Increasing Duplex Connector Density While Maintaining User Accessibility

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Abstract

As data consumption continues to increase, so does the relative bandwidth of data centers, central offices and head-ends. Reducing the overall optical hardware footprint in these highly controlled environments reduces real estate capital expenses, maintenance and speeds up installation. One method to achieve a reduced hardware footprint is by increasing connector density at the panel and transceiver by reducing the size of the connector and adapter. Until now, the smallest standardized single fiber connector is the LC connector, with a typical 1 rack unit capacity of 144 fibers. The LC connectors are commonly installed in pairs, called duplex LC, for transmit and receive communications.

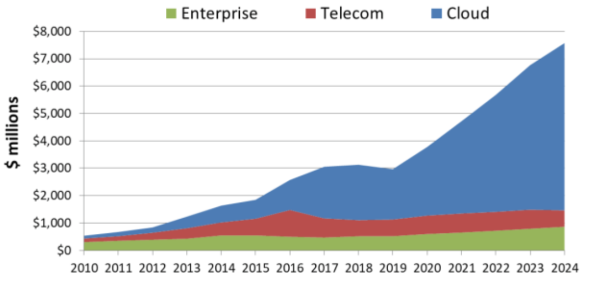
A new Very Small Form Factor (VSFF) connector, the MDC connector, was developed in an effort to achieve an appropriate balance of usability with minimal size while continuing to meet the carrier grade performance requirements of Telcordia GR-326.

Keywords: Optical, duplex, connectors; adapters; increased; density; reduced; size; QSFP-DD; OSPF, SFP-DD; MDC; VSFF; form; factor.

1. Introduction and Background

The optical connectors used in Datacom and Telecom links have remained stagnate for much of the last two decades. The LC for duplex link connectivity and the MPO for multi-fiber, high density trunk cables and parallel transceiver modules have been the mainstay of data centers. The SC connector has been a primary format for controlled environments in carrier based applications with proprietary, hardened formats often deployed in outside plant access networks.

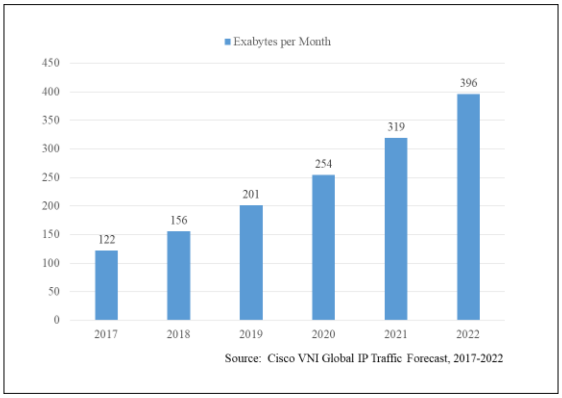
As we look forward, the 10 year growth trend in cloud based data services is anticipated to continue for the foreseeable future. Figure 1 highlights the anticipated Ethernet optics spend from cloud based services as reported by LightCounting in July 2019[1].



Source: LightCounting

Figure 1. Predicted Cloud Ethernet Spend Through 2024

According to the Cisco Visual Networking Index (VNI), "IP traffic is expected to grow to 396 EB per month by 2022, up from 122 EB per month in 2017, a CAGR of 26 percent" [2] (see Figure 2).



Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

Figure 2. Internet Protocol (IP) Traffic Growth

Due to the continued bandwidth demand surge and the sheer size of data center growth, new architectures are emerging which are driving the need for new connectivity formats.

High fiber density transceiver formats can support point to point transmission or alternatively 2, 4 or even 8 individual duplex links. When supporting individual duplex links, the fiber plant has typically been managed via complex harnesses, breakout cassettes and patching. These fiber solutions require additional fiber demarcation points while consuming valuable floor and rack real estate. The advent of new, double density transceiver module Multi Source Agreements (MSAs) has introduced the possibility to directly breakout out these links at the transceiver with smaller connector formats rather than via cabling infrastructure.

The promise of On Board Optic or ASIC + Tx/Rx Co-packaged optics introduces the possibility that existing connectivity options could become a limiting factor for scaling to higher switching port counts or fiber migration areas typically served by copper (e.g. fiber to the server). For direct duplex connectivity, the 'small form factor' formats of the past like the LC will no longer be suitable for these applications. While multi-fiber, arrayed connector formats like the MPO will always provide maximum fiber density, a new duplex format is required to support higher densities with two fiber granularity.

Reducing connector size below the duplex LC format presents two primary challenges:

1. Human access usability. The average human index finger tip width is 18mm. The LC duplex connector width is 15mm resulting in minimal size for traditional actuated release duplex connector usability

2. Connector stability, strength and performance required to meet established carrier grade performance requirements pert Telcordia.

The MDC connector format is proposed to increase duplex density by a factor of three over the traditional duplexed LC. (see Figure 3)

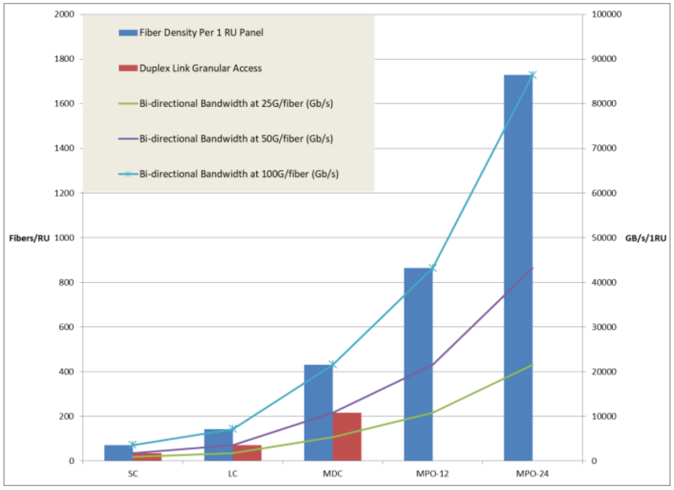


Figure 3. Fiber and Bandwidth Density by Connector Format

2. Design Needs

2.1 Reduced Connector/Adapter Size

The first challenge to increasing density of any form is typically to reduce the size of one or more component(s). From the optical hardware perspective, in many cases, the limiting factor of fiber density or optical hardware capacity is the number of connectors and/or adapters that can physically fit in a panel or module. Duplex LC connectors provide a fiber density of 144 fibers per 1 rack unit. Increasing fiber density beyond this limit will require a VSFF connector and adapter that is smaller than the LC duplex footprint.

Splitting parallel transceivers supporting multiple duplex links into two fiber cabling is currently accomplished by connecting a single MPO based transceiver to multiple duplex transceivers via an optical breakout cable or via cables attached to optical breakout modules (see Figure 4). Both solutions work well, however, both add cost and space to the optical rack footprint.

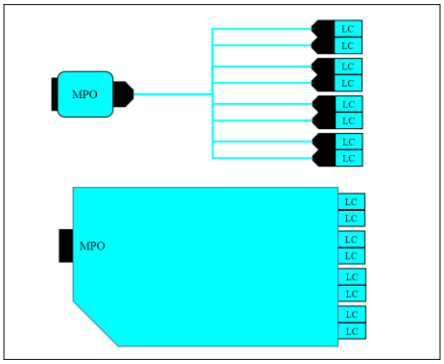


Figure 4. Breakout Cable and Breakout Module

A new breakout application based on several new MSA transceiver form factors (QSFP-DD, OSFP, SFP-DD) promotes methods to divide the optical signal directly at the optical transceiver interface allowing optical transceivers to be directly connected with multiple two fiber optical cable assemblies instead of more expensive optical breakout cables or modules. QSFP-DD allows for a 4:1 breakout at the transceiver[3] and SFP-DD allows for a 2:1 breakout at the transceiver.[4] The optical connector interface footprint for both the QSFP-DD and the SFP-DD form factors are not large enough for standard duplex LC optical connectors to provide the requested 4:1 or 2:1 breakout.

2.2 Finger Access

In theory, reducing the overall connector size would only be limited by the overall size of the installed fiber and cable. However, without tools or automation, installers and operators must be able to access one connector while not interfering with neighboring connectors that may be active. Placing many connectors and adapters in close proximity to one another creates a second challenge of accessibility. A smaller format connector must be individually accessible by human fingers while installed in a high density panel or module. Therefore, accessibility will increase the theoretical minimum connector size. Novel connector functionality can minimize the finger access limitation.

2.3 Backwards Compatibility

One challenge introduced by new connector formats is the need to create new hardware components such as panels and modules because the new connector/adapter format does not fit into existing tooled metal panels or plastic components. Backwards compatibility to an existing adapter cutout reduces development time and expense for hardware manufacturers. Ideally, fiber density at the optical hardware could be increased by simply replacing the adapters and connectors.

2.4 Polarity Reversal

Cables using duplex connectors are typically providing communication via a signal from transceiver A to transceiver B on fiber 1 and a signal from transceiver B to transceiver A on fiber 2. Using transceiver B as a reference, fiber 1 would be receiving a signal and fiber 2 would be transmitting a signal. If these fibers were crossed at any point in the transmission path, communication would cease and damage could be caused to either of the transmitters. The complexity of cabling infrastructure deployed in today’s fiber optic networks requires duplex connectors made with both polarity options. Polarity reversal at the connector level is necessary for quick and efficient adjustments to ensure design compatibility, minimize inventory management, correct operational errors and should also be considered during connector development as a required need.

2.5 Strength

Telcordia, standards were originally created as the stringent test requirements products must meet to be purchased by the Regional Bell Operating Companies. These performance standards have become the common requirement for most fiber cabling applications. Cylindrical ferrule based cable assemblies are considered very durable, or ‘carrier grade’, when they meet or exceed the Telcordia GR-326 standard. Even though a smaller format connector is being designed, the mechanical and optical requirements should not be reduced for a VSFF connector if the new format is to be used in a similar breadth of applications. However, a VSFF connector and adapter will have less material available to create its support structure and less material typically means less strength. Design elements will need to be added to the VSFF connector to allow the smaller connecters and adapters to meet the same test requirements as the larger LC duplex connectors.

3. Design Solutions

3.1 Determining Appropriate Size

Based on the design needs, the VSFF connector size must be between the cable OD and the LC connector. The transceiver breakout applications further define the maximum connector/adapter size limit. Optical connectors are attached to the transceivers on a front panel. QSFP-DD specifies a front panel area of 19 mm wide x 13.5 mm high. The QSFP-DD 4:1 breakout use case will require 4 VSFF connectors in the designated area. SFP-DD specifies a front panel area of 14 mm wide x 12.05 mm high. SFP-DD 2:1 breakout application will require 2 VSFF connectors in its designated area (see Figure 5).

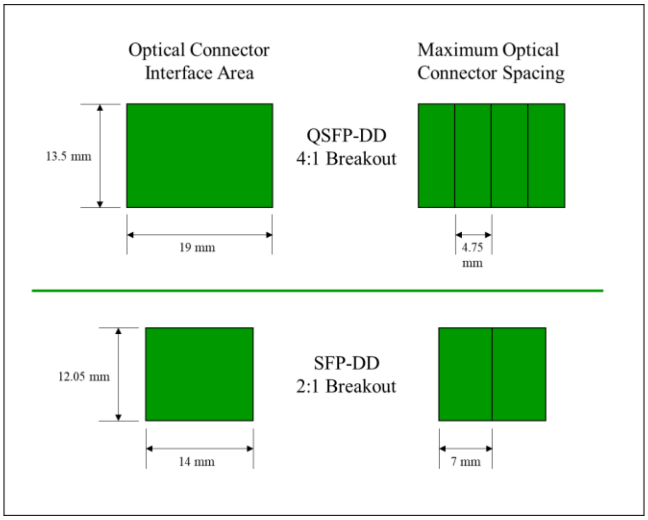


Figure 5. QSFP-DD and SFP-DD Breakout Application Size Limitations

For a new VSFF connector to be used for both QSFP-DD and SFP-DD breakout applications, the maximum width will be determined by the QSFP-DD 4:1 breakout and the maximum height will be determined by the SFP-DD optical interface. The VSFF maximum target connector size is 4.75 mm wide by 12.05 mm high constrained by the breakout transceivers.

Before determining the size based on the two new breakout applications alone, a desired objective is to allow for backwards compatibility with existing hardware. One of the most common adapters used in high density applications is the LC duplex adapter. The LC Duplex adapter will fit into a 13 mm wide x 9.5 mm high panel cutout (TIA 604-10-B, M=3)[5]. For the short axis, two 4.75 mm wide VSFF connectors will easily fit into the LC Duplex cutout. However, a slight reduction in width will allow three VSFF connectors to fit side by side in that same LC Duplex cutout (see Figure 6). Further reduction in width allows the density to increase from double to triple that of the LC while allowing for ample clearance between VSFF connector plugs. This would increase fiber density in a 1 rack unit patch panel to 432 fibers.

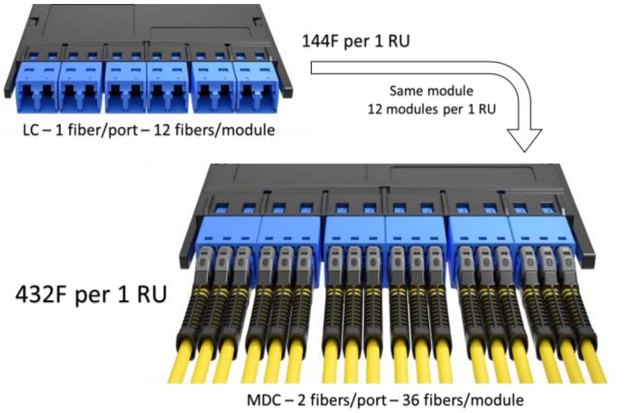


Figure 6. 3x Density and Backwards Compatible VSFF Connector Design

After considering all of the design constraints, a reduced target size of 4.33 mm wide by 12.05 mm high was determined. The final MDC connector dimensions are 3.7 mm wide by 8.9 mm high. The further reduced connector size allows for vertical and horizontal adapter walls and proper clearance between the connectors and the adapter.

3.2 Provisioning for access

Due to a smaller connector size, the method for accessing a VSFF connector has to be evaluated. The LC connector was designed in the early 1990's to be similar to an RJ-45 electrical connector. This was an effort to make the transition from copper to fiber easier for telecommunications technicians. Squeezing a thumb latch connects and/or disconnects the connector from the adapter. This type of latching mechanism requires area above the thumb latch and below the connector for finger and thumb access to actuate the latch. "A past study from the MIT Touch Lab found that the average person's fingertips are 1.6 - 2 cm (0.6 - 0.8 in) wide. The impact area of the typical thumb is even larger - an average of 2.5 cm (1 inch) wide!" [6]. This added 10 - 20 mm of finger access area further limits the overall fiber density at the panel or module level. A different type of release method must be used for the increased fiber density provided by the MDC connector.

Some optical connectors, including some LC duplex connectors, use a push-pull mechanism, usually with a push-pull tab. The push-pull tab is a rod that extends from the connector latch away from the congestion at the module/panel. The use of the push-pull tab eliminates the extra area needed for finger access for an RJ-45 style latching mechanism at the module/panel. The push-pull tab does make the individual connector access easier by moving the finger access point away from the module/panel, however, the tab itself adds obstructions in front of the connector/adapter panel. Although finger access using a push-pull tab is better than a standard LC duplex connector, finger access can be further improved if the push pull tabs are not present with the aggregation of cable and transceiver release tabs.

Most connector boots are designed for one purpose: to maintain proper strain relief and bend radius during cable loading to eliminate or minimize increased insertion loss. Connector boots typically attach to the connector crimp band and/or crimp body by friction and extend over the cable jacket. The connector boots on most cable assemblies with push-pull tabs extend a similar distance from the adapter module/panel as the push-pull tabs.

Combining the function of the push pull tab and boot removes the added congestion of the push-pull tabs from in front of the adapter module/panel.

The MDC connector boot is designed to translate axially over the crimp band and cable jacket allowing it to also serve as the push-pull insertion and extraction mechanism. The connector boot is directly attached to the connector latching mechanism. The MDC boot design and thermoplastic material chosen has an axial stiffness to overcome the spring force (approximately 10 N) of both ferrules during connector insertion. The boot also withstands collapse from normal finger pressure during connector insertion or removal. This prevents the boot from adding frictional forces between the boot and cable prohibiting axial movement of the boot during insertion or extraction.

The boot also has lateral flexibility to allow for side to side bending. Due to the smaller size, MDC connectors can be spaced at a 3.9 mm pitch. The boot flexibility allows adjacent connector boots to flex left and right allowing fingers (approx. 18 mm) to access one individual connector. Finally, the lateral flexibility of the boot also provides a smooth radius of curvature to the cable assembly during testing up to 135° of rotation (GR-326 Transmission With Applied Load/TWAL).[7]

3.3 Designing for strength

Two mechanically strenuous Telcordia GR-326 tests, Proof and TWAL, qualify connector attachment to the cable in addition to connector attachment to the adapter. These loads can be applied along the axis of the cable and at angles up to 135°.

Loads applied at angles greater than 0° will cause the connector to rotate relative to the adapter. There are many ways to limit the angular rotation of a connector within an adapter. Connector engagement length in the adapter plays a significant role. Keeping all connector and adapter dimensions the same while simply increasing the engagement length of the connector into the adapter will reduce the maximum allowable amount of angular rotation by the connector (see Figure 7). Applying this principle to both axes will minimize connector angular rotation in both axes.

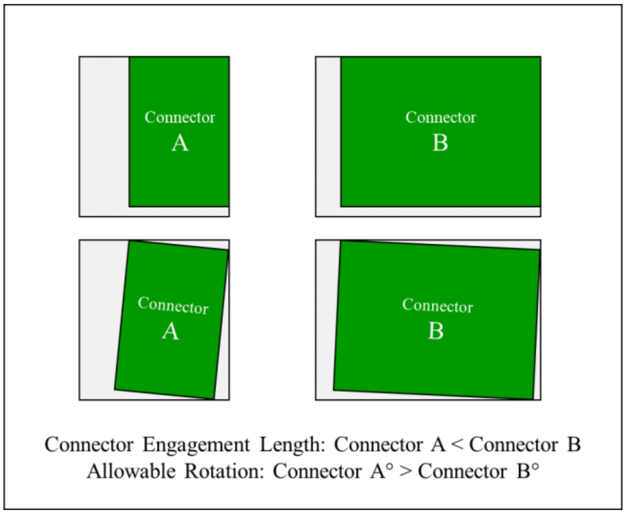


Figure 7. Effects of Connector Engagement Length on Connector Angular Rotation

Another important factor that limits connector angular rotation within the adapter is to minimize clearance between the connector and adapter. There must be a certain amount of clearance between the connector and adapter to allow for manufacturing size variances of the two mating parts while ensuring minimal friction and wear during insertion and extraction. However, increasing the clearance between the connector and adapter will adversely allow a higher degree of angular rotation (see Figure 8) by the connector.

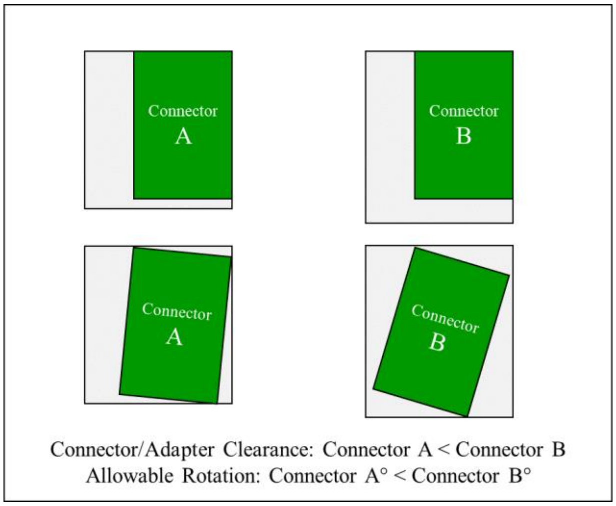


Figure 8. Effects of Connector/Adapter Clearance on Connector Angular Rotation

Minimizing connector rotation relative to the adapter during side load is beneficial, but minimizing ferrule movement is paramount for optical stability. To further minimize stresses seen by the ferrule, the connector housing can be designed to allow the ferrules to rotate within the connector housing at a larger rotational angle than the connector can rotate within the adapter (see Figure 9). Conversely the ferrules can remain stationary while the housing rotates about the ferrules. This 'ferrule float' relative to rotational translation between two connector plugs ensures proper axial alignment of the ferrules and ultimately optical stability of the connector system.

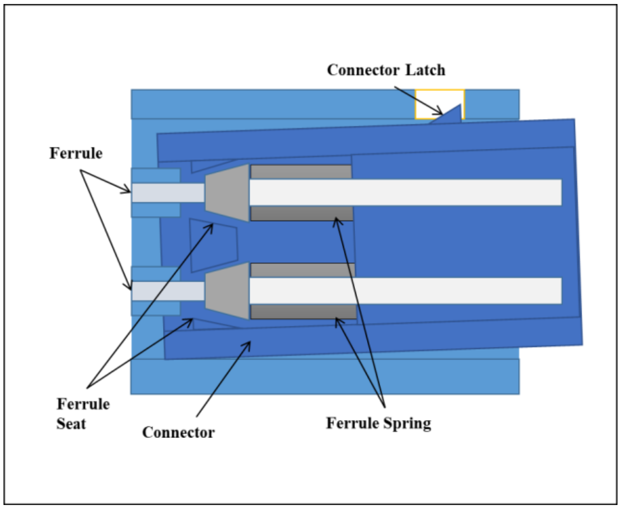


Figure 9. Connector Designed to Allow Minimal Ferrule Rotation

Using the principles above, the MDC connector housing and adapters are designed to minimize connector angular rotation to less than 1° relative to the adapter in the vertical and horizontal directions. (Figure 10) The MDC connector housing also allows the ferrules to rotate more than 2° relative to the connector housing, isolating the ferrules and eliminating forces seen at the connector ferrule during cable loading.

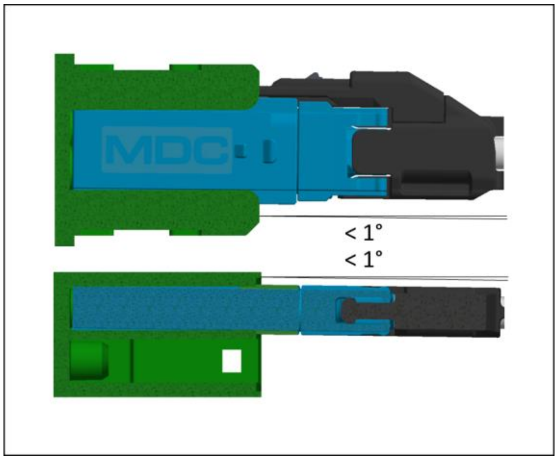
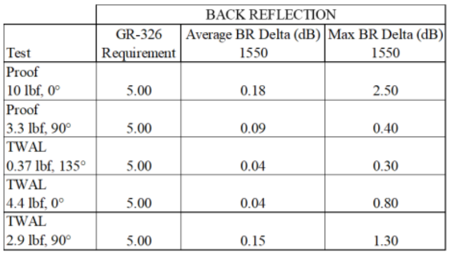


Figure 10. MDC Connector Design Limits Angular Rotation

The MDC connector components have been designed, produced and installed onto various manufacturer's two fiber single mode optical cables. Successful testing to the Telcordia GR-326 mechanical and optical requirements prove the design concepts discussed in this paper are valid. The cable assemblies containing the MDC connectors consistently met the GR-326 Service Life Mechanical tests. Results from Proof and TWAL, are shown in Table 11.

Table 11. GR-326 Proof and TWAL Insertion Loss and Back Reflection Deltas

	INSERTION LOSS		
Test	GR-326 Requirement	Average IL Delta (dB) 1550	Max IL Delta (dB) 1550
Proof 10 lbf, 0°	0.30	0.01	0.02
Proof 3.3 lbf, 90°	0.30	0.00	0.01
TWAL 0.37 lbf, 135°	0.50	0.05	0.11
TWAL 4.4 lbf, 0°	0.50	0.03	0.07
TWAL 2.9 lbf, 90°	0.50	0.04	0.10



	BACK REFLECTION		
Test	GR-326 Requirement	Average BR Delta (dB) 1550	Max BR Delta (dB) 1550
Proof 10 lbf, 0°	5.00	0.18	2.50
Proof 3.3 lbf, 90°	5.00	0.09	0.40
TWAL 0.37 lbf, 135°	5.00	0.04	0.30
TWAL 4.4 lbf, 0°	5.00	0.04	0.80
TWAL 2.9 lbf, 90°	5.00	0.15	1.30

4. Conclusion

By using a new, high density connector technology, 432 fibers with duplex access granularity can be installed in 1 RU using the MDC and still meet the stringent carrier grade performance requirements of GR-326. Fiber density can be increased by a factor of three in existing cabling hardware.

By reconsidering how connectors function, and by using novel design elements and materials, a new level of accessible duplex fiber connectivity was demonstrated with a novel connector design. This new connector design enables telecommunications and data center applications to achieve duplex connector density levels previously considered unattainable while maintaining user accessibility and still meeting the carrier grade performance requirements of Telcordia GR-326.

5. References

[1] "2019 Mega-Datacenter Optics Report", Lightcounting, p. 63 (2019).

[2] "Cisco Visual Networking Index: Forecast and Trends, 2017-2022 White Paper", https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html#_Toc532256803 (February 27, 2019)

[3] QSFP-DD MSA, QSFP-DD Hardware Specification for QSFP Double Density 8X Pluggable Transceiver, Rev. 5, 2019

[4] SFP-DD MSA, SFP-DD Hardware Specification for SFP Double Density 2X Pluggable Transceiver, Rev. 3.0, 2019

[5] TIA-604-10-B, FOCIS 10B Fiber Optic Connector Intermateability Standard- Type LC, August 2008

[6] Aurora Harley, "Touch Targets on Touchscreens," Nielsen Norman Group, https://www.nngroup.com/articles/touch-target-size/ (May 5, 2019)

[7] Telcordia GR-326, Issue 4, Generic Requirements for Singlemode Optical Connectors and Jumper Assemblies, 2010

[8] OSFP MSA, Specification for OSFP Octal Small Form Factor Pluggable Module, Rev 2.0, 2019

6. Author Biographies

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