Best practices and requirements for data center interconnect test orchestration

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Cloud-based applications are everywhere. According to the latest Cisco Visual Networking Index survey[1], 8.5 billion connected devices are currently being used, a number that will grow to 11.5 billion in 2020, and which includes machine-to-machine (M2M) Internet of Things (IoT) modules. This massive number of devices, in addition to increasing fiber-to-the-home (FTTH) and fiber-to-the-building (FTTB) connections, will scale up bandwidth requirements in metro networks and data centers.

When data center infrastructures must deal with more bandwidth, the data center interconnect (DCI) must grow accordingly. The Cisco Global Cloud Index[2] forecasts that global data center traffic will triple to 10.4 zettabytes by 2019, with 83% coming from cloud services and applications. Cisco also anticipates that 73% of this traffic will come from within the data center due to factors such as storage, production and authentication traffic; 18% from traffic between data centers and users; and 9% from traffic between data centers, such as replication and interdatabase links.

This application note will review the best practices and considerations for testing when planning the turn-up or upgrade of DCI links, especially in the case of a 100G/400G migration. Our discussion will address the full network lifecycle from construction to turn-up, and troubleshooting to monitoring and service assurance.

DCI PHYSICAL LAYER CHARACTERIZATION

Before putting any traffic on the network, the fiber should be tested to ensure it was properly installed and can support the high data rates typical of DCI connections. **Physical layer characterization should start with an optical time domain reflectometer (OTDR) test.** An OTDR device measures loss as a function of distance in order to identify any element that might cause excessive attenuation, such as dirty connectors, macrobends (fiber bent too tightly and inducing loss), pinched fiber and lossy splices. Excessive fiber attenuation might prevent the detector at the far end from properly recovering the signal, thereby breaking the communication.

The OTDR measurement will most likely reveal that some connectors exhibit high loss, which may arise because of scratches or dirt particles on the connector endface. **The best way to assess connector cleanliness is to use an inspection probe that automatically compares** the captured image against industry standards like the IEC. An automated approach eliminates guesswork, false positives and ensures that the same quality standards are applied throughout the workforce.

Next, field technicians should test dispersion in DCI links, as recommended by the ITU-T G. 650.3 standard for any transmission at 10 Gbits/s or more. Dispersion is pulse broadening or pulse spreading that occurs as light travels in the fiber. In extreme cases, pulse broadening is so high that it leads to bit error rate (BER), as shown in Figure 1.

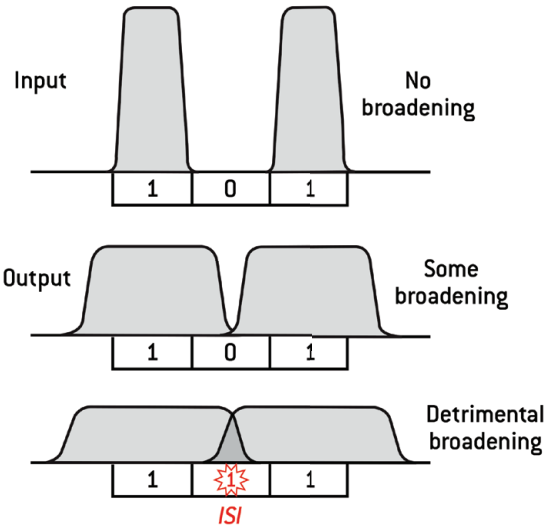


Figure 1. Intersymbol interference (ISI) caused by dispersion (pulse broadening) which leads to BER

There are two main types of dispersion: chromatic dispersion (CD) and polarization mode dispersion (PMD). CD occurs because different wavelengths travel at different velocities in the fiber, while PMD stems from the fact that polarization modes travel at different velocities. Though PMD can occur in all types of networks, older fibers and aerial cables in particular are very prone to PMD issues. CD and PMD dispersion thresholds depend on modulation format–coherent formats like quadrature phase-shift keying (QPSK) for 100G are more tolerant than direct detection formats like PAM4–which is why EXFO recommends verifying with the system vendor the CD and PMD limits for your particular system. Dispersion increases as a function of distance, so long-haul or submarine DCI links are more likely to suffer from dispersion issues. As a rule of thumb, dispersion should be tested for links longer than 10 km. Dispersion testing concludes the optical testing process during the construction phase.

During turn-up, field technicians should perform spectral analysis of the optical channels to prevent loss of signal at the receiver side due to wavelength or power drift, which occur when the wavelength or power strays too far from the expected value. The expected values for central wavelength are found in the ITU standard for dense wavelength division multiplexing (DWDM) grids. Also, loss of signal can occur if signal power becomes lower than receiver sensitivity, which is the minimum power the receiver can detect.

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2015-2020 White Paper, February 01, 2016

[2] Cisco Global Cloud Index Infographic 2015

In the case of amplified networks, it is critical to carry out an optical signal-to-noise ratio (OSNR) test with an optical spectrum analyzer (OSA) because amplifiers are the optical devices that generate the most noise. To obtain an accurate result, it is important to use the right OSNR measurement method (in-band OSNR, Pol-Mux OSNR, etc.) because the OSNR method choice depends on the signal data rate and the presence or absence of reconfigurable optical add-drop multiplexers (ROADMs). Usually, amplification with erbium-doped fiber (EDFA) or Raman amplifiers becomes necessary in spans longer than 70 km. Accordingly, shorter unamplified links do not require OSNR tests.

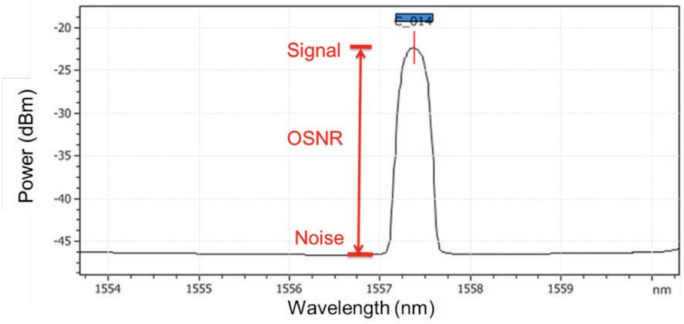


Figure 2. OSNR concept

DCI PERFORMANCE EVALUATION

Once the physical layer characterization is completed, we need to look at turn-up and troubleshooting at the transport layer. Data centers are going through structural network changes to increase their bandwidth offering; the support of new data rates is forcing a switch from lower capacity transceivers, like the 10G SFP+, to higher capacity transceivers like the QSFP+/QSFP28. These new transceivers, also known as pluggables, vary based on the data rates they transmit and receive. It is also important to mention that pluggables—especially the CFP4 and QSFP28—are new to market and have therefore not yet attained a satisfactory level of reliability, and can be a source of network failure or even complete network outage. Before validating network performance, it is imperative to test each pluggable with a tool like EXFO iOptics, which was designed to provide the easiest way for quickly validating the sanity of currently available optical transceivers, using minimal configuration.

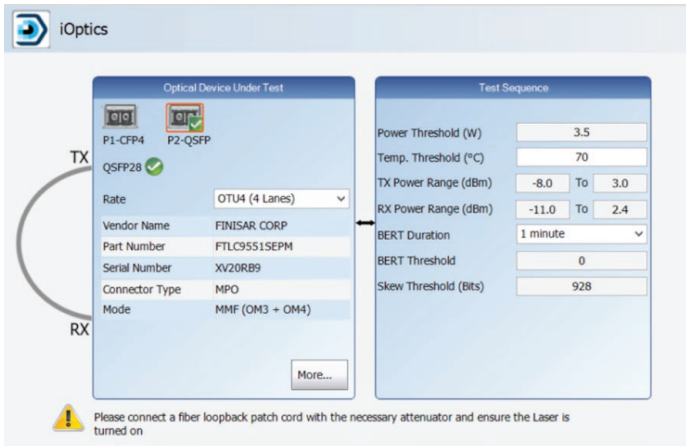


Figure 3. EXFO iOptics

NETWORK PERFORMANCE

A key performance indicator (KPI) is linked to transmission delay in the network; for many companies, long transmission delays can have a major impact on network performance. The impact is even larger and more detrimental for data centers, where the industry has switched to an approach using multiple smaller data centers all interconnected using high-speed links. In this case, delay—also known as latency—can bring new challenges, and there are different tolerance factors based on the application.

Figures 4 and 5 highlight the different levels of latency thresholds based on different industries. A long latency can degrade Ethernet service quality, which in some applications can be a critical issue. For example, in the banking and securities industry, the timing of each transaction is critical and a long transmission delay can have major financial impacts. As such, it is critical to ensure that keep latency levels can be kept below specific thresholds.

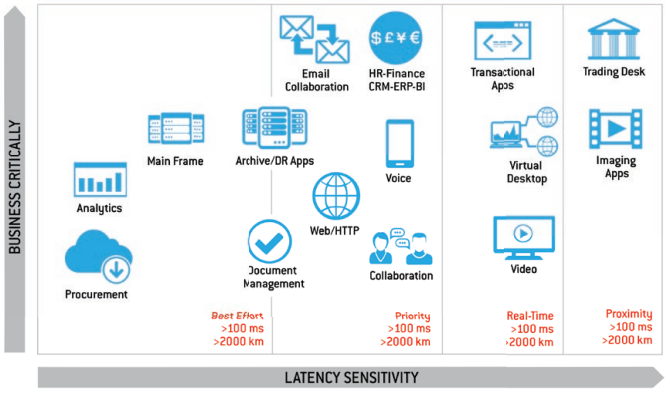


Figure 4. Latency thresholds

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Traffic type	Main applications	Examples of services
Best-effort data	Non-real-time data transport	- Data - Internet access - FTP download/upload - Server, storage applications
Real-time data	Real-time broadcast that cannot be created once lost	- VoIP - IPTV, video on demand - Internet radio, TV - Internet gaming - Videoconference
High-priority data	Mandatory traffic used to maintain stability in the network	- OAM frames - Switching/routing control frames - Network synchronization such as SyncE, 1588v2

Figure 5. Network traffic types

Ideally all KPIs, including latency, should be measured to ensure optimal network performance. Throughput, frame loss and frame jitter can directly affect popular streaming applications like Netflix—too much packet jitter can affect quality of experience (QoE) because packets arriving at a faster rate cause network buffers to overfill, resulting in packet loss. On the other hand, packets arriving at a slower rate will cause buffers to empty, leading to frozen images or choppy sound.

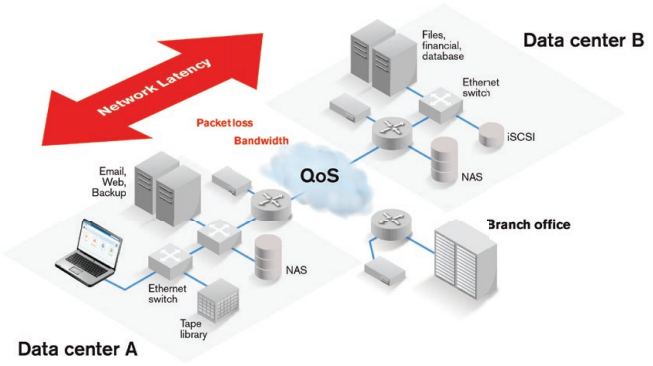


Figure 6. Packet delay variation (jitter)

During the performance test phase, data centers are now looking for simple tools to help them quickly validate and characterize their DCI network performance.

DCI key performance indicators:

- Throughput
- Traffic or frame delay
- Packet or frame loss
- Latency, frame delay, out of sequences
- BER estimation

EXFO's **intelligent service activation method (iSAM) testing application**, based on the IEEE Y.1564 standard, allows the user to perform priority-level tests, based on similar traffic available in the data center network. Figure 7 and 8 below highlight the single iSAM configuration and monitoring pages.

Real-time services such as voice and video are sensitive to network degradations. iSAM on top of testing different classes of service (CoS) as a performance test option that can quickly help identify the KPIs to guarantee the best quality of service (QoS).

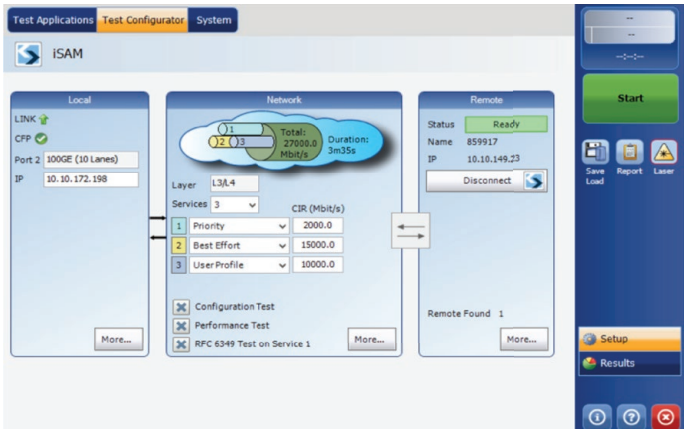


Figure 7. iSAM service configuration test

Service Configuration Test — Completed, Pass — Start Time 2015-11-13 04:49:39 PM

Service		TX CIR (Mbit/s)	FD (ms) (RTT) (Latency)	IFDV (ms) (Jitter)	FLR (%) (Frame Loss)	RX Rate (Mbit/s)
1 Priority	L->R	2000.0	0.103	< 0.015	0.0000	1999.9
	R->L	2000.0		< 0.015	0.0000	2000.0
2 Best Effort	L->R	15000.0	0.103	< 0.015	0.0000	14999.9
	R->L	15000.0		< 0.015	0.0000	15000.0
3 User Profile	L->R	10000.0	0.103	< 0.015	0.0000	9999.9
	R->L	10000.0		< 0.015	0.0000	10000.0

Service Performance Test — Completed, Pass

Service		TX CIR (Mbit/s)	FD (ms) (RTT) (Latency)	IFDV (ms) (Jitter)	FLR (%) (Frame Loss)	RX Rate (Mbit/s)
1 Priority	L->R	2000.0	0.101	< 0.015	0.0000	1999.9
	R->L	2000.0		< 0.015	0.0000	2000.0
2 Best Effort	L->R	15000.0	0.101	< 0.015	0.0000	14999.9
	R->L	15000.0		< 0.015	0.0000	15000.0
3 User Profile	L->R	10000.0	0.101	< 0.015	0.0000	9999.9
	R->L	10000.0		< 0.015	0.0000	10000.0
				Total RX Rate (Mbits/s)	L->R	26999.7
					R->L	27000.0

Figure 8. iSAM service performance and configuration monitoring

DCI FIBER OPTIC NETWORK MONITORING

The monitoring phase is key for full network lifecycle testing. Data centers are located either in urban, metro-like areas or in very remote locations. In both cases, the installations can be considered as access-type fiber optic networks, which have challenges similar to those of FTTx.

When built in densely populated areas, cables are subject to urbanization-induced stresses, which are caused by accident or on purpose, as is the case with damage from rodents (see Figure 9).

When built in remote locations, implementing a truly diverse or redundant architecture may simply become impractical or cost prohibitive.

Unpredictable events that turn down part or all of the cable infrastructure—which now carries data far faster than at terabyte speed—can quickly get out of control. In these situations, poor decisions are often made based on inaccurate assumptions; a lack of accurate data about the outage source frequently results in costly, lengthy restoration efforts.

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Figure 9. Rodents are quite often responsible for damage to fiber optic cables.

When a cable is partially lost, which means that only one or few fibers within the trunk is damaged, it is harder to identify animal causes!

The permanent installation of optical fiber test equipment such as OTDRs at main fiber optic interconnections was considered a luxury in the early days of trunk-type, peer-to-peer (P2P) transmission. This type of solution allows for rapid, automatic and accurate detection and localization of optical loss or reflectance changes occurring on the fibers. This luxury has now become a necessity due to the complexity of packet-based networking in metro and access, supported by very high-speed and low-latency routes, with a more automated way to plan and deliver IP-based services. It is clear that with permanent supervision, similar to cameras on freeways or mobile tools providing traffic information in real time, constant monitoring of optical fibers allows operators to stay in control and on top of any event that may impact what is now an invaluable asset.

Who should own and operate the fiber monitoring solution? This is the subject of frequent discussion between cloud-based solution providers, communication service providers and dark fiber / utility-type providers. Fiber optic infrastructure vendors could provide fiber monitoring as a value-add service, improve their repair time and thereby offer higher-end support or repair services. The vendors could provide their customers with new metrics of the fibers being leased or historical data on them, improving their overall leasing offering. Vendors should view test and monitoring equipment as a new source of revenue, rather than as an additional expense. The EXFO Fiber Guardian solution is a feature-rich stand-alone OTDR-based monitoring instrument that dark fiber providers and utilities can add to their tool box, as a first step to build such value-add remote test and monitoring services.

Although fiber optic infrastructure vendors should own and operate the fiber monitoring solution, this is not usually the case—enterprise and webscale operators are reluctant to let anyone touch the fibers they lease. In fact, an OTDR-based solution does not tap or interfere with traffic, nor does it involve the measurement of any bit stream. It is an out-of-band, single-ended measurement that is completely isolated from traffic.

No matter who owns and operates the solution, the fiber quality metrics captured should be shared in an intelligent and controlled way with all parties involved, so that the different organizations are informed at the same time of issues potentially affecting the availability and performance of their IP-based network.

DCI SERVICE ASSURANCE AND 3D ANALYTICS

Service assurance probes and systems can be leveraged using the EXFO Worx performance management system and the EXFO Xtract open analytics platform when:

- More frequent performance evaluations are required
- Data center operators are required to deliver high quality of experience (QoE), which can be actively assured using virtual or physical probes
- Using either physical or virtual probes, data center assurance can look at performance from different levels, such as intra-data center (within the data center itself) or through DCI

Assuring the performance and quality of services can provide data center operators with exceptional performance and efficiency by allowing them to:

- Quickly identify link failures among the thousands of physical or logical links, whether inter- or intra-data center
- Measure transport performance with visibility on per-direction metrics
- Assure availability and response time of servers without any additional software
- Access a solution that can scale significantly as the data center grows

The EXFO Xtract advanced analytics platform enables data centers operators to handle massive amounts of metrics and create contextual dashboards and reports.

Ensuring and assuring the performance and quality enforcement of data centers is a critical step that must not be overlooked. Networks are constantly evolving and service-impacting events like congestion, equipment failures and incorrect human intervention can drastically impact the performance of data centers and ultimately impact quality of service.

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It is essential to continuously validate and assure a data center's performance to ensure its proper operations. EXFO's service assurance solution is designed to provide complete visibility of data center performance by using a probe-based approach and leveraging active performance tests.

There are three key segments to focus on in the context of service assurance:

1. **Measuring performance within the POD**, which is the lowest level. This allows a deeper view of a POD's performance by measuring the connectivity and response time of devices in the rack that the POD is servicing. This effectively isolates the pod's performance from an end-to-end perspective to facilitate troubleshooting.

2. **Measuring performance within the data center itself** (intra-data center). Data centers are complex in the fact that they interconnect a significant number of critical elements. Connectivity between these elements is key because otherwise performance loss can be caused by events such as physical failure, loss of connectivity, equipment failure or even congestion in interconnect equipment.

3. **Ensuring the performance of pipes that interconnect data center to data center**. With traffic often being serviced by third-party providers, how do we ensure compliance with strict performance service level agreements? The answer: through continuous assurance of the performance between data centers.

EXFO's service assurance solution, which integrates active test probes, can continuously measure the reachability and performance of servers and devices, and report metrics to a centralized correlation system. This ensures that all target elements are reachable from the perspective of the active test probe. More importantly, this also ensures that the latency from the active test probe to the targets is within an acceptable limit.

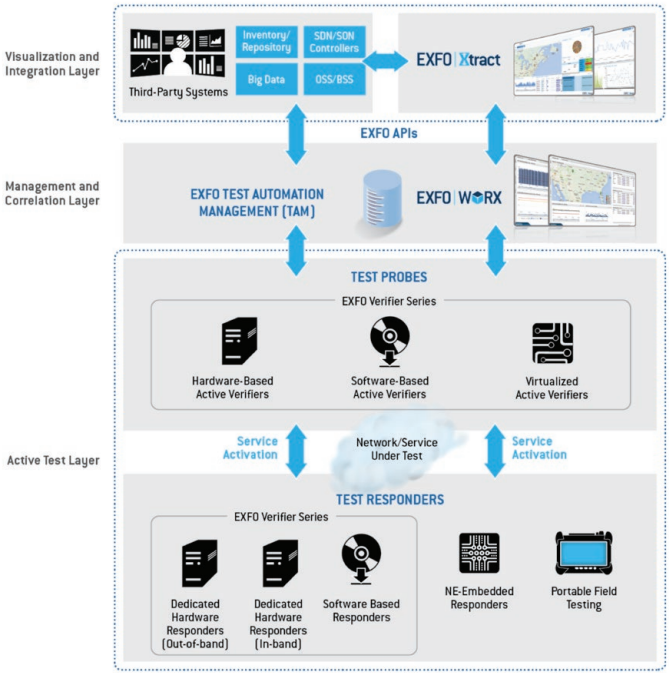


Figure 10. EXFO service assurance solution

All probes are managed through a single control server called EXFO Worx, which enables the rapid deployment of test routines, and stores and manages all test results.



Figure 11. EXFO Worx

The EXFO Worx active test probes, also called verifiers, can come in a variety of formats:

- **Physical verifiers** are ideally suited for situations in which the task requires scalability and highly precise, low-latency measurements. With probes ranging from small gigabit verifiers supporting hundreds of endpoints to large-scale 10G probes supporting thousands of simultaneous endpoints, operators can easily define test strategies and deploy the appropriate solutions to meet scaling needs.
- **Active test probes** provide significant deployment flexibility and are also available as software-only probes. These virtual test probes can be deployed on bare metal as virtual machines, which saves costs by using COTS x86 host hardware, or deployed dynamically as needed through orchestration on hypervisor-enabled network functions virtualization (NFV) devices. This additional flexibility can enable the rapid deployment of services.

In the context of data centers, EXFO Worx becomes the focal point of operation where managers and operators can access test results, and perform troubleshooting tests at any time. EXFO Worx's robust platform is built on the latest web server technologies, and leverages powerful database capabilities to handle dozens of simultaneous users and millions of measurements every second, a capability that has been deployed in production networks across the world.

EXFO Worx is also the focal point for integration through a robust set of APIs, and integrates with the existing OSS/BSS engines, reporting and business intelligence, FCAPS and alerting systems. This ensures the seamless addition of assurance strategies for data centers, using the existing OSS with minimum investment in changes. EXFO Worx APIs are fully flexible and provide bi-directional communication where external systems can pull information from the EXFO Worx platform or push commands and execute actions. This enables complete operators to implement fully closed/automated systems and ultimately reduce human intervention in the system's deployment, delivery or operation.

In data centers, time is of the essence and it is essential to be able to quickly identify and resolve issues. A key challenge with data center assurance is the high volume of metrics. As the number of test probes and volume of metrics increase, it is essential to be able to pinpoint degradation and identify its impact on systems or services. The EXFO Xtract advanced analytics solution is designed to provide deep correlation and analytics by processing massive amounts of data generated by the probes, and put them in the context of the data center. Using service modelling techniques, users can drill up and down to identify the degradation and–more importantly–the impact of the degradation and root cause issue.

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CONCLUSION

This paper has reviewed the different testing considerations for data center interconnect (DCI) and for maximizing quality of service (QoS) on all segments of the fiber optic network. If these guidelines are followed, network subscribers will benefit from exceptional quality of experience (QoE).

The following table summarizes the various issues for DCI and the test solutions that can solve them.

Potential issue	Test instrument	Comment
Dirty and damaged connectors	Fiber inspection probe (FIP)	Inspects the connectors endface, 95% of optical networking issues are related to connectors' cleanliness
Broken fiber, dirty connectors, macrobends	OTDR/iOLM	Maps faults along the optical fiber, measures reflectance at the patch panels, a major issue when migrating from 10G to 100G
Chromatic dispersion	CD tester	Should be tested for links of more than 70 km, potentially an issue at the maximum reach PAM4 transceivers
Polarization mode dispersion	PMD tester	Should be tested for links of more than 10 km, potentially an issue with aerial fiber use cases
Power/ wavelength drift	OSA	Prevents loss of signal leading to BER
Noisy amplifiers/ ROADM	OSNR measurement, to be carried out with an OSA	Test only for amplified links; use to avoid BER
Bit error rate, throughput, packet loss, latency	BER/protocol tester	Tests each class of services (CoS) to identify the KPIs for guaranteeing the best quality of service (QoS) using an intelligent service activation method (iSAM), based on the IEEE Y.1564 standard
DCI fiber optic network monitoring	Remote fiber test system	Manage fiber assets or keep a close watch on dark fiber providers with preventive insights allowing to view degradations or map faults quickly
DCI service assurance (3D analytics)	Passive and active, virtual or hardware-based test probes, EXFO Worx performance management system and EXFO Xtract open analytics platform	Easy to scale intra-DC or DCI to monitor servers, services, transport/ network performance and subscriber quality of experience (QoE)

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