broadband forum

MARKETING REPORT

Application Layer Testing (ALT): The Key to Optimizing Quality of Experience

MR-433

The key to optimizing quality of experience

Providing a unique value for a wide range of scenarios by defining traffic and metrics that reflect the complex time domain behavior and interactivity present at the application layer.

The confluence of new networking technologies, architectures, and applications is creating an urgent need for standards in Application-Layer Testing (ALT). Every participant in the broadband service delivery value chain – network operators and service providers, network function vendors, access equipment vendors, and test systems vendors – stands to benefit significantly from ALT standardization. The Broadband Forum is leading a multi-tiered approach to standardize ALT data models, test methodologies, and applications-specific metrics with the end goal of optimizing user experience. Now is an ideal time to get involved to influence the course of the work and to get a head-start in this emerging area. Get involved with the groundbreaking work taking place in the Broadband Forum today, and shape the future of broadband.

Introduction

The broadband industry is experiencing an unprecedented and exciting period of technological upheaval. Subscriber demand for traffic continues to grow, as streaming video, cloud storage, and other applications have turned anytime, anywhere connectivity from a marketing catchphrase into reality. Access technologies like Passive Optical Networks (PON), Gfast, and wireless continue to evolve to deliver higher and higher levels of performance. Operators are increasingly adopting network convergence, offering multiple services for diverse subscribers over common network architectures. In addition, operators are introducing network sharing, in which multiple providers lease resources on a common infrastructure to offer increasingly complex and dynamic services to their retail customers. Many of these advances are facilitated by SDN and NFV, two closely coupled technologies that are themselves upending the industry by changing how operators and vendors approach network design and operation.

These new architectures, products, and services require sophisticated testing techniques to ensure that they will deliver the desired performance under a wide range of conditions. In particular, testing that incorporates the complex behaviors generated at the application layer is required in many instances to understand the Quality of Experience (QoE) delivered to subscribers.

This white paper describes how standardized Application-Layer Testing (ALT) compares with other test techniques and explains why it is a valuable addition to the testing repertoire for a wide variety of stakeholders - network operators, service providers, and network and test equipment vendors. We'll describe the Broadband Forum's goals for ALT and the how these goals add value within the existing framework of industry capabilities. Finally, we'll discuss how the BBF is specifying ALT and how interested parties can participate.

Why Application-Layer Testing?

Application-Layer Testing defines a set of traffic generation techniques, test methodologies, and performance metrics that focus on the traffic generated by applications running over the network and the resulting QoE. ALT differs in this respect from testing that uses traffic flows generated at Layers 2-4 and that measures network characteristics like speed, latency, jitter, and packet loss. ALT doesn't replace lower layer test techniques; in fact, the two types of testing complement each other, each with advantages and disadvantages:

- Different applications can generate very different traffic patterns, even when the content is superficially similar. The plots in Figure 1 illustrate how two video applications (streaming and conferencing) with the same average bit rate can exhibit completely different behavior.
- The broadband traffic to even a single household can represent a complex mix of applications, devices, and end users. This traffic then interacts with traffic from other households to create even more complex patterns across the access network. These interactions can be emulated in the lab using ALT techniques in a way that would be difficult or impossible with lower layer testing.
- Some applications (and protocols such as QUIC) perform rate adaption on their own instead of using a transport layer mechanism like TCP congestion control. This type of adaptation cannot be simulated using lower level testing.
- Subscribers' QoE is dependent not only on network performance, but each application's sensitivity to different network performance characteristics. By measuring the performance of the application rather than the network, it becomes possible to predict QoE more directly.

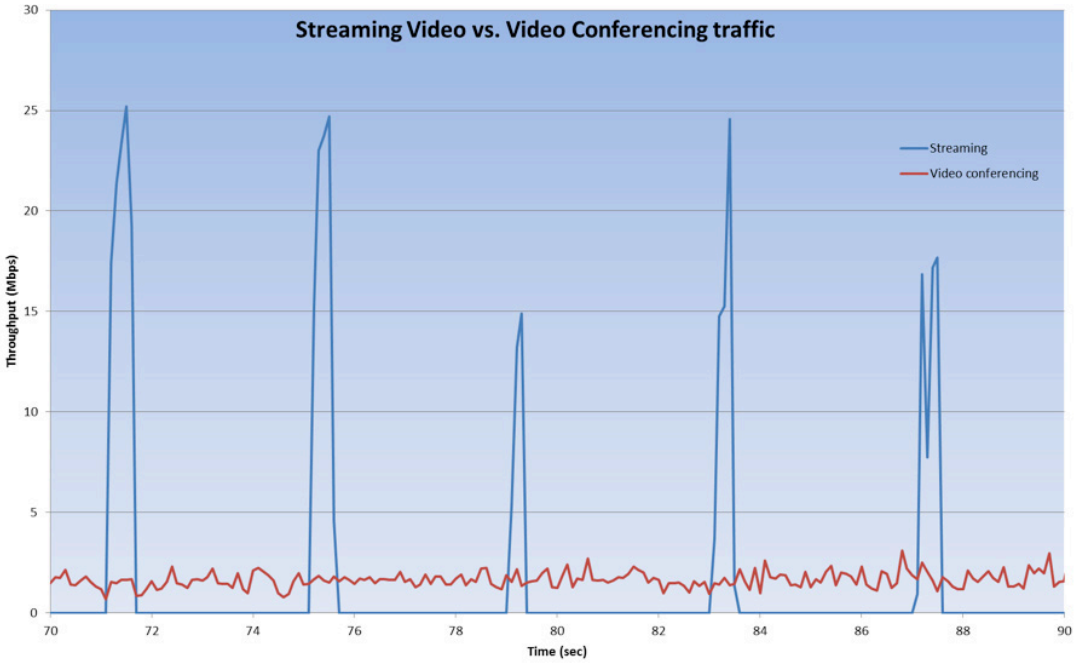

Figure 1 – streaming video vs. video conferencing traffic

ALT complements lower layer testing rather than replacing it. Since ALT typically involves more complex traffic patterns and test cases, it takes more time, and requires more complex analysis. Each type of testing can be applied as appropriate to extract the optimum value from lab-based testing.

A wide variety of network scenarios can be modeled and tested using ALT. Examples include:

- As operators deploy NFV-based solutions, functions are virtualized on a common infrastructure and resources are orchestrated dynamically based on network load. The ability to orchestrate resources efficiently while preserving required performance depends on a complex interplay between orchestrator, functions, and traffic. Testing that interplay requires traffic that accurately emulates the behavior of multiple types of applications interacting with each other and with the network.
- Virtualized network architectures such as CloudCO provide a QoS framework that supports both wholesale and retail service providers sharing the network. This framework can require complex traffic shaping and policing, especially when sharing capacity between retail service providers at potential congestion points such as oversubscribed PONs. "Worst-case" flows that fill pipes to capacity can't test these scenarios, but less-than-worst case flows generated at lower layers don't reflect the burstiness associated with application-layer behavior.
- The QoE of many applications is best measured at the application layer. For example, the QoE for adaptive rate streaming video can degrade as the streaming rate is reduced, even if the reduction is momentary. Of course, video QoE degrades significantly if the receive buffer in the video client empties, resulting in a video "freeze." Both of these occurrences can be observed directly at the application layer, but they are difficult or impossible to infer from network QoS metrics.
- The long-term stability of components in the network can be affected by events and protocols that extend to the application layer. Devices like home gateways which need to process a wide variety of protocols and services, sometimes with limited CPU and memory resources, can be particularly susceptible to stability issues. Testing these devices requires exercising protocols at all layers of the network stack, as well as application-specific traffic and protocols.
- Some physical layer access technologies, such as PONs and wireless networks, use time domain multiplexing to share capacity. Other access technologies such as Gfast use time domain duplexing to mitigate interference between loops. These technologies benefit from adaptive algorithms that allocate capacity based on near-instantaneous reporting of traffic demands. To optimize these algorithms, developers need to test with traffic exhibiting realistic time domain behavior.
- Operators seeking to understand how performance requirements on their networks will evolve over time can study traffic and its performance over emulated networks. By modeling the traffic at the application layer, engineers can investigate complex interactions that would not occur using lower layer techniques.

The above scenarios demonstrate the value added by ALT for every participant in the value chain:

- Network operators and service providers can use ALT to test new network services, components, and architectures in the lab before deploying them in the field. These tests can help establish the parameters for network performance, prove out new designs, and find any problems early. ALT can test scenarios and conditions which are impractical with lower layer testing. System integrators, working closely with network operators on new architectures and services, benefit from ALT in the same ways.
- Network function vendors working within an NFV infrastructure can test their products along with orchestration and other NFV infrastructure vendors to verify performance under realistic conditions, including bursty and interactive traffic aggregated from many sources.
- Access equipment vendors can test adaptive functions for which performance is affected by the time domain behavior of traffic.
- Test system vendors can incorporate the models and control plane features associated with ALT standardization to add significant value to test cases at the application layer, opening up new application areas for their solutions.

The ultimate goal is that end users experience better, more consistent QoE, resulting in fewer service calls and higher subscriber satisfaction.

ALT standardization in the Broadband Forum

Test equipment vendors have long recognized the value of testing at all layers in the network stack, and many already provide proprietary ALT traffic generation and measurement capabilities of different types. By standardizing aspects of ALT, the Broadband Forum's aims to complement and strengthen these capabilities by focusing on three aspects:

- Specificity. Test cases need to be specified unambiguously, independent of specific implementations.
- Portability. A given test case needs to be consistently applied, independent of the lab where it is implemented or the equipment used. A test performed in one lab should be directly comparable to the same test performed in a different lab.
- Repeatability. A given test case, performed on the same system under the same conditions, should generate the same results within expected margins of statistical error.

The Broadband Forum is taking a tiered approach to modeling to address these goals. First, we describe classes of applications (e.g., "adaptive rate streaming video") behaviorally by assigning qualitative values to data model parameters such as the primary direction of associated traffic, session size distributions, and the protocols used. Second, we create application profiles for specific test cases by assigning quantitative values and ranges to additional parameters. Finally, application profiles for different classes are grouped and additional parameters are added, creating an overall subscriber profile with the desired traffic statistics. Subscriber profiles with different characteristics can be instantiated as many times as needed for a given test case.

The BBF has initiated a set of related projects for this work.

- The first project focuses on Architecture and Requirements, describing use cases, data models, test methodologies, and metrics at a high level and providing formal requirements.
- The second project provides formal definition of the data models.
- The third project describes best practices and provides implementation guidance.
- Finally, the BBF is creating an open source reference implementation of an ALT control plane, including generation of data profiles and related test control.

Once the initial projects are delivered, the BBF will maintain the work on a regular basis, extending models and creating new ones as new application classes emerge.

Summary

Application-Layer Testing provides unique value for a wide range of scenarios by defining traffic and metrics that reflect the complex time domain behavior and interactivity present at the application layer. The Broadband Forum seeks to capture this value for use in industry test specifications by creating formal descriptors to ensure the specificity, portability, and repeatability of test cases.

Now is the ideal time to get involved, whether you are a network operator, service provider, system, software or hardware vendor, test system vendor, or other stakeholder. The BBF's ALT project is still in its initial deliverables phase, so participants have a great opportunity to influence the course of the work. In addition, BBF participants can be involved in development discussions, and have access to pre-publication drafts, giving you a head start on understanding and using this material. Full details can be found on the BBF Wiki (BBF members only), or at the public BBF Papers and Tutorials page. If you are interested in joining the Broadband Forum and shaping the future of broadband through this initiative and a wide variety of other activities, contact our Membership Development Manager at info@broadband-forum.org or visit us at our membership page.

Abbreviations

This Marketing Report uses the following abbreviations:

ALT Application-Level Testing

DBA Dynamic Bandwidth Allocation

NFV Network Function Virtualization

PON Passive Optical Network

QoE Quality of Experience

QoS Quality of Service

QUIC Quick UDP Internet Connections

SDN Software Defined Networking

TCP Transport Control Protocol

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