Testing and Troubleshooting Data Center Cable Plants

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Given today's competitive landscape, businesses must always be on the lookout for ways to improve data center (DC) performance and reliability. As legacy data center hardware and software gets swapped out with modern technologies with the goal of better application performance and stability, one must not forget about the impact this has on the existing DC copper and fiber plants. It's not uncommon, for example, for a brand-new technology to be implemented within a data center only to have it be plagued by connectivity issues, lower than expected speeds and other inconsistencies caused by cabling.

Additionally, data center trends that leverage power over Ethernet (PoE) for various IoT purposes within a DC are also on the rise. Common examples include surveillance cameras, LAN-connected door controllers, temperature/humidity sensors and PoE lighting. These additions are creating a much higher demand for PoE within the data center than ever before. Significant increases in the number of PoE connections can cause several unforeseen problems – especially when twisted-pair cable plants were not designed with PoE delivery in mind. The distribution of electricity over copper cables increases heat and electromagnetic interference that can impact individual cables as well as cross-cable interference with other twisted-pair runs within a cable bundle.

Because the data center is evolving at an unprecedented rate, it becomes more important than ever to have the right tool or tools for the job, to verify the operational performance of new and existing data center plants. Doing so ensures operability with modern use-case scenarios including transmit/receive performance bumps and power delivery through low-voltage copper. Keep in mind that there's often more cabling in the data center compared to any other part of an organization's network. It should also come as no surprise that the data center is the heart of every enterprise network. Thus, a great deal of testing and troubleshooting will take place in this demanding location.

In this report, readers will first learn about the nuances of testing and troubleshooting cabling in data center environments. We'll then go on to explore 11 real-world situations where a data center administrator would benefit from an all-in-one copper and fiber test and measurement tool that can also perform common network identification and troubleshooting tasks.

The Different Data Center Plant Layouts

Unlike in-building and campus-wide cable plants that are relatively predictable as it relates to cable and connector types used, data center cable plants vary far more widely. Depending on the age of the data center facility, existing cabling may consist of any number of copper and fiber optic cable types ranging from legacy CAT 5 copper and OM1/OS1 multimode and singlemode fiber up to the latest CAT 8 copper and OM5/OS1a fiber standards. Additionally, one can expect to see a range of fiber connector types going all the way back to the SC/ST days and into more modern LC and MTP/MPO connector styles which allow for higher port density.

Next, it's important to understand that the design and layout of a data center will be different from one DC facility to the next. Let's look at three of the most common cable layout designs within data centers.

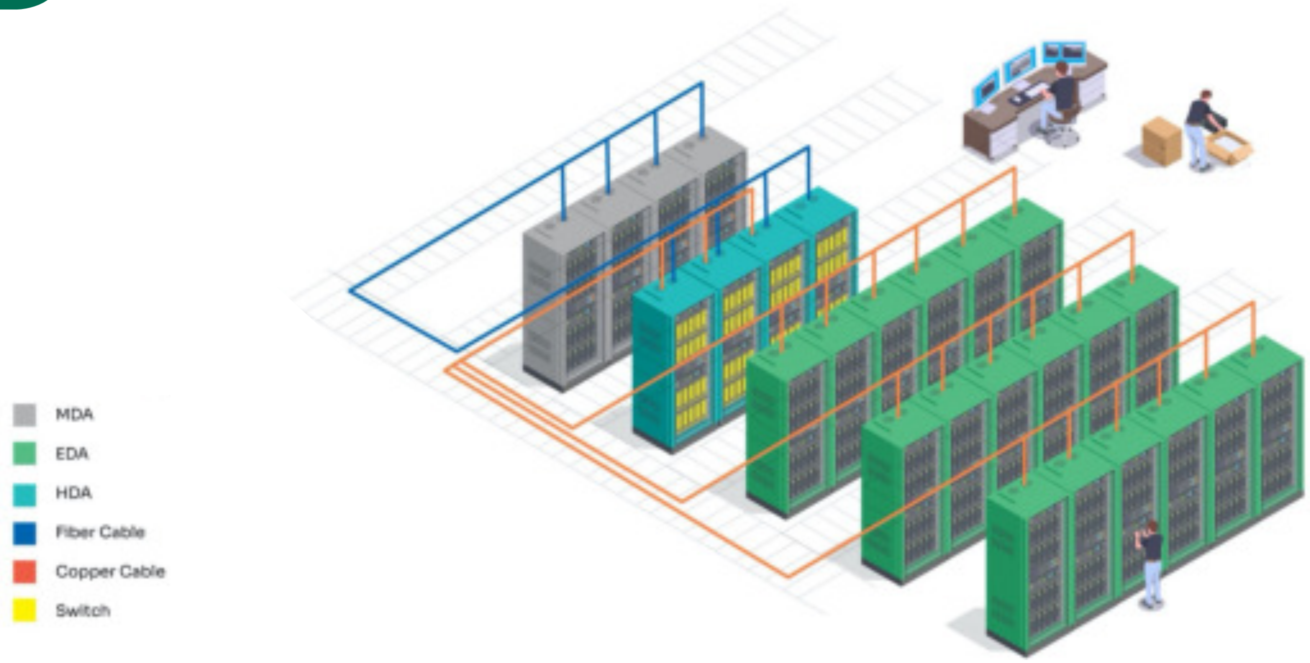
Centralized Cable Plant Layout

Small data centers -- or those that formed in an unstructured manner, such as pre-existing data centers where technologies were adopted after the initial design that might include support of IoT initiatives, Single Pair Ethernet, or adoption of Hyper Converged Infrastructure (HCI) as just a few examples.

These types of data centers will centralize cabling and patch panels into a consolidated rack or group of racks. Backhaul cabling that connects the DC to the corporate LAN also often occurs in this location. Servers and storage located in racks surrounding the patch panels can connect with relatively short patch cables. However, the further away servers and other network-connected devices are, the longer the patch cables need to be. It's often the case that cable management becomes disorganized and sloppy as the number and lengths of cabling required to connect data center devices becomes significant in such a small and centralized section of the server room.

Fig 1 : AEM Illustration

Centralized Cable



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End-of-Row Cable Plant Layout

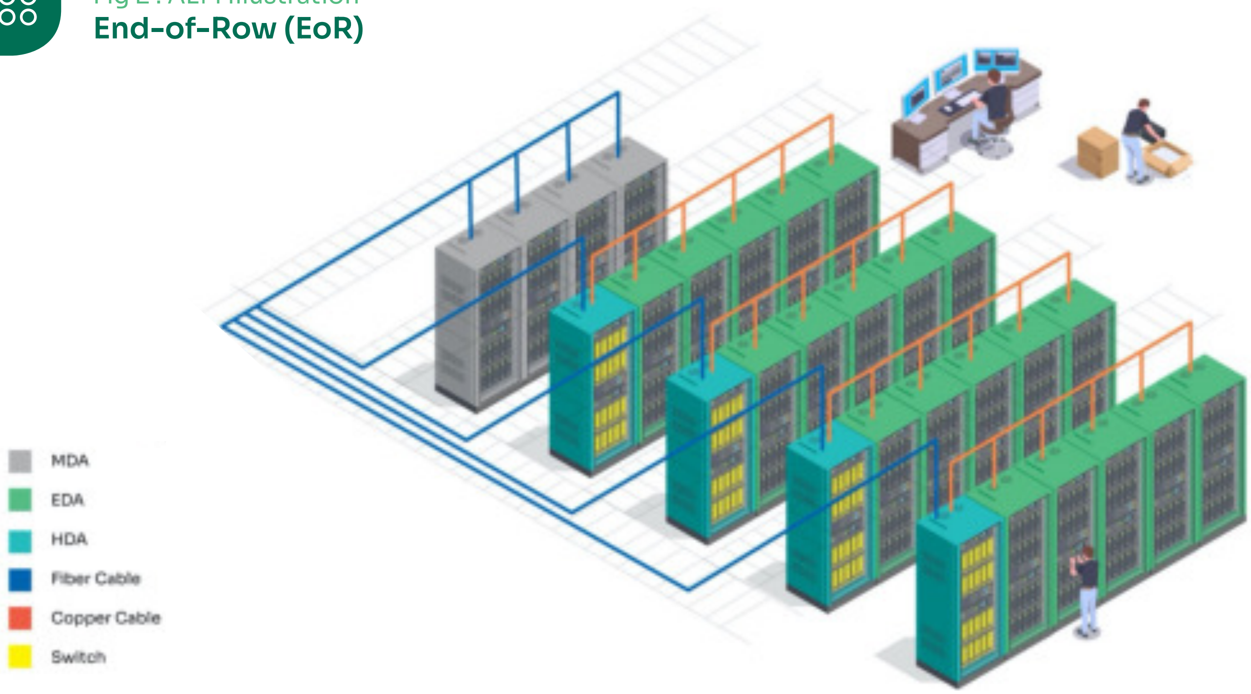
Looking to alleviate much of the cabling congestion of a centralized patch panel design, larger legacy data centers are known to utilize distributed cable patch panels and switching/ fiber channel switch hardware into several locations within the DC facility.

In many cases, each DC row will have their own rack that is designated for cabling and patch panels. This is known as an "end-of-row" structured cabling design. All devices mounted in this row connect to the data center network at the end-of-row distribution point.

While this design does help to disperse the density of patch cables to multiple locations, the layout can still suffer from cable congestion in data centers that have racks stacked full of equipment that must be connected.

Fig 2 : AEM Illustration

End-of-Row (EoR)



Top-of-Rack Cable Plant Layout

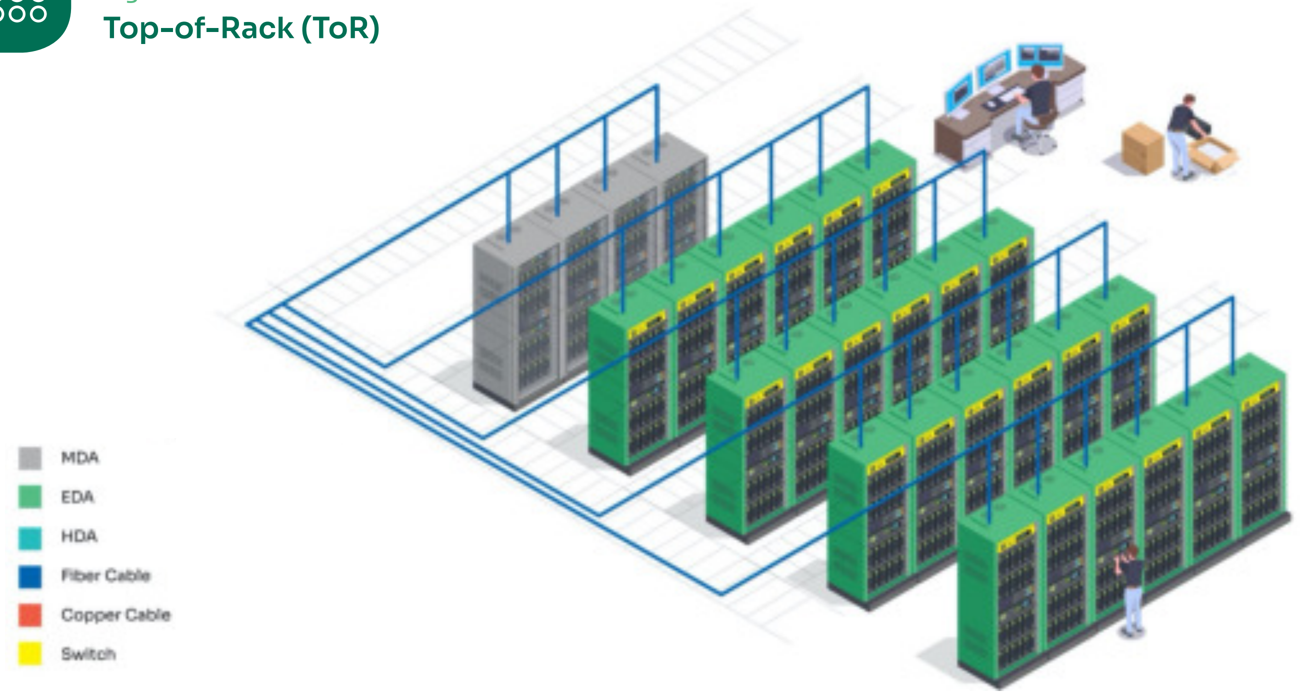
The top-of-rack design is newer than the end-of-row and centralized architectures. Using this plant blueprint, the cabling termination points become distributed even further. Each equipment rack in the DC is installed with an Ethernet and/or fibre channel switch at the top.

Any equipment installed in the rack is in close proximity to network switch ports. This keeps patch cable lengths short, uniform and under control. Each top-of-rack switch then uses high-speed uplinks to interconnect all distributed switches in the facility to one or more racks of aggregation switches.

While this model indeed reduces cable management issues inherent in other designs, it increases the amount of switch hardware required and can complicate cable troubleshooting efforts as a data must pass now through multiple cables and network hardware.

Fig 3 : AEM Illustration

Top-of-Rack (ToR)



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Types of Commonly Deployed Data Center Equipment

The types of devices administrators must connect differs widely from one data center to the next depending on the organization's needs. One can expect to connect bare metal servers, hypervisor clusters, hyperconverged systems and fibre-channel connected storage area networks (SANs). All the power, battery backup and cooling systems required to operate the data center will likely be network-connected as well.

From a network infrastructure perspective, expect to see routers, top-of-rack switches, aggregation switches, fiber channel switches, fiber-channel over IP (FCIP) gateways and network security appliances such as firewalls, intrusion prevention systems (IPS) and secure web gateways. Additionally, many data centers provide Wi-Fi connectivity within DC facilities. Thus, it's common to have several wireless access points connected to data center switches as well.

Finally, expect to come across smart building and smart facility devices being deployed to help modernize data center operations. These IoT devices are deployed to secure and protect the data center equipment and its occupants – or to provide supplemental services such as Wi-Fi connectivity throughout the facility.

As organizations look at ways to cut costs, reduce their environmental impact and converge traditionally disparate operational and IT systems, support for Intelligent Building deployments is on the rise. In these types of deployments, devices connected to the network and become part of the IoT infrastructure are environmental controls and sensors, secured building entry systems, security cameras, WAPs, phones, meeting room controls, and lighting are the most common. With the influx in IoT connected devices, organizations are now deploying IoT connected monitors and even window coverings, that automatically adjust based on data from the environmental control sensors.

As you can see, the sheer amount of copper/fiber cabling designs and the wide variety of connected devices makes the data center a truly unique spot to manage within the larger corporate LAN. Compounding the relative complexity and density of DC equipment is the fact that data centers are required to be operational around the clock and operating at high levels of performance. Any problems to hardware, software and cabling must be addressed and resolved as quickly as possible. In the next section, several common use-cases will be presented that show common types of cable and network challenges that data center administrators face -- as well as what tools/techniques can be used to solve them.

Multi-Gigabit Signal-to-Noise Ration (SNR) Testing

Data must be transported and received with a high degree of reliability. This is especially true inside the data center. One test to ensure transmission reliability this is to evaluate the signal-to-noise (SNR) ratio along a twisted-pair cable path between the server/device and the network switch. SNR measures the strength of a transmitted signal against external signal interference. This interference is often referred to as noise. The closer an SNR reading gets to zero, the worse the transmission reliability will be. As a general rule of thumb, SNR should read 3dB or higher to overcome most noise interference. It's also important to note that the higher the speed at which data is sent, the more important SNR becomes. For multi-gigabit connectivity – as is often the case in data centers – testing for SNR is becoming an absolute must.

Because noise is the result of electro-magnetic interference, testing PoE loads is also an important step for cables that will deliver power over the twisted-pair cabling. Some testers can simultaneously test for SNR while also recording PoE information including connected PSE type, PD Class and real-time power load values. It is also important to be able to measure SNR at varying link speeds to ensure optimal performance of IoT connected devices can be achieved. A good example of this is Wi-Fi 6, which requires 2.5 / 5GigE for optimal performance. While these types of APs can run at 1GigE, they will bottleneck at this speed, resulting in user's inability to realize true connection speed to the internal LAN or internet, causing users dissatisfaction and calls to the help desk.

A twisted-pair validation test tool can accurately measure SNR by connecting test equipment to both ends of the cable. An example of a SNR test run at 2.5,5 and 10Gbps speeds and PoE load is shown here:

Fig 4 : SNR based link speed measurement while under traffic and PoE load

Power over Ethernet (PoE)

Power over Ethernet has never been prevalent inside data centers until recently. As IT departments rollout IoT initiatives intended to better monitor and automate the data center using IP-connected surveillance cameras, door controllers, temperature/humidity monitors and smart lighting solutions, DC admins are having to add PoE-capable switches throughout the facility in order to power these IoT devices over twisted-pair copper.

As PoE demand increases in the data center, it's important to thoroughly test power-delivery capabilities on all existing and new copper runs. Most twisted-pair Ethernet test tools that are PoE capable can be plugged into one side of a cable run while the other is connected to a PoE switch or midspan device.

The test tool can then act as a PoE endpoint and communicate with the PoE switch/midspan to negotiate which IEEE power level standard can and should be delivered. Current PoE standards are as follows:

PoE Method	Advertised Power Delivery at PSE	Actual Power Avaialbe at PD
IEEE 802.3af - Type 1	15.40W	12.95 W
IEEE 802.3at - Type 2	30.0W	25.5 W
IEEE 802.3bt - Type 3	60.0W	51 W
IEEE 802.3bt - Type 4	90.0W	71.3 W
UPoE	60 W	54.4 W

Fig 5 : PoE Power Delivery matrix

While understanding the advertised capabilities of a PoE switch or midspan panel is useful, keep in mind that it does not provide real power delivery numbers. Afterall, just because a switch advertises it can deliver up to 25.5 W of power using the 802.3at standard doesn't mean that this is going to be the wattage received at the other end. As power is sent across a twisted-pair cable, understand that a variable percentage of that power will be lost in transit. Factors that increase or decrease the amount of power lost include cable quality, length, number of physical hops and surrounding electrical interference.

To truly understand what wattage a PoE endpoint can actually receive on a given cable run, the PoE cable test tool must go one step further to draw and calculate the true power load from the PoE source device. Additionally, having a tester that can mimic the power delivery of a PoE switch or midspan helps in situations where no PoE switch or midspan actually exists. Thus, a tester can first verify that cabling can deliver the necessary power required by PoE endpoints prior to investing any money on power delivery sourcing equipment.

Fig 6 : PSE Configuration and PoE Load Test

Another consideration is to ensure the twisted-pair cables that will support the supply of DC power, particularly when deploying Type 3 and Type 4 Four-pair PoE, is tested using extended parameters during certification. The primary parameter needed in addition to PoE load testing, is DC Resistance Unbalance and can be selected by choosing the "+" parameters during test setup, if the certification tester you are using supports these extended tests.

Fig 7 : Example of extended test parameter - DC Resistance Unbalance

Network Compliance

Fig 8 : Identification of Network Capacity based on Performance and Structured Cabling

Making assumptions about infrastructure components within a data center commonly leads to disaster. When it comes to upgrading copper or fiber links from 1Gbps to multi-gigabit speeds, a proper certification test can eliminate any unknowns about the capability of the connections. In just a few seconds, a certification tester can assess whether a twisted-pair or fiber optic cable is suitable to run at multi-gigabit speeds up to 40GBASE-T – and which multi-gigabit data rates the cabling can achieve before succumbing to a host of physical issues that will impact performance.

Quick Access to Switch and Port Information

Not everyone that works in the data center has access to networking hardware and software management interfaces. There will come a time when an administrator or field engineer needs to connect or move a device in the DC, yet they have no way to quickly see which switch and switchport they're connected to without tracing cables. Additionally, having information regarding how a switchport is configured will help to speed up the process of properly configuring the endpoint's network interface.

Certain test tools come with the ability to plug in a test unit -- which can in turn connect and pull pertinent details from the switch it's connecting to. This includes information collected using LLDP or CDP to view detail about the switch vendor/model and configured device name. Additionally, port-specific information can be gleaned including port number/description and configured VLAN of each.

Ethernet port. Having quick availability to this information without the need for direct access to a switch management interface is useful for network adds, moves and changes in addition to basic troubleshooting uses at layer 2.

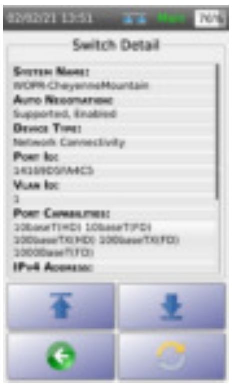

Fig 9 : Switch detail views allow quick visibility to verify switch port connectivity and configuration

Network Visibility

Most data centers operate using a highly-organized VLAN structure to categorize the various servers, applications and devices for streamlined management and performance purposes. Sometimes, however, endpoints are incorrectly placed into the wrong VLAN. While network administrators can login and view MAC and IP address information of all connected devices, operations administrators working on the data center floor can use a cable test tool for faster verification results.

A network visibility scan can show administrators useful visibility information such what and who is connected be it wired or wireless. They can view dynamically learned IP information pulled from a DHCP server including IP address, subnet mask, default gateway DNS domain/ server and the configured DHCP lease times. Additionally, a network test shows the MAC and IP addresses of all devices that reside on the same VLAN. Thus, verifying that equipment is on the proper VLAN is relatively painless.

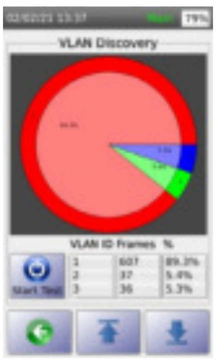

Fig 10 : Example of ability to gain quick visibility to see what devices are connected be it wireless or wired and assure proper configuration

Basic Network Troubleshooting

When data center administrators troubleshoot a network connectivity or performance problem in the data center, often they must weave their way through row after row of infrastructure equipment to find the right server and network rack where the issue resides. If the problem is thought to be related to the network equipment or connected cabling, administrators often rely on basic troubleshooting techniques to find the root cause. If speed is of the essence – as it typically is within the data center – it's common for administrators and field technicians to bring a cable test unit that also comes with basic network troubleshooting capabilities, such as ping, traceroute and discovery. In many cases, the results of these tests can prove to be helpful in identifying and remediating issues as quickly as possible.

Fig 11 : Basic network troubleshooting tests are fundamental requirements to understand potential connectivity issues

Stimulating Network Traffic

One way to truly verify network performance from the physical layer of the OSI model all the way up the stack to the application layer is to use a network traffic generator. This feature found in some multifunction test tools allows administrators to transmit fixed-sized broadcast or unicast UDP packets and have the results calculated to prove overall network transport capability.

In most cases, unicast traffic should be used for the purpose of testing end-to-end performance. This type of test requires a traffic generation test unit on one end and a traffic receiving tester on the other. On each test unit, the appropriate source and destination IP addresses are configured, and the units can begin generating and collecting the observed results. The receiving unit will then measure the performance of the packets sent including the total number of packets received, packet size, the calculated total of all packets received and how many milliseconds it took each packet to arrive.

Ultimately, these tests can verify the robustness of an end-to-end connection and whether traffic is being delayed along the path. Below is a screen capture showing how a traffic monitor can be configured to listen and record network performance statistics by indicating the IP address of the generating unit:

Fig 12 : Example of quick and simple packet generation function

Testing to Verify Native Fibre Channel Operability

Not everything that operates in the data center uses Ethernet for network transport. Fibre channel, for example, is a highly efficient SCSI-based network protocol that is ideal for connecting back-end storage to server farms located on separate storage area networks (SANs).

While fibre channel uses the same single- and multi-mode fiber optic cabling that Ethernet traffic operates over, understand that a fibre channel network may operate at vastly different speeds compared to the data center's Ethernet LAN. For example, a fibre channel link can run natively on a SAN up to 128 Gbps. As such, fiber optic cabling that is used on a SAN should be specifically tested using a certification test tool in accordance to those speeds. Fiber certification testers will not only certify the cabling for maximum Ethernet transport speeds, but many certification tools also let the technician know whether the fiber will support fibre channel.

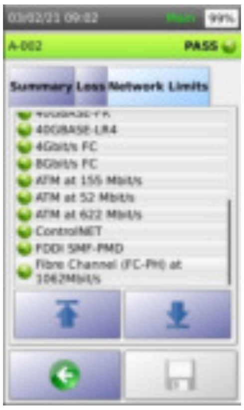

Fig 13 : Based on the performance of the cable tested, it is useful to be able to have a detailed view on what network types the link is capable of supporting

Fiber Inspection

Fiber inspection is an absolute must anytime a device is added, moved or cabling/connectors/switches are swapped out. This is also true for brand new patch cables. If not properly inspected and any cleaned on both sides of the cable, contaminated fiber can cause high connector loss and reflectance issues. Both can cause significant reductions in TX/RX performance. In fact, the number one likely cause of fiber optic performance problems in the data center are due to dirty fiber ends.

As new standards and technologies allow for faster speeds along optical cabling, the need to inspect fiber is only going to grow in terms of importance. The faster data is sent, the lower the overall loss budget is for the link. A single speck of dust can prove the difference between high-performing and reliable connectivity and a degraded, unreliable network experience.

Because most contaminants cannot be seen by the naked eye, a fiber inspection scope is typically used for magnification purposes. Some multifunction testers include the ability to connect a fiber inspection scope

to the unit and display the output of the magnified fiber end on the tester's display. This allows data center administrators to easily check for dirt and dust on the fiber ends. Fiber ends that are found to be contaminated should be properly cleaned and then retested prior to placing them into any production environment.

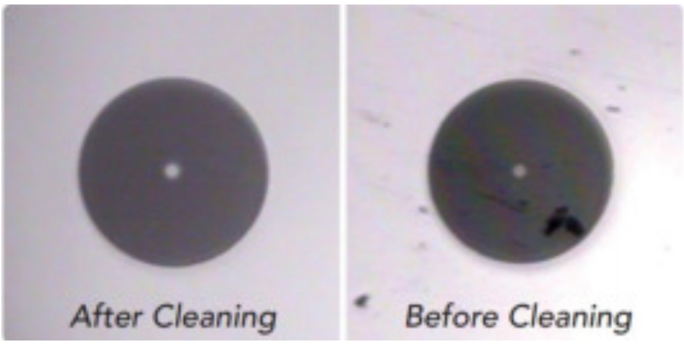

Fig 14 : The importance of cleaning the fiber before usage and testing can't be overstated. Dirty fiber can lead to performance degradation. Users should have tools that allow them to see if dirty fiber could be the cause of a performance issue

Identifying Cable Installation Mistakes – Four Pair and Single Pair

Regardless of whether your data center cabling is run by in-house staff or a professional third-party cabling crew, mistakes do happen. Problems with existing cabling may go unnoticed for weeks, months or years for several reasons. For example, it's possible that the cabling was never put into production until recently. Or perhaps upgraded network hardware now requires the cabling to support higher transport speeds. Another factor is build-out to support emerging technologies, such as those discussed earlier in this document, and might include Single Pair Ethernet (SPE).

Finally, cabling may need to transport power over twisted-pair cabling for the first time. Regardless, the precise location of the cabling mistake will lead to far faster problem resolutions. It's not uncommon for cabling to become bent, stretched or kinked beyond manufacturer specifications. Enterprise-grade cable test equipment can often not only identify that there indeed is a performance problem – but can also pinpoint the precise location of where the fault has occurred on the cable. Knowing this can significantly reduce the amount of time required to fix this issue – as well as point to other cables in a bundle that may also have been damaged due to improper installation techniques.

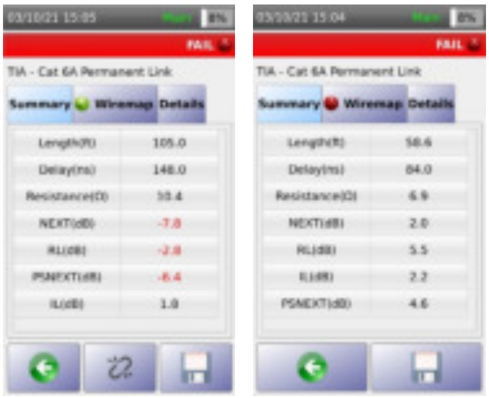

Fig 15 : Four Pair Ethernet cable integrity assurance

Fig 16 : Single Pair Ethernet (SPE) cable integrity assurance

Multiple Test Tools vs. Multifunction Testers

When it comes to choosing the right test tool for your data center, there are a couple of factors to consider. Test tools can be purchased individually or as a broad-based multifunction test solution.

While some may opt to purchase individual tools on an as-needed basis, understand that the cost of each tool will eventually surpass the cost of a multifunction tester purchased up front. Additionally, multifunction testers leverage the same user interface making training an easier endeavor.

Finally, understand that some multifunction test units are modular by design. This means that test functions can be upgraded over time and new test capabilities – both from a hardware and software perspective – can be upgraded to extend the usefulness of the tester over time.

Having the right toolset could save thousands of dollars from lost productivity from both the users themselves as well as those responsible for overseeing network infrastructure and datacenter support.

Summary

The modern datacenters of today as well as the underlying network infrastructure will continue to evolve to meet the requirements of leading technologies such as Intelligent Buildings, as organizations look at ways to cut costs, reduce their environmental impact and converge traditionally disparate operational and IT systems. In order to keep pace with assurance of deployment stability and uptime, it is important to realize that testing needs have also evolved.

The test equipment you will rely on should be able to perform the following:

- ✓ Standards based Copper and Fiber Certification
- ✓ Fiber Inspection
- ✓ SNR-based Multi-Gigabit Link Speed Testing
- ✓ Wireless Network Connectivity Testing including Signal Strength and Connectivity Assurance
- ✓ Copper and Fiber Network Compliance Reporting for Tested Link
- ✓ PoE Load Testing
- ✓ Wired Network Connectivity Testing and Connectivity Assurance including Switch/ Slot/Port/LAN

Notes/Serial Numbers :

Technical Support

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- Register your products (upon product registration, receive link to free on-demand training modules)
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For more information and details specifications, please visit: **AEM-Test.com/testpro-100**

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