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Cost-Effective, Scalable Quality of Experience (QoE) Monitoring for SD-WAN Networks

A Technical Paper prepared for SCTE/ISBE by

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1. Executive Summary

Today, SD-WAN vendors offer some type of quality of service (QoS) visibility, but they do not extend this to true application quality of experience (QoE).

While SD-WAN solutions provide visibility into such things as network performance between platforms or bandwidth/capacity usage for top protocols, these metrics are provided only within the walls of the network. As such, they cover application performance from WAN edge to WAN edge only—not to the true edge (the end user's experience).

This paper will focus on the importance of, challenges surrounding, and requirements for true SD-WAN QoE visibility, including a look at costing benefits of metadata-based monitoring compared to traditional stream-to-disc.

Problematic QoE visibility are gaps created by the limitation of SD-WAN solutions:

- No way to pinpoint location/cause of application performance degradations
- Insufficient granularity to perform troubleshooting or optimization across the entire application delivery chain

Areas of visibility needed to measure real user experience include:

- Network performance
- Application delivery (through the network and infrastructure)
- Application transaction delay

Limitations of traditional QoE monitoring solutions using stream to disc include:

- Expensive to deploy and maintain
- Excessively short retention times
- Lack of flexibility to adapt to data growth (storage and interface types)

True SD-WAN QoE monitoring requires:

- Visibility into underlay network
- Visibility into end user application QoE
- Visibility into the root cause of application performance degradation

True, end-to-end QoE SD-WAN monitoring using metadata benefits operators with:

- Efficient capture of only the performance information of interest
- Long-term retention for context and future planning
- Fast performance degradation investigation
- High affordability compared to traditional monitoring

Content

2. SD-WAN Value

The value for software-defined WAN (SD-WAN) varies somewhat depending on whether the organization deploying it is a communications service provider (CSP), managed service provider (MSP), or an enterprise.

For enterprises the ever-growing use of cloud-based applications makes SD-WAN more relevant every day. Software-defined networking (SDN), initially reserved for data center applications—along with a number of other technology enablers—have set the table for SD-WAN to disrupt traditional WAN architectural models prevalent within most enterprises.

From the service provider point-of-view, SD-WAN is appealing for similar reasons, primarily to offer a low-cost bandwidth enhancement to offered services—but also because it unlocks the ability to turn up new features on-demand, enhancing agility and speed for service delivery and the initial service turn-up.

Service providers typically deploy SD-WAN in their network to gain agility and flexibility first and foremost. The software automation at the heart of the SD-WAN solution allows for the creation of fully dynamic networks and give end-users a control into the nature and level of services they require on an ongoing basis. A crucial benefit for service providers is the ability to both deploy and maintain features and services via software deployment. Running software on commercial off-the-shelf (COTS) servers dramatically lowers both risks and costs when compared with the traditional dedicated hardware appliance solutions that required extensive trials to approve and the trained personnel, space, power and cooling to run.

Collectively (across enterprises and service providers), the main benefits of SD-WAN are:

- Access independence
- More bandwidth for less cost
- Cloud migration ease (remote site direct internet connection to the cloud)
- Ability to support hybrid networks (Applications no longer reside exclusively in the data center, and workloads are moving from enterprise data centers to private and public cloud)
- Application performance visibility over the network
- Automated provisioning
- Centralized policy control and management

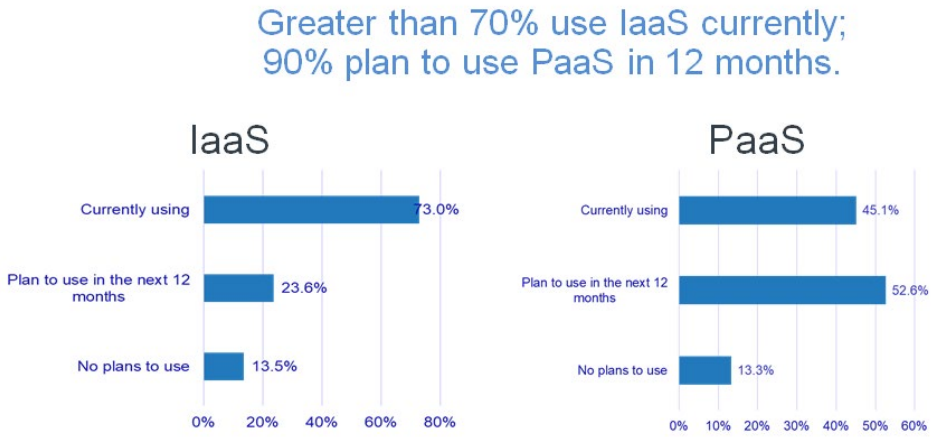
But, there's a very important item missing from this list: quality of experience (QoE) visibility at the true edge of application delivery—the end user. SD-WAN vendors typically offer some type of quality of service (QoS) visibility, but they do not extend this to true application QoE.

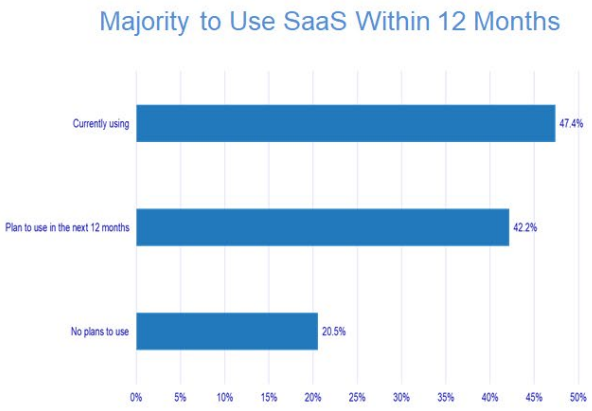
3. SD-WAN Enterprise Adoption Overview

Enterprises are adopting SD-WAN as a way to gain access independence, leverage more bandwidth for less money, streamline cloud migration, automate service provisioning, and centralize policy control and management—among other benefits. However, the move to SD-WAN also involves moving a lot of the network control to the service provider's cloud.

The IDC enterprise SD-WAN survey below illustrates the adoption trend: two-thirds of survey respondents indicate they will deploy SD-WAN within the next two years. These results also show that cloud usage continues to rise, as does its importance in WAN technology selection:

- 70% of enterprises currently use infrastructure as-a-service (IaaS) and 90% plan to use platform as-a-service (PaaS) in the next 12 months
- A significant portion of enterprise apps are accessed using the internet





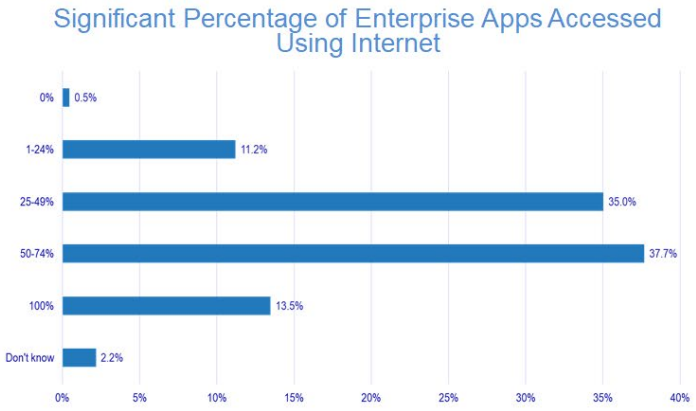


Figure 1 - IDC Worldwide Enterprise SD-WAN survey on cloud usage showing that the majority of enterprise plans to use SaaS within 12 months and a significant percentage of apps are accessed using the internet. (Source: IDC Worldwide Enterprise SD-WAN survey)

By moving to the cloud, enterprises can stand to benefit in several ways: more processing bandwidth for less cost, greater flexibility to scale resources up or down according to organizational needs, and reduced cost by taking away the burden of proprietary hardware or fixed circuits.

4. Service Providers Adoption Challenges

4.1. SD-WAN Adoption Complexities

Service providers are also adopting SD-WAN services as a way to enrich their offerings. But while SD-WAN brings significant, immediate benefits to the enterprise, it makes things more difficult for service providers. One of the largest challenges they face in adopting SD-WAN is dealing with increased complexities, which then translate to increased costs.

Many service providers support multiple SD-WAN solutions, because of preference for certain providers or to continue support for previous deployments. But, each SD-WAN vendor presents its own set of capabilities, management systems, and interoperability issues. This introduces complexities to manage:

- Within a single vendor, there are multiple product generations, models and update cycles to manage.
- Each protocol supports different control and monitoring functions.
- Reporting differs between SD-WAN systems:
    - Performance assurance standards are not uniformly implemented.
    - Different degrees of 'compliance' create interoperability gaps.
    - Different monitoring methods deliver different levels of detail.
- Reporting tools are not agnostic: there is no way to compare performance between vendors.

4.2. Increased Network Complexities

In addition to SD-WAN adoption complexities, service providers also need to deal with the increased network complexity as a result of the emergence of virtualization and cloud-native applications. Finally, these complexities are worsened by users' constant demand for more data, more bandwidth, and a seamless experience. Consequently, the challenge of assuring all parts of the network has never been more difficult for service providers who are already struggling to keep up with user experience visibility.

4.3. SD-WAN Limited Visibility

The solutions offered by SD-WAN vendors provide visibility of network performance between SD-WAN nodes (e.g. latency, packet loss) and usage (e.g top protocols, top talkers). Because these metrics are only provided through Netflow or gateway nodes, SD-WAN solutions fail to offer visibility into network underlay without additional cost (such as additional hardware or software). Network level diagnostics required to provide meaningful data for mean time to resolve (MTTR) add compute burden to SD-WAN platforms (requires x86 resources to monitor the network).

Furthermore, by moving connectivity to the cloud, existing monitoring and performance assurance tools are unable to monitor what happens beyond their own network edge, unable to provide end to end application performance visibility and root cause of application performance degradation.

4.3.1. Visibility Limited to WAN Edge

Some SD-WAN solutions provide visibility into such things as network performance between SD-WAN platforms or bandwidth or capacity usage for top protocols. But, because these metrics are provided

within the walls of the network, they cover application performance from WAN edge to WAN edge only—not to the true edge which is the end user's experience.

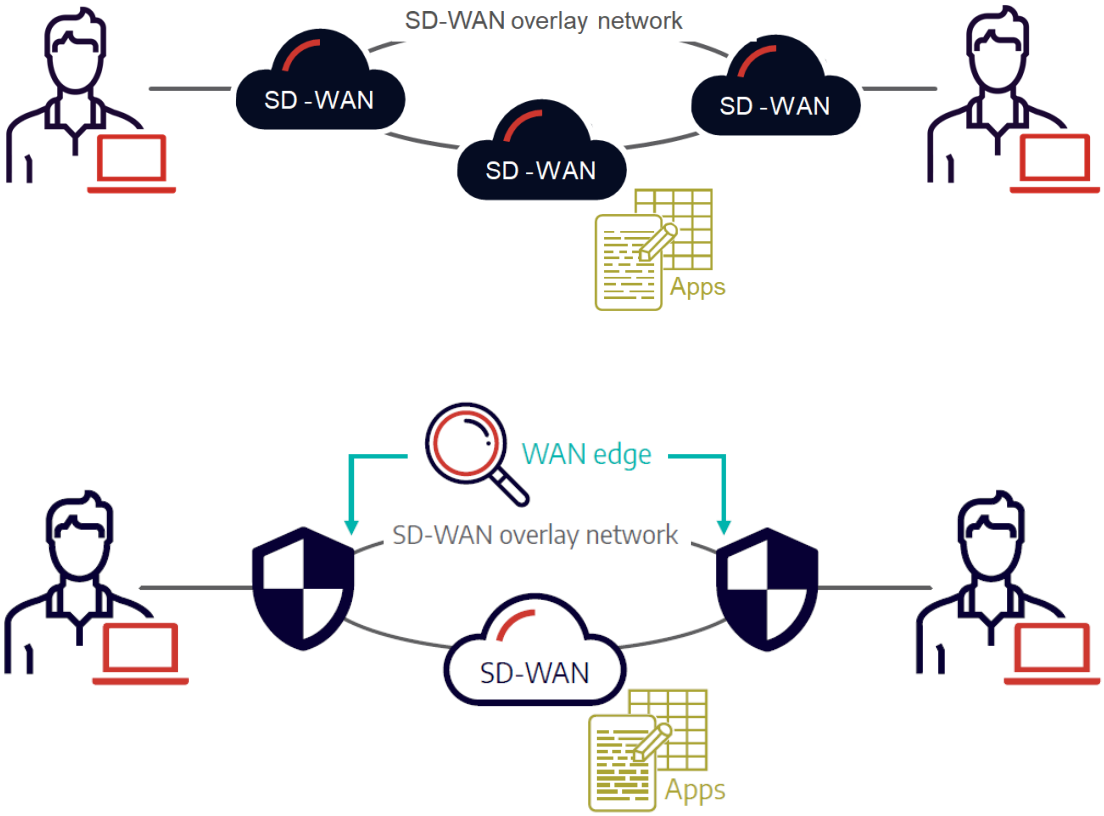


Figure 2 - SD-WAN vendor solutions monitor limited visibility

As such, service providers experience visibility gaps outside of the confines of their wide area network (WAN) edge and will be unable to see problems that may be affecting users. For example: an inability to pinpoint location or cause of application performance degradations, or insufficient granularity to perform troubleshooting or optimization across the entire application delivery chain, creating problematic QoE visibility breaches. As such, WAN performance indicators may all be green but users could still be experiencing degradations.

Consequently, as more enterprise applications run on SD-WAN overlays, service providers will struggle to assure QoE because they don't have visibility beyond their existing MPLS networks, and cannot correlate events/issues to ensure any application or network problems are being identified.

5. End-to-End Application QoE

For SD-WAN to show value to service providers and measure the real user experience (QoE), their performance assurance tools need to go beyond the confines of their MPLS or Carrier Ethernet networks, and beyond the overlay monitoring services offered by SD-WAN vendors. It also implies a performance

assurance management tool that is able to monitor the network from end to end and from layers 1 to 7 of the open systems interconnection (OSI) model, while bridging the existing visibility gap between network performance (layers 1-3) and application delivery (layers 4-7).

As such, measuring the real user experience requires full visibility into:

- Network performance
- Application delivery (through the network and infrastructure)
- Application transaction delay

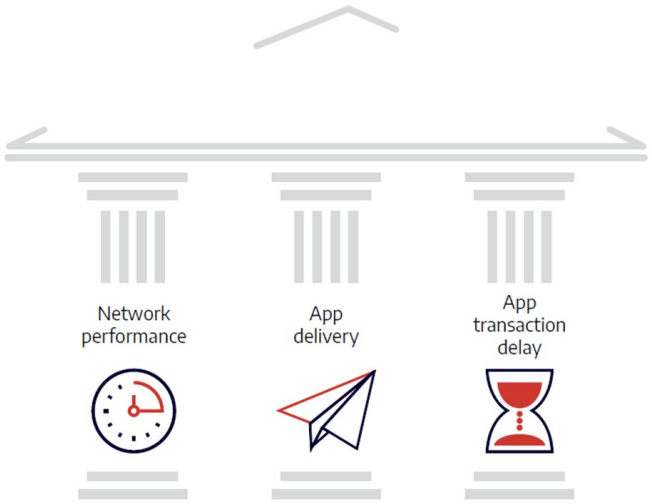


Figure 3 - Three essential pillars of visibility required to measure application QoE

If any one of these is missing, it's not possible to have complete QoE visibility. Most SD-WAN vendor solutions fall short because they do not offer:

- Visibility into the underlay network
- Visibility into end user application QoE
- Visibility into the root cause of application performance degradation

Furthermore, these tools need to go beyond simply monitoring: they also need to be able to identify issues by building a profile of the network and application, what it is doing, and how it is being experienced by the end-user. This unification of network and application performance assurance will provide IT and service provider teams with a single source of truth and will help remove the silos created by having different teams monitor different parts of the network or application chain. Through this single platform, network operations, development, and business line owners can understand the interactions between infrastructure, application and user experience. What's more, this holistic view provides service providers with the opportunity to go beyond mere QoS and towards achieving, real-time full QoE visibility across the entire network chain.

With the right performance management tools that span both the network and application layers, service providers can meet the QoE demands of users, even in an SD-WAN environment.

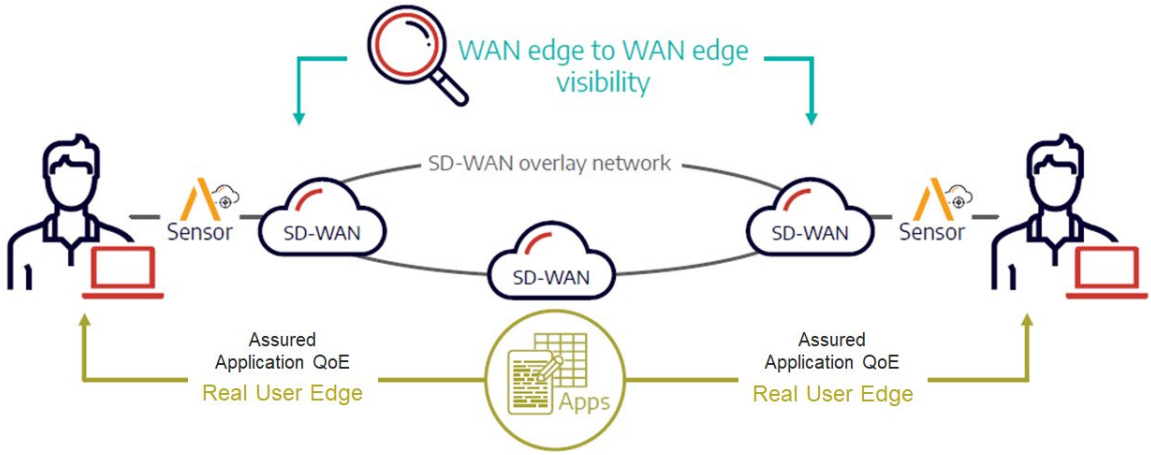


Figure 4 - Complete application QoE visibility

6. Adding Active Performance Monitoring for Underlay Visibility

Most SD-WAN customer premises equipment (CPE) solutions provide passive analysis (bandwidth monitoring) of traffic/flows going and very rudimentary (ping / DNS query) methods of active link assurance. No SD-WAN CPE solutions have service activation testing (SAT) type capabilities built-in, which are key in providing underlay visibility. Such SAT and specific key performance monitoring (PM)-type capabilities for active testing include, but are not limited to:

- Service Activation Testing (SAT)
  - L2/L3 RFC2544 / Y.1564 - Standards-based service activation testing supporting commonly employed IEEE RFC-2544 and ITU-T Y.1564 turn-up testing approaches.
  - RFC6349 Framework for TCP Throughput testing
- Performance Monitoring (PM)
  - Y.1731 Ethernet OAM to ensure service availability meets SLA definitions, and to measure continuity and latency using CCM and DMM/DMR messages, respectively.
  - RFC-5357 Two-Way Active Measurement Protocol (TWAMP).

SD-WAN architectures virtualize some or all customer premises functions with a simple COTS server at the customer site. As part of their standard feature-set, SD-WAN solutions implement path monitoring and measurement. However, these measurements are typically insufficient for managed business services over SD-WAN deployments because those service assurance functions implemented purely in software:

- Lack sufficient time stamping precision and packet transmission scheduling control to meet the requirements of:
  - Full line-rate test traffic generation and loopback for SAT and troubleshooting.
  - Precise traffic generation sequencing required by common turn-up test standards (where inter-packet delay needs to be controlled for burst testing, for example).
  - Microsecond-level latency measurement precision required to monitor and report on commercial services SLAs.
- Are subject to the resource-sharing of the x86 system. This causes additional uncertainty in the results by bundling the performance of the x86 system with the performance of the network itself.

In addition, SD-WAN solutions typically use proprietary monitoring and reporting methods that do not interoperate with existing network equipment (or other SD-WAN vendors). Because SD-WAN may only

be required in certain locations, any service assurance implementation has to interact seamlessly with the traditional service delivery methods.

Relying on built-in SD-WAN monitoring creates a potential blind spot. This is especially true when considering SAT such as RFC2544 or ITU-T Y.1564 that have no support from SD-WAN vendors. Built-in SD-WAN performance monitoring functions can only provide a top-down view of performance—the over-the-top (OTT) path. This view presents no insight into why a specific path is operating badly; just that it is not performing. Complementing this top-down view with a bottom-up perspective provided by hop-by-hop or layer 2-3 path monitoring (such as SAT or PM) can add the missing pieces to more efficiently run an assured SD-WAN services, enabling detailed troubleshooting and measurable quality improvements

Running a unified assurance solution, which includes both active and passive monitoring, across both the incumbent part of the network and the SD-WAN part of the network also has the benefit of offering a unified level of precision and reporting intervals. As such, pinpointing events and segmenting the network will ease troubleshooting and accelerate mean time to resolution (MTTR) when issues arise.

6.1. SD-WAN Point-to-Point or Point-to-Multipoint Deployment Model

Many SD-WAN vendors offer an architecture based on centralized gateways to act as the virtual hub for any number of remote locations (spokes), as shown in Figure 9. The connected sites (branch, head office, HQ) need little hardware and a number of network transports (internet links or traditional WAN links) to establish the overlay network needed for the SD-WAN to operate (purple lines going to the SD-WAN gateway). The overlay network is built by having each remote site establishing encrypted tunnels to the SD-WAN gateway over each provisioned path.

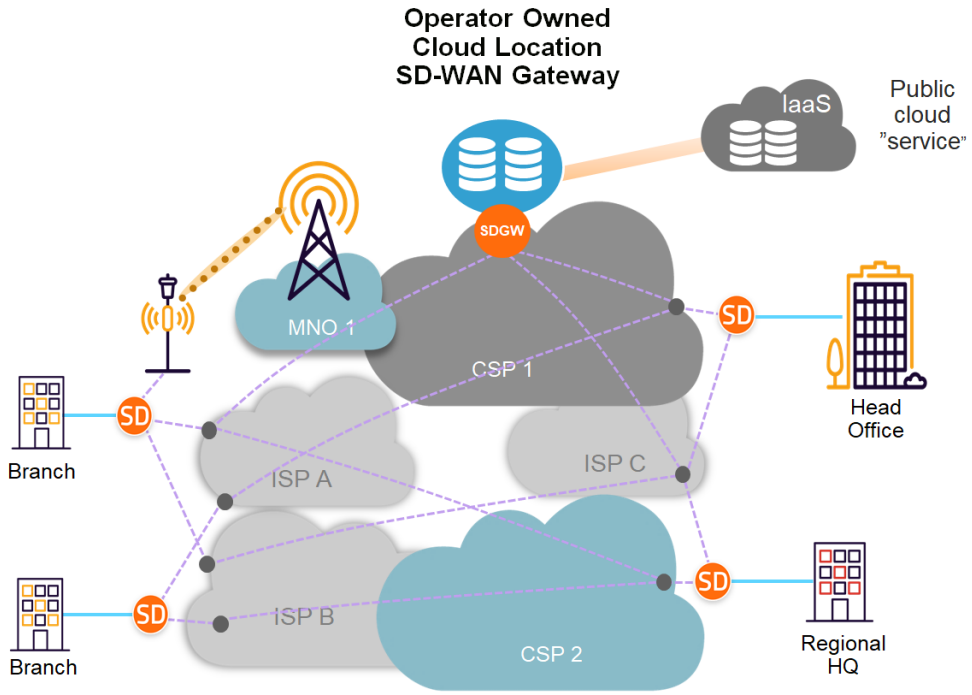


Figure 5 - Centralized Gateway SD-WAN Model

In such a model, deploying an active and passive monitoring solution in the SD-WAN CPE enables:

- Core-to-edge or edge-to-edge active PM and SAT
- Cloud gateway location-to-edge active PM and SAT

And in addition, for the cloud service(s):

- Cloud gateway location-to-cloud service location
- Cloud service location-to-edge active PM and SAT

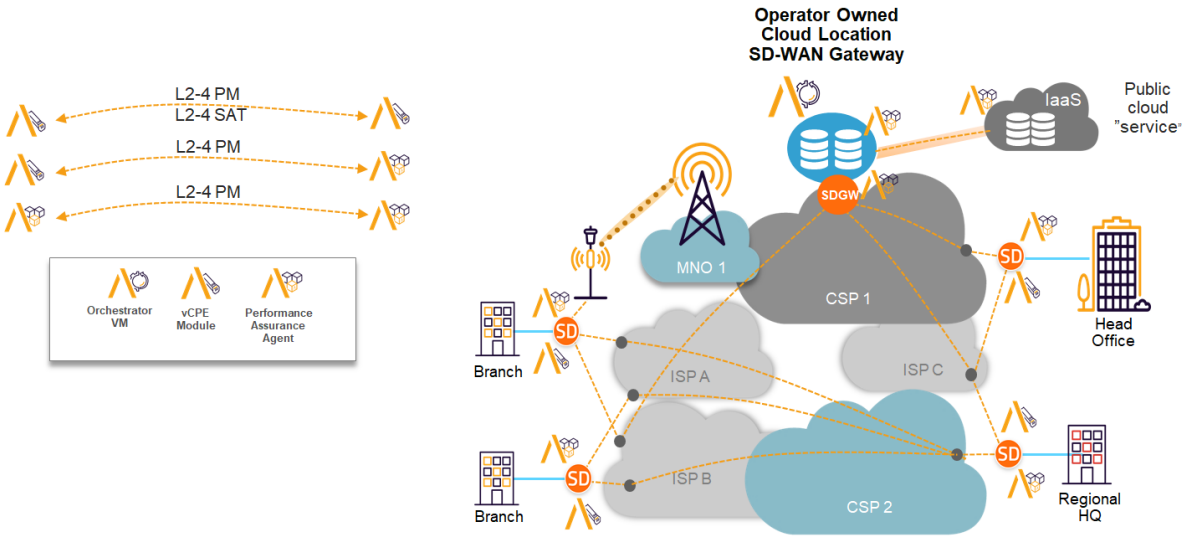


Figure 6 - Point-to-point or point-to-multipoint business VPN

7. Customization for Different Types of Organizations

Most organizations that move to SD-WAN have some reliance on the cloud but still haven't solved their monitoring problem. Fundamentally, monitoring user experience of network and cloud applications requires new methods and different metrics. Without these in-place before, during, and after an SD-WAN deployment, IT teams are left with little visibility and big headaches. This is where new solutions need to provide organizations with the insights and edge that they need, filling in the gaps, extending performance visibility to the real edge and going beyond QoS to true QoE.

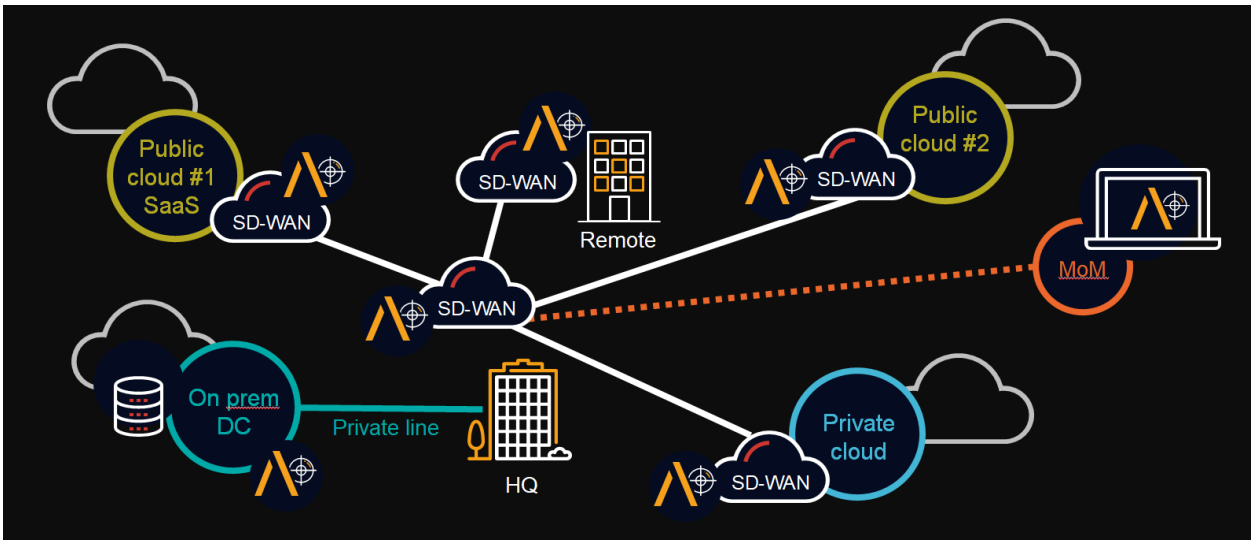


Figure 7 - Ubiquitous application QoE visibility across the entire cloud
(prem=on premises, DC = datacenter, MoM=manager of managers)

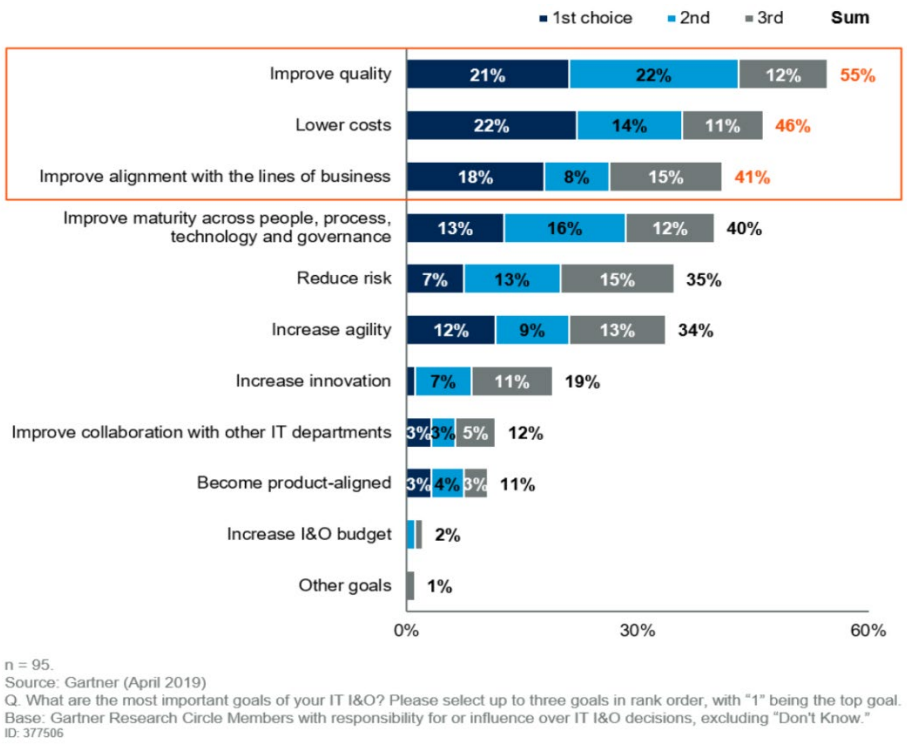
In short, such tools serve as a complement to SD-WAN monitoring capabilities, adding depth (underlay network monitoring) and breadth (application QoE) performance visibility and offering one single source of 'truth' about user experience.

8. Significant Cost Reduction Option for Passive Monitoring Solutions

8.1. Cost Optimizations Driving Cost Innovation

According to Gartner, 60% of enterprises will have implemented SD-WAN by 2024 (compared with 20% today), a change made to increase agility and enhance support for cloud applications. But, budgets are not expected to keep pace: the forecast for IT budget growth in 2019 is 2.7%, down from 3.1% in 2018, and network budgets are roughly flat. Meanwhile, 71% of IT budgets are dedicated to "running the business," so that tends to be where the large focus of efficiency gains lie. With network budgets essentially flat, organizations need to do the proverbial "more with less."

The figure below shows the top three goals of I&O leaders based on Gartner's Infrastructure and Operations (I&O) Executive Leaders 2018 Survey. Lowering cost was the second most important goal for I&O leaders in 2018 and remains a critical goal still today.



n = 95.
Source: Gartner (April 2019)
Q. What are the most important goals of your IT I&O? Please select up to three goals in rank order, with "1" being the top goal.
Base: Gartner Research Circle Members with responsibility for or influence over IT I&O decisions, excluding "Don't Know."
ID: 377506

Figure 8 - Most important Goals of Organizations' IT I&O

Cost optimization will also be apparent with new on-demand consumption models, inspired by closer alignments with cloud principles. This will result in a migration from traditional capital-expenditure (capex)-centric "buy and manage" models to opex-centric services, where nothing is "owned" by the enterprise. This also offers the flexibility to scale up/scale down without cost penalties.

8.2. Stream to Disk versus Metadata

One often overlooked option that reduces the total cost of ownership (TCO) for passive application and network monitoring is leveraging metadata versus stream to disk methods. Below is an overview of how the two methods operate.

Figure 9 - Stream to Disc vs Metadata operation

The two technologies can provide similar results but their requirements and cost can vary greatly. For example, the large storage and CPU requirements for a stream to disk solution is much larger compared to metadata. As shown in the comparison table below, even though metadata storage does vary depending on type of requests, it still uses 20x to 100x less storage capacity when compared to stream to disk.

Storage	Stream to Disk	Metadata
12Gbps at **TCP level** for 7 days	**154 TB** 12Gbps x 7 days x 128B/750B	**2 TB - 8 TB**
12Gbps at **Application level** for 7 days	**907 TB** 12Gbps x 7 days x 750B/750B	**9 TB - 45 TB**

Bandwith(bps) **x** RetentionTime (t) **x** SlicingKey **/** AveragePacketSize **=** Storage

Figure 10 - Stream to disc versus metadata storage capacity usage for 7 days

METHOD	PROS	CONS
Stream to Disk	• Packet level analysis • Compliance	• Short retention • TCO+ • Dynamic environment / cloud
Metadata	• Long retention • TCO • Speed of investigation • East-West visibility	• Packet level analysis

Figure 11 - Pros and cons of the two main approaches to passive traffic analysis

Stream to disk retention time is often short; increasing retention time requires more storage, consequently increasing TCO. Furthermore, stream to disk is not fit for dynamic environment or cloud environments. When performing stream to disk, users will target specific points for traffic capture in their environment, defining the points that will capture traffic. This is harder to do in an environment where points are always changing such as a cloud environment.

Application and TCP monitoring using passive monitoring is the tool of choice when you want to get the most accurate picture of the user experience. But, you must be able to answer two critical questions: *What data do I need?* and *how far back in time do I need to look?* When it comes to retention periods, the bottleneck becomes storage space. As shown above, with stream to disc, storage space increases drastically. Storage comes at a cost, so TCO is always a concern.

To make this fit the TCO model, metadata is the preferred solution. The depth and breadth of metadata today will more than satisfy the requirements for TCP monitoring and, more importantly, application monitoring down to the transaction level for months rather than days. Metadata makes it much simpler and faster to retrieve, present, and correlate data. Plus, this makes it possible to go back in time, monitor progress during transitions, and provide data for collaboration.

Stream to disk does have its place (for compliance/regulation, for example) but is probably not the effective solution to monitor QoE for SD-WAN networks. It is simply too expensive, and retention times are not adequate for application and network troubleshooting. Metadata offers a lightweight software solution that aligns with the SD-WAN solution, and also offers the longer retention time that is critical for monitoring moves and changes.

To keep SD-WAN a cost effective, flexible and programmable solution, network and application performance monitoring tools should provide detailed information that aligns with the limited IT and network budgets of I&O leaders today.

Conclusion

Today, SD-WAN vendors offer some type of quality of service (QoS) visibility, but they do not extend this to true application quality of experience (QoE).

While SD-WAN solutions provide visibility into such things as network performance between platforms or bandwidth/capacity usage for top protocols, these metrics are provided only within the walls of the network. As such, they cover application performance from WAN edge to WAN edge only—not to the true edge (the end user's experience).

These limitations create problematic QoE visibility gaps:

- No way to pinpoint location/cause of application performance degradations
- Insufficient granularity to perform troubleshooting or optimization across the entire application delivery chain

Measuring the real user experience requires full visibility into network performance, application delivery (through the network and infrastructure) and application transaction delay. If any one of these is missing, it is not possible to have complete QoE visibility. SD-WAN vendor solutions fall short because they do not offer:

- Visibility into the underlay network
- Visibility into end user application QoE
- Visibility into the root cause of application performance Degradation

In addition, cost optimization goals are driving on-demand consumption models, inspired by closer alignments with cloud principles, resulting in a migration from traditional capital-expenditure (capex)-centric "buy and manage" models to opex-centric services, where nothing is "owned" by the enterprise. This also offers the flexibility to scale up/scale down without cost penalties.

Traditional application monitoring solutions measuring QoE are expensive as they typically use stream to disc capabilities—with short retention times, lack of flexibility to adapt to data growth (storage and interface types), and a high TCO. However, new solutions are available which use metadata (capturing only the information of interest). Such solutions offer longer-term retention and increased investigation speed at a fraction of the cost, aligning with the cost reduction that SD-WAN solutions deliver.

Metadata is best solution for SD-WAN, because it delivers depth and breadth of metadata to more than satisfy IT and network operator requirements delivering TCP monitoring and, more importantly, application monitoring (down to the transaction level for mounts not days). Metadata also addresses the limited IT and network budgets of I&O leaders today.

Abbreviations

CBS	Committed Burst Size
CCM	Continuity Check Message
CFM	Connectivity Fault Management
CIR	Committed Information Rate
CoS	Class of Service
COTS	Commericial off-the-Shelf
CPE	Customer Premises Equipment
CPO	CoS Performance Objectives
C-VLAN	Customer VLAN
CE	Carrier Ethernet
DMM	Delay Measurement Message
DMR	Delay Measurement Response
DSCP	Differentiated Services Code Point
EBS	Excess Burst Size
EIR	Excess Information Rate
EMIX	Ethernet Mix
EVC	Ethernet Virtual Connection
FDV	Frame Delay Variation
FEC	forward error correction
FL	Frame Loss
FLR	Frame Loss Ratio
FTD	Frame Transfer Delay
Gb	Gigabyte
GUI	Graphical User Interface
HD	high definition
HFC	hybrid fiber-coax
Hz	hertz
IR	Information Rate
ITU-T	International Telecommunication Union – Telecommunication
KPI	Key Performance Indicator
LBM	Loopback Message
LBR	Loopback Reply
M Factor	Margin Factor
MAC	Media Access Control
Mbps	Megabit per second
MEF	Metro Ethernet Forum
MSO	Multiple Systems Operator
MTU	Maximum Transmission Unit
NID	Network Interface Device
NMS	Network Management System
NFV	Network Function Virtualization
NFVI	NFV Infrastructure
OAM	Operations, Administration and Maintenance
OSS	Operational Support System

PCP	Priority Code Point
QoS	Quality of Service
QoE	Quality of Experience
SaaS	Software-as-a-Service
SAT	Service Activation Testing
SCTE	Society of Cable Telecommunications Engineers
SLA	Service Level Agreement
SLS	Service Level Specifications
SOAM	Service OAM (IEEE Y.1731)
S-VLAN	Service VLAN
TWAMP	Two Way Active Measurement Protocol (ITU-T RFC-5357)
vCPE	Virtual CPE
VLAN	Virtual LAN
VM	Virtual Machine
VNF	Virtual Network Function
AP	access point

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