国立大学法人
九州工業大学

IARIA

IARIA INTERNET2020

Handoff Characterization of Multipath Video Streaming

Kazuya Fujiwara, Shinichi Nagayama,
Dirceu Cavendish, Daiki Nobayashi, Takeshi Ikenaga

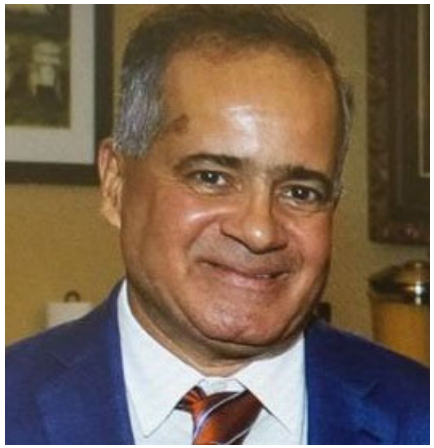
Kyushu Institute of Technology, Japan
{ cavendish@ndrc, nova@ecs, ike@ecs } .kyutech.ac.jp

October 18-22, 2020 - Porto, Portugal (online)

IoTRC Kyushu Institute of Technology

About

- Dirceu Cavendish [IARIA Fellow]

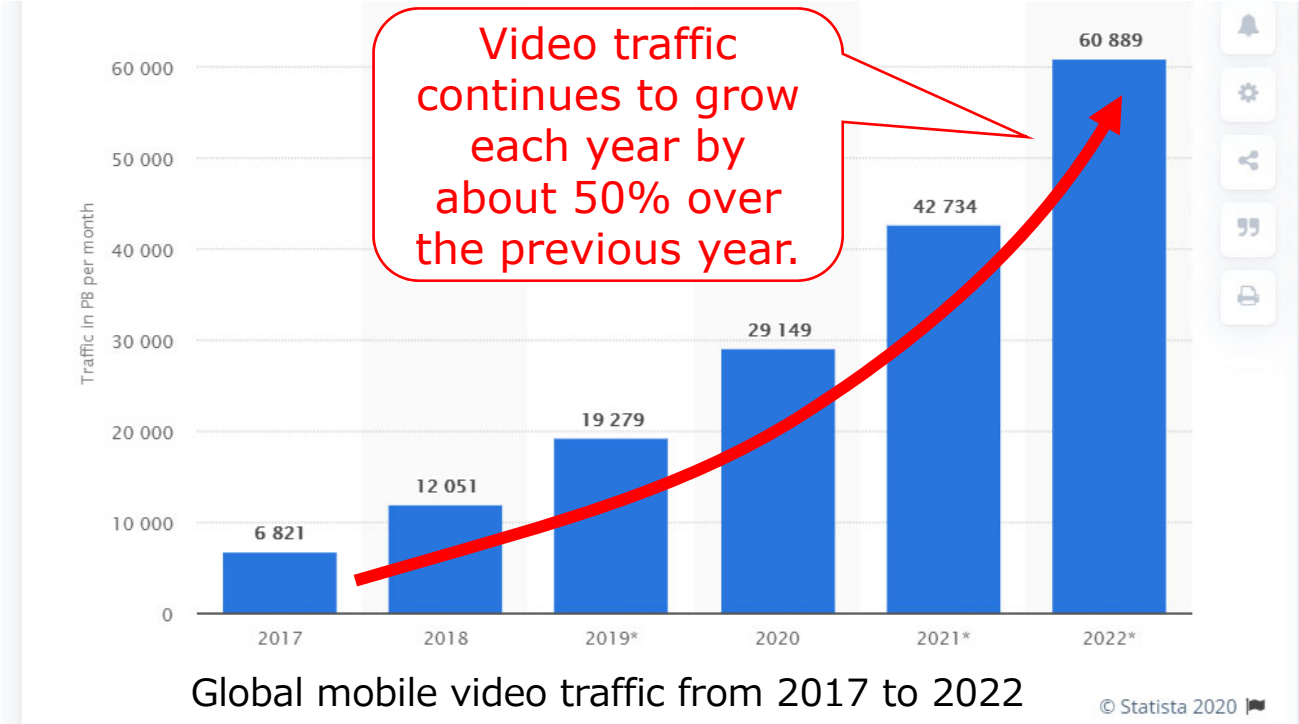


Visiting Professor
Kyushu Institute of Technology
cavendish [at] ndrc.kyutech.ac.jp

Research interests include:
Transport Protocol, IoT, Network Security,
Broadcast and Wireless Systems,
Distributed Computing/Web Services

Introduction

- Video streaming has become the major source of Internet traffic
  - The demand of video streaming has exploded

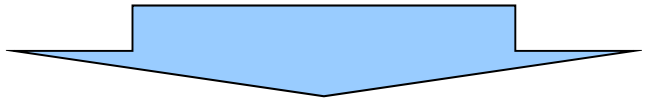


Global mobile video traffic from 2017 to 2022

* https://www.statista.com/statistics/252853/global-mobile-video-traffic-forecast/
* https://www.ncta.com/whats-new/report-where-does-the-majority-of-internet-traffic-come

Video Streaming in Mobile Network

- Mobile Networking
  - High speed and broadband wireless access : 4G/5G/Wi-Fi
  - High frequency bands and small cell : 5GHz/mmW
  - Hybrid of macro-cell and small-cell
- Mobile Devices/Terminals
  - Multiple high speed wireless communication interfaces for the Internet access
  - Switching between multiple interfaces dynamically



- It is effective to use multiple interfaces **simultaneously** for reliable and high quality communications for video applications

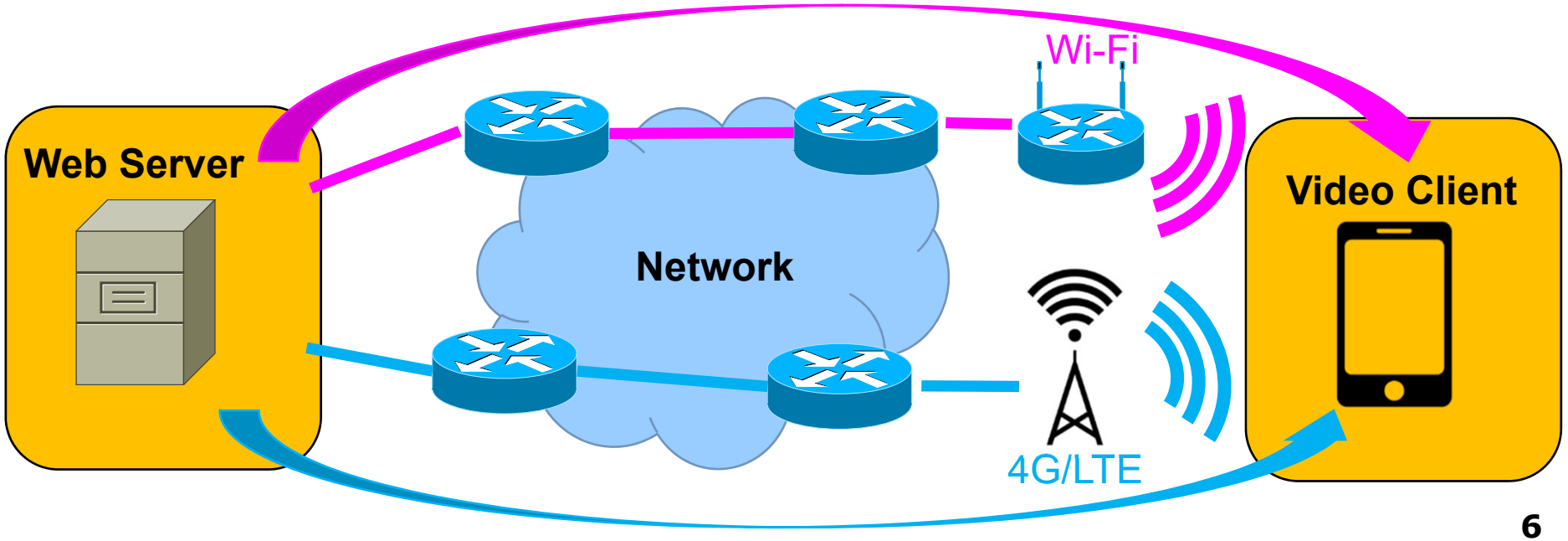
Multipath TCP (MPTCP)

- Newly implemented TCP protocol
  - Use Multiple IP addresses and I/F to deliver data
  - iOS 7 and later version supports MPTCP
- The benefit of MPTCP are that…
  - To provide redundant sessions
  - To increase TCP throughput

MPTCP can improve TCP performance

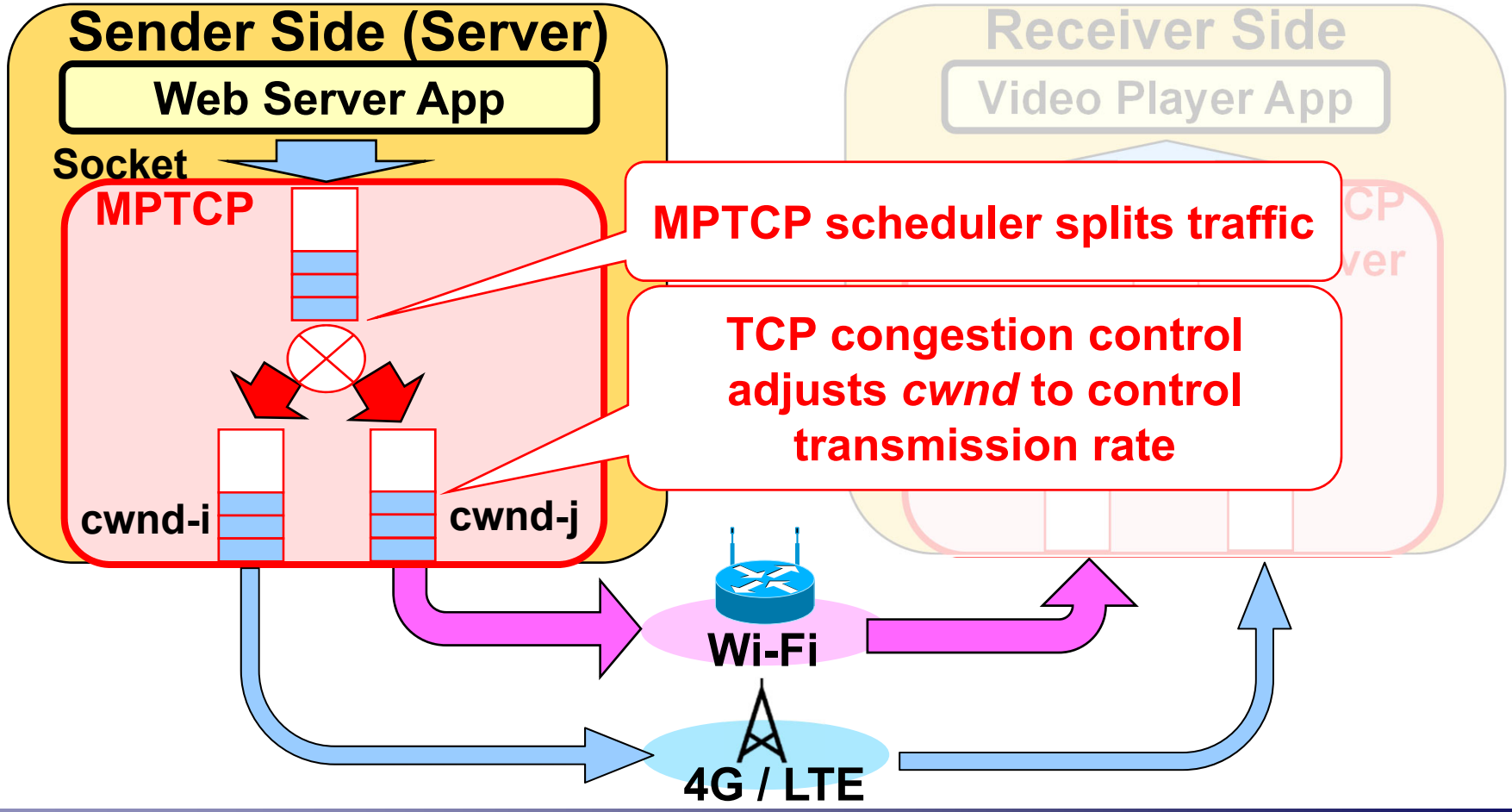
Video Streaming over Multipath TCP

- Web server deliver video data to video client
  - Web server and video client have multiple interfaces and IP addresses.
  - A web server sends video data over multiple interfaces simultaneously.



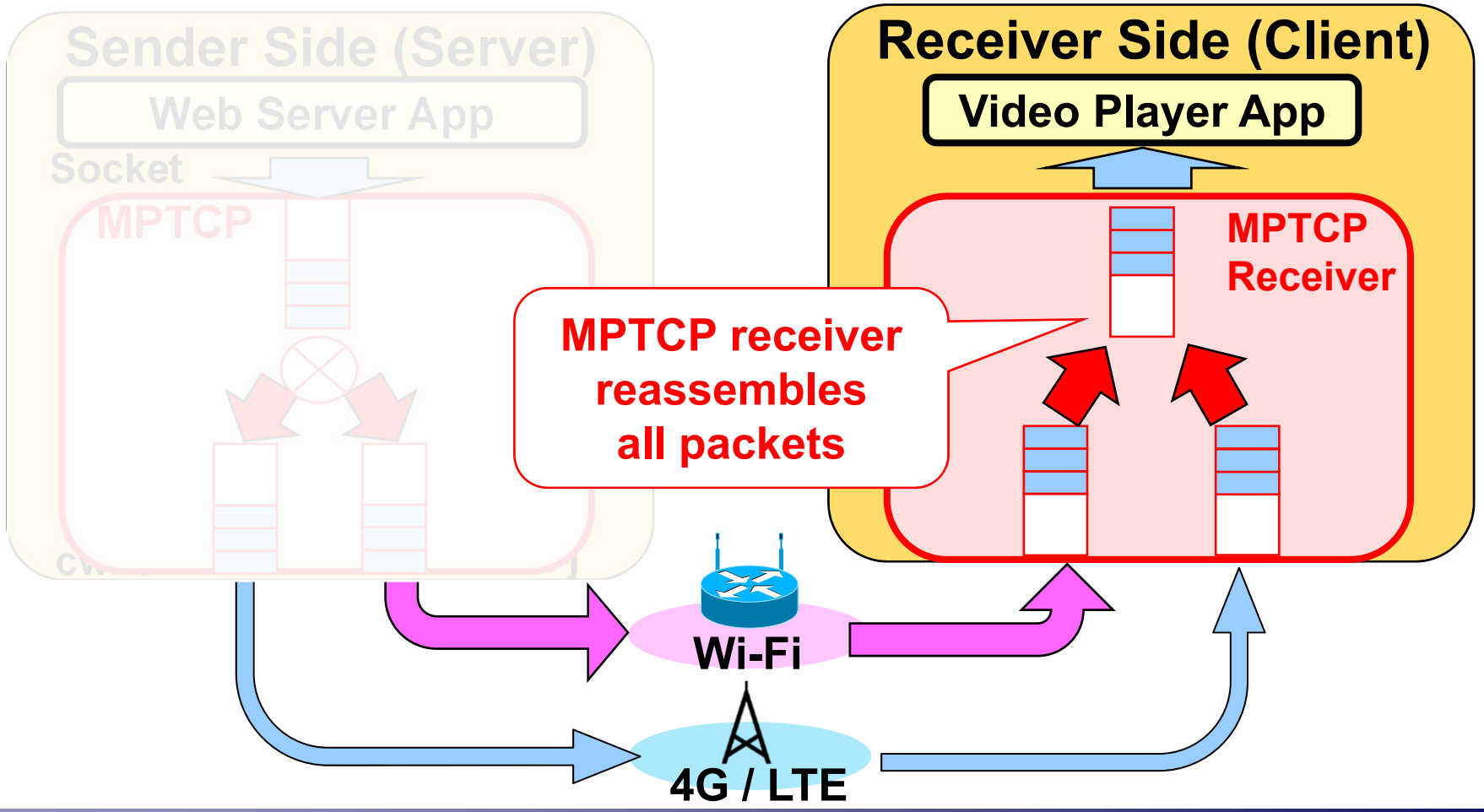
Video Streaming over Multipath TCP

- Web server deliver video data to video client.
  - MPTCP Scheduler splits traffic into multiple path
  - MPTCP congestion controls adjusts *cwnd*



Video Streaming over Multipath TCP

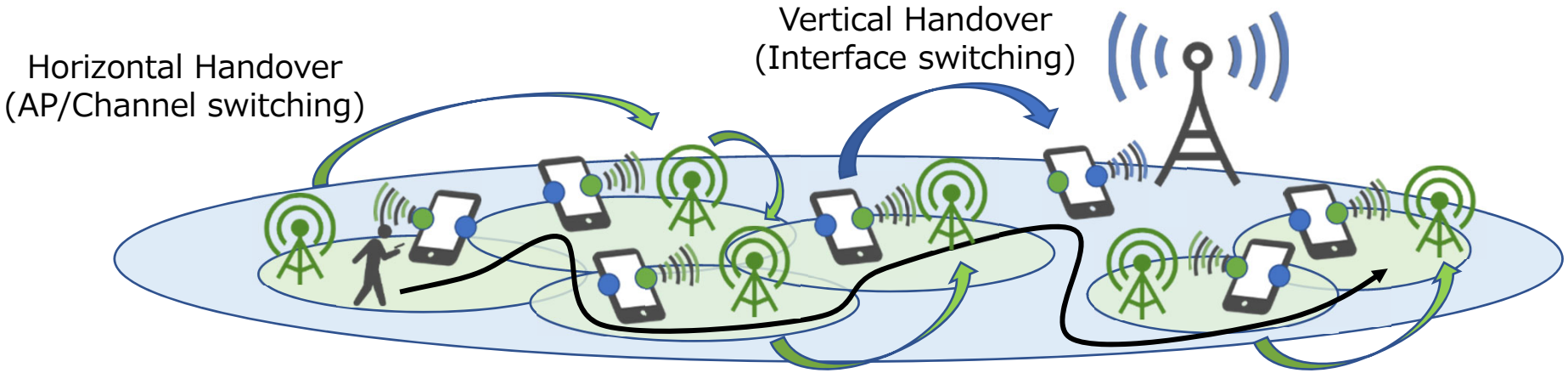
- MPTCP receiver reassembles all packets
- After that, MPTCP delivers data to video client



Recent Mobile Network Environment

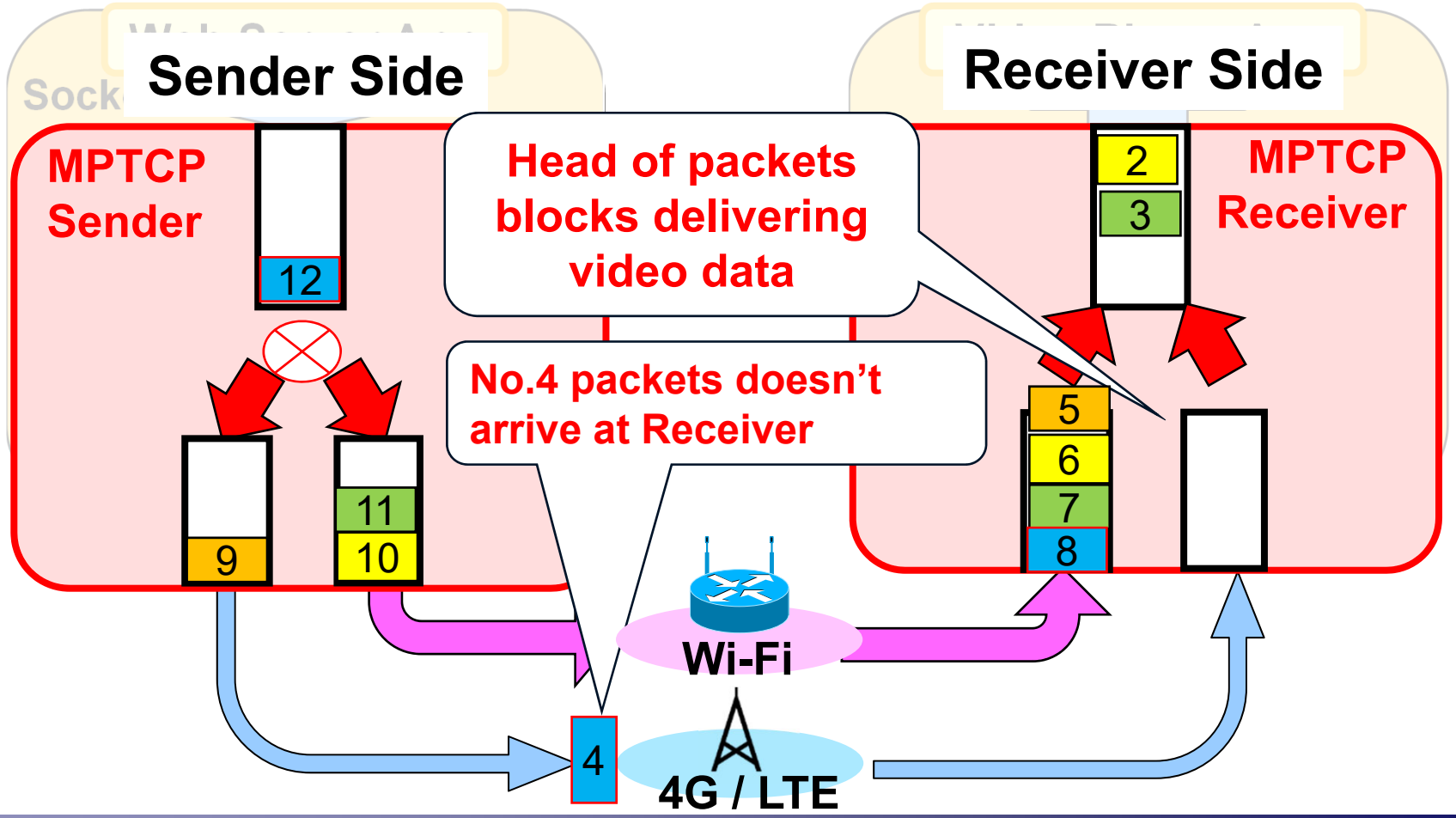
- Small / Hybrid (Macro and Small) cell
  - 4G/LTE , Wi-Fi , 5G (especially mmW New Radio)
  - Around 50-100m radius coverage by single base station
  - Many small cells to cover a wide area

Frequent handover/handoff leads to frequent path switching



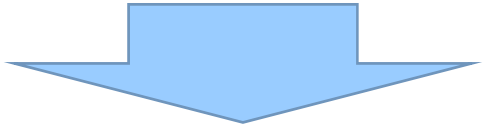
Head-of-Line (HoL) Blocking

- Frequent path switching causes HoL Blocking
  - Because packets do not arrive in order



Objective

- Frequent handoff may causes video performance degradation
  - Because the HoL Blocking is easy to occur, when the path which sends the packet is switched frequently.



- We analyze the impact of handoffs on multipath video streaming and network performance on Wi-Fi and cellular paths.

Performance Evaluation

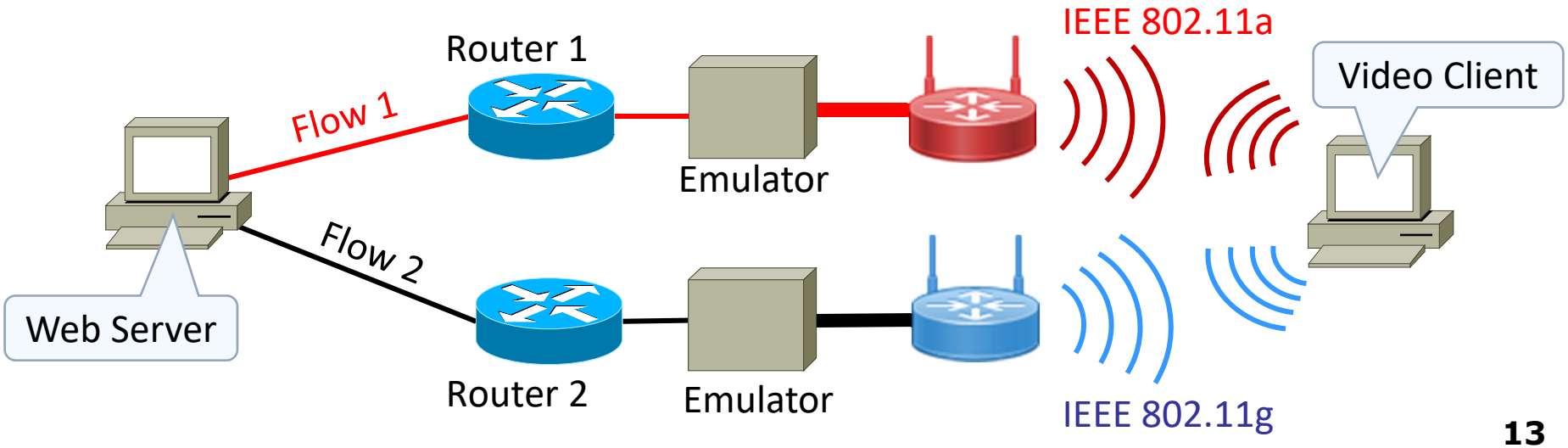
- We evaluate the impact of handoffs on multipath video streaming and network performance on Wi-Fi and cellular paths.

- We utilize network performance measures, as well as video quality metrics, to characterize the performance and interaction between network and application layers of video data for various network scenarios.

Experimental Environment #1

1. Wi-Fi only scenario
   - HTTP Apache video server is connected to two routers
     - access routers are connected to network emulators
   - VLC video client machine is connected to two Wi-Fi APs

Scenario		RTT	BW	Loss Rate
Limited BW	Flow 1 Flow 2	50ms 100ms	6Mb/s	0%
Large BW	Flow 1 Flow 2	50ms 100ms	18Mb/s	0%

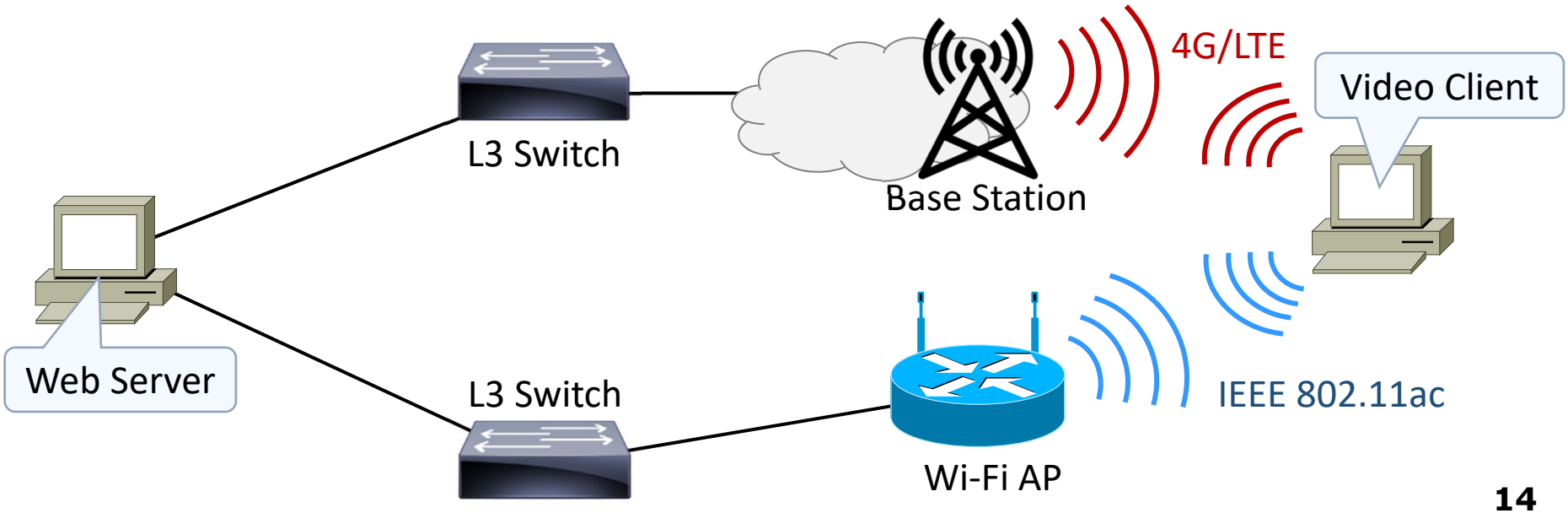


Experimental Environment #2

2. Wi-Fi and Cellular/LTE wireless scenario

- HTTP Apache video server is connected to two L3 switches
  - the one is directly connected to an 802.11ac router
  - the other connected to an LTE base station via a Internet
- VLC video client machine is connected to two wireless links

Scenario		RTT	Bandwidth
Wi-Fi and Cellular	Flow – cellular Flow – Wi-Fi	3.3ms 2.9ms	24Mb/s 433M/s



Video/Network Settings

Table I : Video settings

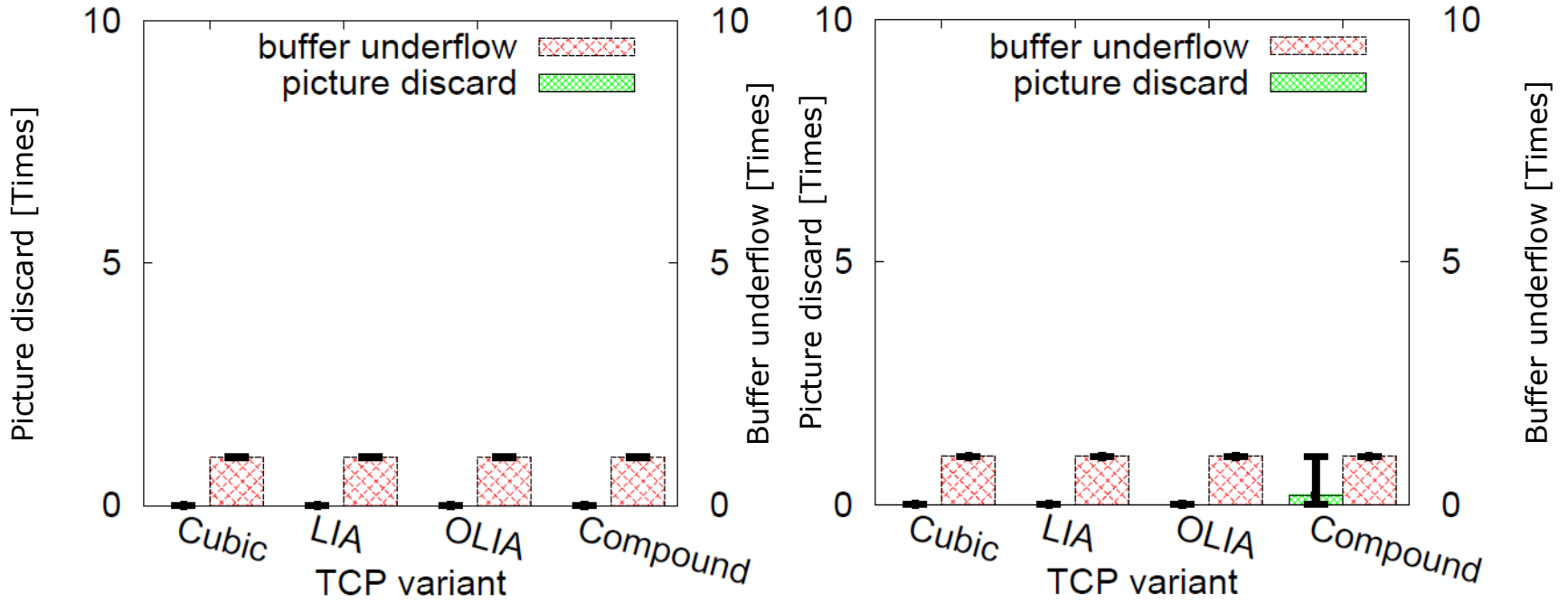
Video Size	409 Mbytes
Video Rate	5.24 Mb/s
Playout time	10mins 24s
Encoding	MPEG-4
Video Codec	H.264/AVC
Audio Codec	MPEG-4 AAC

Table II : MPTCP settings

MPTCP Schedulers	• DFT (Linux Default)

MPTCP Variants	• Uncoupled
	  • Compound
	  • Cubic
	• Coupled
	  • LIA
	  • OLIA

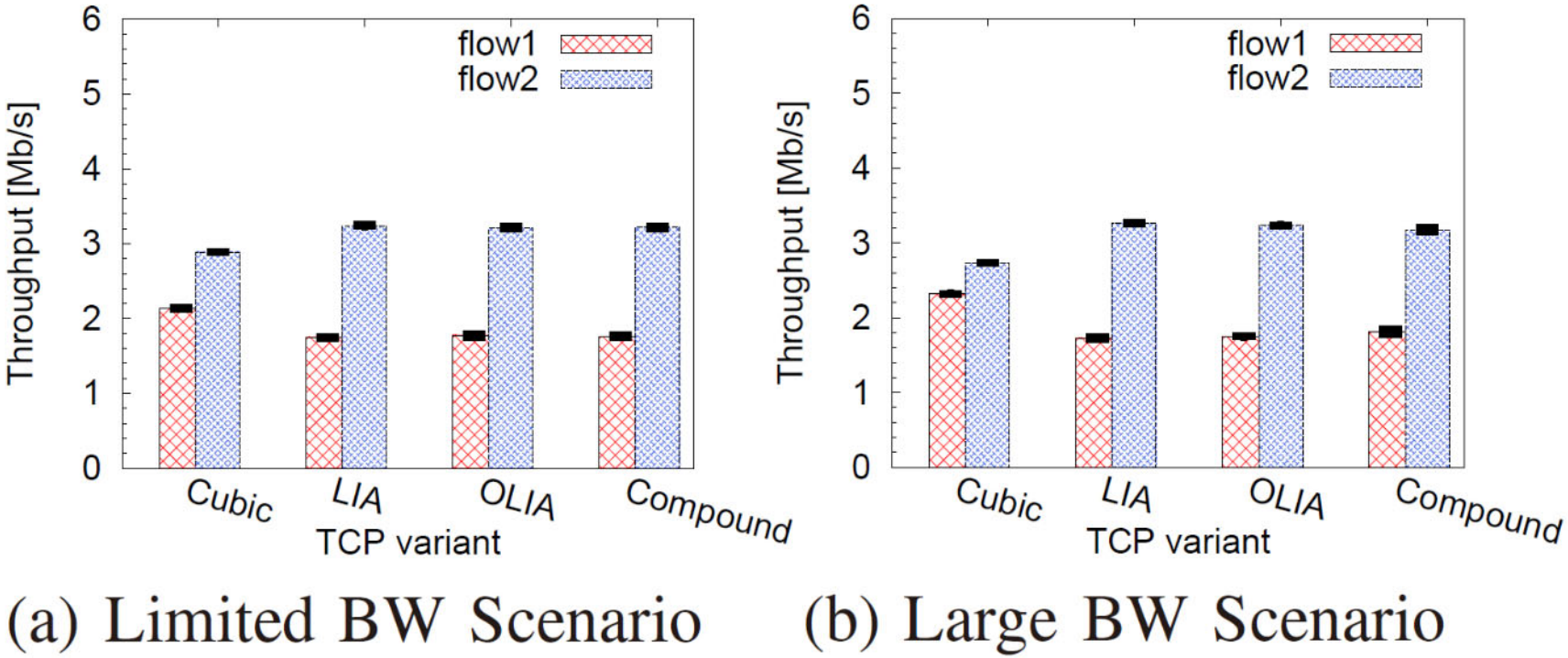
Results(1): Wi-Fi Handoff Scenarios



(a) Limited BW Scenario (b) Large BW Scenario

- We see that picture discards and buffer underflows are as small as they can be, even when per flow bandwidth is limited (a).
- We see that for both limited and large bandwidth scenarios, video performance is not disturbed by Wi-Fi to Wi-Fi handoffs.

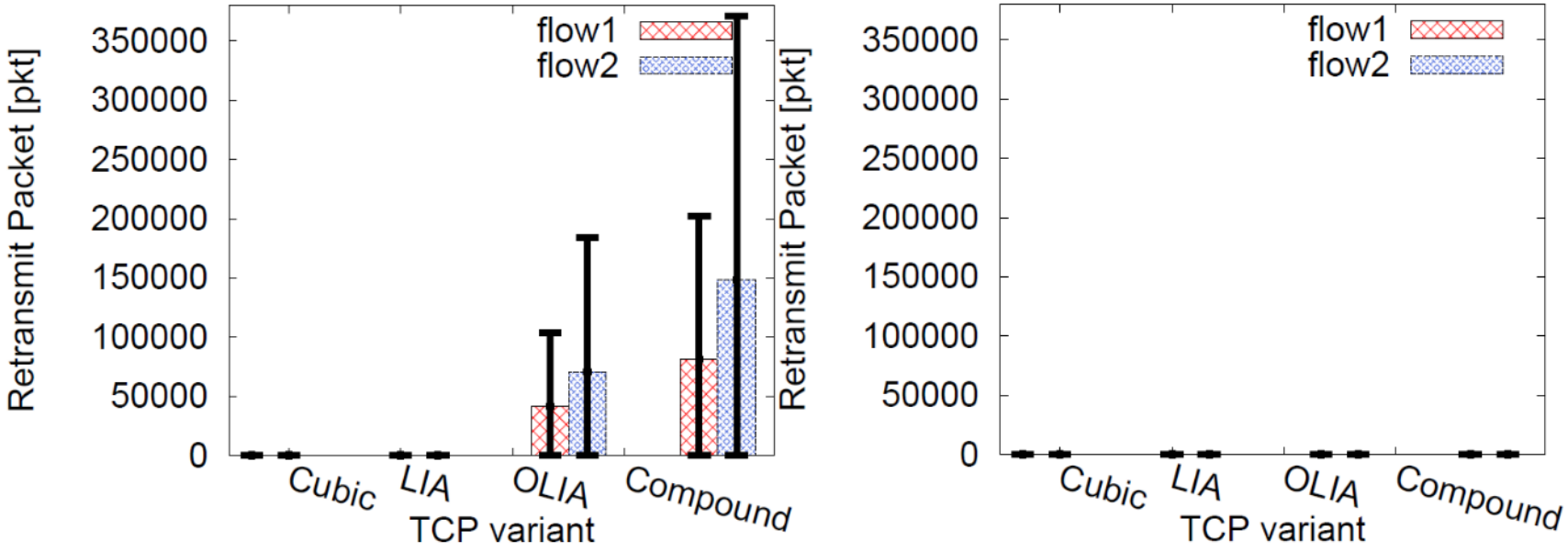
Results(2): Wi-Fi Handoff Scenarios



(a) Limited BW Scenario (b) Large BW Scenario

- Larger throughput results on flow 2, with is the sole flow carrying traffic after handoff

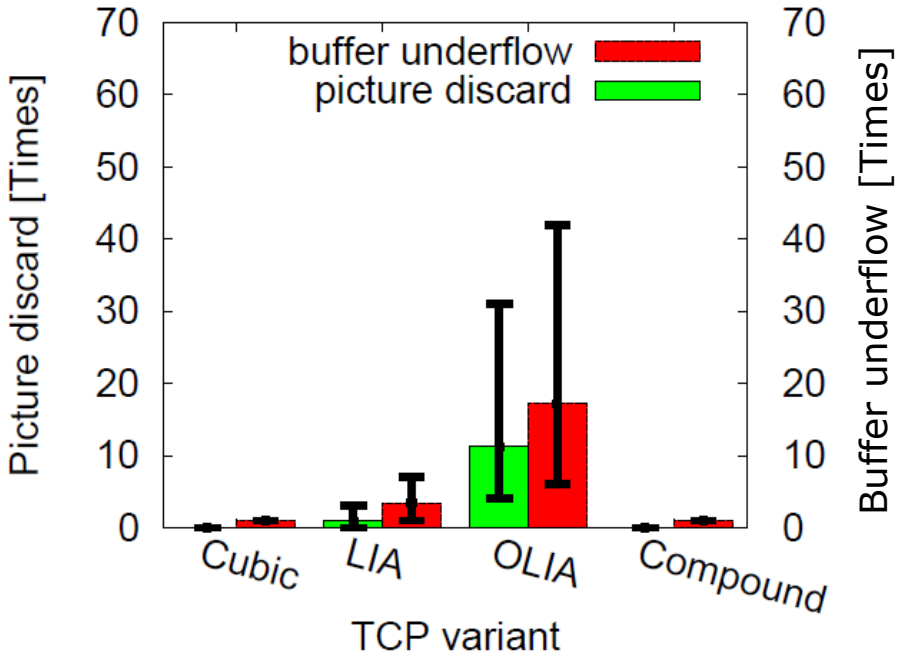
Results(3): Wi-Fi Handoff Scenarios

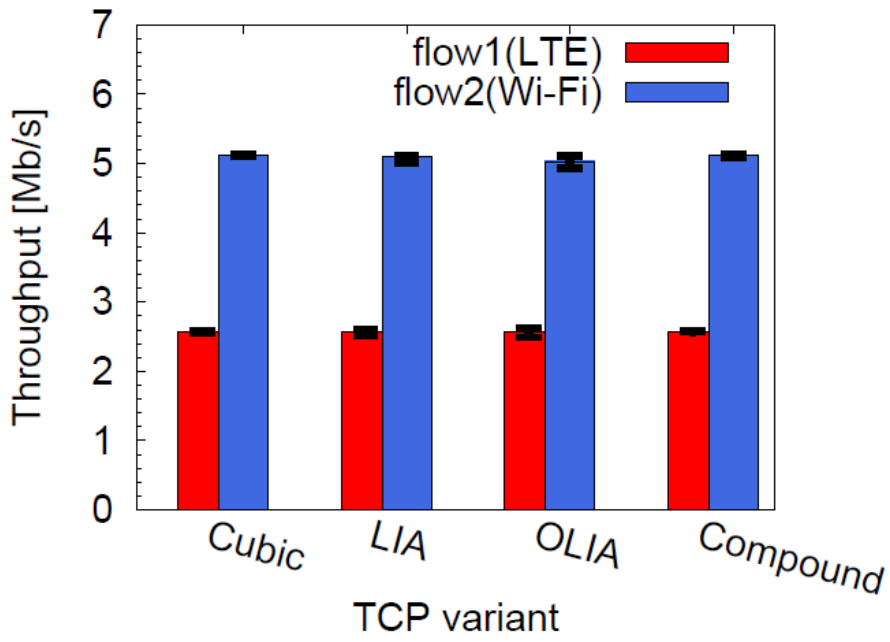


(a) Limited BW Scenario (b) Large BW Scenario

- In limited (tight) bandwidth scenario (a), significant retransmissions occur on both flow 1 and flow 2 for OLIA and Compound TCP variants.
- We notice that these two are the slowest variants to have their congestion window cwnd recover from packet loss.

Results(4): Wi-Fi – Cellular Handoff Scenarios





- When handoffs from Wi-Fi to cellular occur, buffer underflow and picture discards are significant for OLIA.
- Cubic and Compound TCP variants do not suffer video level performance degradation.
- In addition, efficient scheduler helps reduce retransmissions on slow to recover TCP variants such as OLIA and Compound.

Conclusion

- We have analyzed the impact of handoffs on video streaming performance over multiple paths.
  - On a Wi-Fi only scenario, we have shown that video streaming does not get affected by handoffs even on tight path bandwidth conditions.
  - On a Wi-Fi<->LTE cellular handoff scenario, we have shown video performance degradation for LIA and OLIA TCP variants.
  - The path coupling of these TCP variants, where congestion window size depends on all active paths, slows down their recovery from packet losses during handoffs.
- Future Works
  - We will investigate how coupled TCP variants may be made more robust to handoffs.
  - We are also planning a handoff study on 5G cellular links.