Congestion Control in SDN-Enabled Networks

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Introduction and Motivation

- There is a new emerging suite of high-bandwidth Internet apps based on interactive video
  - Example 1: 360-degree video
  - Example 2: Cloud-based gaming services
  - Example 3: JPEG 2000 Interactive Protocol (JPIP)

- Challenges:
  - High bandwidth requirements for interactive video
  - Latency sensitivity for remote user interactions
  - Need to support multiple service classes
  - Overhead of resource reservation mechanisms
  - Limited effectiveness of end-to-end congestion control

This Paper

- Research Question: Can SDN provide effective and responsive congestion control for these applications?
- Answer: Yes!

- Proposed Solution:
  - Network-exposed API for network state visibility
  - SDN-assisted congestion control with low latency, high bw
  - Fair sharing between interactive and non-interactive flows
- Extensive evaluation of effectiveness and scalability

A. Naman, Y. Wang, H. Gharakheilia, V. Sivaraman, and D. Taubman, "Responsive High Throughput Congestion Control for Interactive Applications over SDN-Enabled Networks", Computer Networks, April 2018.

System Architecture

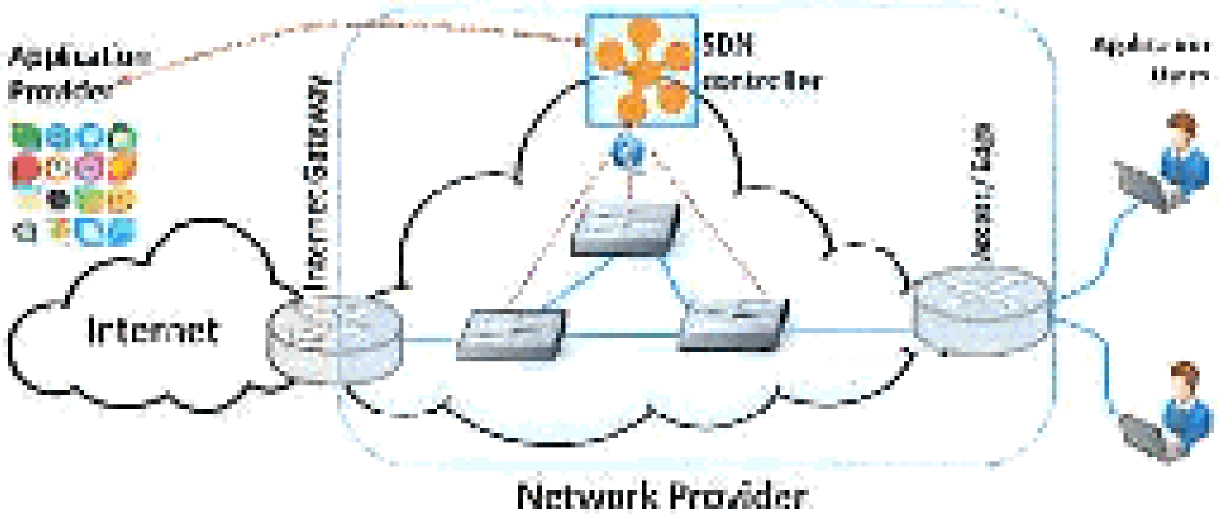


Figure 1: System architecture.

Exposing Network State Information

- RESTful API (HTTP-based)

- Registration required by interactive flows
- Network query response protocol for state info

- Request format:
  - GET /stats/<MyIP>/<PeerIP>/<LastIdx>/<MaxEntr>/
- Response format:
  - Network state entries: [ns entry1; ns entry2; …]
  - Link state entries: [i, L, link_entry1, link_entry2, …]
  - Information and format: [delta_i, b_i, q_i, R_i, d_i]

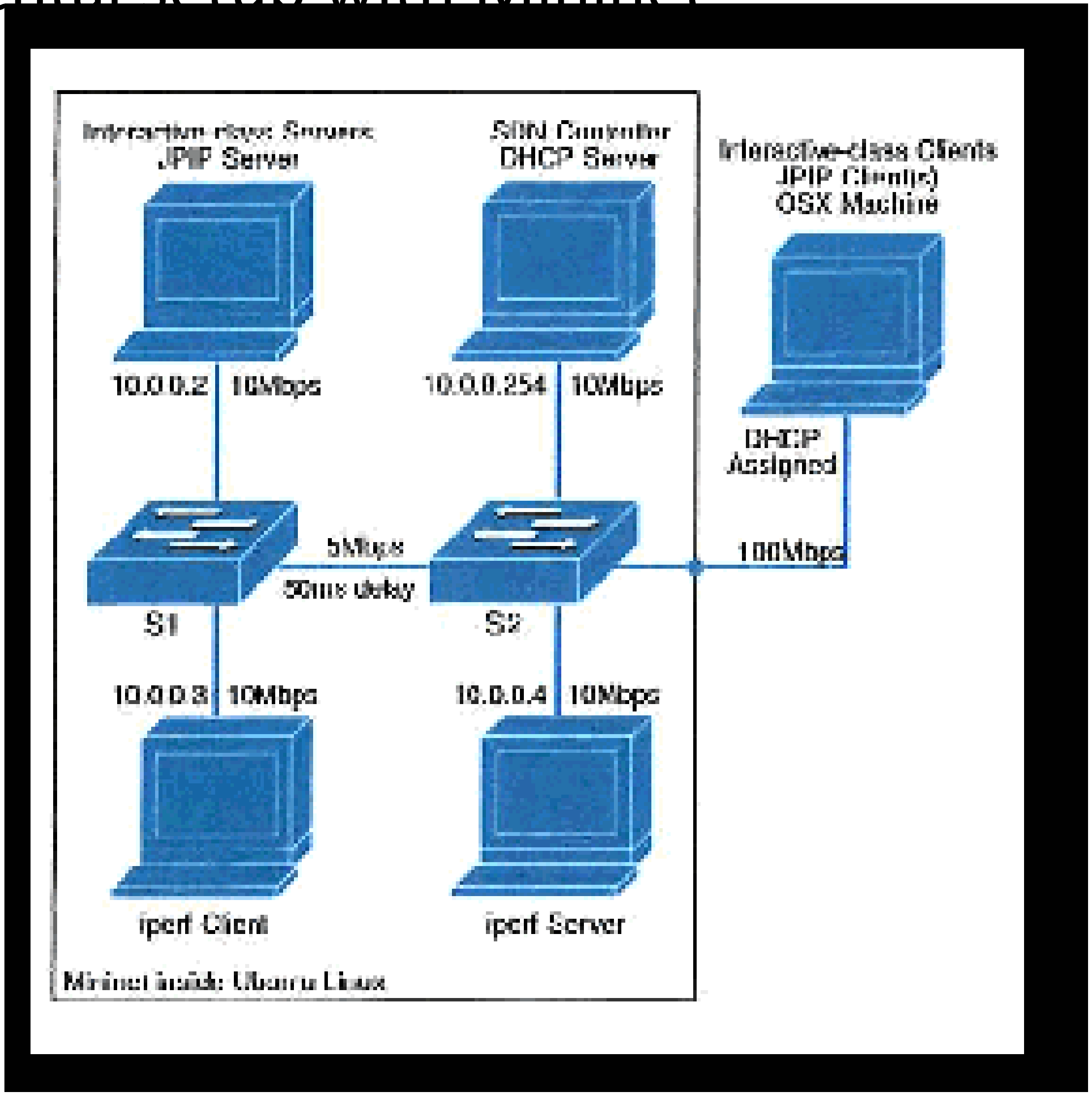
Control Algorithm

- Two queues: interactive and non-interactive
- Dynamic estimation of number of bytes queued at the bottleneck point on an end-to-end path
- Try to limit this queue size for interactive traffic

- Formulas derived for control-theoretic dynamics
- Analogous to “Rate-Delay (RD) Network Services” by M. Podlesny and S. Gorinsky, ACM SIGCOMM 2008

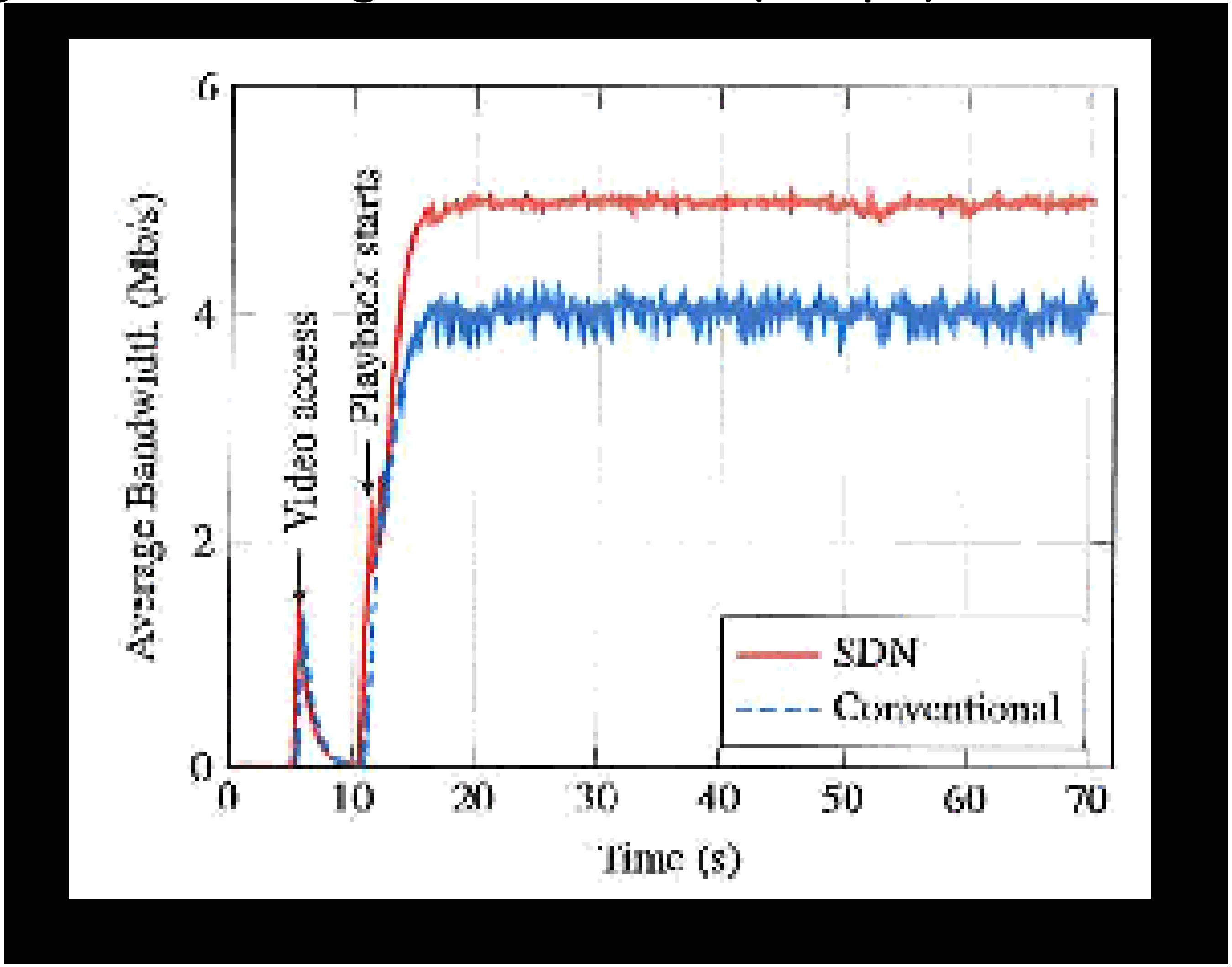
Experimental Evaluation

- Experimental setup with Mininet

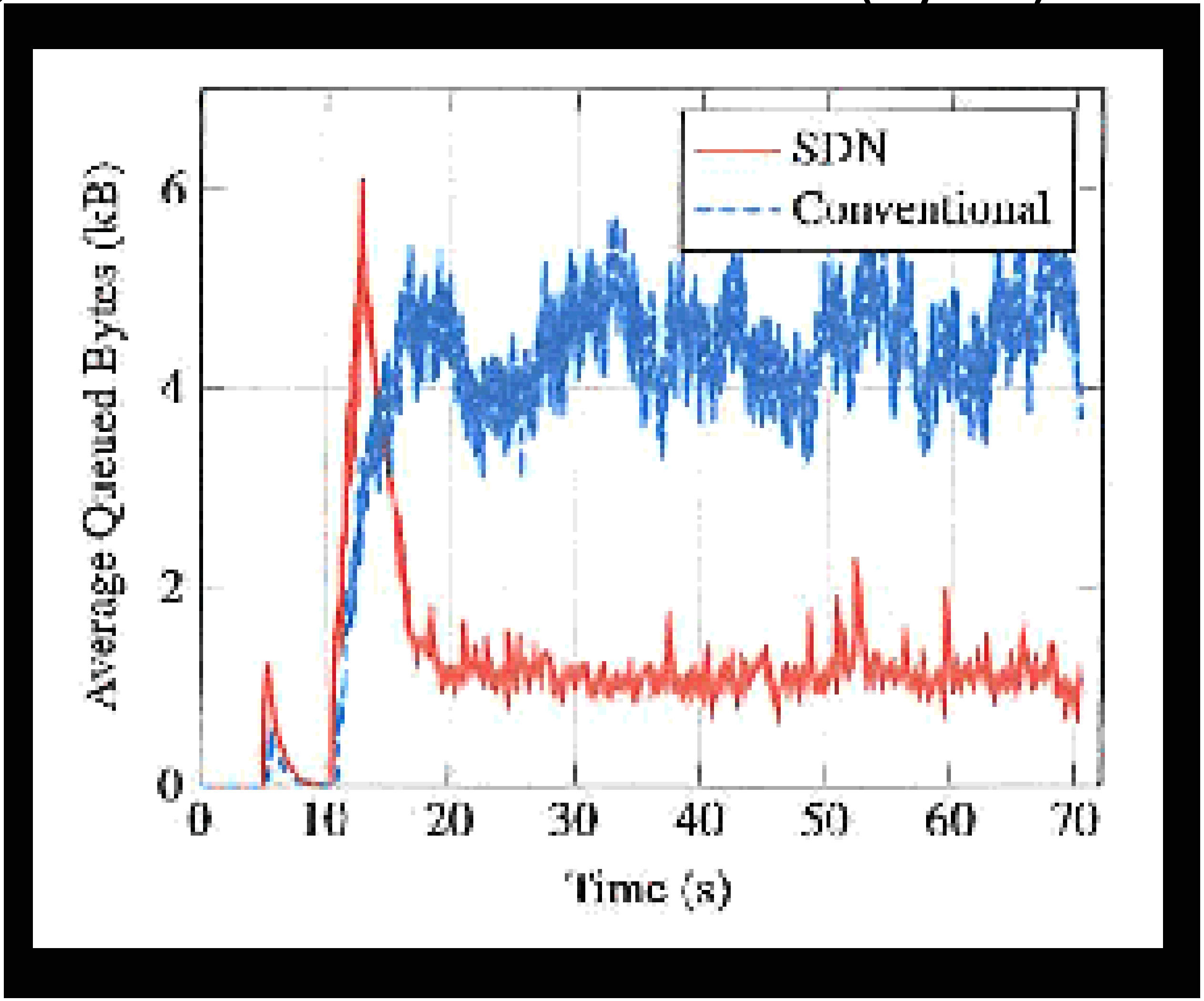


Experimental Results (1 of 12)

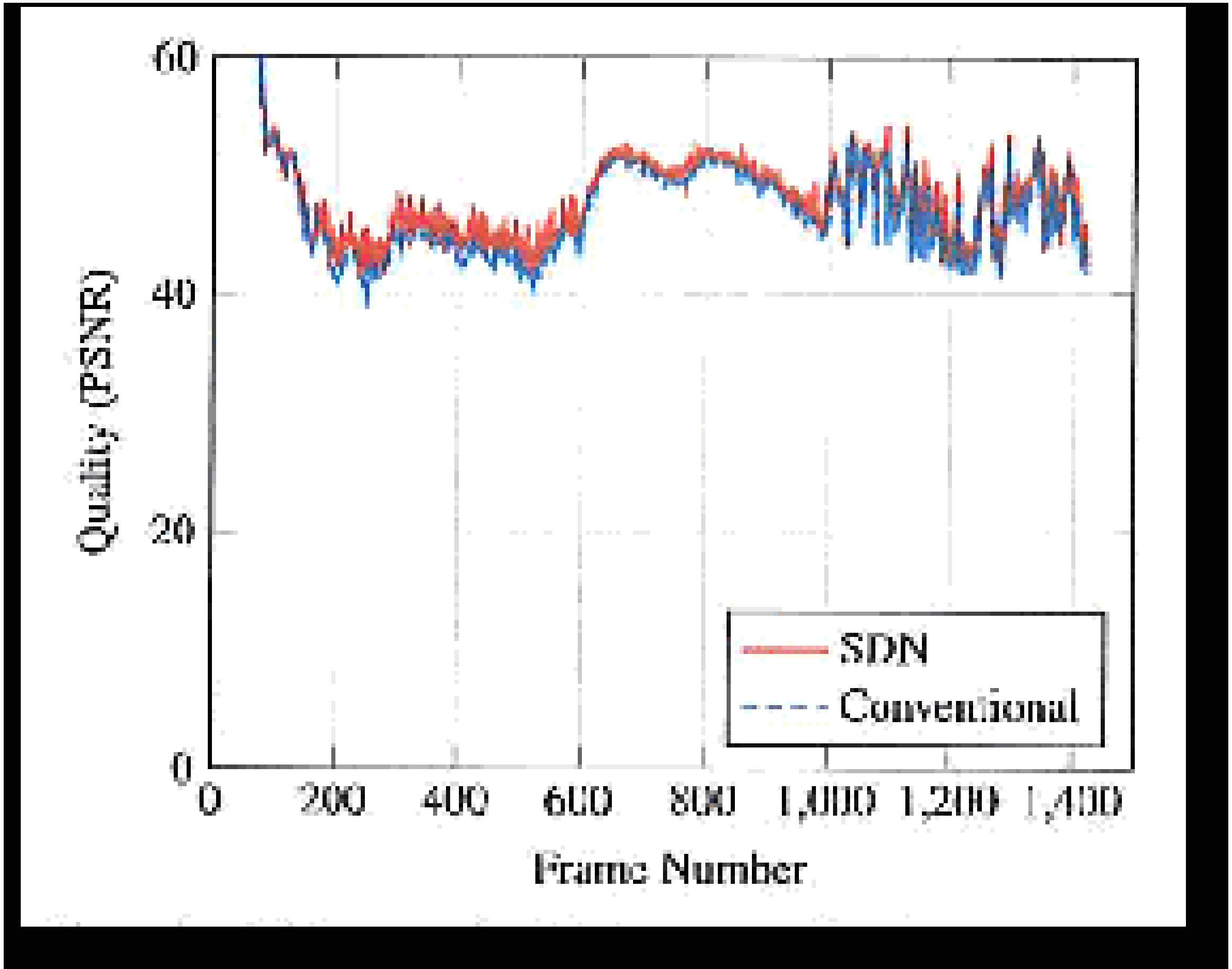
- Figure 3: Average Bandwidth (Mbps) versus Time



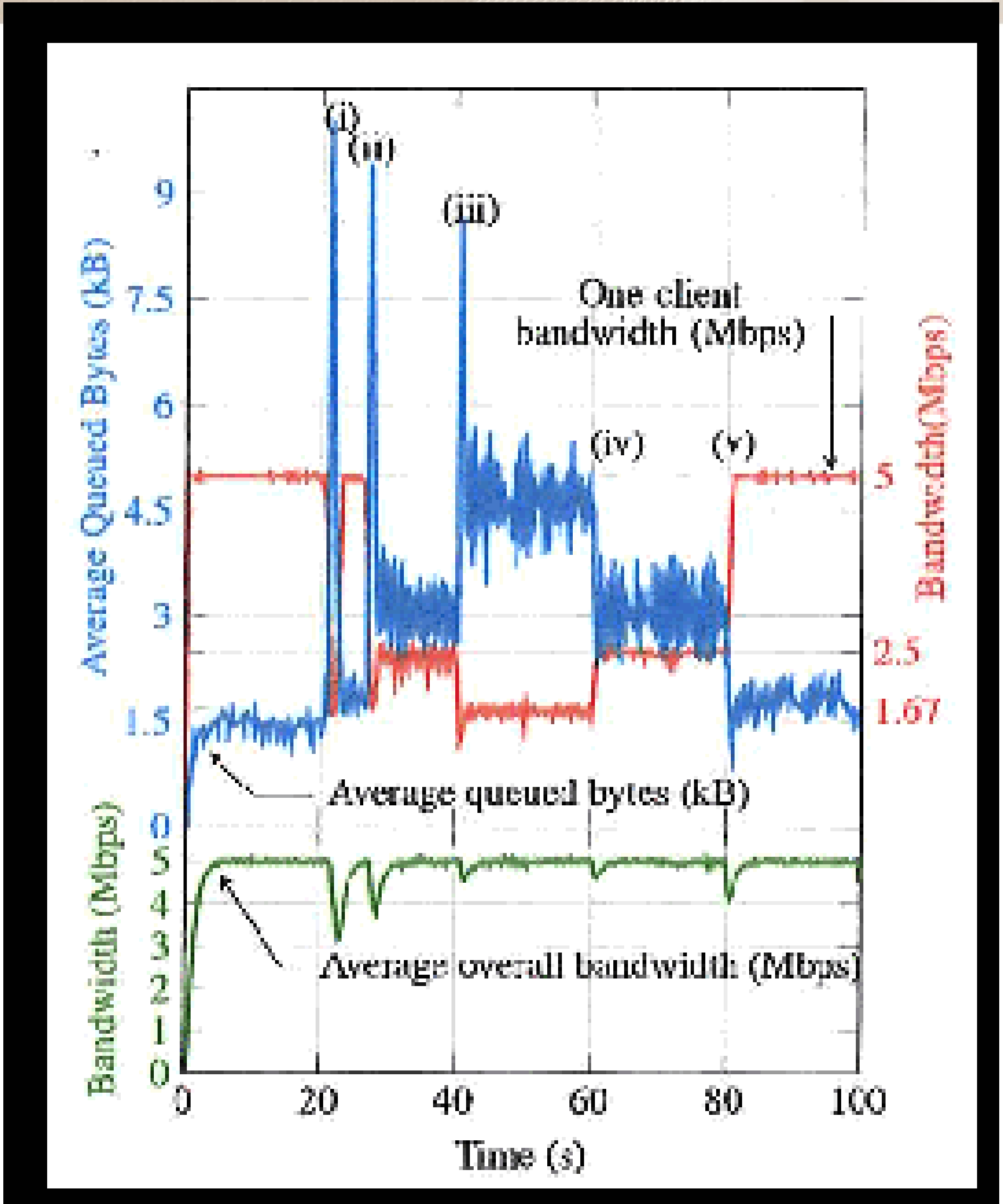
- Figure 4: Bottleneck Queue Size (bytes) vs Time



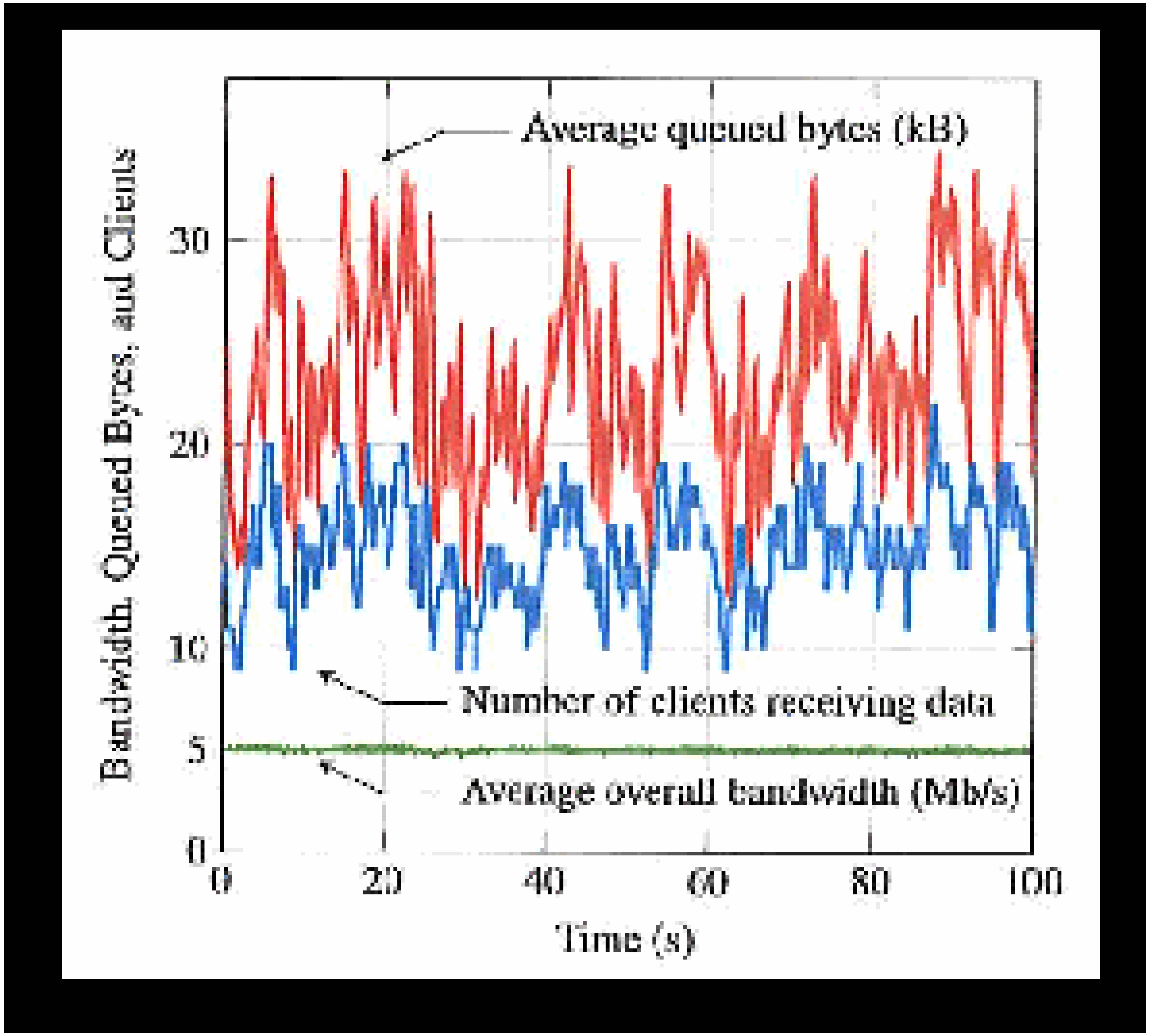
- Figure 5: Video Quality (PSNR) versus Time (frames)



- Figure 6:
  Multiple Flows



- Figure 7: Bandwidth and Queued Bytes vs Time

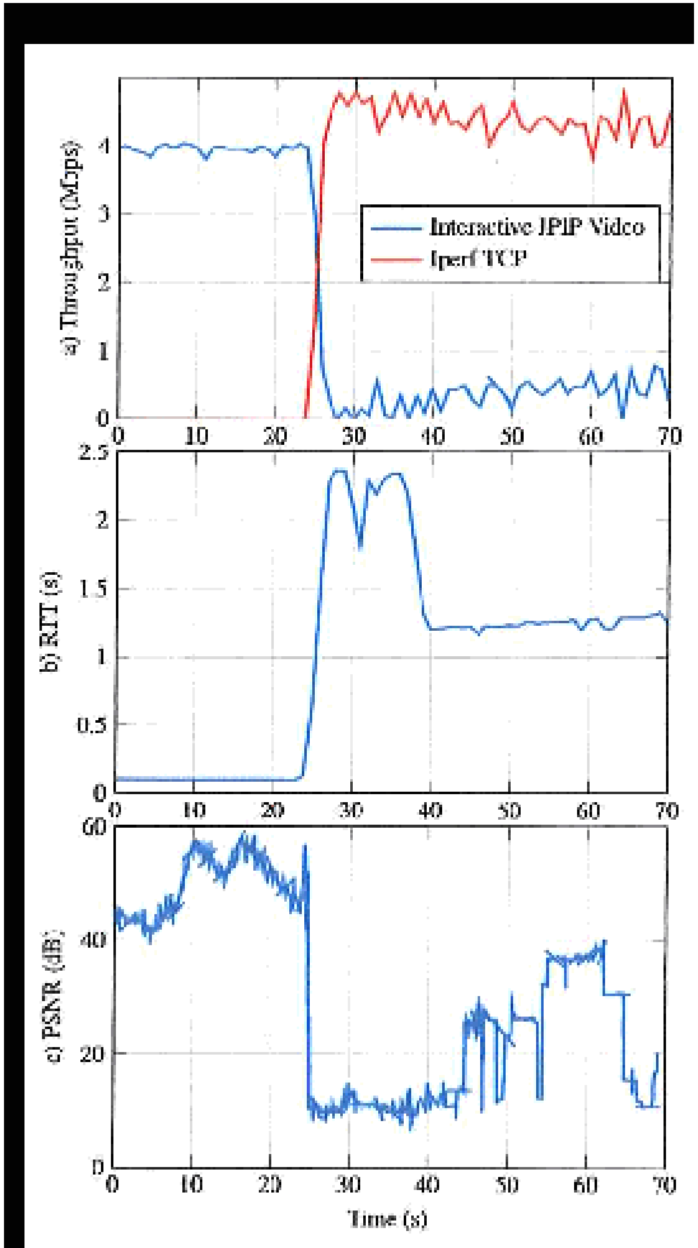


- Figure 8:

  (a) Throughput vs Time

  (b) RTT vs Time

  (c) PSNR vs Time



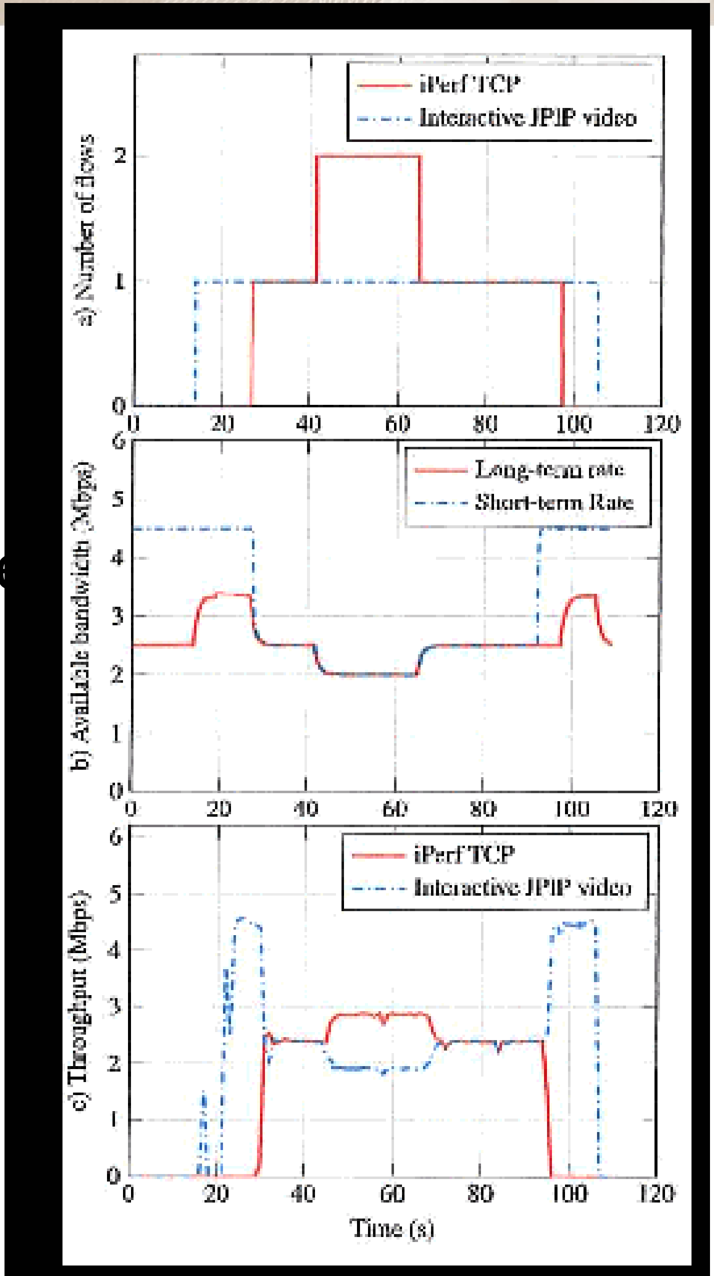
Experimental Results (7 of 12)

- Figure 9:

(a) Num Flows vs Time

(b) Available Bandwidth vs Time

(c) Throughput vs Time

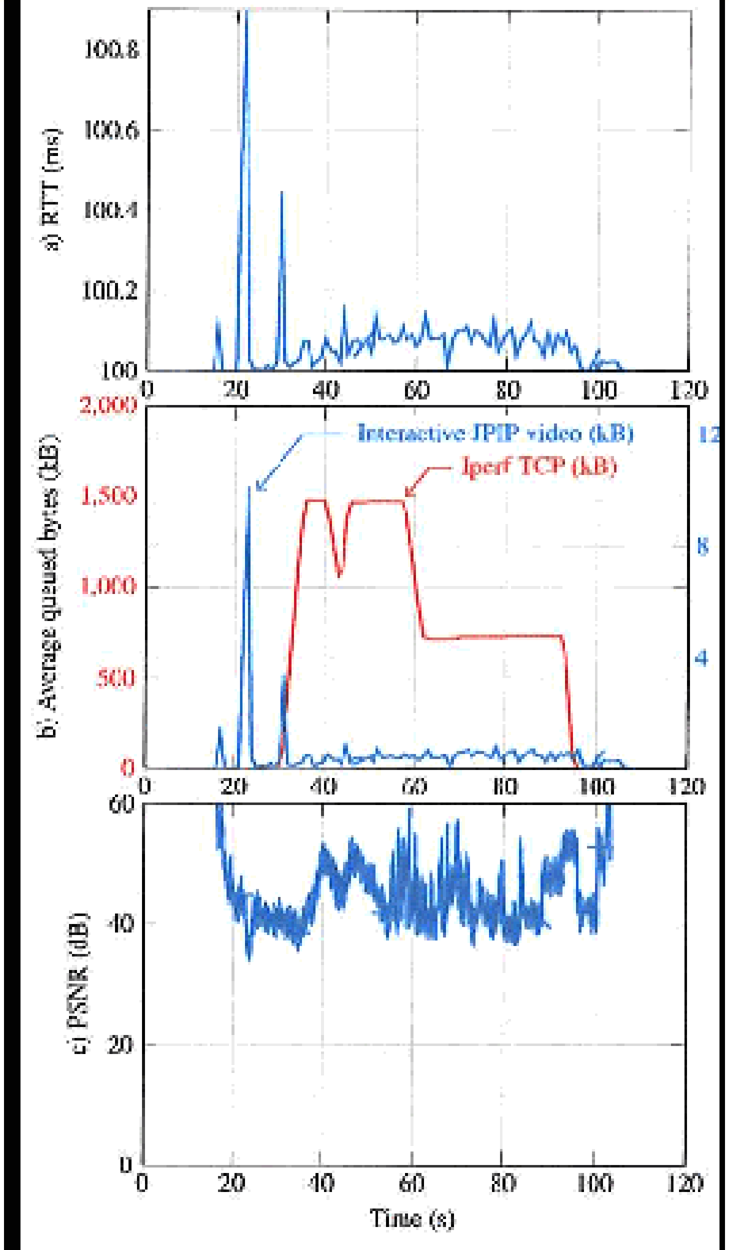


- Figure 10:

  (a) RTT vs Time

  (b) Avg Queued Bytes vs Time

  (c) PSNR vs Time



Federated Network Scenario

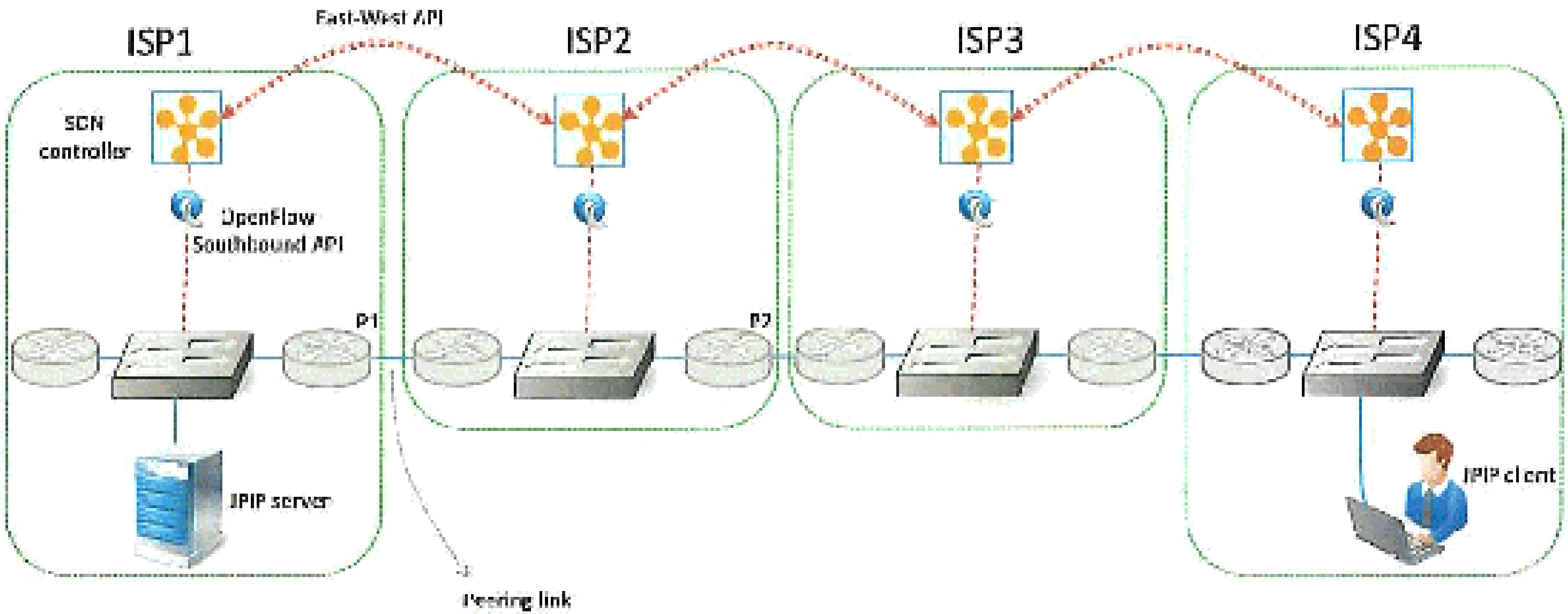
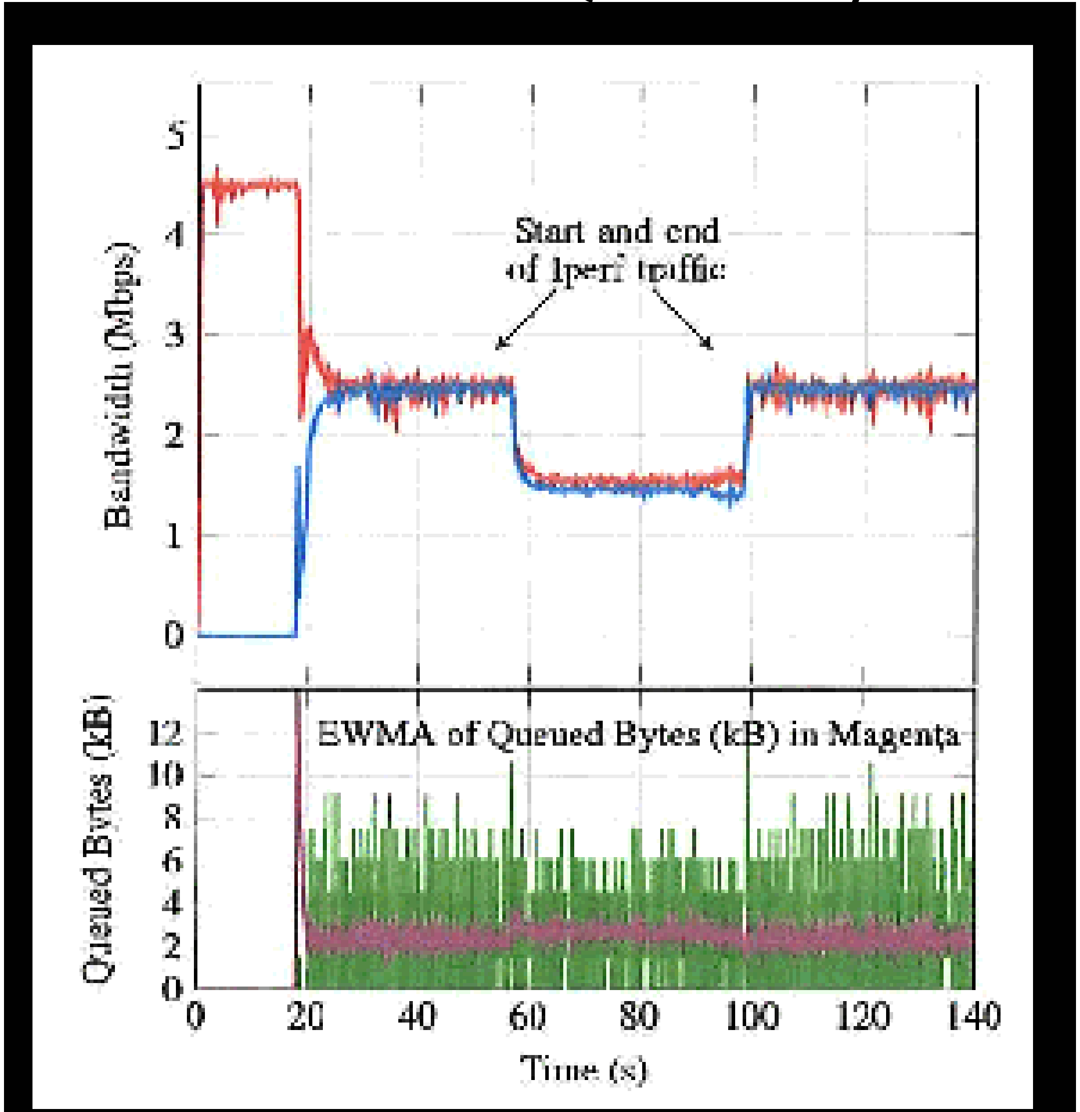


Figure 11: Interactive flows over a federated network.

- Figure 12: Bandwidth and Queued Bytes vs Time

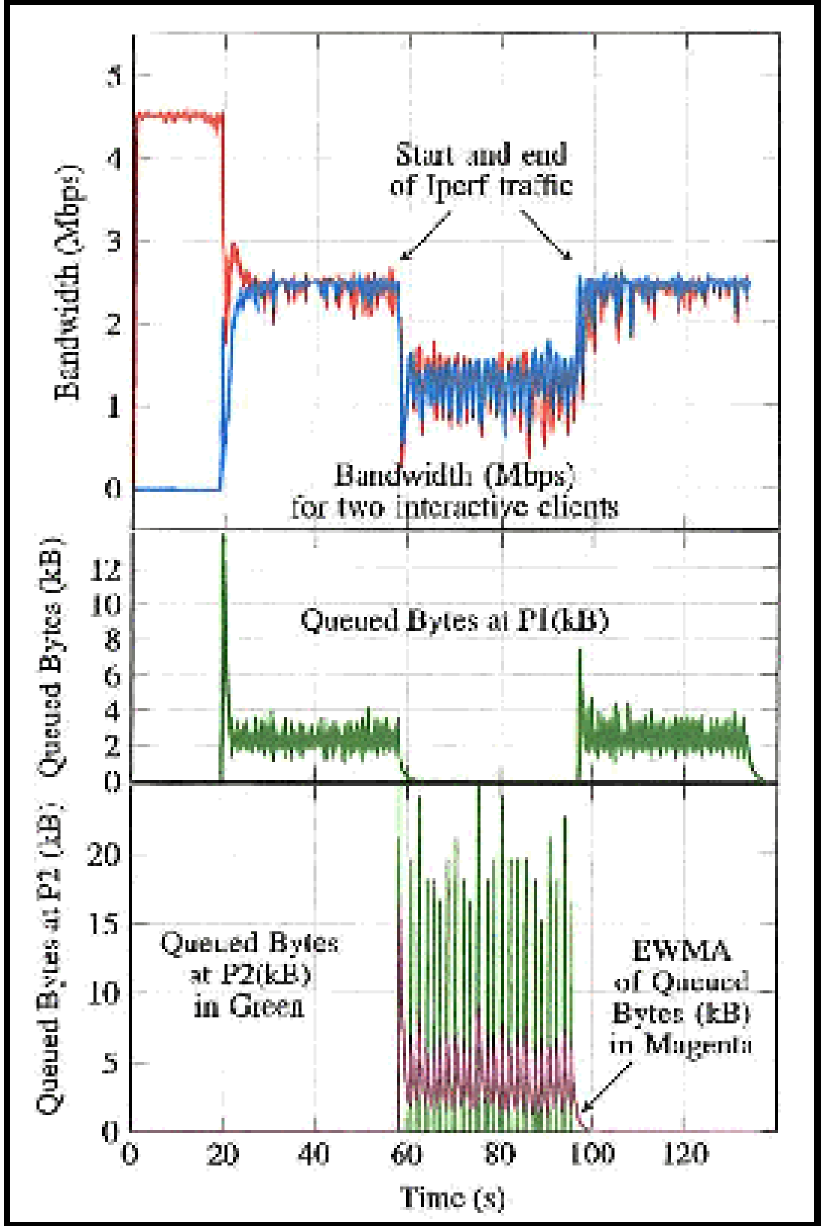


- Figure 13:

  (a) Bandwidth vs Time

  (b) Queued Bytes at P1

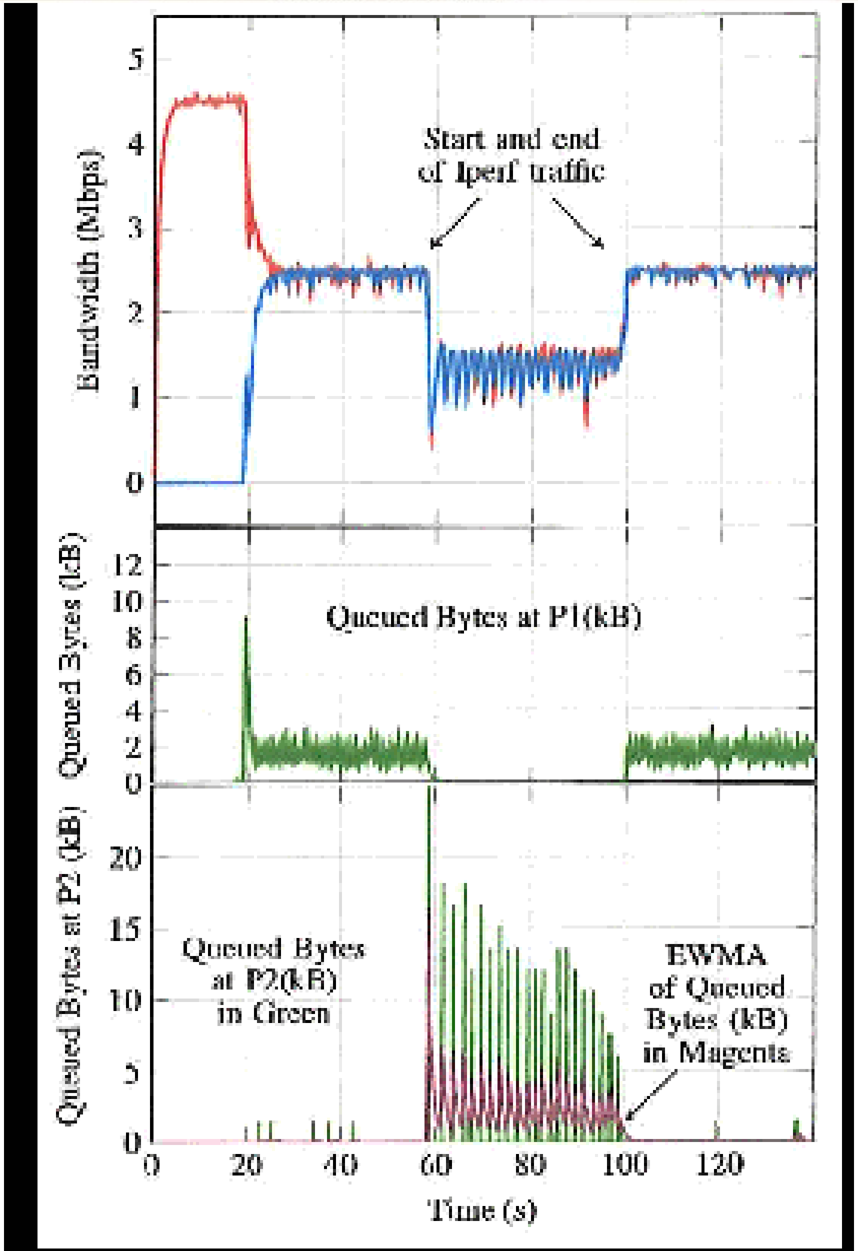
  (c) Queued Bytes at P2



- Figure 14:
  (a) Bandwidth vs Time

  (b) Queued Bytes at P1

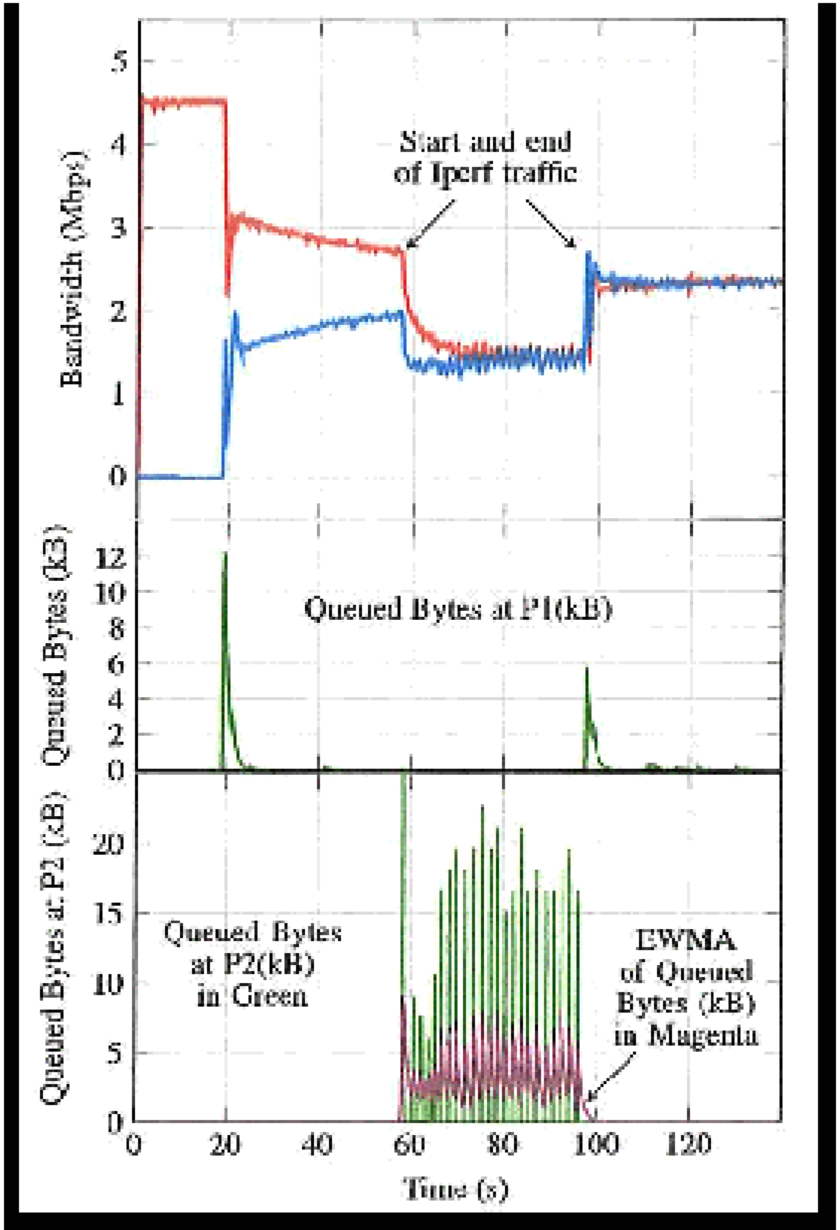
  (c) Queued Bytes at P2



- Figure 15:
  (a) Bandwidth vs Time

  (b) Queued Bytes at P1

  (c) Queued Bytes at P2



Conclusions

- SDN-assisted congestion control can provide the responsiveness needed for interactive video apps
- Key idea is to expose and exploit network state info
- Experimental results show that the proposed approach is responsive and fair, even in the presence of highly dynamic network flows

- Future work:
  - More efficient protocols for streaming network state info
  - More effective solutions for high-latency federated networks