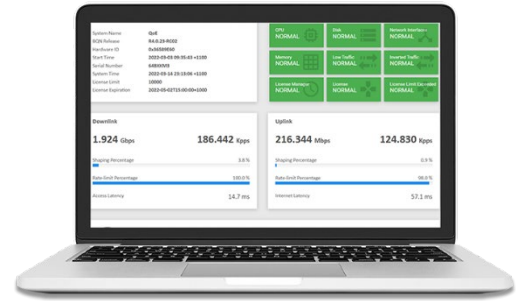


Quality of Experience (QoE) Feature Overview Guide

Cambium Networks' QoE solution enables broadband service providers to reduce churn through improved customer satisfaction, while also saving money with fewer support calls. Operators can offer their customers a range of price points and service levels enabling them to optimize the usage of network resources.



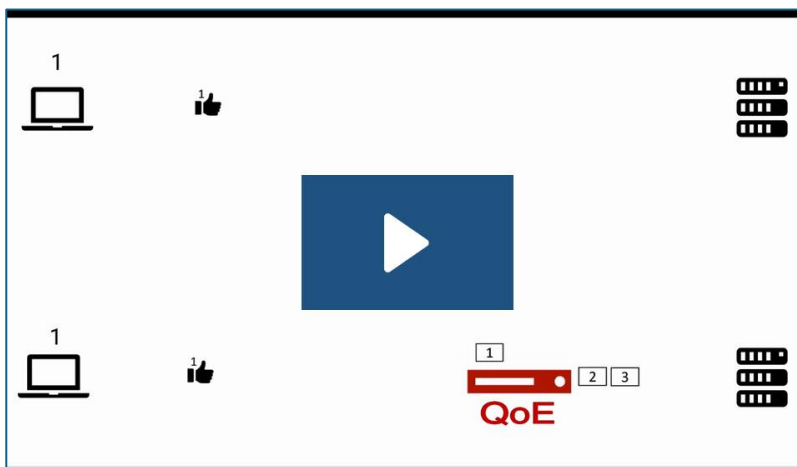
TCP Optimization

TCP is the most widely used protocol on the internet, but like other transport protocols, when networks are not perfect, it tends to transmit at a lower speed than the network allows. Cambium QoE has TCP Optimization functionality that ensures that TCP traffic flowing through it reaches optimal speeds, resulting in faster downloads and uploads.

Cambium QoE platform acts as a transparent proxy for every TCP connection in the network, which increases their speed in two ways:

1. Because as a proxy, contents will effectively appear closer to clients, meaning faster
2. Because our enhanced TCP will still send at the optimal speed in non-perfect networks

Click the thumbnail to play the video.



Cambium QoE TCP stack detects congestion based on the measured delivery rate, as described in our [patent](#) portfolio. Our improved congestion detection algorithm allows our TCP to be more aggressive when there is no congestion and to back off in real congestion, being able to carry out this discrimination in challenging environments: With shallow buffers, wireless links, packet losses, or large network delays.

Key Benefits:

- Faster downloads and uploads
- TCP proxy makes contents closer to the clients
- Optimal speed in non-perfect networks
- Patented and improved congestion detection algorithm
- Average page loading time reduced by 30% among popular web services

View an in-depth report comparing our TCP stack with Cubic, BBR, and BBR2 TCP [here](#).

Rate Limiting with Multi-Queue Approach

Cambium's QoE platform allows you to enforce bandwidth limitations in a flexible and economical way, with the most advanced queueing technology in the market, which will deliver the best possible Quality of Service (QoS) and Quality of Experience (QoE).

When speed is limited, network packets must wait in queues to be delivered, which increases network latency and can create packet losses. As a result, the network Quality of Experience may be severely **degraded**, especially for **interactive applications**, like online games and teleconferences, which are very sensitive to latency and losses.

Click the thumbnail to play the video.



Our unique multi-queue technology guarantees an independent queue for each connection, without any sharing (unlike competing solutions). Multiple independent queues ensure that interactive data do not have to wait in queues with heavy traffic, like video streaming. Moreover, interactive queues are prioritized. In this way, interactive applications will not notice the rate limitation, even in congestion situations.

Key Benefits:

- Reduce application latency
- Prioritize interactive or real time applications

Automatic Congestion Management

We have used the most advanced machine-learning algorithms to allow congestion management with no configuration or integration effort. Our Automatic Congestion Management (ACM), when enabled, will continuously monitor all network users, their speed, latency, and packet losses, and detect if they are reaching a congestion. When congestion is detected, it will just limit the speed marginally, which will reduce latency and losses, and avoid the congestion, providing a much better Quality of Experience.

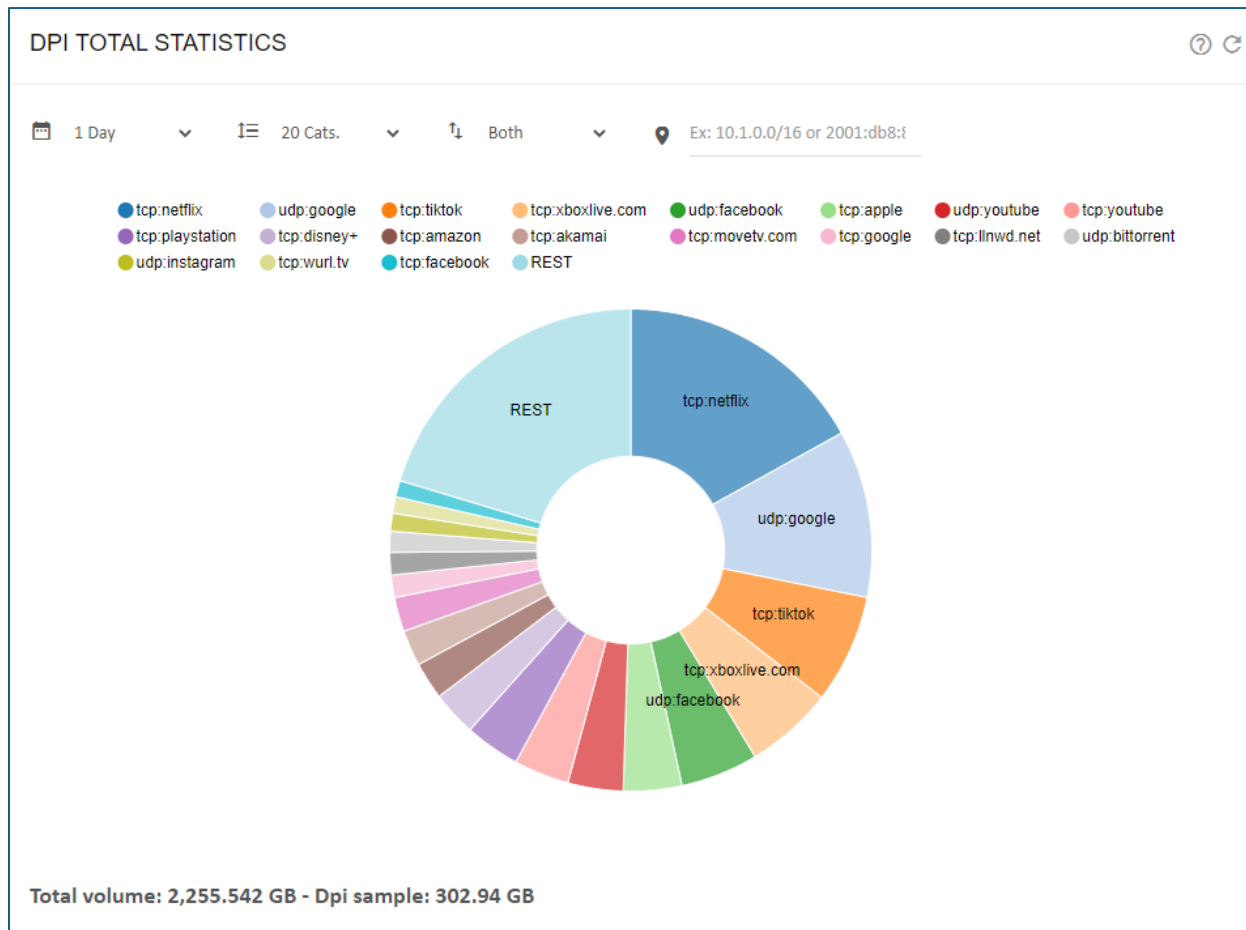
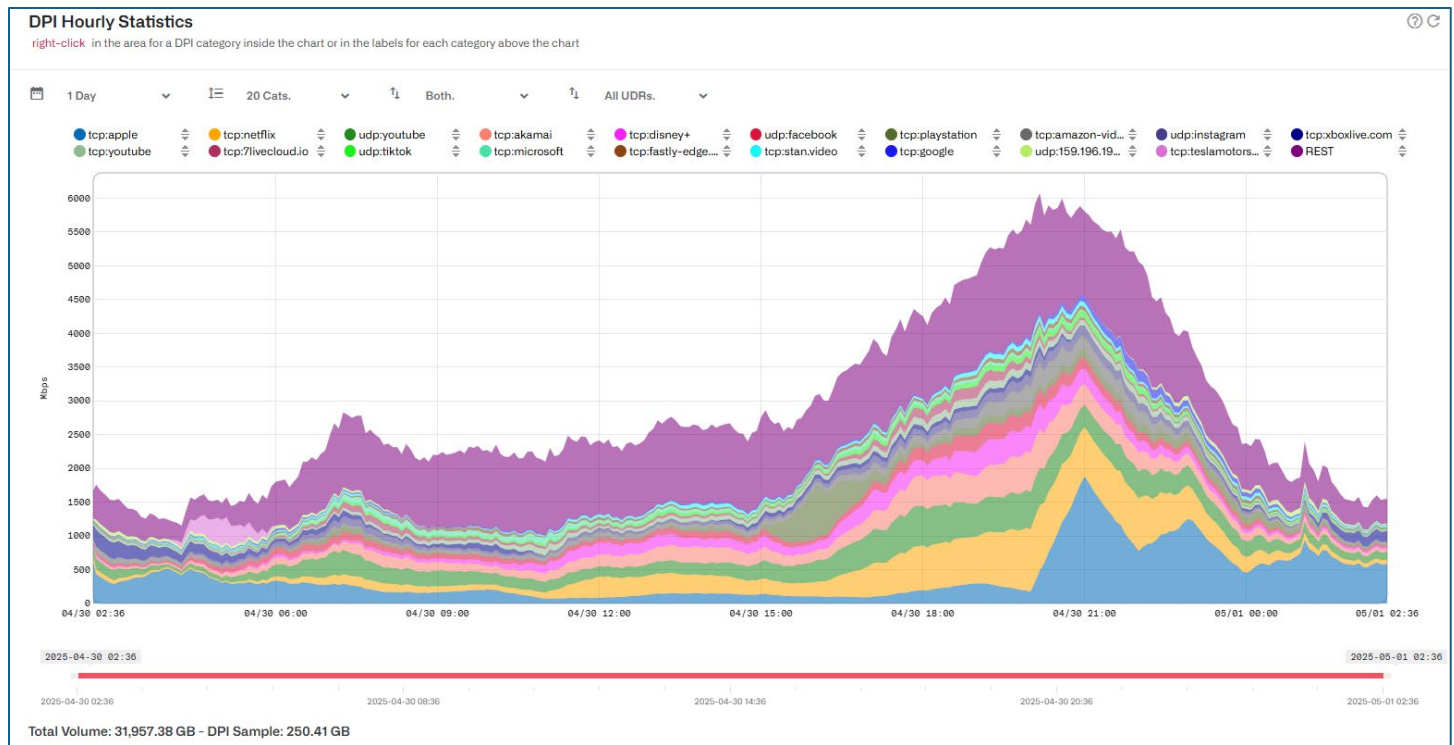
Key Benefits:

- Reduce latency and eliminate packet drops during peak traffic time
- Boost online game, teleconference experience during traffic congestion

Network Visibility

To deliver the best quality to your network users, it's obviously necessary to be able to measure and monitor it. Cambium's QoE provides you with the key metrics to monitor the quality you are delivering to your users and the quality you are getting from those connecting you to the internet.

Our advanced DPI (deep packet inspection) technology can see what services are being used in your network. In this way, you can plan your internet peering, predict the traffic behavior, and diagnose service-specific problems. It also shows the latencies from your network to the different services and how those latencies vary over time, which can help you measure the quality of the services delivered by different providers.

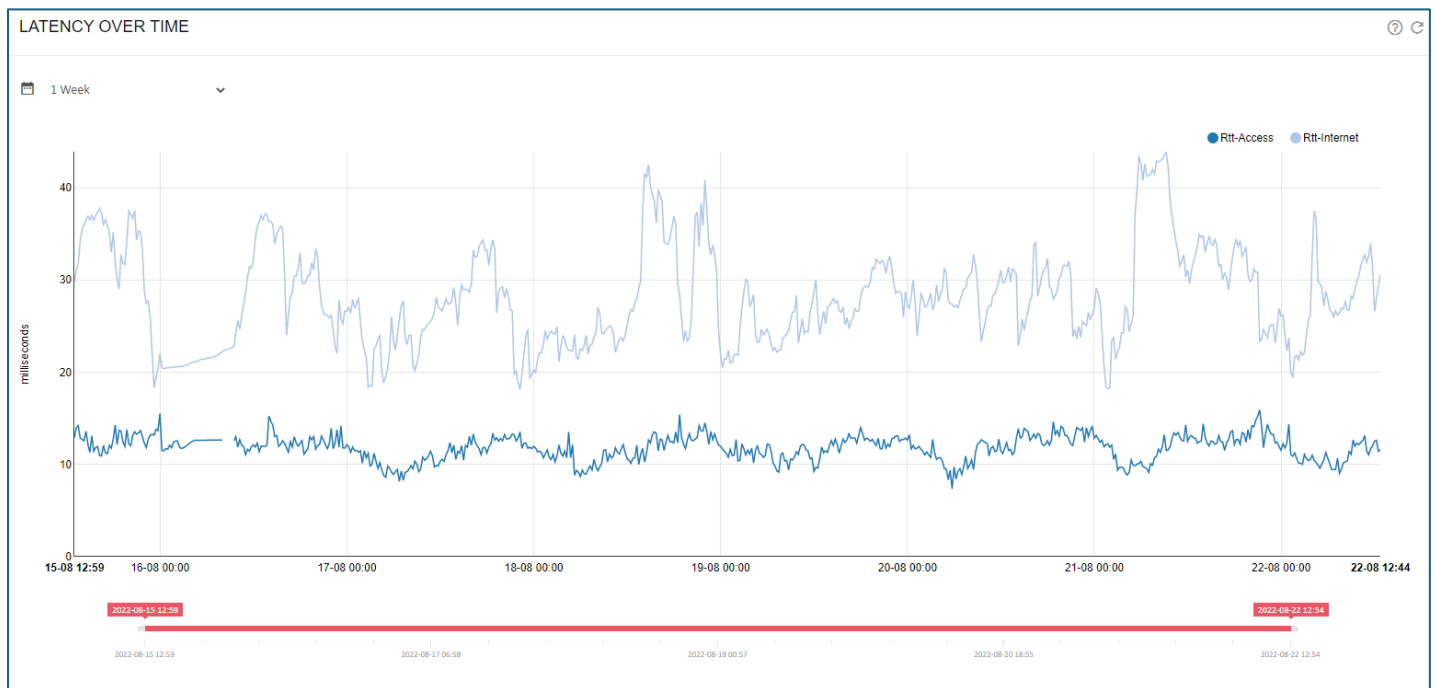


Key Benefits:

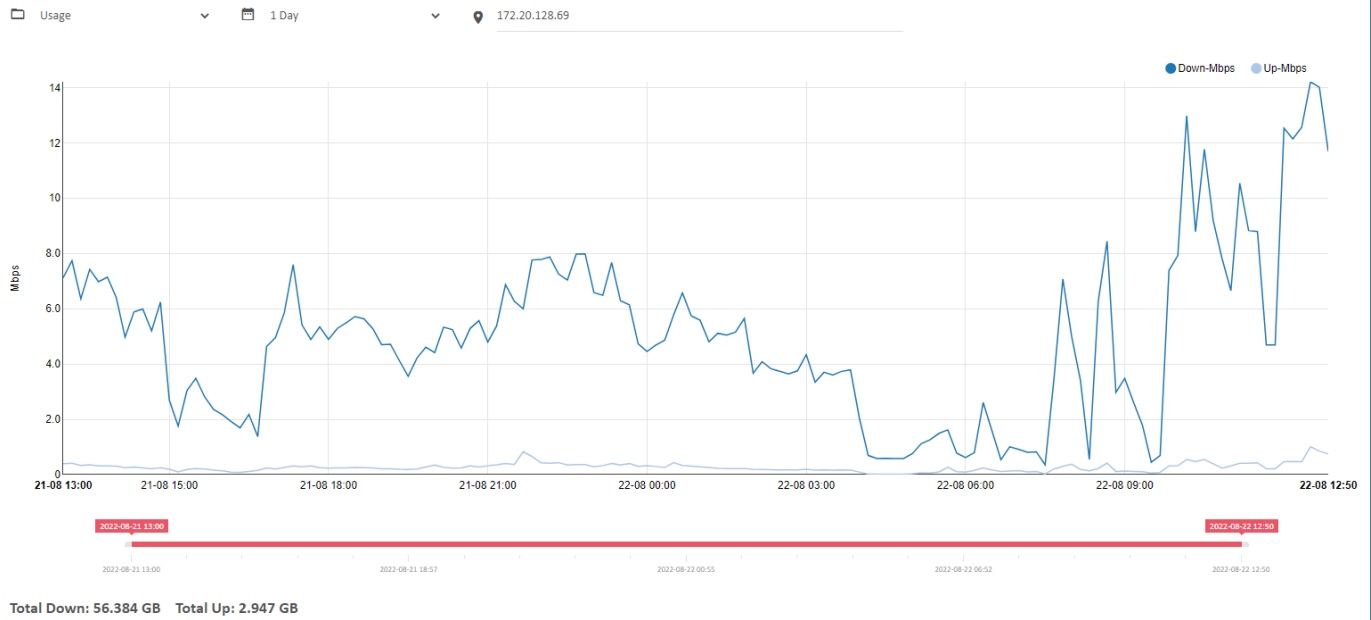
- Discover the services running in your network
- Displays hourly/total volume per service up to 3 days
- Displays % consumption of subscriber IPs for a service
- Displays average internet latency per service
- Help diagnose excessive internet service latency

Statistics

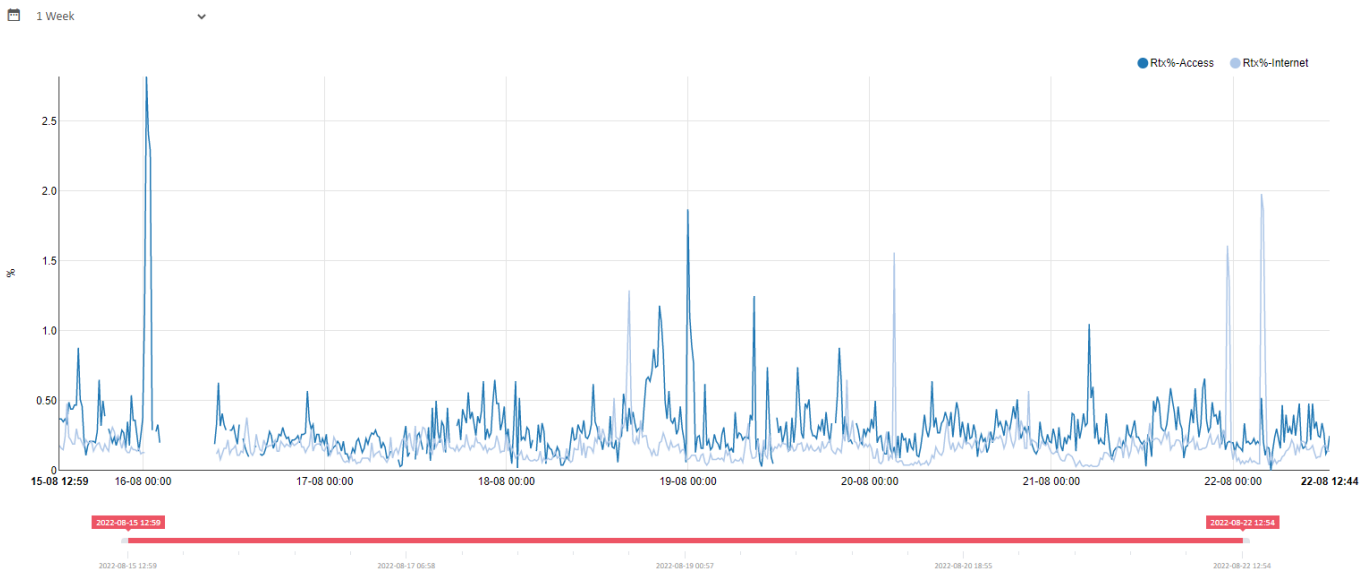
To be in control and to extract the highest quality from your network, you need metrics for your subscribers' quality of experience. Cambium's QoE measures the latency and the packet losses/retransmissions experienced by each subscriber in real time and keeps those metrics for 3 months. It also keeps graphs of actual usage and maximum speed attained (for 3 months), together with the active and created connections. In this way, it's also possible to diagnose complex networking problems.

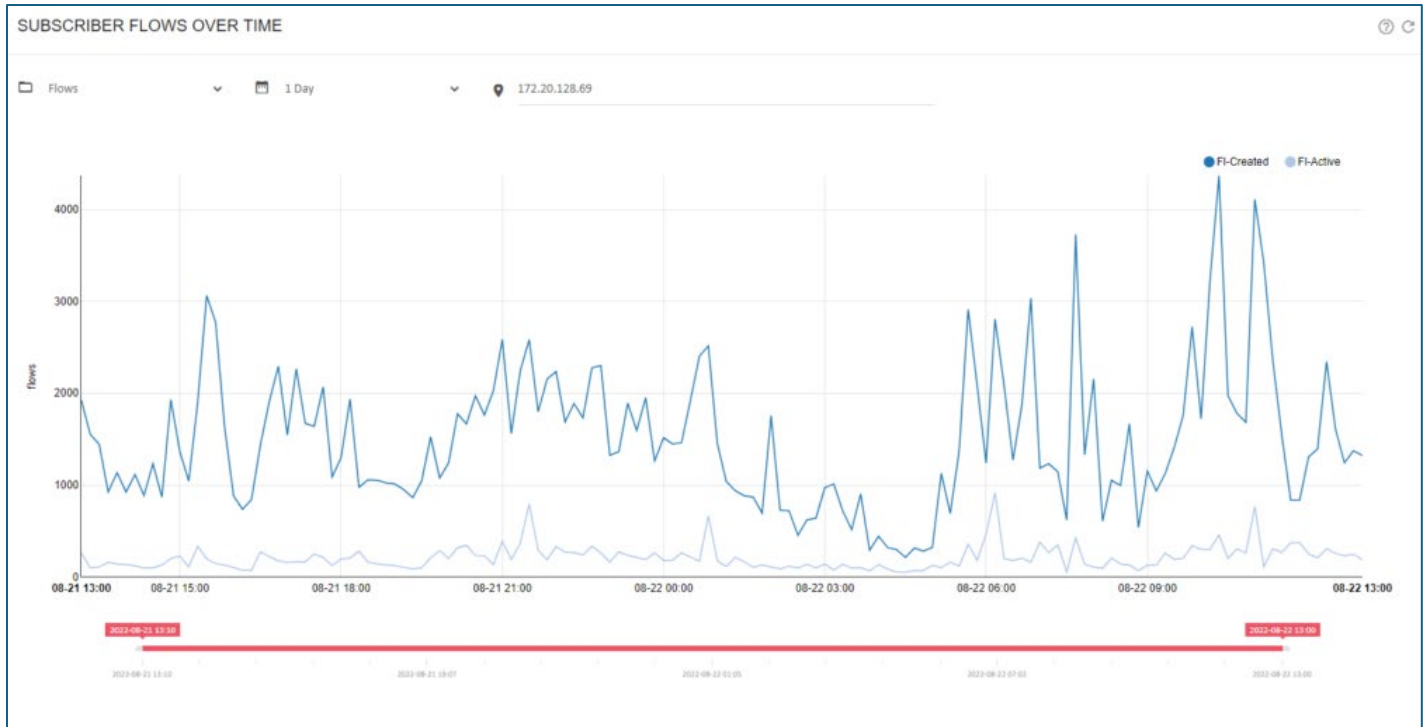


SUBSCRIBER USAGE OVER TIME



AVERAGE TCP RETRANSMISSIONS OVER TIME





Key Benefits:

- Know the RF health of your subscribers and optimize the network
- Know your top bandwidth consumers and help upsell internet packages

Application Shaping

Cambium's QoE limits the speed of all the subscriber flows based on traffic type or matching an application definition. Streaming and software updates are examples of big bandwidth consumers. This can affect quality of experience of other interactive applications like Zoom, Teams, Google Meet, or VoIP calls. Our DPI-based traffic-shaping rules allow users to limit the streaming bandwidth as per streaming providers bit -rate recommendations.

Shaping streaming services to smaller bandwidth will NOT impact performance. Streaming services often work to maximize the speed offered to pre-load their buffers, which can take up a lot of bandwidth. By shaping, you're still allowing the necessary bandwidth but not consuming unnecessary bandwidth. Cambium's QoE offers traffic shaping based on total traffic for an end-user IP or flow-based for an application.

Key Benefits:

- Ensure quality of experience to VoIP service
- Enforce priority to speed test applications

- Enforce priority to teleconferencing applications
- Enforce time-based traffic shaping
- Manage network congestion during peak hours by shaping streaming services
- Restrict software updates, game downloads only during off-peak hours
- Block or limit speed of torrent traffic

Denial of Service

The QoE platform can detect denial-of-service attacks, both starting from your subscribers, or targeted at them. It can inform you about the likely source or target of those attacks on the internet, so that you can take appropriate measures.



Hardware Requirements

This table summarizes the generic QoE hardware requirements depending on network capacity. The processors shown are examples of verified systems. Processors with similar performance characteristics will also work. The older processors or processors with lower frequency than the ones listed may require more cores to reach the same throughput. **Note that CPUs older than Nehalem architecture are not supported.**

Specification	1 Gbps	5 Gbps	10 Gbps	20 Gbps	40 Gbps	100 Gbps	200 Gbps	400 Gbps
CPU Manufacturer	Intel/AMD	Intel/AMD	Intel/AMD	Intel/AMD	Intel/AMD	AMD Epyc 7532/7543	2 x AMD Epyc 7763/9554	2 x AMD Epyc 9754
Cores	4	8	10	16	32	64	128	256
Minimum Threads	4	8	16	24	64	128	256	512
Verified CPUs	Intel N100, Intel i5 (minimum 4 cores), Intel i7, Intel Xeon E3-1220 and E-2314	Intel Xeon E3-1240 / E-2334	Intel Xeon E3-1240 / E-2334	Intel Xeon Silver 4214 / 4310	2 x Intel Xeon Silver 4214 / 4310	2 x AMD Epyc 7532 / 7543	2 x AMD Epyc 7763 / 9554	2 x AMD Epyc 9754
Minimum RAM	8 GB	2 x 16GB	2 x 16GB	4 x 16GB	8 x 16GB	16 x 16GB	512/768 GB	768GB/ 1.536 TB
RAM Configuration	Use 1 or 2 DIMMS	Use 1 or 2 DIMMS	Use 2 DIMMS	Use 4 or 6 DIMMs, all the same size; for Xeon 4310, 8 DIMMs suffice	Use 8 or 12 DIMMs, all the same size and equally distributed between the two CPUs; for Xeon 4310, 16 DIMMs suffice	Use at least one DIMM per CPU memory channel, with equal number of DIMMs per channel	Use at least one DIMM per CPU memory channel, with equal number of DIMMs per channel	Use at least one DIMM per CPU memory channel, with equal number of DIMMs per channel
Minimum Hard Disk (SATA/SAS/ NVMe)	60 GB	2 x 120GB	2 x 120GB	2 x 240GB	2 x 480GB	2 x 960GB	4 TB	8 TB
Data Interface	Intel I210/Intel I350	Intel X520/X540/X550/X710/XL710	Intel X520/X540/X550/X710/XL710	Intel XL710/XXV710/E810	Intel XL710/XXV710/E810	Intel XXV710/E810	Intel E810	Intel E810
Management Interface	Onboard 1 Gb	Onboard 1 Gb	Onboard 1 Gb	Onboard 1 Gb	Onboard 1 Gb	Onboard 1 Gb	Onboard 1 Gb	Onboard 1 Gb

Virtual Platforms

Cambium QoE Supports:

- VMware
- KVM (with Linux kernel of the host machine of 4.11 or later and QEMU of version 2.9 or later)

All resources will be fully dedicated (pinned) to the virtual machine (no oversubscription). As a general guideline, use the following resources. For advanced support, contact [Cambium support](#).

Key Specifications:

Appliance Capacity	1 Gbps	10 Gbps
Virtual CPU*	2	14
RAM	6 GB	32 GB
Hard Disk	60 GB	120 GB
Data Interface	Intel network cards with PCI passthrough	Intel networks cards with PCI passthrough

**Each vCPU is equivalent to one core of an Intel XeonE5-2630 v4 @ 2.20GHz CPUs, with hyperthreading enabled.*

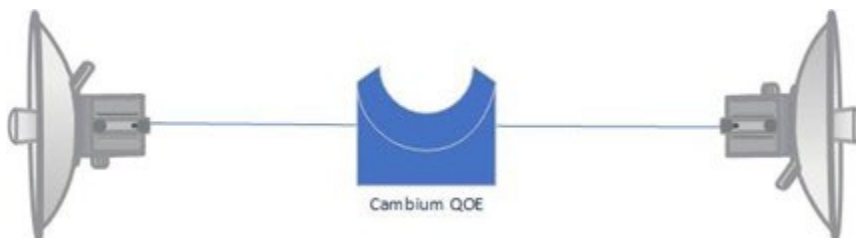
Networks Placement Guidance

There are several ways to introduce the QOE device into your network. Because the QOE box is an inline device, it allows for flexible installation into any service provider network.

The following are 7 common scenarios in which the Cambium QOE can be deployed. Each is dependent on your network architecture.

Scenario-1: Deployment Model—Point-to-Point Bridge

Sustainable for point-to-point links. You can install this either on the service provider side or the customer side before their router.



Scenario-2: Deployment Model—Basic PoP

This scenario is to mainly illustrate the placement of the QoE host into your wireless network. Most customers will have more than one access point (AP) at each location. If you are natting at the router, the QoE host needs to go before the router.



Scenario-3: Deployment Model—Routed PoP

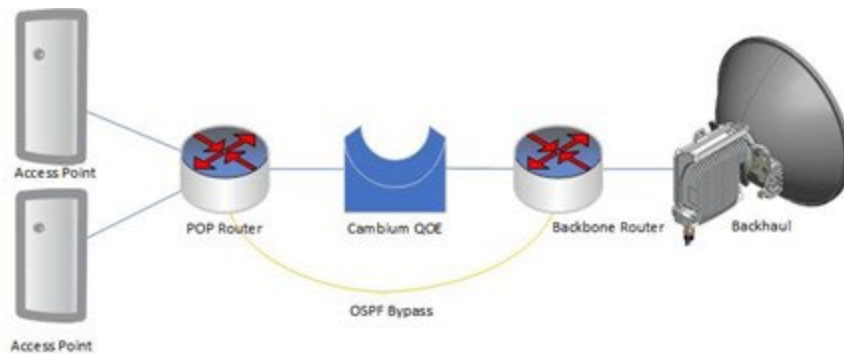
This method is highly dependent on the amount of LAN ports on the QoE. Otherwise, it is no different than Scenario-2. In order to increase the number of ports, we recommend adding a switch. Your APs can plug into the switch with a single uplink through the QoE. You can divide the APs into VLANs if you prefer. The QoE will understand the VLANs and pass them through to the router.



Scenario-4: Deployment Model—Advanced Routed PoP

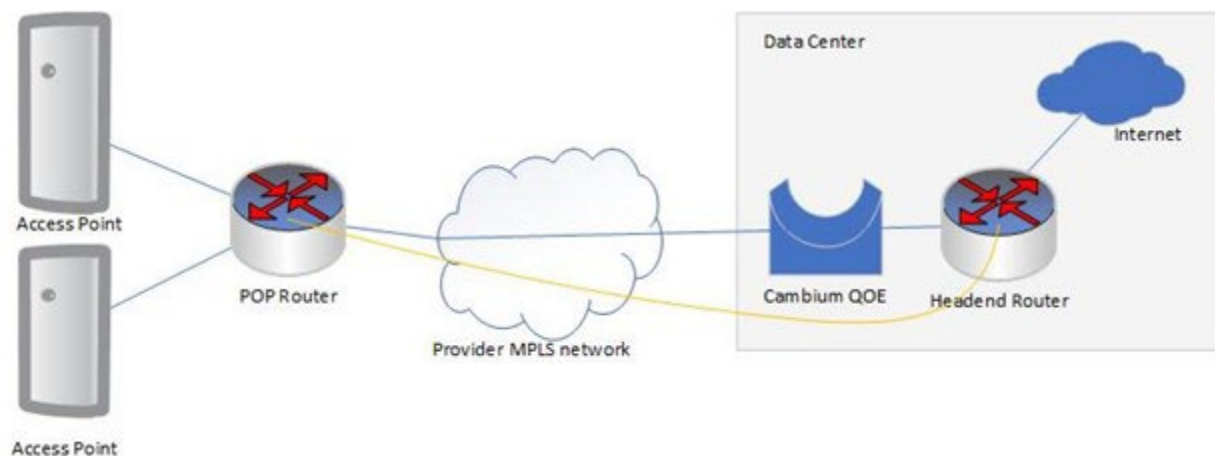
This scenario is the best, in terms of technical implementation. It allows for seamless failover at the PoP level should the QoE host fail due to power or cable damage. If it fails, it just affects that PoP. With the above OSPF bypass you can keep running.

This scenario does require two Layer 3 devices at each PoP talking OSPF between them. The PoP router in the diagram can be a Layer 3 switch to save on the physical footprint.



Scenario-5: Deployment Model—Single Headend

Placing the QoE host at the headend of your network makes the most sense for some operators. This combines the cost-effective nature of centralized shaping with less hardware to maintain. This scenario is easiest to accomplish if you are running MPLS/VPLS on your network. This design allows for a variation of the PoP scenario listed above using VPLS tunnels to route traffic around the QoE box in case of failure or maintenance. In this method, you're moving all of the shaping functions to a central location. This adds an element of failure as your traffic is going through one central box. However, as in the above method, you can mitigate this with a routed bypass.

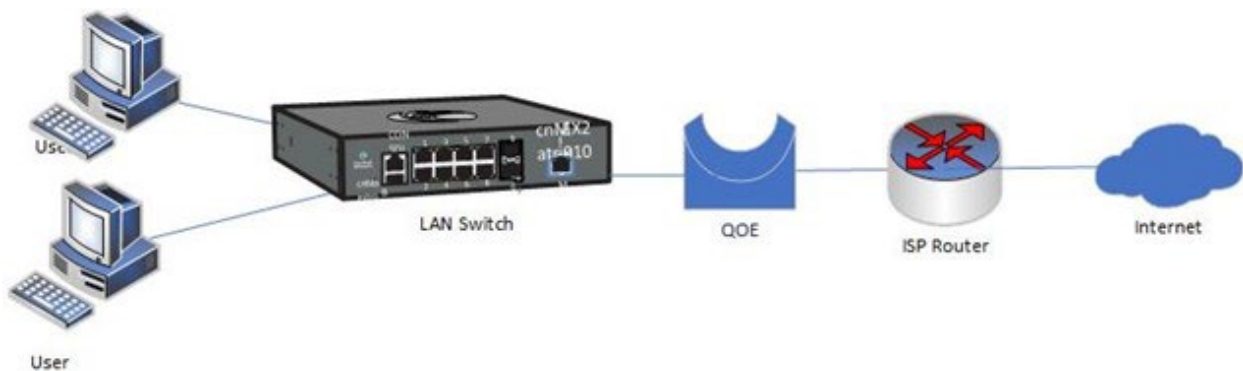


Scenario-6: Deployment Model—Multiple Exit Point

As service providers grow their networks, they often run into having multiple exit points on their network. Because the QoE host is transparent, these can be positioned at each headend in the same scenario as in Scenario-5 above but with hardware at each exit point.

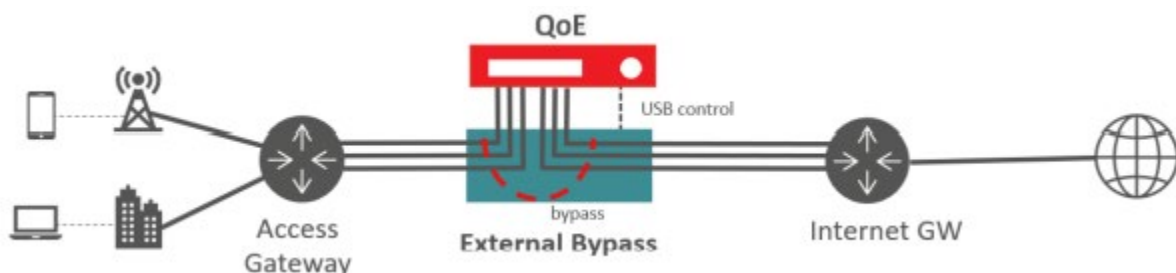
Scenario-7: Deployment Model—MSP- or ISP-Managed Router

This scenario is helpful if you do not control the service provider network but want to give customers a quality of experience. Maybe you are an MSP supporting enterprise clients. In this scenario, you install the QoE host between the customer's LAN network and the ISP router.



QoE Bypass Guidance

It is recommended that a bypass path is established between the neighboring nodes of the QoE access and internet gateways. If there is a failure in the active link or the QoE, the traffic is automatically steered through the bypass path. Monitoring takes place through a USB connection between the QoE server and the bypass appliance.



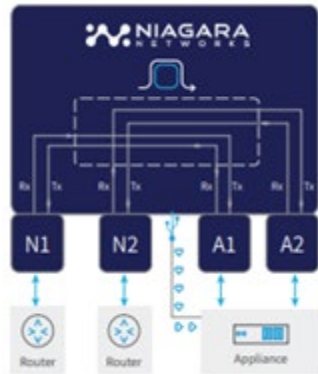
Appliance Model 1: NIAGARA 3296

Key Specifications:

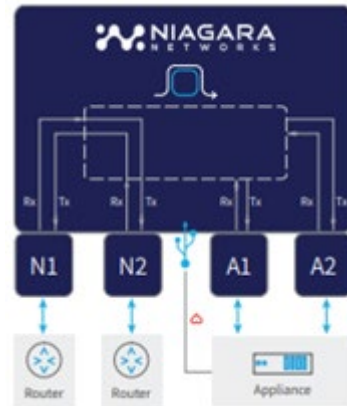


- Up to 8 full bypass segments; each bypass segment includes 2 network ports and 2 appliance ports
- Copper, fiber multimode BiDi, and fiber single-mode network interfaces
- Supports SX, SR, SR4, LX, LR, LR4
- Network links from 10 Mb to 100 Gb

Normal Inline Mode



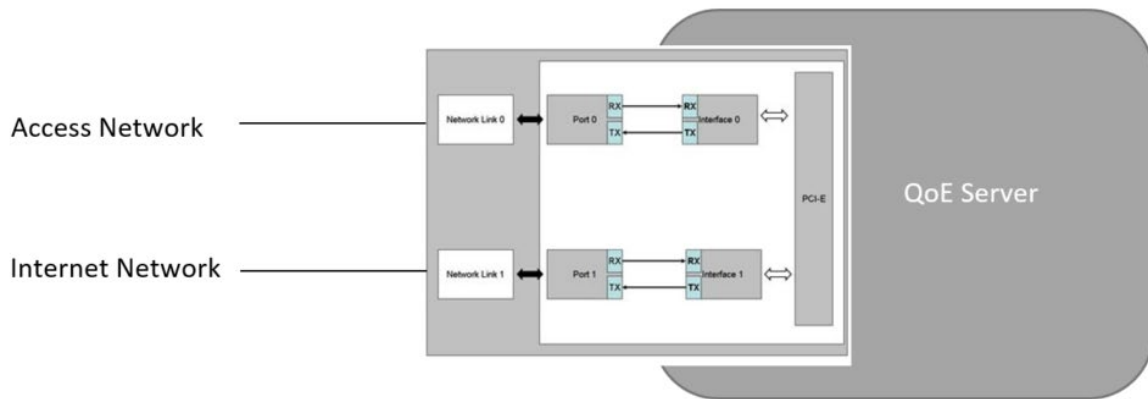
Bypass Mode



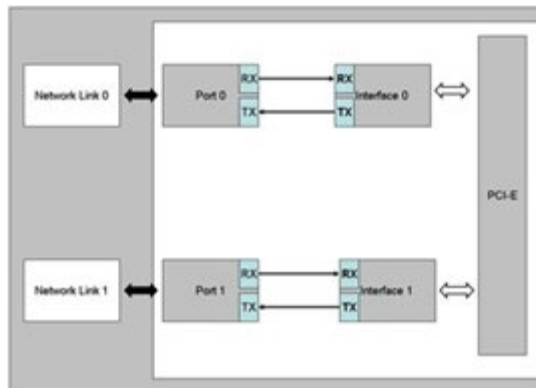
In case an external heartbeat is not received for the appropriate segment, and the countdown timer for that segment expires, the affected segment will go into bypass mode.

Appliance Model 2: Silicom Ethernet Bypass Networking Server Adapters

The Silicom's ethernet bypass networking server adapters are targeted to inline network systems that maintain network connectivity when the system fails. Silicom's dual- or quad-port fiber 10 G ethernet bypass server adapter is a PCI-Express X8 network interface card that contains two or four 10 G ethernet ports on a PCI-E adapter. These adapters should plug in a host server machine as a NIC accessory.

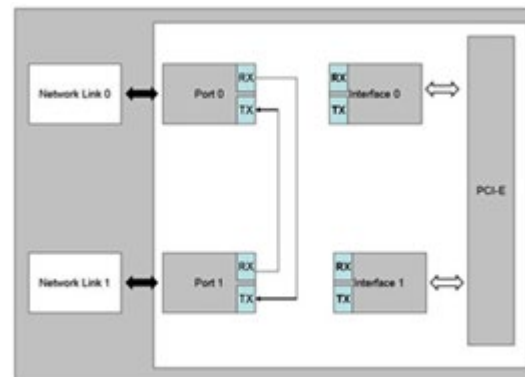


Normal Mode



In normal mode, the ports are independent interfaces.

Bypass Mode



In bypass mode, all packets received from one port are transmitted to the adjacent port.

Key Specifications:

Model	PE310G2BPI71
NIC	Dual-Port Fiber 10 Gigabit Intel® XL710BM1 Based
Interface Standard	PCI-Express Base Specification Revision 3.0 (8 GTs)
Board Size	Standard height short add-in card 167.64mm X 109.1 mm (6.6"X 4.296")
PCI Express Card Type	X8 Lane
PCI Express Voltage	+12V ± 8%
PCI Connector	Gold Finger: X8 Lane
Holder	Metal bracket
I/O	LC located on internal bracket



Key Specifications:

Model	PE310G4BPI71
NIC	Quad Port Fiber 10 Gigabit Intel® XL710BM1 Based
Interface Standard	PCI-Express Base Specification Revision 3.0 (8 GTs)
Board Size	Standard height short add-in card 167.64mm X 109.1 mm (6.6"X 4.296")
PCI Express Card Type	X8 Lane
PCI Express Voltage	+12V ± 8%
PCI Connector	Gold Finger: X8 Lane
Holder	Metal bracket
I/O	LC located on internal bracket



Billing Support

Cambium's QoE integrates with leading ISP billing platforms to retrieve subscriber data and implement rate limits. The integration is between a billing system that controls the plan definition and Cambium's QoE through its management interface.

Integration benefits:

- Auto-create rate control policies (subscription plans)
- Assign a plan to a subscriber
- Obtain subscriber metrics for up to 3 months: Volume used, maximum speed, latency, retransmissions, and active/created flows

Supported billing platforms:



About Cambium Networks

[Cambium Networks](#) enables service providers, enterprises, industrial organizations, and governments to deliver exceptional digital experiences, and device connectivity, with compelling economics. Our ONE Network platform simplifies management of Cambium Networks' wired and wireless broadband and network edge technologies. Our customers can focus more resources on managing their business rather than the network. We make connectivity that just works.