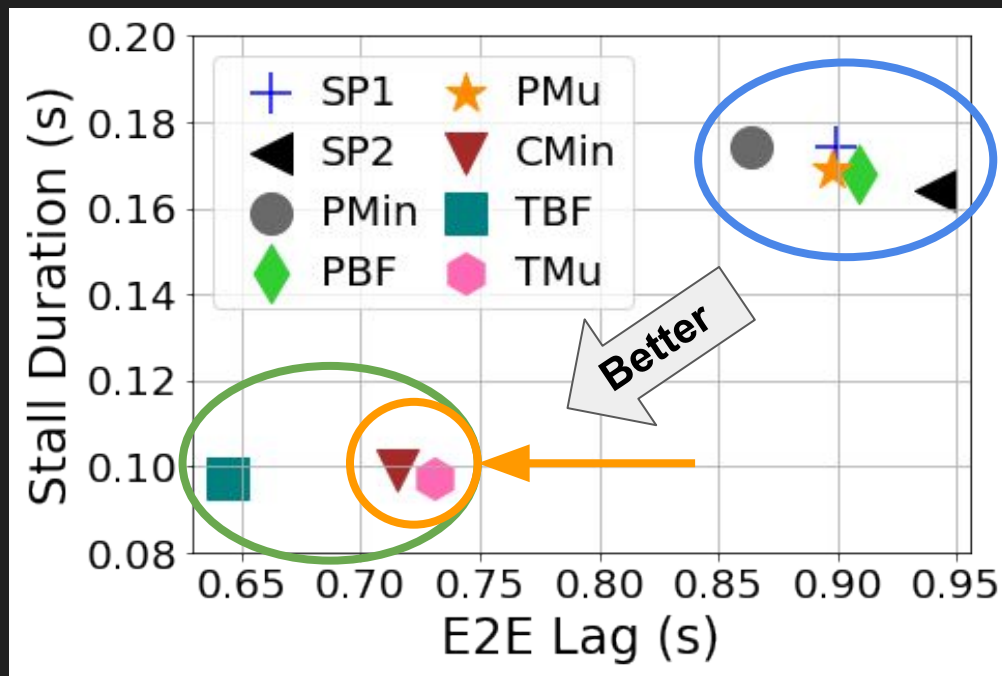


FG1



FG1 + BG1

How Good Are Conventional Schedulers?



SP1 : Singlepath 1

SP2 : Singlepath 2

PMin : Non-tile minRTT

PBF : Non-tile balanced flow

PMu : Non-tile Musher

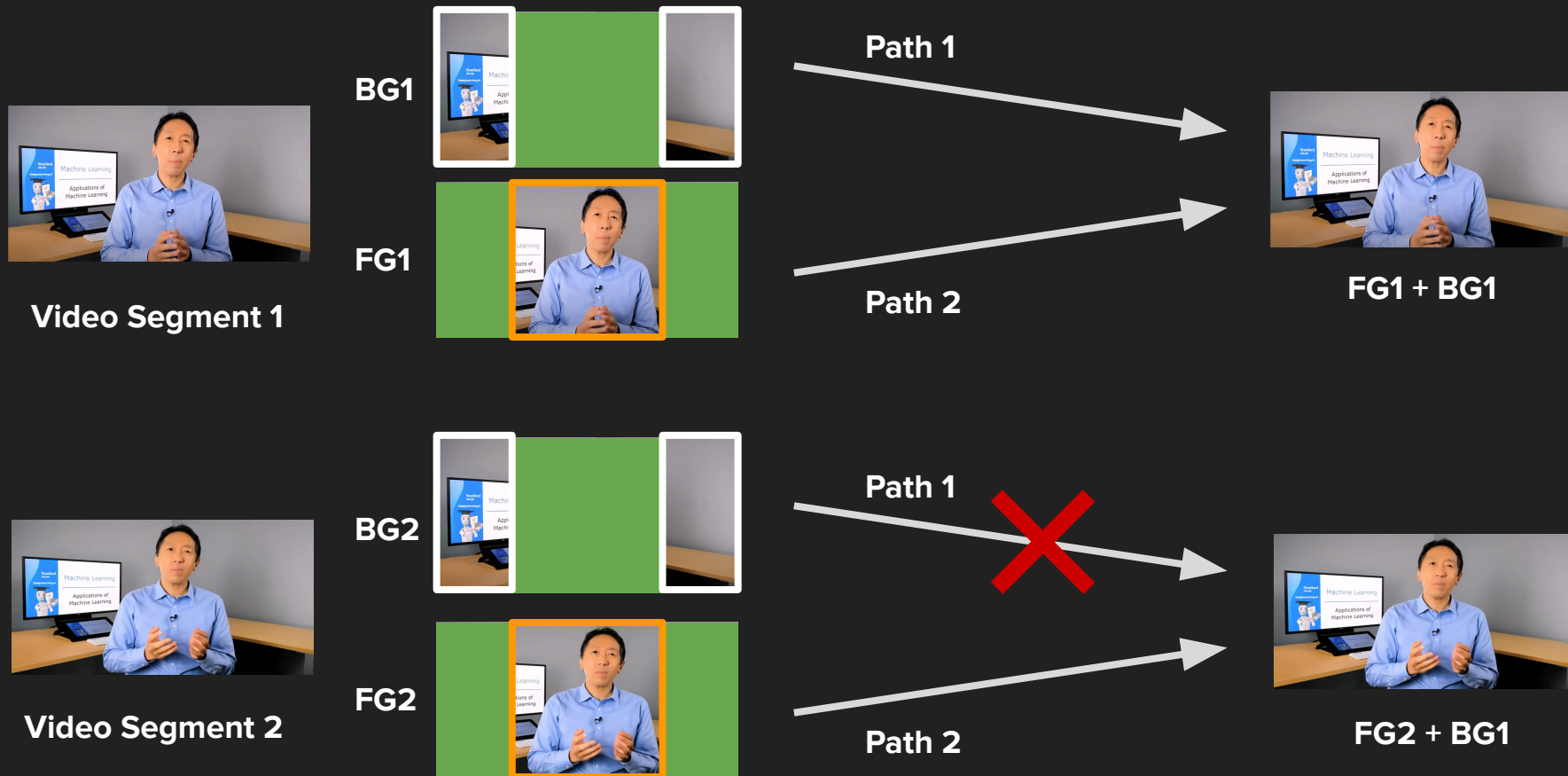
TBF : Tile-level balanced flow

TMu : Tile-level Musher

CMin : Content-aware minRTT

Conventional schedulers fail to adapt to the path heterogeneity.

Idea 2: Possible To Render Spatial Content Out-of-order



Our Scheduler



Quality



Intra Segment Quality



Inter Segment Quality

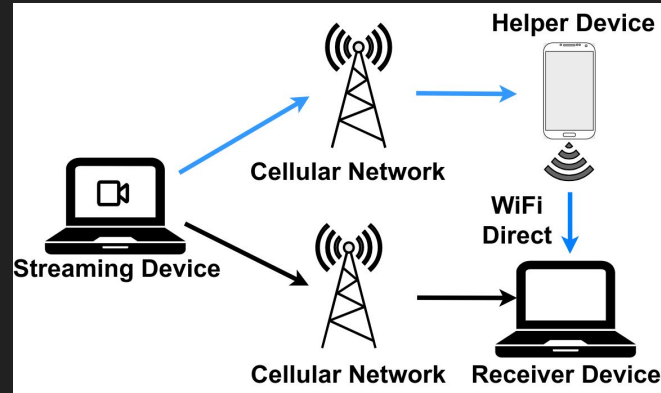


Stall Duration

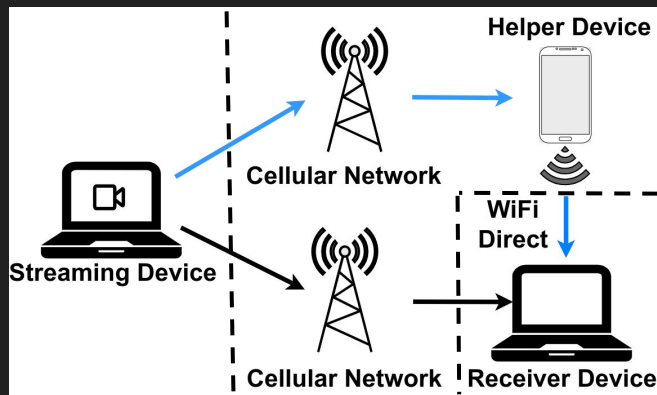
$$\text{Maximize Utility} = \alpha_1 \text{Quality} - \alpha_2 \text{InterSegment Quality Switch} - \alpha_3 \text{IntraSegment Quality Switch} - \alpha_4 \text{Stall}$$

We exhaustively search for the right values.

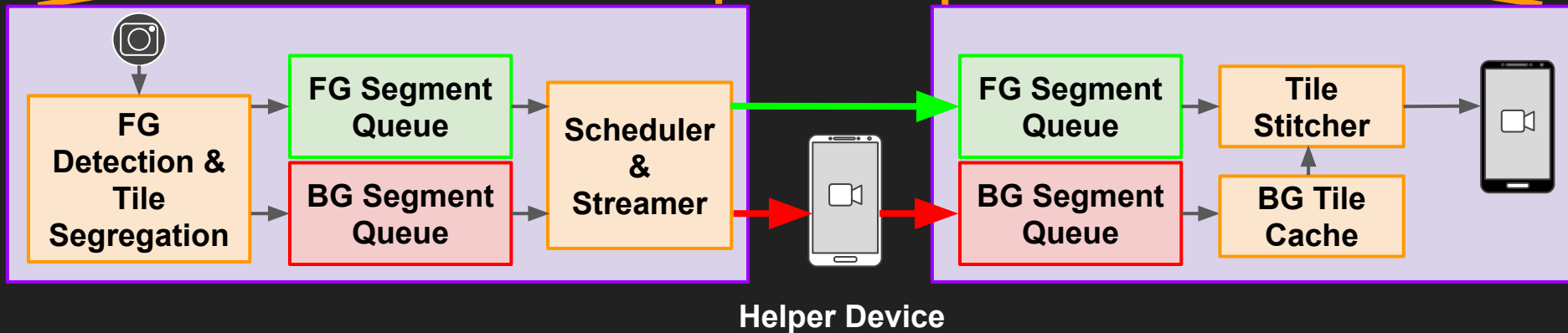
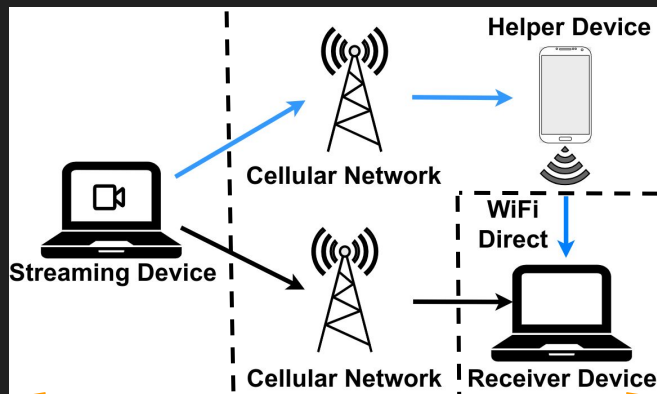
COMPACT: Content-aware Tile-level Multipath Streaming



COMPACT: Content-aware Tile-level Multipath Streaming



COMPACT: Content-aware Tile-level Multipath Streaming



Brief Implementation Details

COMPACT is implemented in Java.

We use a pre-trained neural network for foreground detection.

We use Kvazaar and GPAC for tiled video encoding with 4x4 tiles in all experiments.

COMPACT utilizes SCTP transport protocol for streaming (intend to look into QUIC).

We run SOCAT (a Linux tool) at the helper to relay tiles to primary device.

Evaluation Dataset And Metrics



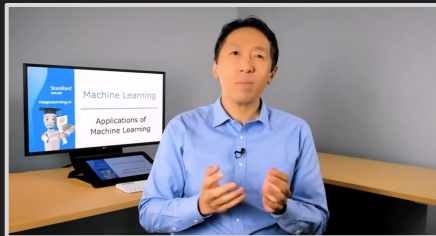
Video 1

Has two instructors with simple background.



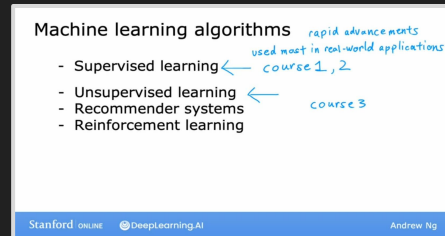
Video 2

Has one instructor with a complex background.



Video 3

Instructor with animation in between.



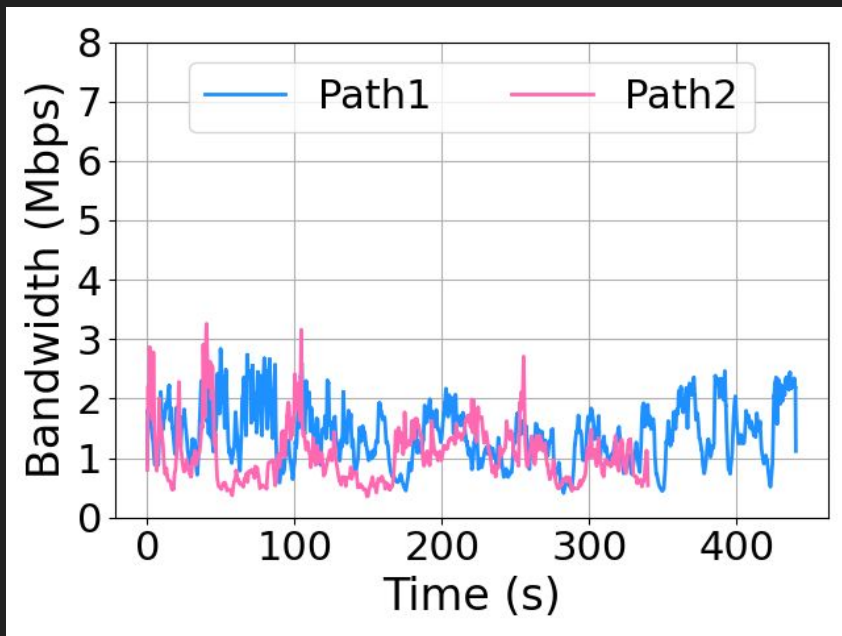
Video 4

Contains slides with instructor popping in between.

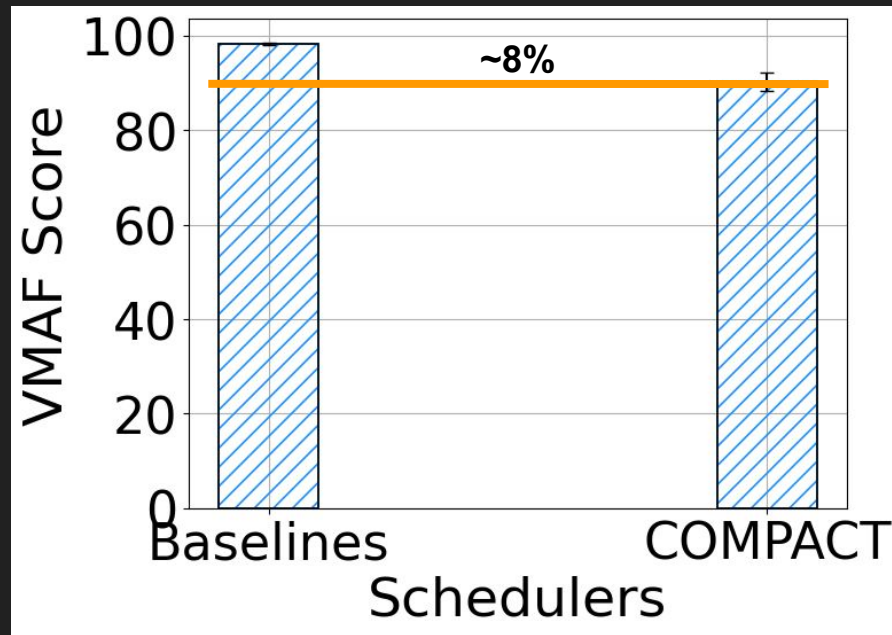
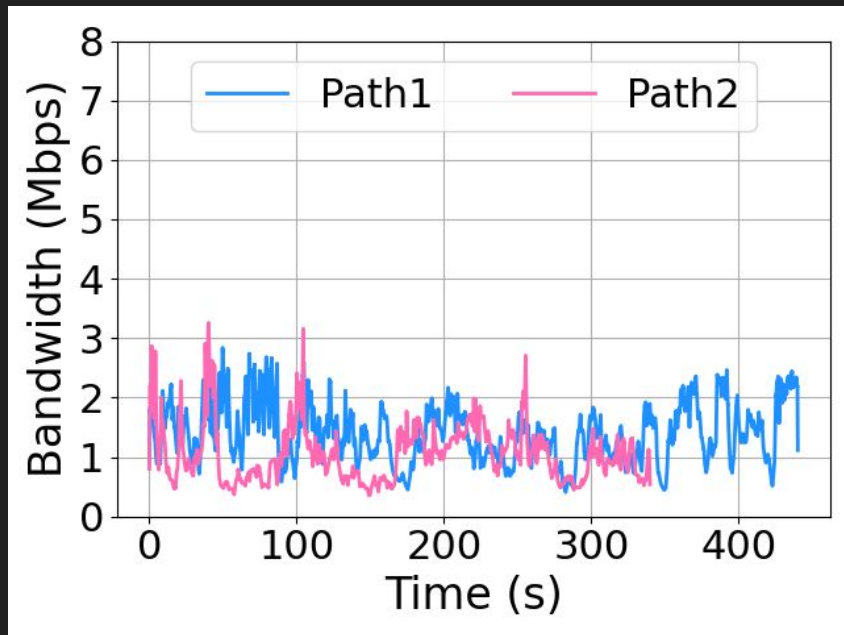
Evaluation Metrics:

1. Application level **end-to-end lag**.
2. **Stall duration** between two consecutive video segments.
3. **VMAF score** for perceived quality.

Evaluated Under Diverse Conditions Using Traces



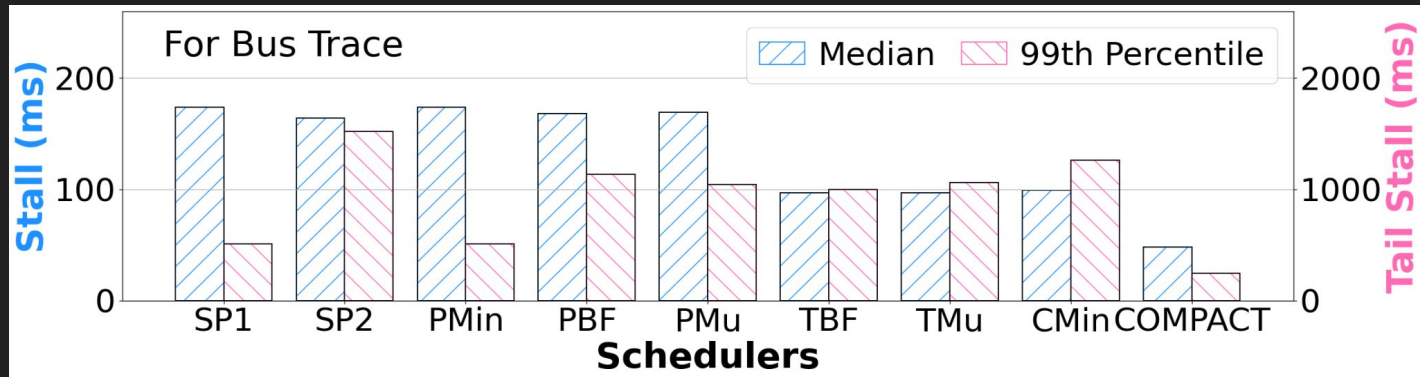
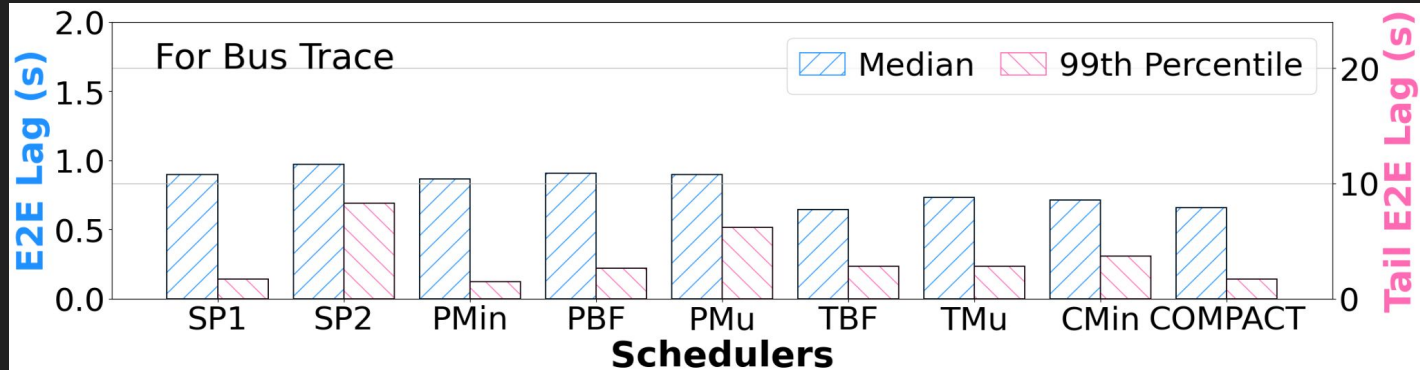
Perceived Quality



Out-of-order stitching degrades VMAF score marginally.

End-to-End Lag And Stall

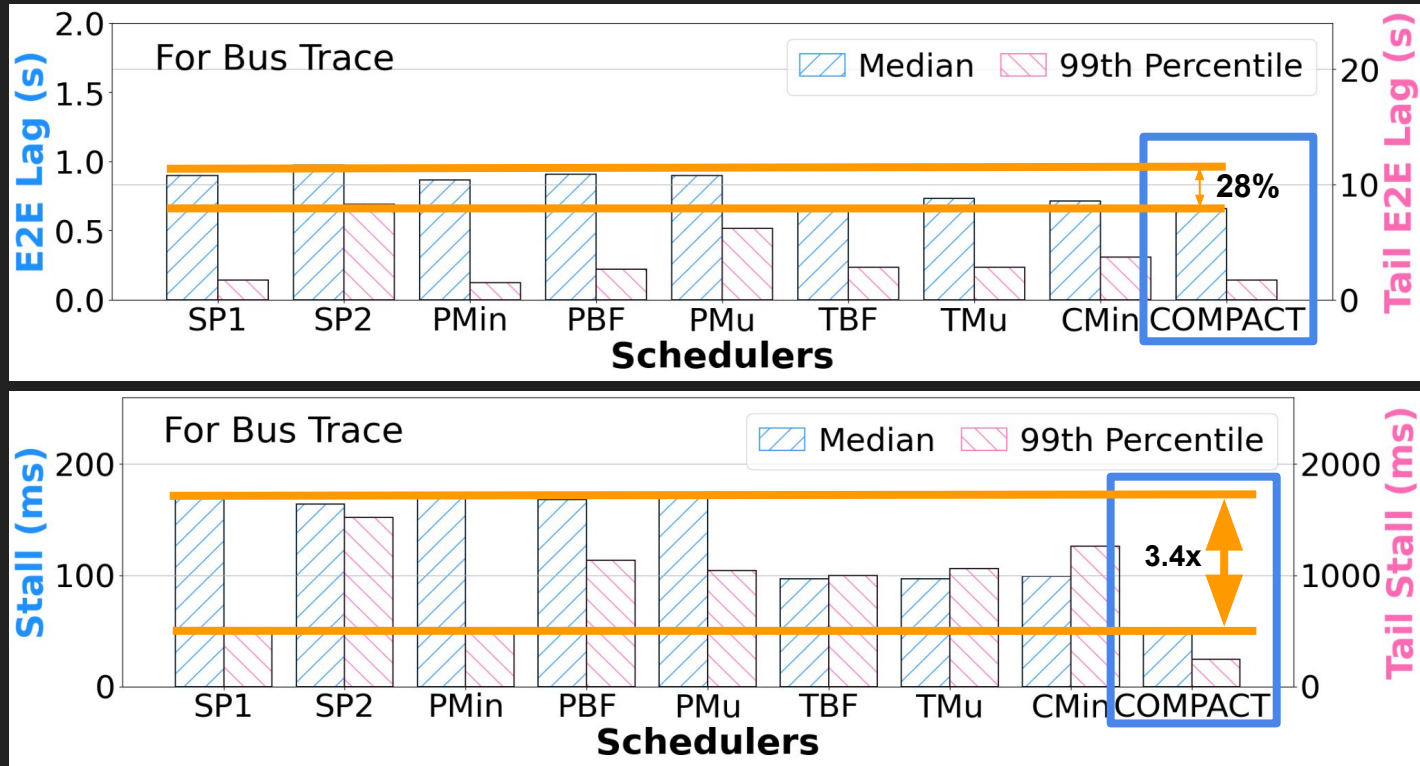
SP1 : Singlepath 1
SP2 : Singlepath 2
PMin : Non-tile
minRTT
PBF : Non-tile
balanced flow
PMu : Non-tile
Musher
TBF : Tile-level
balanced flow
TMu : Tile-level
Musher
CMin : Content-aware
minRTT



COMPACT significantly improves median and tail E2E lag and stall.

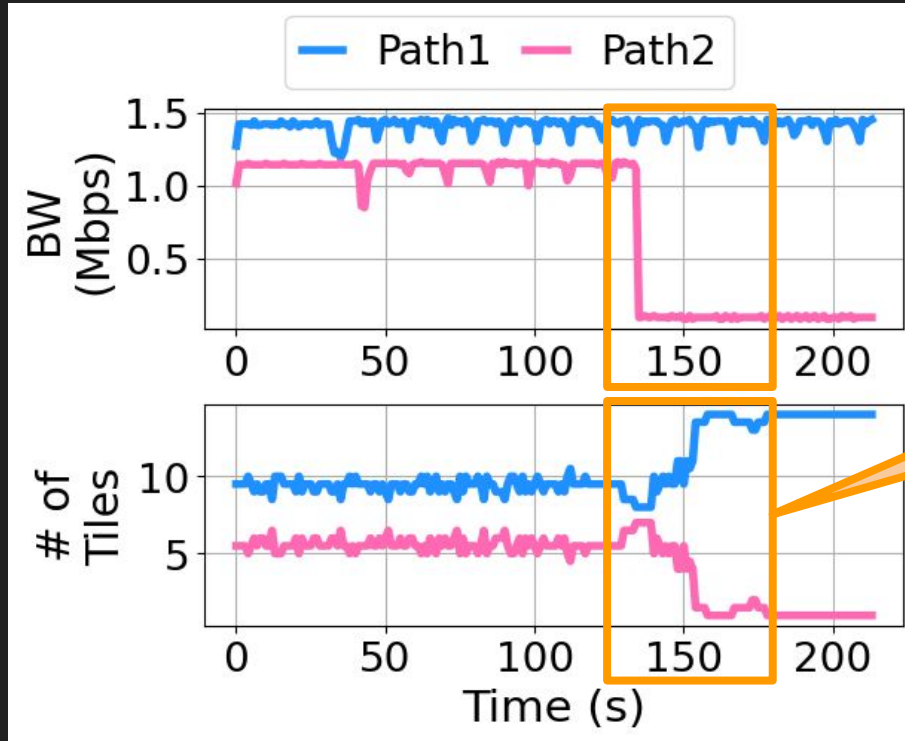
End-to-End Lag And Stall

SP1 : Singlepath 1
SP2 : Singlepath 2
PMin : Non-tile
minRTT
PBF : Non-tile
balanced flow
PMu : Non-tile
Musher
TBF : Tile-level
balanced flow
TMu : Tile-level
Musher
CMin : Content-aware
minRTT



COMPACT significantly improves median and tail E2E lag and Stall.

Adaptability To Path Fluctuations



Detects heterogeneity and adapts

COMPACT gracefully handles the sudden path fluctuations.

Live Experiment On Cellular Network

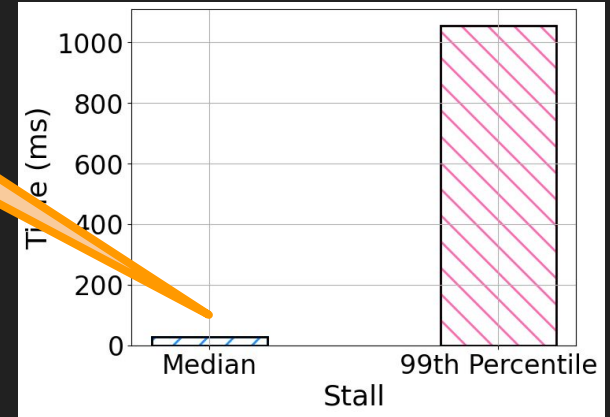


Streamed over 4G Network

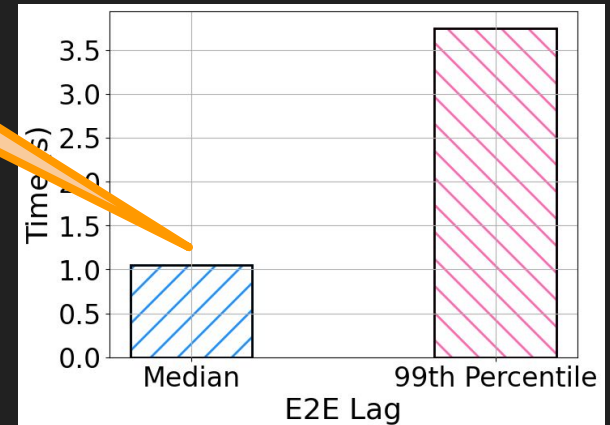
USB Tethered phones network to PCs

Utilized IPv6 addresses to access server

28ms

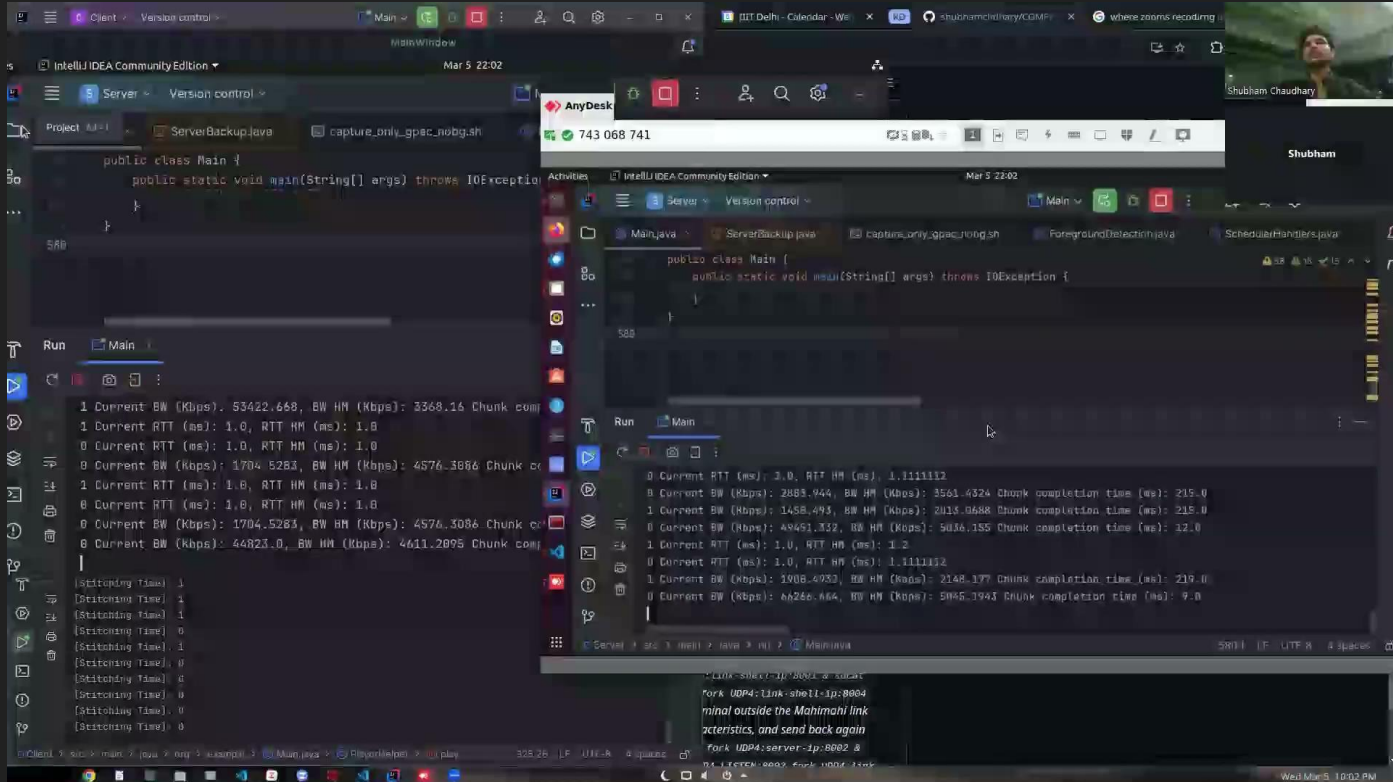


Approx.
1s



Short Demo Of COMPACT

Player



Streamer

Summary of COMPACT

With people using multiple devices nowadays, multiple paths can improve user QoE.

We found tile-based multi-device streaming can be a better technique.

We propose COMPACT to aggregate the BW of the multiple devices at the user end.

COMPACT reduces median stall and E2E lag by 70.6% and 28.57% on a bus trace compared to single path.

