A Closed-Loop Self-Adaptive Management Scheme Based on YANG Data Model Policy

Xudong Wang*, Jiwon Yoo*, Jimin Lee*, Jisuk Chae*, Mose Gu*, Jaehoon (Paul) Jeong*, and Tae (Tom) Oh†
* Department of Computer Science and Engineering, Sungkyunkwan University, Suwon, Republic of Korea
†School of Information, Rochester Institute of Technology, Rochester, NY, USA
Email: {wangxudong28, sowra1, jm.lee98, sue030124, rna0415, pauljeong}@skku.edu, thoics@rit.edu

***Abstract*—This paper presents a closed-loop Software-Defined Networking (SDN) based Quality of Service (QoS) mechanism designed to protect TCP Adaptive Bitrate (ABR) video streaming under severe bandwidth contention. By continuously monitoring real-time throughput and loss at bottleneck links, the system dynamically applies YANG-modeled bandwidth control policies, which are validated and translated into OpenFlow 1.3 meter configurations. Emulation results under a 10 Mbps bottleneck show that aggressive multi-flow TCP downloads significantly degrade video quality without control, while the proposed mechanism successfully preserves stable 1080p video playback.**

***Index Terms*—QoS, SDN, YANG Model, RESTCONF, Network Congestion**

I. INTRODUCTION

In modern networks, real-time video streaming frequently coexists with bandwidth-intensive download traffic, leading to service degradation under limited external capacity. Static network configurations lack the flexibility required to adapt to such dynamic conditions, often resulting in unstable video quality during congestion [1].Most video platforms rely on TCP-based ABR streaming, which reacts to congestion by reducing video quality to avoid buffering [2].However, parallel TCP downloads aggressively occupy bandwidth, overwhelming ABR traffic and causing persistent quality degradation [3]. These challenges motivate the need for adaptive, traffic-aware QoS mechanisms that can protect high-priority services such as video streaming.

II. RELATED WORK

Prior studies have shown that ABR streaming effectively mitigates buffering at the cost of reduced resolution under congestion [2], Meanwhile, phenomena such as bufferbloat and aggressive TCP behavior exacerbate unfair bandwidth allocation [3]. SDN has emerged as a promising approach for dynamic traffic management by enabling centralized monitoring and fine-grained control through programmable switches [4].YANG-based policy modeling further enhances reliability by providing structured, verifiable configurations that can be safely deployed in network devices [5]. Recent work emphasizes combining monitoring, learning, and policy enforcement to achieve adaptive QoS control in SDN environments [6].

III. DESIGN

The proposed system adopts a closed-loop SDN architecture composed of an Application Layer, a Ryu Controller, and a

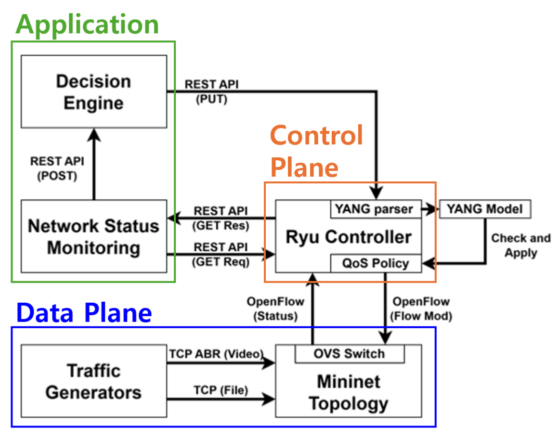

Fig. 1. Closed-loop QoS Control Architecture Based on SDN and YANG Models.

Mininet-based data plane. The Application Layer periodically retrieves OpenFlow statistics via a REST API and analyzes throughput and inferred packet loss at bottleneck links. Network throughput at time t_n is computed from cumulative byte counters as:

$$R(t_n) = \frac{(B(t_n) - B(t_{n-1})) \times 8}{\Delta t}.$$

Based on these metrics, a Decision Engine determines whether congestion is present. When video degradation or loss exceeds a threshold, the system activates a QoS policy that limits download traffic to a minimum bandwidth of 1 Mbps. Policies are expressed using a YANG data model, validated by a YANG parser, and translated by the controller into OpenFlow 1.3 meter rules. If network conditions improve, the bandwidth restriction is gradually relaxed, enabling adaptive and stable control.

IV. EMULATION RESULTS

Table I summarizes the emulation setup and key experimental parameters. Fig. 1 illustrates the closed-loop QoS control architecture of the proposed system, integrating monitoring, policy decision, YANG validation, and OpenFlow-based enforcement into a unified adaptive control loop. Fig. 2 shows the Mininet-based emulation topology, where video and download traffic traverse a shared 10 Mbps bottleneck link between two switches to induce controlled congestion. Fig. 3 depicts the bottleneck congestion scenario in which aggressive multi-flow

TABLE I
EMULATION SETUP

Component	Description
Topology	2 switches (s1, s2), 4 hosts (vSrv, dSrv, h1, h2)
Bottleneck Link	s1–s2 connection limited to 10 Mbps
Video Traffic	TCP Adaptive Bitrate (ABR), 1080p baseline quality
Download Traffic	10 parallel TCP connections (download booster)
Monitoring Interval	1-second OpenFlow statistics collection
QoS Mechanism	OpenFlow 1.3 Meter-based bandwidth limiting
Controller	Ryu SDN Controller with REST API and YANG validation

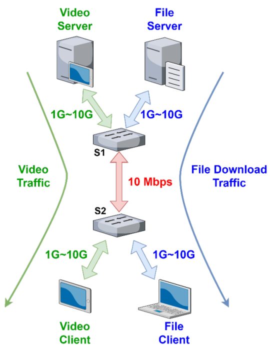

Fig. 2. Mininet Topology

TCP downloads monopolize bandwidth, leading to throughput starvation for video traffic without QoS control. Fig. 4 presents the evaluation scenarios with different traffic start orders and QoS configurations, designed to assess both video quality preservation and recovery under congestion. Fig. 5compares throughput with and without QoS. Without control, video throughput drops below 1 Mbps, whereas with QoS enabled, bandwidth limiting on download traffic maintains stable 6–8 Mbps throughput, sufficient for 1080p playback.

V. CONCLUSION

This work demonstrates that a closed-loop SDN-based QoS mechanism using YANG-modeled policies can effectively protect TCP ABR video streaming in bandwidth-constrained environments. By integrating real-time monitoring, policy validation, and dynamic enforcement, the system rapidly responds to congestion and maintains high video quality even under aggressive multi-flow TCP downloads. The results confirm the practicality of adaptive QoS control for preserving service-level guarantees in modern networks.

The source code for the implementation of our Hybrid Control Framework are available at GitHub [7].

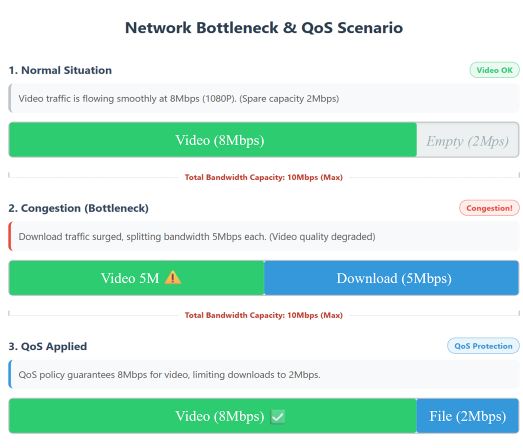

Fig. 3. Network Bottleneck & QoS Scenario

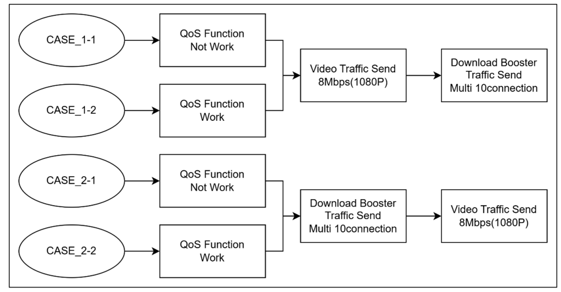

Fig. 4. Test Scenario

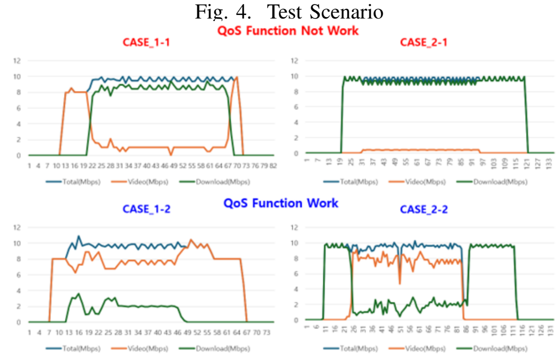

Fig. 5. Test Results

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